EVERYDAY WITH PRACTICAL ELECTRONICS

OCTOBER 1994

INCORPORATING ELECTRONICS MONTHLY

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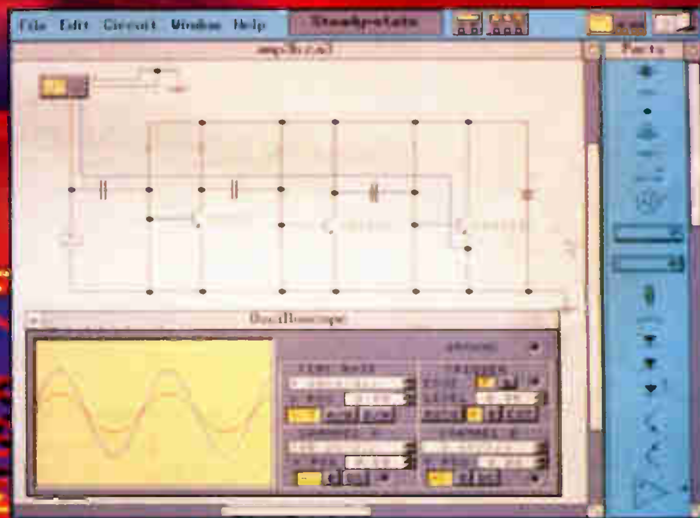
SPECIAL LIMITED VERSION
ELECTRONICS WORKBENCH PC SOFTWARE

ENABLES YOU TO CARRY OUT THE ASSIGNMENTS IN THE FIRST TWO PARTS OF OUR

ELECTRONICS FROM THE GROUND UP SERIES



VISUAL AUDIO GUITAR TUNER

DIGILOGUE CLOCK

HOBBY PSU

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

NEW BULL ELECTRONICS STORE IN

WOLVERHAMPTON

55A WORCESTER ST TEL 0902 22039

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

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

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

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

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

COMPUTER COMMUNICATIONS PACK Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PC's over a long distance. Complete kit £15.99 Ref MAR16P2

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

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

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

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

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

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

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

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

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

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

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

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

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

***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective 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

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

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

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

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

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

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

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

BULL ELECTRICAL

250 PORTLAND ROAD HOVE SUSSEX BN3 5QT

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

PLEASE ALLOW 7 - 10 DAYS FOR DELIVERY
TELEPHONE ORDERS WELCOME

TEL: 0273 203500
FAX: 0273 323077

VISA

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: MAG3P6 5.25" only.

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

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

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

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

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

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

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

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

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

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

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

BOTH SHOPS OPEN 9-5.30 SIX DAYS A WEEK

INFRARED LASER NIGHT SCOPES
Second generation image intensifier complete with hand grip attachment with built in adjustable laser lamp for zero light conditions. Supplied with Pentax 42mm camera mount and normal eye piece. 1.6kg, uses 1xPP3,3xAA's (all supplied) £245+Vat

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

££££££££WE BUY SURPLUS STOCK££££££££
TURN YOUR SURPLUS STOCK INTO CASH
IMMEDIATE SETTLEMENT. WE WILL ALSO QUOTE FOR COMPLETE FACTORY CLEARANCE.

1994 CATALOGUE.

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

(PLUS £4.50 SPECIAL PACKAGING CHARGE)

TOP QUALITY AMORPHOUS SILICON CELLS HAVE ALMOST A TIMELESS LIFESPAN WITH AN INFINITE NUMBER OF POSSIBLE APPLICATIONS, SOME OF WHICH MAY BE CAR BATTERY CHARGING, FOR USE ON BOATS OR CARAVANS OR ANYWHERE A PORTABLE 12V SUPPLY IS REQUIRED. REF: MAG34

PORTABLE RADIATION DETECTOR
£49.99

A Hand held personal Gamma and X Ray detector. This unit contains two Geiger Tubes, has a 4 digit LCD display with a Piezo speaker, giving an audio visual indication. The unit detects high energy electromagnetic quanta with an energy from 30K eV to over 1.2M eV and a measuring range of 5-9999 UR/h or 10-99990 Nr/h. Supplied complete with handbook Ref MAG50.

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

VOL. 23 No. 10 OCTOBER 1994

EVERYDAY WITH PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

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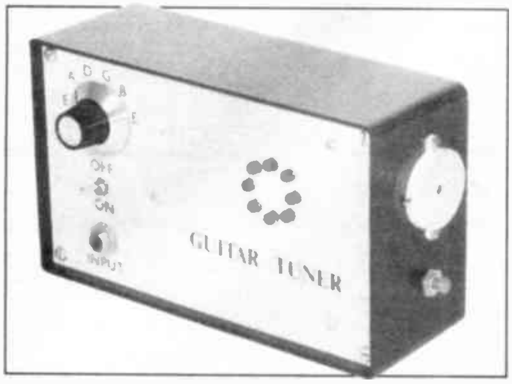

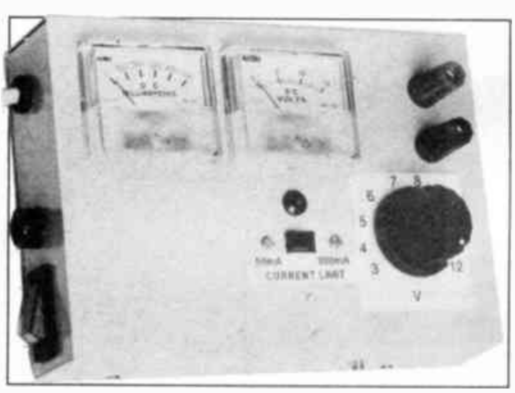

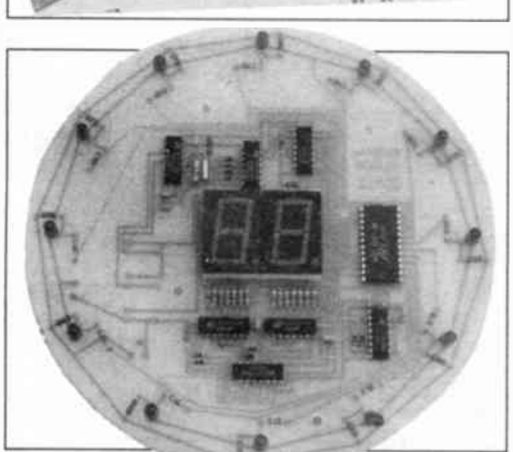

Projects

Series

Features

Our November '94 issue will be published on Friday, 7 October 1994. See page 719 for details.

NEXT MONTH

FREE

196 PAGE GREENWELD 1995 CATALOGUE

worth £2

DUAL VOLTAGE INSULATION TESTER

A simple to use hand-held meter which tests insulation at 500 and 1000 volts d.c. Finds potentially dangerous faults in wiring, domestic appliances, and industrial equipment.

The unit employs a safe, high voltage supply produced from batteries via an efficient inverter circuit. It gives a clear read-out of insulation resistance from 0 to 100 megohms.

POWER CONTROLLER

Have you got an electric fire blazing away, racking up a large fuel bill? The Chancellor of the Exchequer will be delighted! For the benefit of our many overseas readers, Her Majesty's Government has now taken a shine to our fuel bills, so much so that it has added Value Added Tax to them. Hence any device which helps to cut those electricity bills will be welcomed, by everyone apart from the Chancellor that is!

This 13 amp burst firing controller is designed for immersion heaters, electric fire elements, large heaters etc. It uses zero crossing to ensure freedom from radio interference.

VIDEO MODULES

The rise in popularity of camcorders and home video productions over the past few years has been phenomenal. Camcorders are now standard consumer items which are available in every high street, and at surprisingly low prices. Most users probably do not bother with editing their tapes, but a tape of recorded highlights is much more watchable than one which simply includes all the recorded material.

A good video production is generally reckoned to be produced by using about 10 per cent of the recorded footage, and discarding the other 90 per cent. With practically any camcorder and video recorder combination it is possible to achieve the required editing, but results will not necessarily be particularly polished.

Most video editing is easier if a few accessories are added to the system. Devices such as faders and wipers to process the video signal, and a mixer in the audio signal path, permit much more professional results to be obtained. In this series of articles seven video modules are covered, as follows:

Simple Video Fader; Improved Video Fader; Horizontal Wiper; Vertical Wiper; Video Enhancer; Four Channel Audio Mixer; Audio Dynamic Noise Limiter.

A modular approach makes it easy for constructors to build a video controller which only provides the functions that he or she really needs. There is actually an eighth module, which is a simple mains power supply unit. Mains operation represents the most economic means of powering the modules, but battery operation is also possible.

EVERYDAY WITH PRACTICAL ELECTRONICS

OUR NOVEMBER ISSUE WILL BE ON SALE FRIDAY 7th OCTOBER

£1 BARGAIN PACKS

In fact ... cheaper than £1 because if you buy 10 you can choose one other and receive it free!

1 x 12V Stepper Motor. 7.5 degree. Order Ref: 910.
1 x 10 pack Screwdrivers. Order Ref: 909.
2 x 5 amp Pull Cord Ceiling Switches. Brown. Order Ref: 921.
5 x reels Insulation Tape. Order Ref: 911.
4 x 14mm Bull-races. Order Ref: 912.
2 x Cord Grip Switch Lamp Holders. Order Ref: 913.
1 x DC Voltage Reducer. 12V-6V. Order Ref: 916.
1 x 10 amp 40V Bridge Rectifier. Order Ref: 889.
Lightweight Stereo Headphones. Moving coil so superior sound. Order Ref: 896.
2 x 25W Crossovers. For 4ohm loudspeakers. Order Ref: 22.
2 x NiCad Constant Current Chargers. Easily adaptable to charge almost any NiCad battery. Order Ref: 30.
18V-0-18V 10VA mains transformer. Order Ref: 813.
2 x White Plastic Boxes. With lids, approx. 3" cube. Lid has square hole through the centre so these are ideal for light operated switch. Order Ref: 132.
2 x Reed Relay Kits. You get 8 reed switches and 2 coil sets. Order Ref: 148.
12V-0-12V 6VA mains transformer, p.c.b. mounting. Order Ref: 938.
1 x Big Pull Solenoid. Mains operated. Has ½" pull. Order Ref: 871.
1 x Big Push Solenoid. Mains operated. Has ½" push. Order Ref: 872.
1 x Mini Mono Amp. 3W into 4 ohm speaker or 1W into 8 ohm. Order Ref: 495.
1 x Mini Stereo 1W Amp. Order Ref: 870.
15V DC 150mA p.s.u., nicely cased. Order Ref: 942.
1 x In-Flight Stereo Unit is a stereo amp. Has two most useful mini moving coil speakers. Made for BOAC passengers. Order Ref: 29.
1 x 0-1mA Panel Meter. Full vision fact 70mm square. Scaled 0-100. Order Ref: 756.
2 x Lithium Batteries. 2.5V penlight size. Order Ref: 874.
2 x 3m Telephone Leads. With BT flat plug. Ideal for 'phone extensions, fax, etc. Order Ref: 552.
1 x 12V Solenoid. Has good ½" pull or could push if modified. Order Ref: 232.
4 x In-Flex Switches. With neon on/off lights, saves leaving things switched on. Order Ref: 7.
2 x 6V 1A Mains Transformers. Upright mounting with fixing clamps. Order Ref: 9.
2 x Humidity Switches. As the air becomes damper, the membrane stretches and operates a micro switch. Order Ref: 32.
5 x 13A Rocker Switch. Three tags so on/off, or changeover with centre off. Order Ref: 42.
Mini Cassette Motor. 9V. Order Ref: 944.
1 x Suck or Blow-Operated Pressure Switch. Or it can be operated by any low pressure variation such as water level in tanks. Order Ref: 67.
1 x 6V 750mA Power Supply. Nicely cased with mains input and 6V output lead. Order Ref: 103A.
2 x Stripper Boards. Each contains a 400V 2A bridge rectifier and 14 other diodes and rectifiers as well as dozens of condensers, etc. Order Ref: 120.
12 Very Fine Drills. For PCB boards etc. Normal cost about 80p each. Order Ref: 128.
5 x Motors for Model Aeroplanes. Spin to start so needs no switch. Order Ref: 134.
6 x Microphone Inserts. Magnetic 400 ohm, also act as speakers. Order Ref: 139.
6 x Neon Indicators. In panel mounting holders with lens. Order Ref: 180.
1 x In-Flex Simmerstat. Keeps your soldering iron etc always at the ready. Order Ref: 196.
1 x Mains Solenoid. Very Powerful as ½" pull, or could push if modified. Order Ref: 199.
1 x Electric Clock. Mains operated. Put this in a box and you need never be late. Order Ref: 211.
4 x 12V Alarms. Makes a noise about as loud as a car horn. All brand new. Order Ref: 221.
2 x (6" x 4") Speakers. 16 ohm 5 watts, so can be joined in parallel to make a high wattage column. Order Ref: 243.
1 x Panostat. Controls output of boiling ring from simmer up to boil. Order Ref: 252.
2 x Oblong Push Switches. For bell or chimes, these can switch mains up to 5A so could be foot switch if fitted in pattress. Order Ref: 263.
50 x Mixed Silicon Diodes. Order Ref: 293.
1 x 6 Digit Mains Operated Counter. Standard size but counts in even numbers. Order Ref: 28.
2 x 6V Operated Reed Relays. One normally on, other normally closed. Order Ref: 48.
1 x Cabinet Lock. With two keys. Order Ref: 55.
6½ 8Ω 5 Watt Speaker. Order Ref: 824.
1 x Shaded Pole Mains Motor. ¾" stack, so quite powerful. Order Ref: 85.
2 x 5 Aluminium Fan Blades. Could be fitted to the above motor. Order Ref: 86.
1 x Case. 3½ x 2¼ x 1¾ with 13A socket pins. Order Ref: 845.
2 x Cases. 2½ x 2¼ x 1¾ with 13A pins. Order Ref: 565.
4 x Luminous Rocker Switches. 10A mains. Order Ref: 793.
4 x Different Standard V3 Micro Switches. Order Ref: 340.
4 x Different Sub Min Micro Switches. Order Ref: 313.

BARGAINS GALORE

Infra Red Controller. Made for Thorn TV sets but suitable for other control purposes. Fully built and ready to operate, real bargain, £2, Order Ref: 2P304.
Hall Effect. Give positive or negative pulses when magnet passes over. Mounted on small PCB, 2 for £1, Order Ref: 1032.
Digital Multi Tester. 30 range, model no. 3800, normal price £40, our price £25, Order Ref: 25P14. Brand new and guaranteed.
Water Pump with spindle for operation by portable drill, £5, Order Ref: 5P240.
Three More Transformers. Order Ref: 4P81 is a 12V-0-12V 40W, clamp mounted, price £4 each less 10% for 10 or more. Order Ref: 5P236 is a 43V at 2.4A, frame mounted, heavy construction, will withstand considerable overloads, price £5. Order Ref: 3P181 is a 12V 3A frame mounting type but without the frames, price £3. We have tested this and find it quite suitable for 50W lamps.
Multi Voltage Auto-Transformer. Could be used to give 350W at 115V for operating regular 115V equipment or it could give this some current at 85V, 120V or 130V. Another use for it is to boost the output from a long line. Could give a 30V or 50V boost up to 300W. Probably has many other uses for its outputs are 85V, 115V, 120V, 130V, 200V, 220V and 240V. A big transformer, price £4, Order Ref: 4P79.

> **£1 Super Bargain**
> 12V axial fan for only £1, ideal for equipment cooling, brand new, made by West German company. Brushless so virtually everlasting. Needs simple transistor drive circuit, we include diagram. Only £1. Order Ref: 919. When we supply this we will include a list of approximately 800 of our other £1 bargains.

If You Use An Invertor to operate radios or TV and similar frequency controlled equipment, then it is advisable to know the frequency of the invertor, otherwise this and/or the equipment it operates can be damaged. We have 100mm square faced panel meters which electronically display the frequency of the supply, providing it it between 45 and 55Hz. Really top class instrument price £15, Order Ref: 15P19.
Mains Klaxon Type Alarm. Very loud output but adjustable. Completely encased, shelf or wall mounting, £5, Order Ref: 5P226.
12V 10A Switch Mode Power Supply for only £9.50 and a little bit of work because you have to convert your 135W PSU. Modifications are relatively simple – we supply instructions. Simply order PSU Ref: 9.5P2 and request modification details, price still £9.50.
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Just occasionally we get involved with a business deal that seems to benefit everyone and our Free Electronics Workbench software package represents one such arrangement. The idea was suggested and organised by Mike Tooley following his review of the complete package back in the April issue. Mike produced our *Electronics From The Ground Up* series which is designed around the use of a Special Limited Version of the Electronics Workbench software package.

The disk given free with this issue enables you to perform the assignments for the first two parts of the series and, for a small fee, you can upgrade this software so that it covers all the assignments in the whole series. (We strongly suggest you register now for the upgrade – see the ordering information at the end of Part 1 of the series.)

As I said, it seems that this arrangement should suit everyone; we get an excellent and valuable free gift which should help our issue sales (we have printed 42,000 copies of this issue); you, the reader, get some excellent software, which will be useful if you are learning electronics or if you are designing your own circuits, and Robinson Marshall, who market Electronics Workbench in the UK, get their product more widely known to hobbyists, students, teachers, trainees and to the general electronics industry.

We hope you approve of the arrangement, we are sure that once you have tried the software you will be amazed at its capabilities and no doubt those of you who have a serious intention in electronics, either as a hobby or as a career, will want to upgrade to the full Electronics Workbench package at some stage, either now or in the future.

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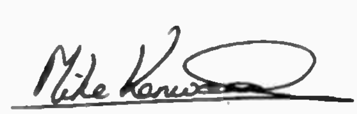

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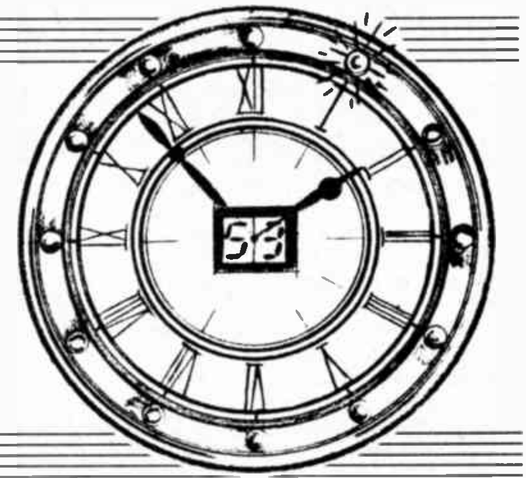
Constructional Project

DIGILOGUE CLOCK



John Scott Paterson

A new look for an old face. Displaying accurate digital timing at all hours around the clock.

THE clock to be described here takes a different approach to other electronic digital clocks in that the display is partly digital and partly analogue. The minutes are displayed on two one-inch high 7-segment displays, while the hours are represented by 12 light emitting diodes (l.e.d.s) located around the clock face in the usual manner.

The "face" of the clock is always visible even in the dark since the eleven l.e.d.s which are not "on the hour", are dimly lit at all times. This style makes readability easy since all you need do is look for the hour l.e.d. and then read off the minutes, as shown in Fig. 1, for example.

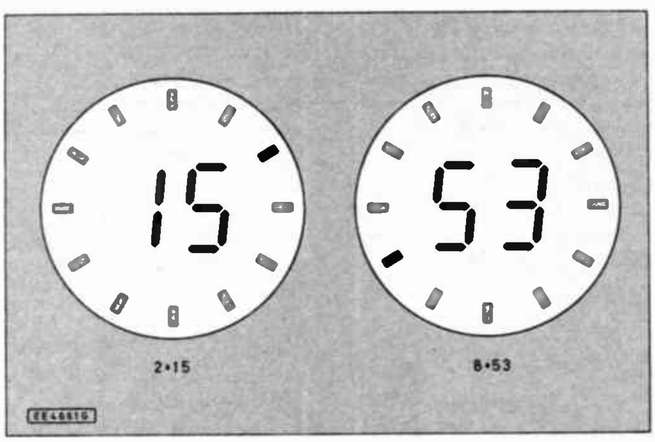


Fig. 1. Two examples of time display readout.

Special clock i.c.s are not required for the design, which is based on readily available and relatively inexpensive 4000-series CMOS chips. All the components, including 7-segment displays and switches, are available from many electronics suppliers.

The clock is powered by a small mains adapter of the kind used to power portable calculators and the like. For ease of construction, the complete clock is built on a single circular printed circuit board (p.c.b.) which allows the final clock to be very thin, and ideal for wall-mounting.

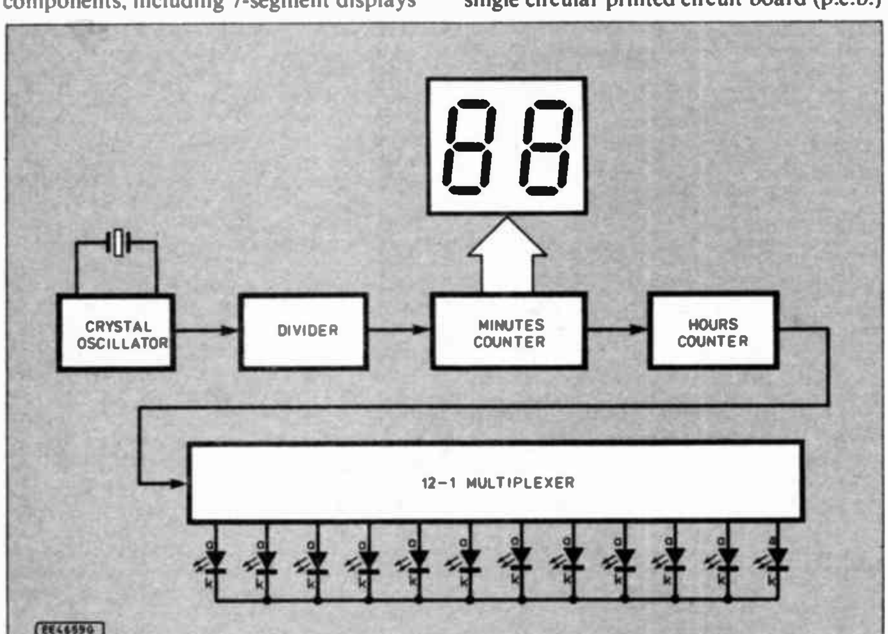


Fig. 2. Block schematic diagram for the Digilogue Clock.

BLOCK DIAGRAM

The block diagram for the Digilogue Clock is shown in Fig. 2. A crystal oscillator is the timing heart of the unit, the output of which is divided down to produce the minutes and hours signals.

The minutes counter drives a two-digit 7-segment display whilst the hours counter drives a 12-to-1 multiplexer, to whose outputs are connected 12 l.e.d.s. Only one output of the multiplexer goes high at any time, causing the corresponding hour l.e.d. to glow brightly.

TIMING AND DIVIDING

The complete circuit diagram of the clock is shown in Fig.3. In this figure, crystal XTAL1 and IC1 generate a basic frequency of 32768Hz. Since the chip used for IC1 is a type 4060 oscillator and 14-stage divider, an output frequency of 2Hz is available at its Q14 output, pin 3.

The 2Hz signal is fed to IC2, a 4024 7-stage binary divider, which is set to divide the count by 120. Diodes D1 to D4 and resistor R2 form a wired-AND gate which provides a reset pulse to IC2 on each 120th pulse count.

The author preferred to use a wired-AND gate instead of an AND-gate chip in order to simplify the p.c.b. design, and also to reduce the chip count. Dividing the 2Hz signal by 120 provides a one-pulse-per-minute signal which is used to drive the minutes counter.

Ignoring the operation of IC3 for the moment, the reset pulse for IC2 is also fed to IC6a pin 1. IC6 is a dual 4-bit binary counter, the two halves of which are cascaded, with the first half set to divide by 10, giving a count range of zero to nine. Diodes D7 and D8, and resistor R20 are used as another wired-AND gate, which is used to reset IC6a on each tenth clock pulse.

The second counter, IC6b, is set to divide by six, giving a count range of zero to five, as controlled by the third wired-AND gate around diodes D5 and D6, and resistor R19. Thus the two counters give a count from 0 to 59 for the minutes display. Jointly, IC4 and IC5 decode the BCD (binary coded decimal) outputs from the two counters and control the two 7-segment displays, X1 and X2, via resistors R5 to R18.

The reset pulse as seen by the second counter IC6b at its pin 15 is a one-pulse-per-hour signal and this is used to clock a third counter, IC7. This is also a dual 4-bit binary counter, of which only one half is used. The counter is reset by the feedback through the wired-AND gate formed by diodes D9, D10 and resistor R21, dividing the input clock pulses by 12 to give an output count range of 0 to 11.

The BCD outputs of IC7 control the 16-to-1 analogue multiplexer IC8. The common input/output pin 1 of IC8 is connected to the positive supply line so that as the count progresses each of the multiplexer's outputs goes high in turn. When any output goes high, the l.e.d. on the corresponding output is turned fully on to indicate the hour of the day.

As mentioned earlier, the other 11 l.e.d.s not currently "on the hour" are kept dimly lit. This is done by providing a trickle current via resistors R34 to R45 and preset potentiometer VR1, which can be adjusted to set the preferred brightness of the "off" l.e.d.s.

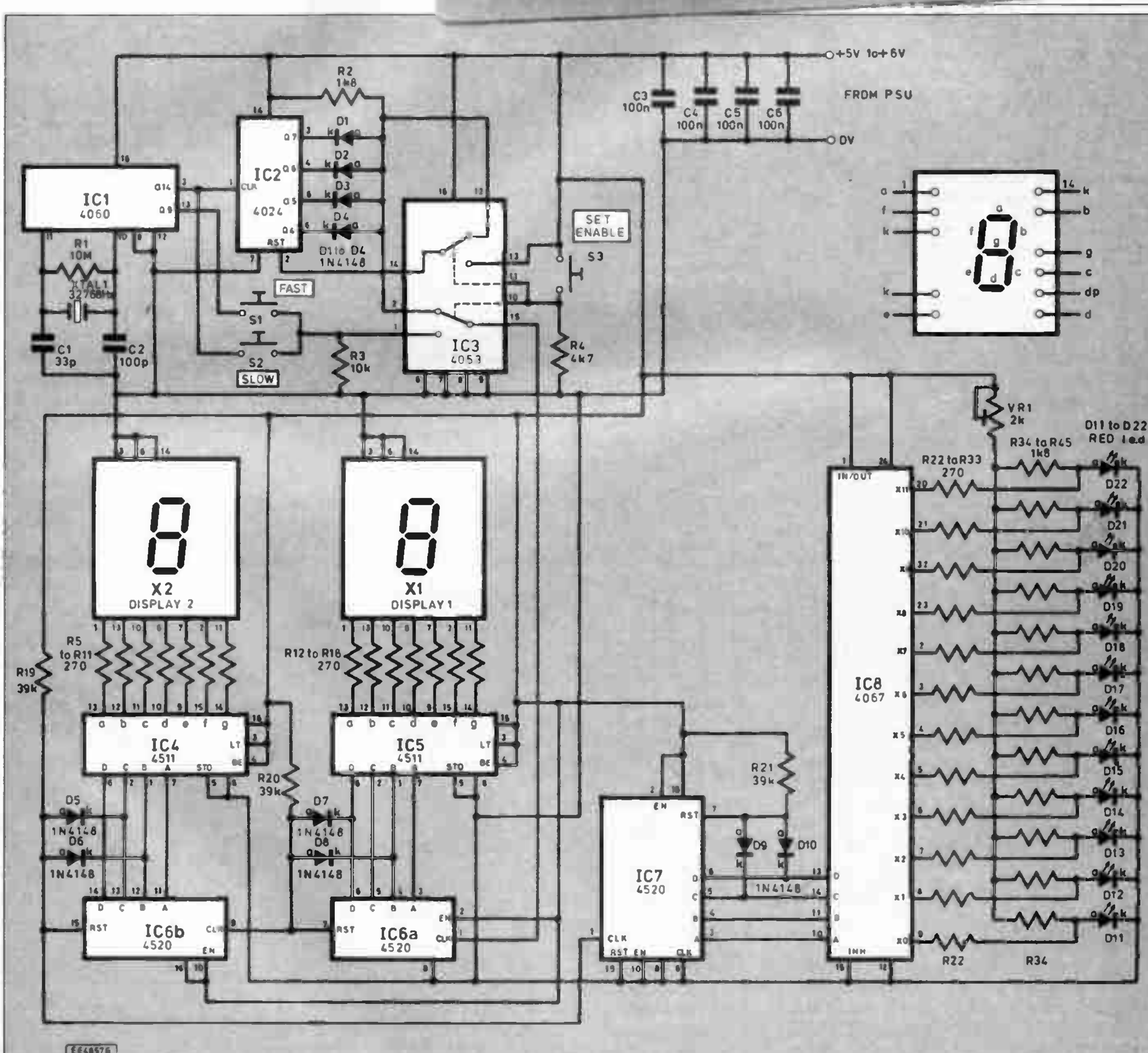


Fig. 3. Complete circuit diagram for the Digilogue Clock. Note that if 8mm l.e.d.s (D11 to D22) are used the mains adaptor (p.s.u.) will have to be up-rated to 250mA minimum – see text.

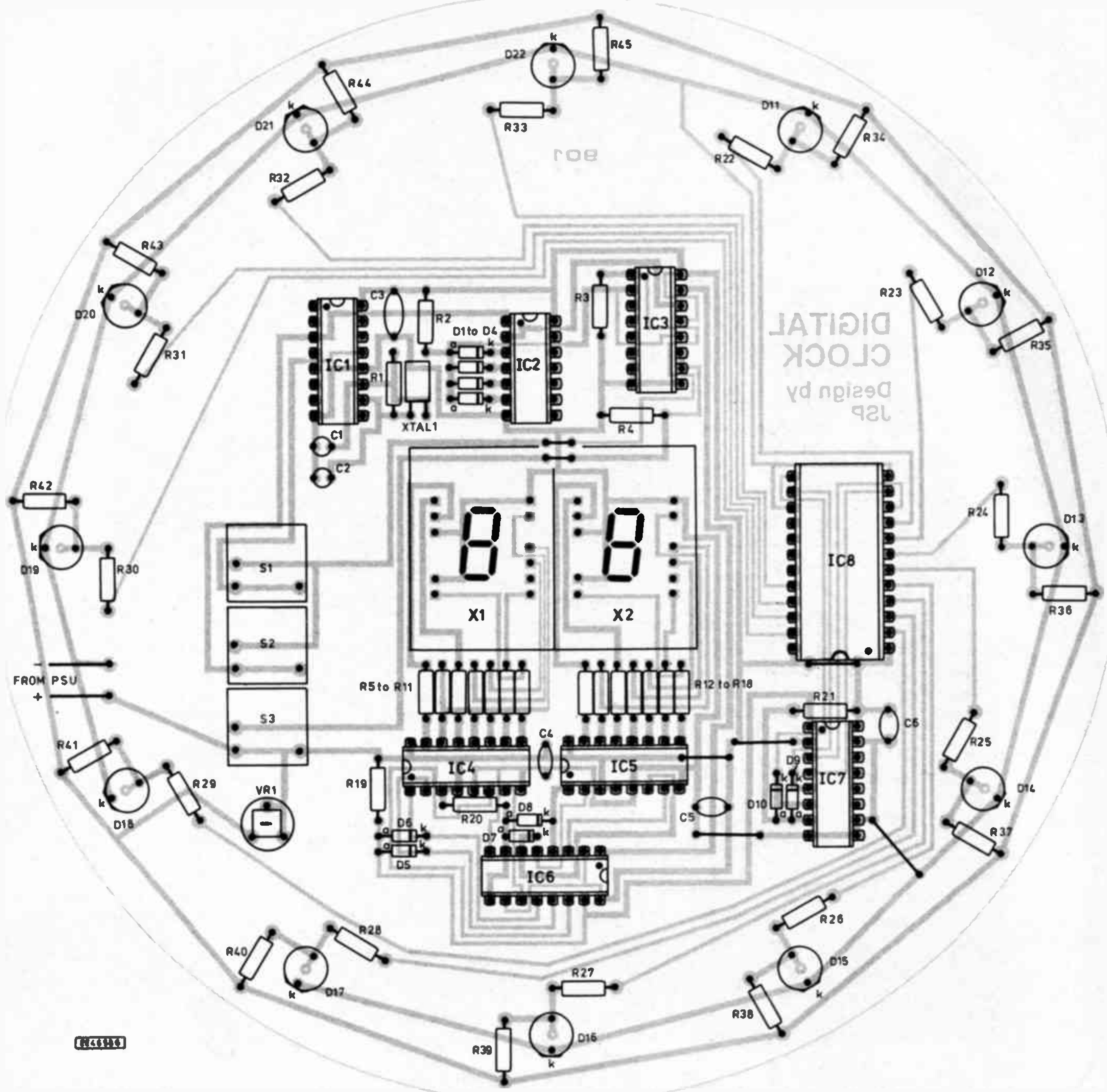


Fig. 4. Printed circuit board component layout and (far right) full size copper foil master pattern for the clock. Note that switches S1 to S3 and preset VR1 are soldered directly on the copper side.

SWITCHED RESETTING

In the prototype, a 2-pole 2-way slide switch was originally used to select the desired clock mode, of either Set or Run. This worked well when setting the time, but as soon as the switch was set back to run, spurious signals caused by switch contact bounce falsely clocked on the counters. To get over this, analogue multiplexer IC3 was added and operated as follows.

When none of the push-button switches, S1 to S3, are pressed the analogue switches are as shown in the main circuit diagram of Fig. 3. With the switches in this state, the clock is in its normal running mode. The reset pulse from the junction of the diode-resistor network around D1 to D4 and R2 is routed from IC3 pin 12 to IC3 pin 14 and thence to the reset pin of counter IC2 (pin 2) and also to the clock input (pin 1) of the minutes counter IC6.

When the Set Enable switch S3 is pressed, the two CMOS switches within IC3 change over their signal routings. This does two things, first it enables the two Set switches S1 and S2. When pressed, these respectively take fast pulses from IC1 pin 13 and slow pulses from IC1 pin 3, feeding them to IC6a pin 1, to allow the setting of the clock. The Fast switch S2 should be used to set the hours and the Slow switch S3 to set the minutes.

Simultaneously, the reset pin of IC2, pin 2, is taken high, stopping the chip from counting. If this counter was not stopped whilst setting the time, it would produce unrequired output signals, erroneously clocking on the minutes counter when returning to the normal Run mode.

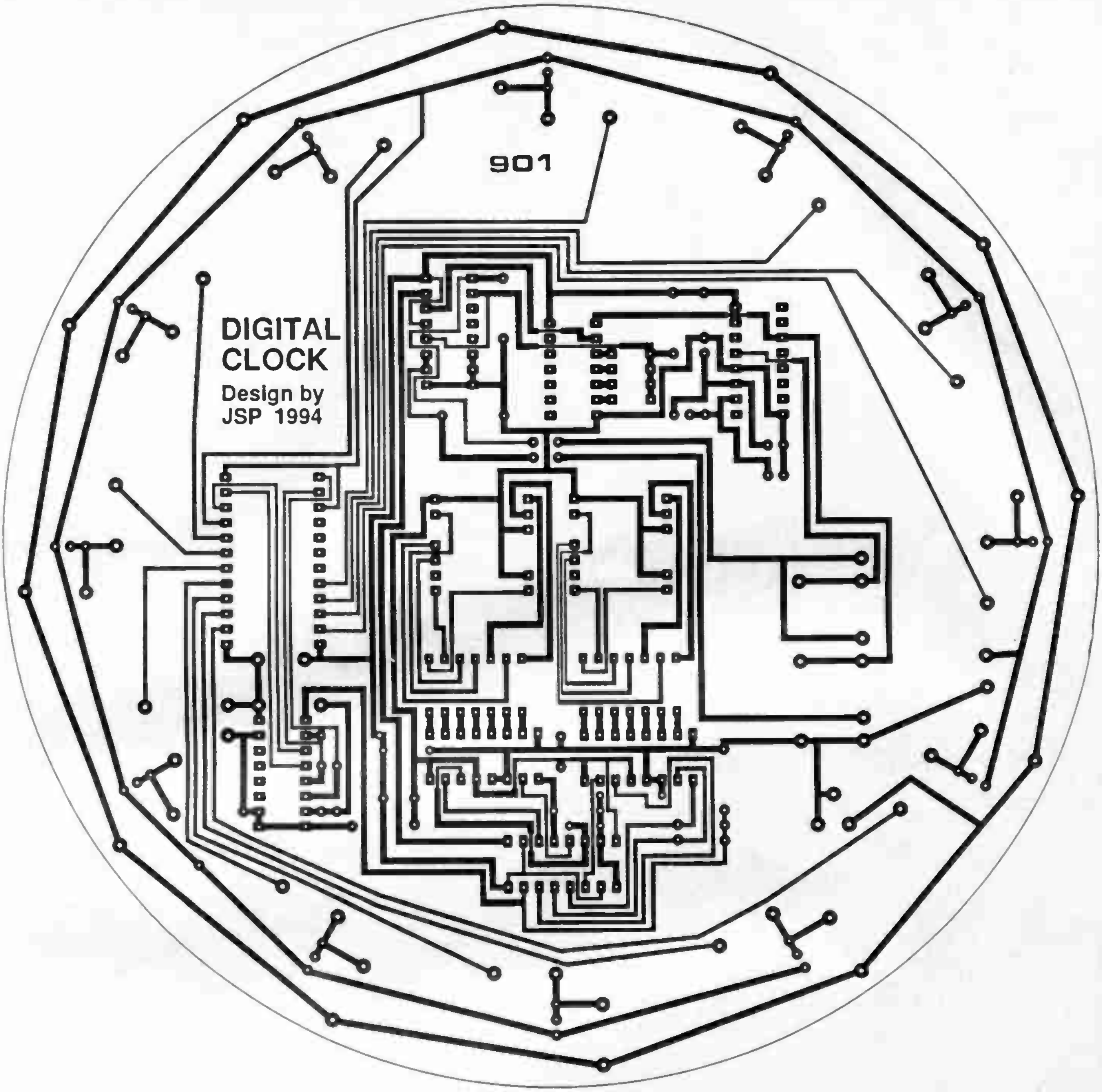
CONSTRUCTION

The entire clock circuit is built on one single-sided printed circuit board (p.c.b.) measuring 18cm in diameter. The p.c.b. component layout and full size copper foil master pattern are shown in Fig. 4. This board is available from the *EPE PCB Service*, code 901.

Begin construction by soldering in the seven on-board link wires. This is important since two of them are underneath the 7-segment displays. Next, the diodes, resistors and capacitors should be fitted. Try wherever possible to lay components as flat as you can. Next fit crystal XTAL1.

How the 12 l.e.d.s and the two 7-segment displays are fitted depends on how you wish to install the i.c.s. To keep the overall thickness of the finished clock to a minimum, the author decided not to use i.c. sockets. If you go for this option, you can fit the displays and l.e.d.s as normal, ensuring that the bodies of the components rest on the p.c.b. The l.e.d.s should then just protrude through the front panel and the displays be flush with it.

Note that all the i.c.s are CMOS devices and that the usual anti-static precautions should be taken at all times when handling them. Ensure that you periodically discharge static electricity from yourself by touching a grounded (earthed) item.



If you decide to fit i.c. sockets you must take a different approach. First, the displays will also have to be mounted in i.c. sockets, to raise their profile above the board. Make sure the displays are high enough to just protrude through the front panel.

Next, the l.e.d.s must be inserted so that they protrude slightly more than the displays. The author found that the best way to fit them was to get a piece of balsa wood sheet, just the right thickness to raise the l.e.d.s up from the p.c.b.

Make a hacksaw cut at right angles to the plane of the sheet, then simply pop the l.e.d. into the cut, and then into the board. Solder the l.e.d. in place and then remove the balsa wood. This allows all the l.e.d.s to be inserted at the correct height and angle, as shown in Fig.5.

Lastly, fit switches S1 to S3 and preset potentiometer VR1. So as not to spoil the face of the clock, the author decided to mount these components on the reverse of the p.c.b. With this in mind open-sided switches and a skeleton-type preset were chosen to allow easy soldering to the board.

COMPONENTS

Approx cost guidance only **£28**

excluding mains p.s.u.

Resistors

R1	10M
R2, R34 to R45	1k8 (13 off)
R3	10k
R4	4k7
R5 to R18, R22 to R33	270 (26 off)
R19 to R21	39k (3 off)

All 0.25W 5% carbon film or better

See SHOP TALK Page

Potentiometer

VR1	2k min. skeleton preset, horiz.

Capacitors

C1	33p polystyrene
C2	100p polystyrene
C3 to C6	100n ceramic (4 off)

Semiconductors

D1 to D10	1N4148 signal diode (10 off)
D11 to D22	Red l.e.d. (12 off) (see text)
IC1	4060 14-stage binary counter and oscillator
IC2	4024 7-stage binary counter
IC3	4053 triple 2-Chan. multiplexer
IC4, IC5	4511 BCD to 7-segment decoder (2 off)
IC6, IC7	4520 dual binary up counter (2 off)
IC8	4067 16-Chan. multiplexer
X1, X2	7-segment common collector l.e.d. display, 1 inch high, red (2 off)

Miscellaneous

Printed circuit board available from *EPE PCB Service*, code 901. S1 to S3 click switch (open sided) (3 off); caps for switches (3 off); red filter sheet; case to suit (see text); 6V mains adaptor (see text); terminal solder pins; connecting wire; solder, etc.

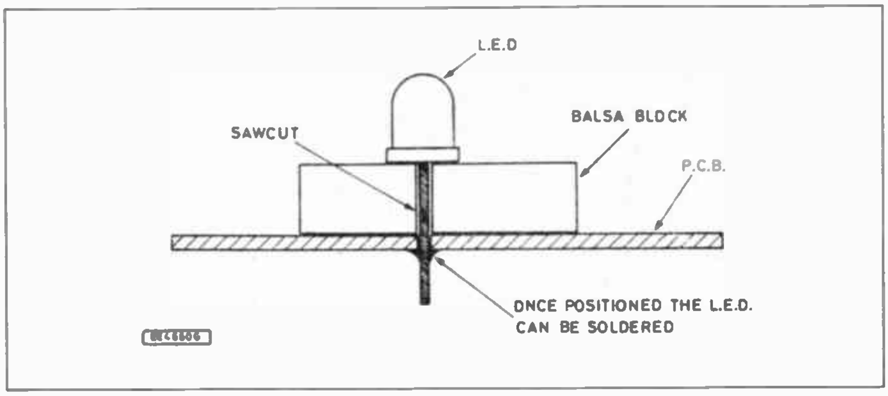
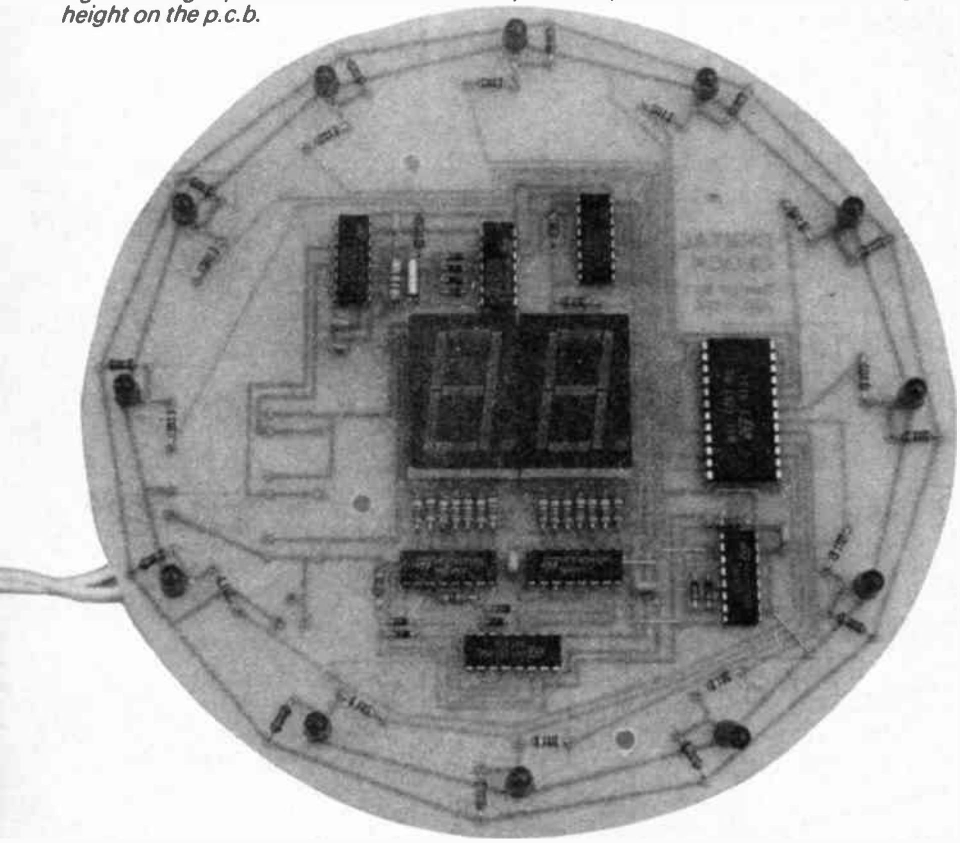
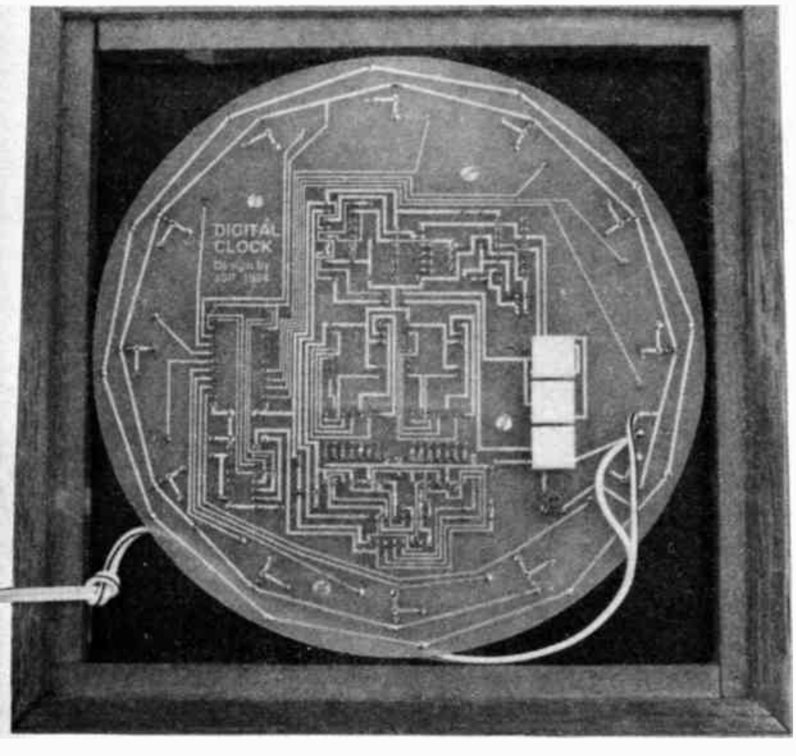
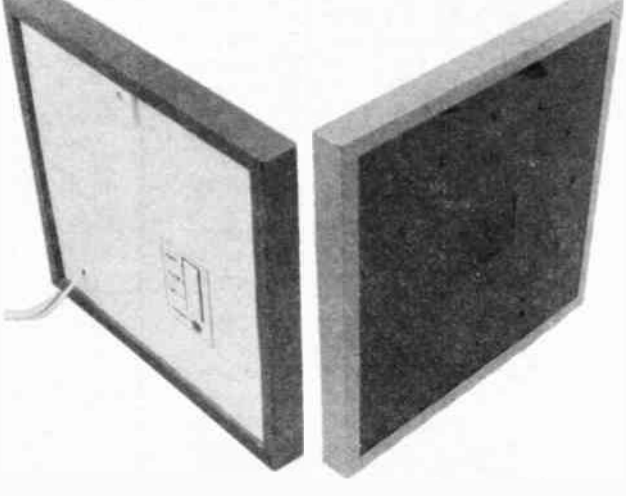


Fig. 5. Using a piece of balsa wood as a spacer to position the l.e.d.s at the right height on the p.c.b.







POWERING THE CLOCK

Having completed the assembly of the p.c.b., thoroughly check it for incorrectly positioned components, and for inadequately soldered joints and solder shorts across the tracks.

The clock can now be connected to the power from a 5V to 6V d.c. mains adaptor. The circuit draws about 130mA and so an adaptor with a rating of 250mA or more should be satisfactory. The output from mains adaptors is usually via a jack plug. However, the author felt that he did not wish to use a jack plug and socket for connecting the power to the clock as any movement of the supply wire could, perhaps, cause momentary power loss which, of course, would corrupt the time setting.

For the prototype, the author used a phono plug and socket. Since it was also necessary to extend the power supply cable, a length of similar cable was soldered directly to the clock board (using terminal pins to anchor the wires) and the free end fitted with the phono plug. The jack plug was cut off the adaptor and replaced by an in-line phono socket. This arrangement proved to be very reliable.

CLOCK HOUSING

The clock can be housed in a variety of ways, but the author recommends the use of either a deep red or a black perspex front panel. If red polarised perspex is available, all the displays can be mounted beneath it.

This removes the need for any awkward drilling and will also look attractive. Otherwise, holes must be drilled for the hours l.e.d.s, and a rectangular hole cut out for the 7-segment displays. A small piece of polarising filter, which greatly increases the contrast of the displays, should be fitted in the rectangular window.

For the clock surround, either wood or plastic can be used. The author used balsa with a teak veneer. Metal picture framing material should also work well and is easy to use. For the back panel, a piece of sheet ABS plastic was used.

The l.e.d.s used in the prototype were 5mm round types but the clock should also look pleasing with 8mm round ones instead. Note that in the latter instance, the current drawn will probably increase to about 230mA so the adaptor will need to be up-rated accordingly. If you are good at drilling and filing holes, you could go for rectangular or triangular types of l.e.d. in place of the round ones.

The design is very flexible and several clocks, in various shapes and sizes, have been built. □

MEASURING THE HUMAN BODY

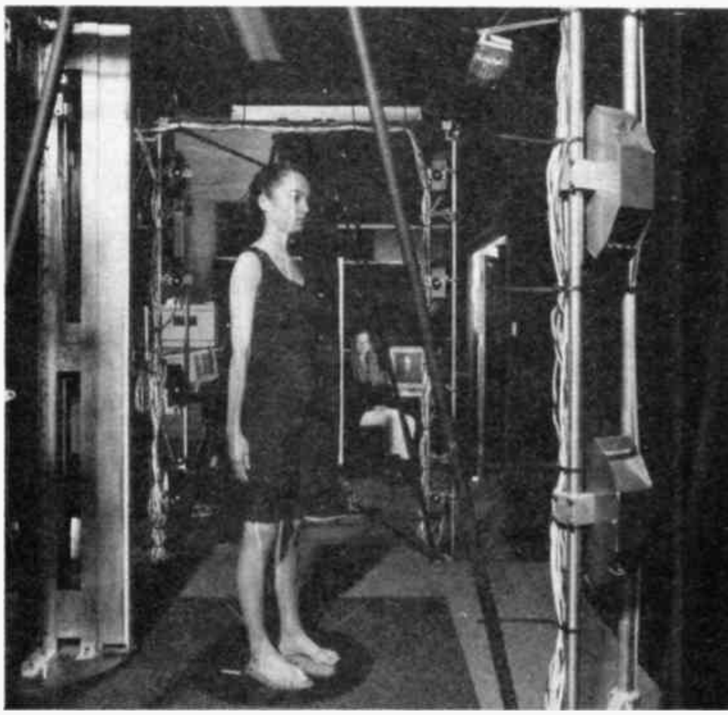
New Body Scanner is "a lass unparalleled" – *by Hazel Cavendish*

THE accurate measurement of human body size and shape is as essential to textile manufacturing and industrial design as it is to the medical world. Since 1528 when Albrecht Dürer published his *"Vier Bücher von Manschlicher Proportion"* scientists have been experimenting with different ways of measuring people, but the methods used have been slow and laborious and usually involved a degree of physical contact.

Now electronics and computer technology are being used by Loughborough University to research an ultra-sophisticated automated system capable of fast, accurate and comprehensive measurements of the human body with a computerised television and a 3-D scanner.

British, European, Japanese, American and Canadian patents have been registered for LASS (Loughborough Anthropometric Shadow Scanner), which was sponsored by the Science and Engineering Research Council. Marks & Spencer have collaborated in the development of the system in garment manufacturing.

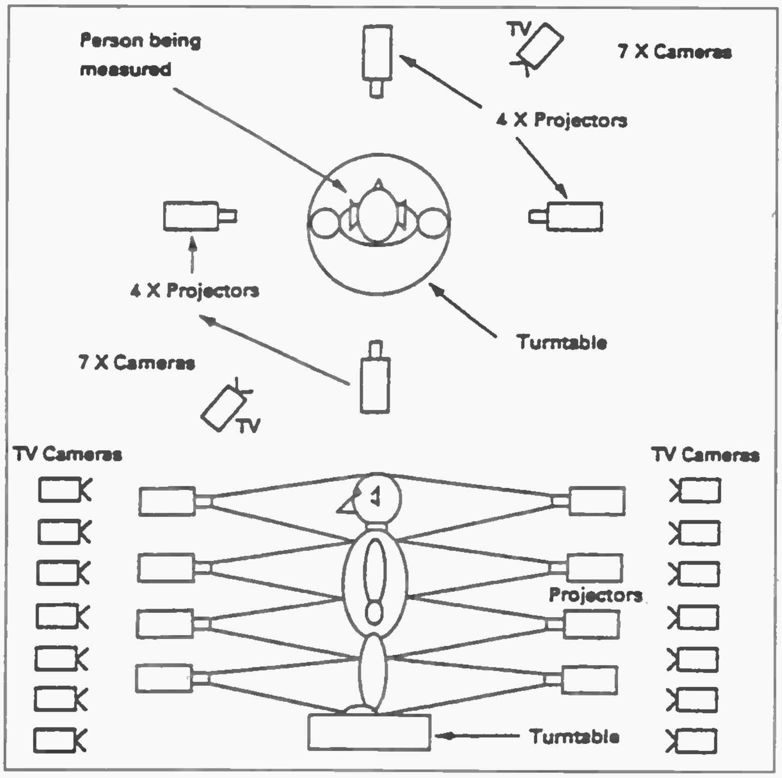
The Human Measurement and Growth (HUMAG) Research Group at Loughborough, have produced a "soft" mannequin dummy called "Annie Murphy" based on the study of 155 British women which proved that the national female figure has changed considerably since the 1940s and 1950s. Women had something of an hourglass figure in that era; today they carry more weight on hips and waist with a larger bust. manufacturers of women's clothing should find this information useful as most British women grumble that UK sizings are frequently inaccurate.



How the Scanner evolved

Professor Peter Jones, who has the Chair of Human Functional Anatomy, says that their research has been based on the concept that a body could be measured in terms of radii and angles in conjunction with height. It defines a plane on the body from which it is possible to measure the radius using a television camera interfaced to a computer. A person wearing a body stocking is scanned on a turntable which is able to be rotated through 360 degrees in measured angular increments.

Four narrow strips of light are projected to fall on the body in vertical planes. These planes are arranged to pass through the centre of rotation of the turntable, with the scene viewed by two banks of seven TV cameras, so aligned that the light slit edge of the field of view conjoined with the centre of rotation of the turntable (see diagram). This alignment enables all points where the edge of the light falls on the body to define the horizontal radii in the vertical plane.



Plan and elevation of the configuration for the 16 projectors and 14 TV cameras in relation to the turntable.

Further television lines measure radii further down the body, and information from a transducer mounted on the turntable gives the angle at which the radii are measured, the full shape of the body being defined in cylindrical coordinates. An Eltec mini computer (R.C.S. Microsystems Ltd) is used to collect the digitized information which can be displayed numerically on the screen in x, y and z coordinates.

Medical Aspect

Although numerous medical applications of LASS are expected to be developed, attention has presently been focussed on providing practical help to women facing mastectomy. Another application is likely to be of considerable interest to the medical world is directed to radiotherapy. In the context of mastectomy the team has considered the patient who has to undergo a series of radiation treatments where the X-ray tube heads would have to be aligned accurately over the areas to be treated, so that the central rays of the radiation beam avoid the blood-forming organs and bone marrow.

"To do this it is essential to have an accurate mould of the body so that medical physicists can use positioning wires through the mould to locate the exact site of the tumour," says Professor Jones. "It is envisaged that LASS could scan a patient and via a computer, accurately position the X-ray tube heads to the required angles and be readily accessible for recall whenever a patient came for follow-up treatments."

"As far as is known," says Professor Jones, "no system exists in the public domain which can automatically measure human forms. Our intention is to establish at Loughborough University a databank of body shapes taken from sample populations. Direct beneficiaries will not only be the manufacturers, retailers and purchasers of clothing, but also design and bio-engineers, medical and health scientists and ergonomists."

PICO

Pico Technology have added three products to their popular PC based instrument series. Like the rest of the range the units offer the performance of desktop instruments with all the benefits that PC connection offers (clear displays, on screen instructions, disk and printer support).

Slightly larger than a cigarette packet the SLA-16 is probably the smallest and most economical PC based logic analyser. It offers 16-channel operation with an 8K trace buffer. Flexible internal and external clocking modes are supported (up to 50MHz). The supplied software provides state listings and waveform displays, two cursors can be used for time and frequency measurement.

The ADC-100 with the supplied PicoScope software allows your computer to be used as a dual channel digital storage 'scope, spectrum analyser, frequency meter and voltmeter. For long term data logging (and chart recorder emulation), PicoLog software is an optional extra.

The ADC-100 offers 100kHz sampling and 12-bit resolution. Each chanel can be set to any of seven input voltage ranges (±20V to ±0·2V). The ADC-100 is powered from the PC's parellel port so is ideal for potable use with a notebook PC.

The ADC-22 is a data logging unit designed for users who require a large number of input channels (22). Its other specifications are similar to the exsiting ADC-11.

Prices of the units are: ADC-22 £199, SLA-16 £219 and the ADC-22 £199. All are available from Pico Technology. Dept EPE. 149-151 St Neots Road, Hardwick, Cambs. CB3 7QJ. Tel: 0954 211716.

SIMPLIFIED FILTER DESIGN PROGRAM

The filter circuit is one of the basic building blocks in electronic design. Almost every piece of electronic equipment contains at least one filter and their use is becoming more important as EMC legilsation progressively comes into force.

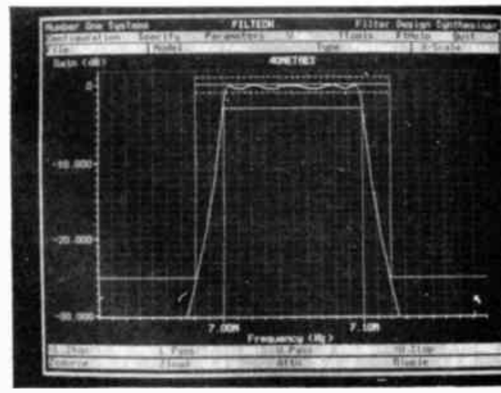
For many electronics engineers, however, designing active and passive filters is a tedious and error-prone process. They must either perform many repetitive and complex calculations or look up dozens of normalised coefficients in tables.

In the same way that the electronic calculator has displaced printed log tables, FILTECH, a new filter design program from Number One Systems, is using the power of the modern PC to free designers from their dependence on these methods.

A major advance of FILTECH is the ability to analyse the synthesised filter circuits independently and display a graphic plot of the calculated frequency response, superimposed on the specified filter limits. This gives immediate confirmation of the accuracy of the synthesis process. It can synthesise both Active and Passive Filters up to sixth order with a frequency range extending from fractions of a Hertz to over a Gigahertz.

Passband and Stopband frequency limits, Ripple and Attenuation levels, and terminating impedances are all FILTECH needs to know before it can complete a design. Naturally, the built-in simulator can superimpose the resulting frequency response on top of that produced using the original ideal component values.

Educationalists will appreciate the way in which the user can choose to override FILTECH's recommendations and see immediately, through the built-in simulator the effects of varying such filter parameters as the filter type, Bessel, Butterworth or Chebyshev, or the filter order.



For in-depth investigation of filter behaviour including the analysis of input and output impedances, phase response and group delay, FILTECH can be linked seamlessly to Number One Systems' ANALYSER III linear circuit simulator. The combination of the two programs offers a unique insight into filter design.

For further details and full ordering information contact: Number One Systems, Dept EPE, Harding Way, Somersham Road, St. Ives, Huntingdon, Cambridgeshire PE17 4WR.

MARS RALLY

For amateur radio enthusaists an event worth attending will be the MARS-Stockland radio/computer rally at Stockton Green Leisure Centre, Slade Road, Erdington, Birmingham. To be held on Sunday 13th November 1994, the rally will include the usual traders, local clubs, special interest stands, bring and sell tables, refreshments and so on. Doors open at 10.00am, admission £1.00. Car parking is free. For more details contact either Norman G8BHE 021-422 9787 or Peter G6DRN 021-442 1189, evenings only.

YABA DABA DO – IT'S BRITISH

★ British Oscar-winning technology in Hollywood's latest blockbuster.
★ Controlled by RISC computer, they're probably the cleverest dinosaurs ever!

THE EXTRAORDINARILY life-like qualities of the main dinosaur characters in the new *Flintstone* movie rely on state-of-the-art computer control technology designed by Cambridge-based MicroRobotics.

Inside the head of dinosaur characters such as Dino the Dogasauras or the Dictabird are tiny embedded controllers driving as many as 20 motors which activate the eyes, lips, jaws, ears and so on. These effects are controlled remotely by command signals sent by radio or wire from a puppeteer using a super-fast RISC-based computer and special joystick-like controls.

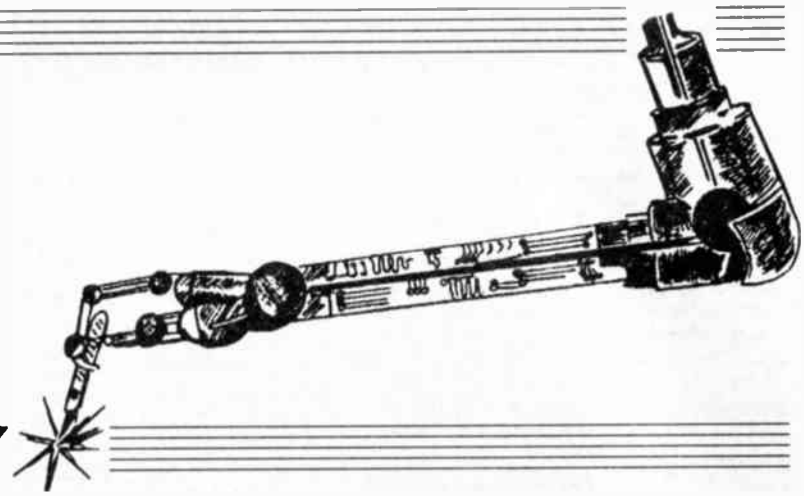
Universal/Amblin's *Flintstones* is the latest application of this computer-based puppet control system. Developed for Jim Henson's Creature Shop – who supplied the dinosaur character heads and animation effects for this new film – MicroRobotics' controller is claimed to provide unparalleled flexibility for synthesizing facial expressions.

This performance stems from state-of-the-art processing technology, and unique control sticks developed by the Creature Shop, which together allow puppeteers to combine multiple movement actions at will to create any desired expression. Unlike earlier puppet control systems which typically execute stored movement sequences only, MicroRobotics' control technology – coupled with the individual skill of the puppeteer – allows stunningly realistic effects to be generated in real-time.

When designing this control system, MicroRobotics looked for ultra high speed response, to give users instantaneous control over the puppet, and found this performance in the 32-bit ARM processor. Also designed in Cambridge, this chip is based on RISC (reduced instruction set computing) architecture, and provides the exceptional computational rates required to translate a puppeteer's control signals into the command strings required by the motors.

Shortly, the company will launch a new version of its RISC-based controller technology – designed specially for embedded systems and industrial control and monitoring applications.

For further information contact Peter Miller at: MicroRobotics Ltd., Dept EPE, 39 Springfield Road, Cambridge, CB4 1AD. Tel: 0223 323100; Fax: 0223 462242.



CIRCUIT SURGERY

ALAN WINSTANLEY

This month in our regular round-up of readers' questions and hints, we look at a Ni-Cad charger which can be powered from a car battery, also a suggestion for d.c. motor control using logic, and Ingenuity Unlimited – what you told us!

D.C. Motor Controller

Andrew Long of Peterborough posed a question which will interest anyone involved with d.c. motor control using logic systems, perhaps in the context of buggies or robotics. Andrew has designed a system which requires an add-on motor interface to control the direction of motor rotation, also a "pause" facility is required:

I need a circuit to reverse the direction of a small 3V d.c. 1A motor. This will be driven from a J-K bistable set as a T-type flip-flop. A logic high "pause" signal is needed to disable the motor. I've tried many ideas without success and hope you can help.

Andrew sketched a block drawing of his requirements in Fig. 1. His T-type (toggle-type) bistable alternates the complementary inputs Input A and Input B, like a changeover toggle switch. There are several avenues we could explore: initially I thought about a simple "discrete" application using individual transistors such as the push-pull arrangement of Fig. 2.

A complementary (*npn* and *pnp*) pair of power transistors form a set of switches centred around the 0V rail. Split supplies (±3V) are needed and whichever transistor is switched on determines the direction of motor rotation since the motor can of course be made to reverse simply by transposing its d.c. supply.

This idea is very simple in some respects but it does have several drawbacks. We need split rails, and there is absolutely no compatibility with standard logic levels, so further interfacing would be needed before it could be hooked up to Andrew's logic circuit. I didn't get as far as the "pause" control and started to search through my groaning Data library instead!

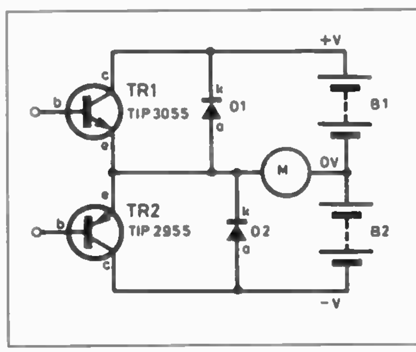


Fig. 2. Push-pull d.c. motor controller.

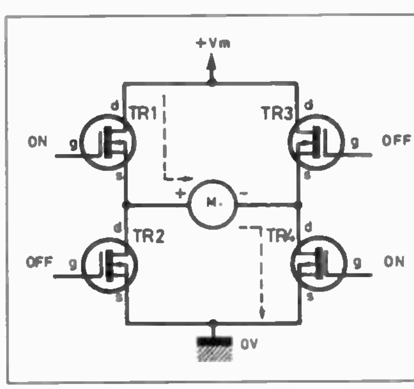


Fig. 3. "H" bridge network motor driver.

Motor control is often provided by means of *bridge driver networks*. These consist of four transistors (e.g. MOSFETs) arranged in an "H" bridge pattern, see Fig. 3. If the appropriate transistors are driven in the correct pattern, the motor in the centre of the bridge can be operated in either direction. In fact two diagonally-opposite transistors are switched on at any one time and this sets the polarity across the motor. For example, the dotted line shows how when TR1 and TR4 are enabled, the motor polarity is as shown.

This "H" bridge is very common, and the most modern way to implement it is to use one of a variety of driver i.c.s which take care of organising the driver transistors for us. Dual drivers which control two motors are also available. Quad drivers too! They usually incorporate a diode suppression network to counter the damaging back e.m.f. generated by the motor windings, and they have more useful features as we shall see.

These special driver i.c.s can power a d.c. motor directly. They may have *two* power supply inputs, one for the chip logic and a second higher voltage motor supply (up to say 50V or more) which is connected to the transistor bridge within the i.c., +Vm in Fig. 3. The biggest drawback I found was that the minimum motor drive voltage specified by most manufacturers was too high for our 3V motor, typically 6V-12V or more being specified, so I opted to include a simple series resistor with the motor as a quick fix, so that the motor can be driven from a higher rail.

A suggested application is shown in Fig. 4. Allegro Microsystems' UDN2953B (available from Electromail, stock number 653-547) will drive directly motors up to 50V 2A current rating. It possesses pulse width modulation (p.w.m.) capability, which is a way of modulating the current demanded by the motor to maximise efficiency and improve power consumption.

The i.c. senses the current flowing out of the motor via a sense resistor R_{sense} (R2) to 0V. When a set current is exceeded, the supply to the bridge is temporarily interrupted by the i.c. for a matter of microseconds, and thus the

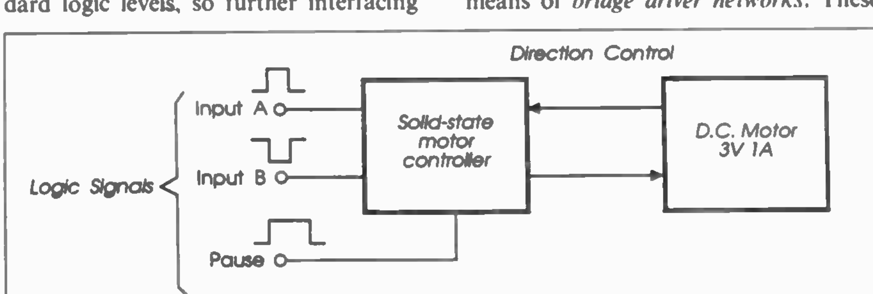


Fig. 1. Block diagram of the required motor controller.

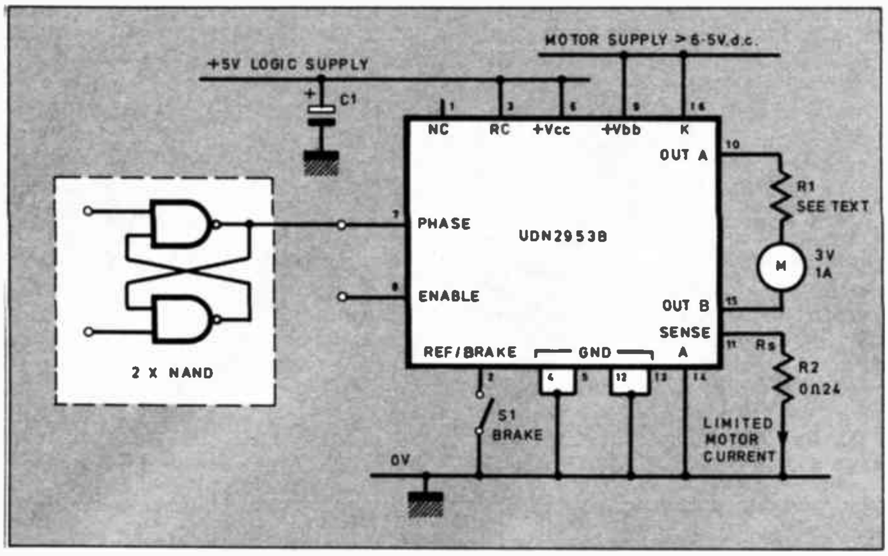


Fig. 4. D.C. p.w.m. current-limited motor controller.

average current to the motor is controlled. The "trip" current in this circuit is 2·5V/10 R_{sense} so I set R2 at 0·24 ohms 0·25W or thereabouts for our 1A motor.

Motor-vated

Other neat features include a "brake" on pin 2 which will effectively short the motor to the main motor supply rail. Connect this pin to 0V and the back e.m.f. generated by the motor will be used to help brake the motor by opposing the "forward voltage" of the motor supply. This feature shouldn't be abused since the i.c. may be damaged if the brake is applied at high motor velocities (when back e.m.f. is highest), so it shouldn't be treated as an "emergency stop".

Similarly, the "phase" control on pin 7 controls the direction of d.c. motors, and this pin is switched between logic high or low as required. Again, sudden switching of the motor at high speeds isn't recommended. The i.c. does include protection diodes but the internal current control circuitry itself doesn't function when the brake feature is used. You have been warned!

The UDN2953B is driven by a standard 5V supply which needs decoupling, hence the electrolytic capacitor C1 which must be placed as close as possible between pin 6 and the 0V connections. The motor voltage dropping resistor is calculated using Ohm's Law and depends on the motor voltage rail used.

I can see no reason why you couldn't drive the motor from the 5V logic rail if it can supply the 1A needed, in which case try a 2Ω 2W series resistor. Current consumption is roughly 20mA for the logic itself.

The i.c. should be soldered directly to a p.c.b. and *large* areas of copper ought to be used underneath to act as a "heatsink" for the central four pins of the d.i.l. package. Maybe use a d.i.l. heatsink too, though the i.c. does have thermal shutdown protection.

Over to you

That's the basic idea – I haven't breadboarded it so you will need to prototype the system yourself, but it is an excellent starting point for further experimentation. Remember this will drive *almost any* d.c. motor up to 50V 2A!

In order to interface it with your own logic system, Andrew, your "pause" control becomes the ENABLE signal. Happily, a high ENABLE signal will stall the motor as per your original requirement.

Since you are toggling *two* inputs from your system (Inputs A and B), you need to use a Set-Reset flip-flop to gate your two input signals into a single high/low signal. Use this to drive the PHASE control of the integrated circuit. The suggested flip-flop is also shown in the circuit diagram. The Truth Table for the device is given below, where X is "don't care".

Table 1: Truth Table for UDN2953B motor controller.

ENABLE	PHASE	BRAKE	OUT A	OUT B	Motor
Low	High	open	High	Low	runs
Low	Low	open	Low	High	reversed
High	X	open	Open	Open	disabled
X	X	Low	High	High	braking

A Data Book which I would recommend is the *Smart Power Application Manual* published by SGS Thomson Microelectronics. This contains several interesting application notes pertaining to the field of motor control. Another Data Book arrived on my desk recently, I can recommend the *Integrated and Discrete Semiconductors* handbook by Allegro Microsystems, this details the UDN2953B motor controller together with the popular UGN- range of Hall effect devices, amongst other products. You can buy this latter book from Farnell of Leeds (Tel. 0532 636311), Stock No. 202-873, £5.00.

Incidentally, since they are appointed distributors for a variety of semiconductor manufacturers, Farnell operate a 24 hour "Dataline" on 0532-310160 which covers their range of semiconductor products. Simply ring and quote the precise and full product name ("2953" won't do!) and they'll send you the manufacturer's Data Sheet free of charge (or so it says in my catalogue).

Ni-Cad charger conversion

Paul Hutchinson of Dunstable is interested in the *Simple Ni-Cad Cell Charger* constructional project (July's issue), and asks:

My main interest is to charge nickel cadmium rechargeable cells from a car or boat 12V d.c. supply and I wondered if it's possible to modify this project, so that it will charge from a 12V battery instead of the mains?

Can it operate (a) with the engine running and (b) with the motor switched off? My knowledge of electronics is limited and I'd welcome any advice.

Converting Steve Knight's mains-powered unit to operation from a 12V battery presents no problem, Mr. Hutchinson – I suggest the following changes:

1. Obviously omit the transformer T1 because you no longer need the a.c. "step down" function. However, if you leave the bridge rectifier in place, you can connect your 12V d.c. battery directly to what was the a.c. input of the bridge rectifier; it will make no difference which way round you connect your 12V battery because the bridge rectifier will "sort out" the polarity for you and will prevent any damage occurring to the regulator i.c. Check out my *Car Electrics Probe (Circuit Surgery*, July issue) and you will see that I did exactly the same thing.

2. The smoothing capacitor C1 can safely be reduced in value to, say 100µF 16V. It's now acting more as a "decoupling" capacitor to help remove noise from the d.c. input.

3. Place a fuse, rated at say 2A, in series with the 12V d.c. input lead. This fuse should be as near as possible to the origin of the 12V d.c. supply, so that the connecting lead receives maximum protection – the fuse's job is of course to melt in case the *cable* (rather than the unit itself) develops a fault, e.g. being severed and shorting to the chassis. As an alternative, you could safely use a *fused* cigar lighter plug if appropriate.

If anything, efficiency will be improved somewhat because the regulator will dissipate less power, since the input voltage is lowered from 17V to 12V-13V. I don't think that there will be any difference in operation when the engine is running or switched off, the alternator may charge the battery at up to nearly 14V but this will not affect the operation of your circuit.

Schools and Clubs

We actively encourage the learning of electronics skills. After all, our younger readers especially are tomorrow's electronics engineers and we need them!

We will do our best to help with any technical queries from those involved in technology and we support the teaching of electronics syllabuses. Our *Circuit*

Surgery Education Service deals with a variety of questions from the education sector from time to time, so feel free to drop us a line with any problems.

If you prefer ***not*** to have your name published, please state this clearly but we do like to share any experiences with readers who may hopefully be inspired by what they read. Also, if any school electronics clubs or groups are looking in, why not drop *Circuit Surgery* a line, tell us how you're doing and we'll give you a mention.

Ingenuity Unlimited

We asked what you thought about our re-introducing the former *Practical Electronics* feature *Ingenuity Unlimited*, and we received a very encouraging response. Amongst others, ***Andrew Hutton*** of Wirral recalled that he was given the 1978 to 1981 *PE* magazines by his school electronics department and found the *Ingenuity* feature very interesting.

Mr. B. Balet of Co. Kerry, Eire thought it was a great pity that the feature had been abolished and would very much like to see its return, a view echoed by ***Rob Ives*** in Maryport, Cumbria. ***Rick Evans*** of Hastings (thanks for the card) said *Ingenuity Unlimited* was sorely missed and ***Tom Baldwin*** of Romsey would be delighted to see its return, he also sent a possible submission, something which quite a few other readers also provided.

Reader ***Neil Johnson*** of Camberley reckons that "readers' own circuits" columns are an increasing rarity and is all in favour of the feature's resurrection. O.K., readers, you're on! *Ingenuity Unlimited* was always a hit feature and now that the *PE* title has been acquired by ourselves, we're delighted to say that *Ingenuity Unlimited* will be returning **next month**. See the announcement in the separate panel, and don't miss it next month!

I'm putting my feet up for a week or two while the *Surgery* goes on holiday. Meanwhile, if you have any topical comments or queries for possible inclusion in *Circuit Surgery*, please write to me: Alan Winstanley, *Circuit Surgery*, at the editorial address. I cannot guarantee to reply individually but will try to offer advice wherever possible.

Inviting Your Unlimited Ingenuity

Readers are invited to submit their own circuit ideas for possible inclusion in the forthcoming series of *Ingenuity Unlimited*. Ideas must be the readers' own work and not already on offer to, or published in, any other publication. We will pay between £10 to £50 for all circuits used depending on length and merit. We're looking for novel applications and interesting circuit tips – *not "electrical" or mechanical ideas.* Please include a brief description, preferably typed or word processed, and draw any diagrams neatly, including all relevant component values.

Send your circuit ideas to: **Alan Winstanley, Ingenuity Unlimited, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF.**

Constructional Project

VISUAL/AUDIO GUITAR TUNER

ROBERT PENFOLD

Be sharp! Tune into the "ring-of-truth" and hit the right note.

THIS guitar tuner for electric guitars is based on the *Visual Guitar Tuner* project which was featured in the June 1987 issue of *Everyday Electronics*. This design was very popular for several years, but is now obsolete because it utilizes a top octave generator integrated circuit which is no longer available.

The present design uses a low power 555 timer i.c. and multiturn presets to produce the six reference notes. This is slightly less convenient in that the six presets must be accurately tuned for the correct frequencies before the unit is ready for use. However, this is not too difficult to achieve, and it means that the circuit uses components that are readily available.

DISPLAY

There are two basic types of electronic guitar tuner. One type has a centre-zero meter which gives a negative indication if the note is flat, or a positive indication if it is sharp. With the correct note the meter reads zero. Tuners in this category are very easy to use, but are relatively complex and do not always offer a very high degree of accuracy.

The alternative form of guitar tuner has a l.e.d. which flashes at a rate that is equal to the difference between the frequency of the reference note and the frequency of the note played on the guitar. The guitar is tuned to give a very low flash rate from the l.e.d.

Devices of this type are usually very simple, and offer a very high degree of accuracy. Tuning errors of well under 1Hz are clearly displayed by the l.e.d. Tuners of this type can be a little awkward to use though, since the direction of the tuning error (sharp or flat) is not indicated.

This guitar tuner gives the best of both worlds by having a flashing l.e.d. display which does indicate whether the tuning error is sharp or flat. The display is actually a ring of eight l.e.d.s. With the guitar accurately tuned, four l.e.d.s in a row will be switched on, the other four l.e.d.s will be switched off, and the display will be stationary.

The block of four l.e.d.s that are switched on will "move" around the display in a clockwise direction if the guitar is slightly *sharp*, or a counter-clockwise direction if it is *flat*. Tuning the guitar to within 0·1Hz is very simple and straightforward, even for someone who is literally tone deaf.

Pressing a push-button switch enables the selected tone to be produced via a built-in ceramic resonator. This enables tuning by ear if preferred, and it is also useful for getting a newly fitted string roughly in tune. The l.e.d. display can then be used to get the string precisely in tune.

SYSTEM OPERATION

The block diagram of Fig.1 helps to explain the way in which the unit functions. A reference oscillator can be set to give one of six frequencies. These reference frequencies are eight times higher than the tones produced by the open strings of a guitar.

The oscillator drives a divide-by-eight circuit, and the main output of this stage drives the ceramic resonator. When activated, the resonator therefore produces tones that are identical to those produced by the open strings of a correctly tuned guitar.

The divider circuit has eight other outputs which go high, in sequence, for one input cycle. These outputs drive the ring of eight l.e.d.s.

The l.e.d.s are therefore switched on, one at a time, in sequence, causing a light to effectively run around the display at high speed. Of course, in practice the display operates at such a high speed that a human observer cannot perceive the action, and all eight l.e.d.s seem to be switched on continuously.

An electronic switch also controls the display l.e.d.s, and no display l.e.d. can light up unless this switch is turned on. The electronic switch is controlled by the input signal via an amplifier stage, and it is turned on during positive input half cycles.

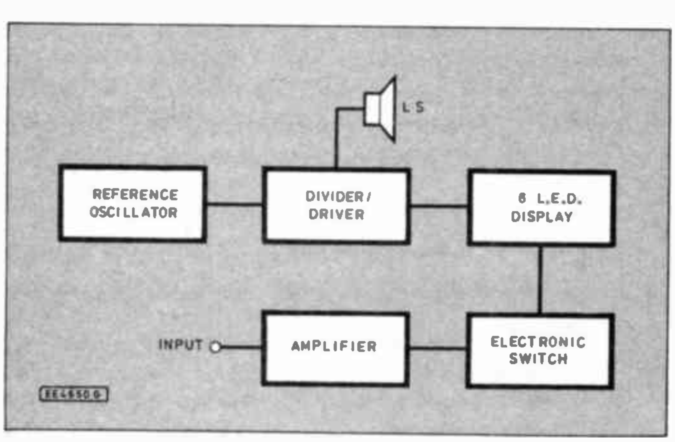


Fig. 1. Block diagram for the Guitar Tuner.

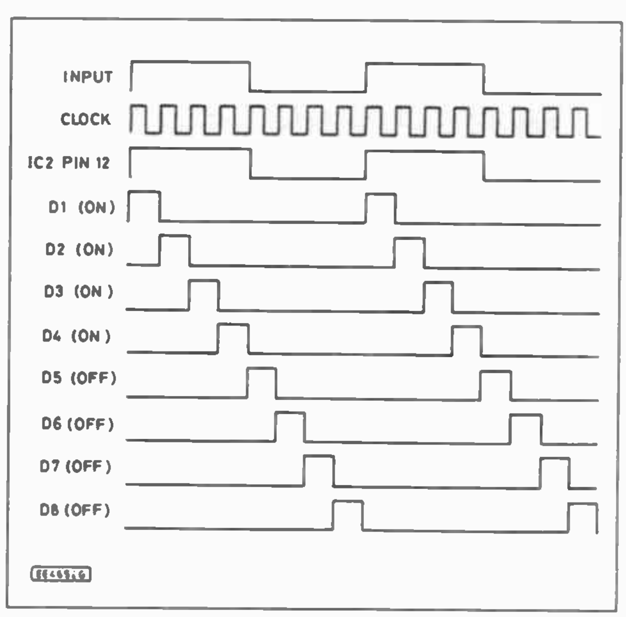


Fig. 2. Waveforms with the input signal and reference tone in-phase.

If the input signal and the divided reference frequency are identical, and in-phase with one another, the electronic switch will be turned on while l.e.d.s one to four are activated, and switched off when l.e.d.s five to eight are activated. Therefore, only l.e.d.s one to four will actually be turned on. The waveform diagram of Fig. 2 should help to clarify this process.

Remember that a display l.e.d. will only be switched on while the input signal is high. It is therefore the polarity of the input signal and the l.e.d. driver signals that are of prime importance.

If the two signals are 180 degrees out of phase, the electronic switch will permit l.e.d.s five to eight to turn on, but will prevent one to four from lighting up. Fig. 3 shows the appropriate waveforms.

Intermediate phase angles give intermediate readings on the display, which acts as a simple phase indicator. Fig. 4 shows the waveforms with the input signal lagging the reference tone by 90 degrees.

Since the display l.e.d.s are in a ring formation, this still gives a block of four l.e.d.s that are switched on. Although the l.e.d.s are actually pulsed on and off at a high rate, to the user they appear to glow continuously.

If the two signals are at the same frequency their relative phasing remains constant, and the display remains stationary. With the two signals at slightly different frequencies they will move in and out of phase, causing the light on the display to rotate as it follows the changes in their relative phasing. The direction of light rotation depends on which signal is at the higher frequency.

CIRCUIT OPERATION

The circuit diagram for the Visual/Audio Guitar Tuner appears in Fig. 5. A low power timer (IC1) is used as the basis of the reference oscillator. Since the output frequency of a 555 astable is almost totally independent of the supply voltage there is no need to use a stabilised supply for the oscillator stage.

Six switched preset potentiometers provide six reference frequencies, and VR1 to VR6 must be carefully adjusted to give precisely the correct output frequencies.

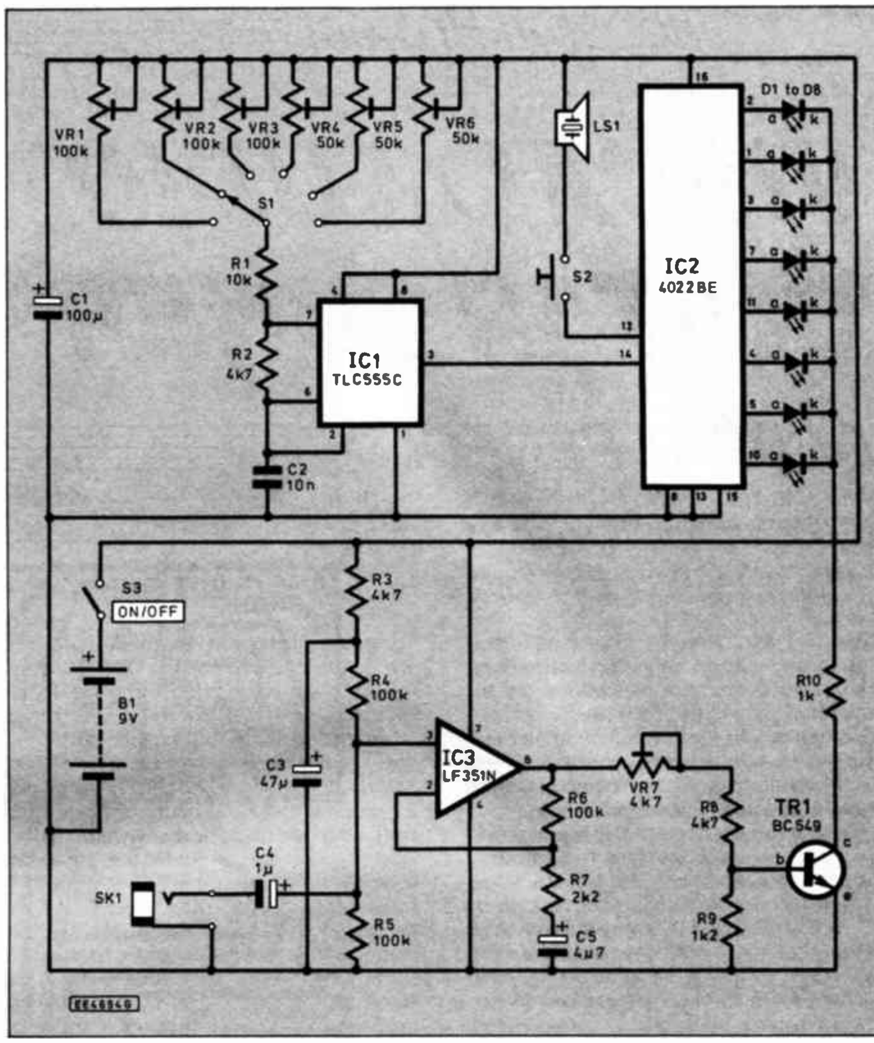


Fig. 5. Complete circuit diagram for the Guitar Tuner.

These presets are actually multiturn types which make it easy to "fine tune" the output frequencies. Multiturn presets also offer good stability.

The divider, decoder, and display driver (IC2) is a CMOS 4022BE, which is very similar to the more familiar 4017BE. The latter will no doubt be familiar to many readers. Whereas the 4017BE provides a divide-by-ten action and incorporates a one-of-ten decoder, the 4022BE gives a divide-by-eight action and incorporates a one-of-eight decoder.

The divided-by-eight signal at pin 12 of IC2 can be connected to ceramic resonator LS1 by pressing push-switch S2. The eight outputs of the decoder/driver are driven via a common current limiting resistor (R10). This is acceptable because only one l.e.d. at a time can be switched on by IC2.

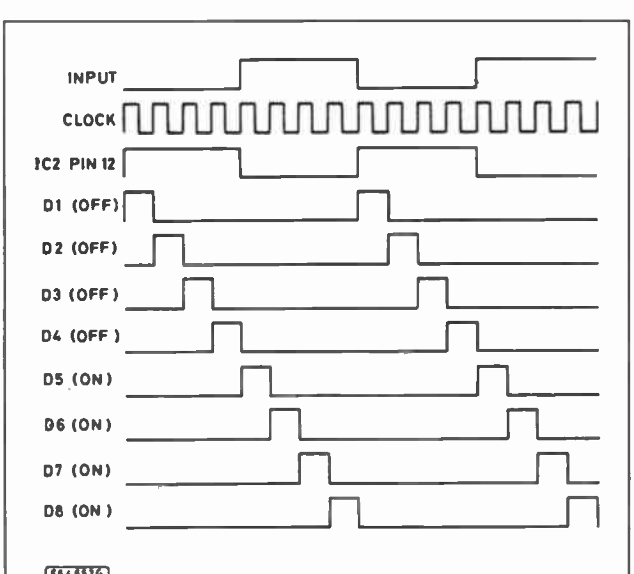


Fig. 3. Waveforms with input signal and reference tone out of phase.

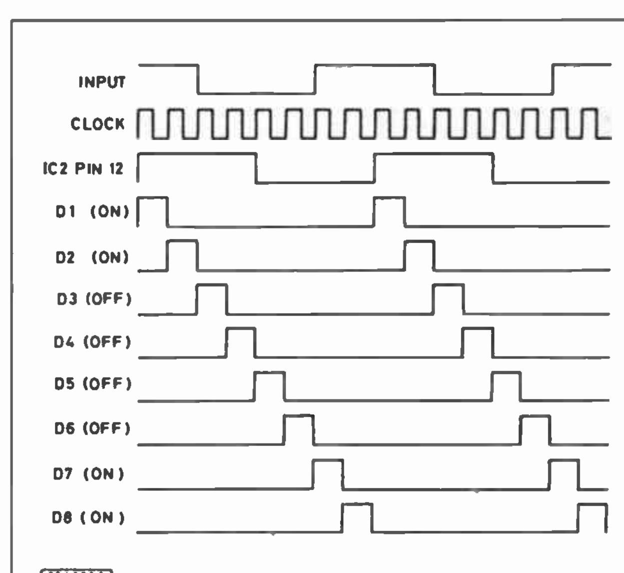


Fig. 4. Waveforms with the two signals 90 degrees out of phase. This still gives a block of four l.e.d.s switched on due to the ring formation of the display.

AMPLIFIER

The amplifier stage uses operational amplifier IC3 in the standard non-inverting mode. Resistors R4 and R5 set the input impedance at about 50 kilohms, which is well suited to most guitar pick-ups. It should also provide quite good results with acoustic instruments via a high impedance dynamic microphone.

Resistors R6 and R7 are the negative feedback network which sets the closed loop voltage gain of the amplifier. The voltage gain is a little under 34dB (50 times). This is adequate to give good results with the vast majority of guitar pick-ups, but with very low output types (and with microphones) it would probably be advantageous to boost the gain slightly by reducing R7 to about one kilohm (1k).

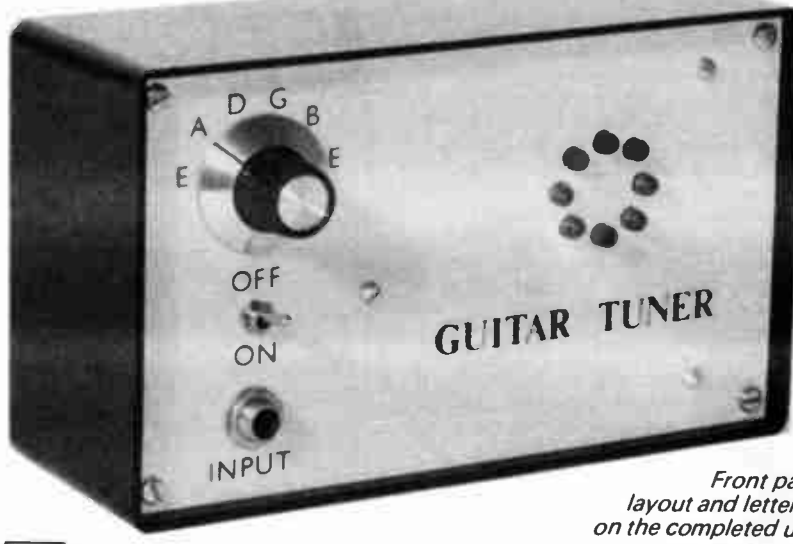
Transistor TR1 is a common emitter switch which controls the l.e.d. display. It is driven directly from the output of IC3, and under standby conditions preset VR7 is adjusted so that TR1 conducts to some extent, but is substantially less than fully switched on.

The signal level at the output of IC3 is normally quite high, and with most guitars clipping will occur until well into the decay section of each note. This results in TR1 being biassed hard into conduction on positive half cycles, and fully switched off on negative half cycles. It therefore switches the display on and off in the required fashion.

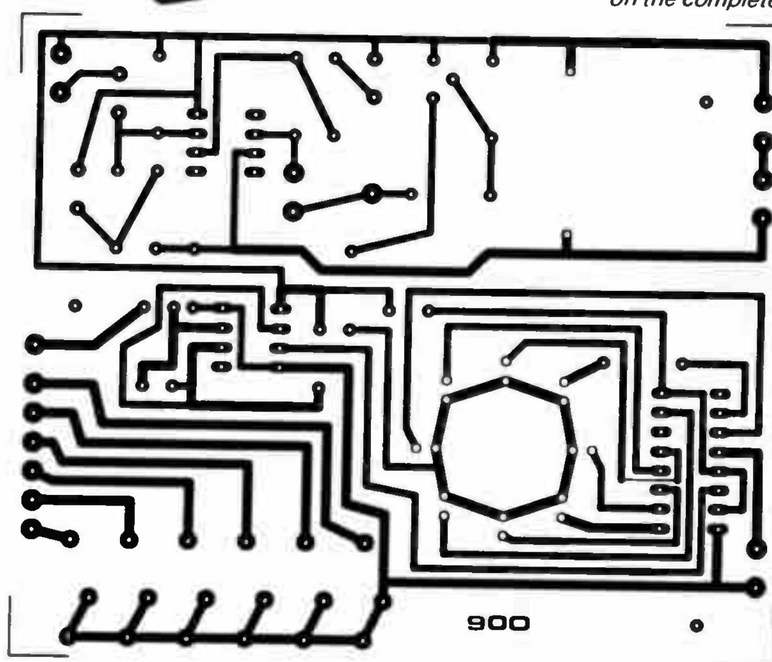
The current consumption of the circuit is about 3·5mA under quiescent conditions, but it is up to about double this figure when an input signal is present. A small (PP3) size battery is therefore adequate to power the unit.

CONSTRUCTION

Apart from the switches, sounder and input jack socket, all components for the Tuner are mounted on a small single-sided printed circuit board (p.c.b.). This board is available from the *EPE PCB Service*, code 900. The p.c.b. component layout and full size underside copper foil master pattern are shown in Fig. 6.



Front panel layout and lettering on the completed unit.



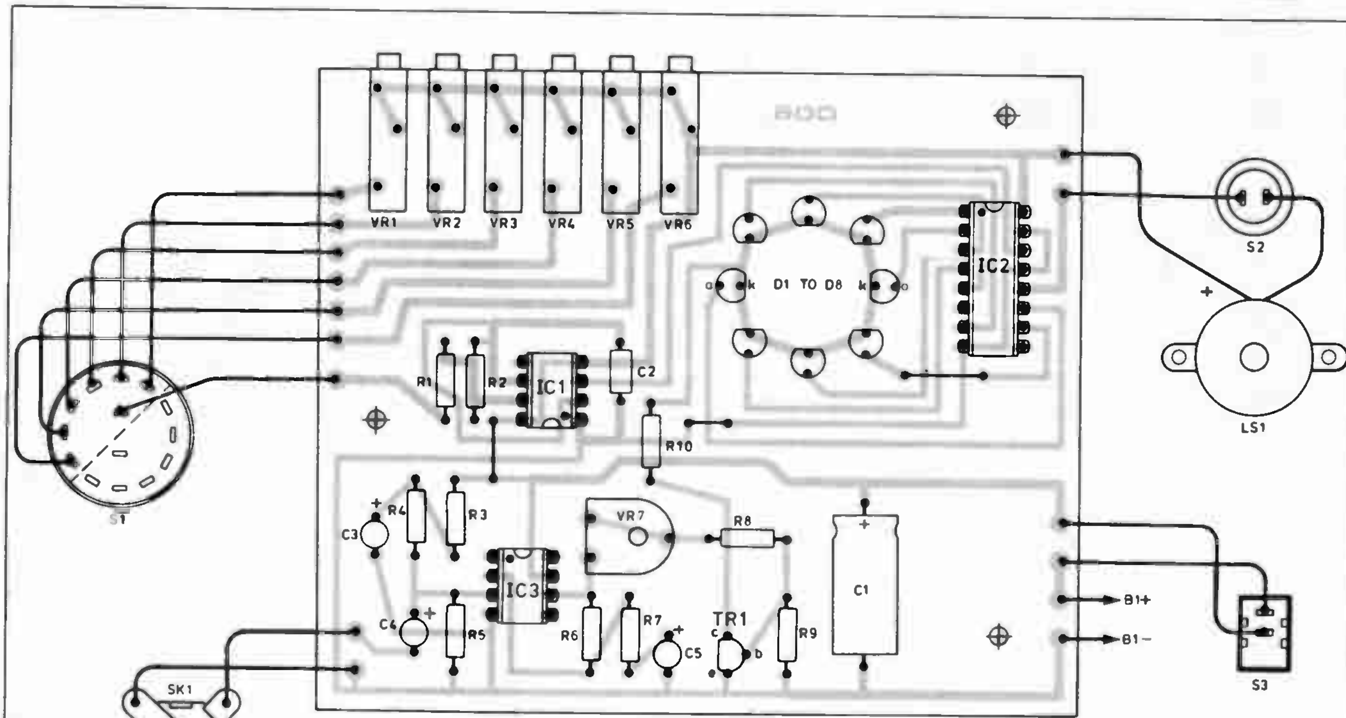


Fig. 6. Printed circuit board component layout and interwiring to the off-board components. The full size copper foil master pattern is shown above.

The divider/driver IC2 is a CMOS integrated circuit, and as such it requires the standard anti-static handling precautions. A holder is therefore essential for this component, and it should not be plugged into place until the board and wiring have been completed.

Although IC1 is a CMOS device and has built-in protection circuits the normal anti-static handling precautions are still necessary. Note that IC1 has the opposite orientation to the other two integrated circuits.

Any *low power* version of the 555 (TLC555C, L555P, etc.) should work well in this circuit. The standard 555 will also work perfectly well, but it would give a much higher current consumption and very short battery life.

Presets VR1 to VR6 must be 18-turn "Cermet" types. Ordinary miniature presets will not fit into the layout correctly, and would be difficult to adjust for precisely the correct reference frequencies.

Three link wires are needed, and these can be made from trimmings from resistor leadout wires. Single-sided solder pins are used on the prototype board at the points where connections to the off-board components are made. However, construction would probably be easier if double-sided pins were used, with the connections made to the underside of the board.

COMPONENTS

Approx cost guidance only **£25**

See SHOP TALK Page

Resistors		
R1	10k	
R2, R3, R8	4k7 (3 off)	
R4, R5, R6	100k (3 off)	
R7	2k2	
R9	1k2	
R10	1k	
All 0·25W 5% carbon film		
Potentiometers		
VR1, VR2, VR3	100k 18-turn cermet preset (3 off)	
VR4, VR5, VR6	50k 18-turn cermet preset (3 off)	
VR7	4k7 min skeleton preset, horiz.	
Capacitors		
C1	100µ axial elect. 10V	
C2	10n polyester	
C3	47µ radial elect. 16V	
C4	1µ radial elect. 50V	
C5	4µ7 radial elect. 50V	
Semiconductors		
D1 to D8	5mm red "high brightness" l.e.d.s (8 off)	

TR1	BC549 *npn* silicon transistor
IC1	TLC555C or similar low power 555 timer
IC2	4022BE CMOS octal counter
IC3	LF351N bifet op.amp
Miscellaneous	
S1	6-way 2-pole rotary switch (only one pole used)
S2	Push-to-make, non-locking push switch
S3	S.P.S.T. min. toggle switch
SK1	Standard jack socket
LS1	Cased ceramic resonator (piezoelectric)
B1	9V battery (PP3 size)

Printed circuit board available from *EPE PCB Service*, code 900; plastic case, with aluminium font panel, size 160mm x 95mm x 57mm; control knob; battery clip; 8-pin d.i.l. socket (2 off); 16-pin d.i.l. socket; connecting wire; ribbon cable; solder; fixings, etc.

DISPLAY L.E.D.s

Although the unit is usable if "bog standard" l.e.d.s are utilized for the display, high brightness l.e.d.s will give much better display brightness. The l.e.d.s are mounted on the circuit board, and should have their leadout wires left quite long.

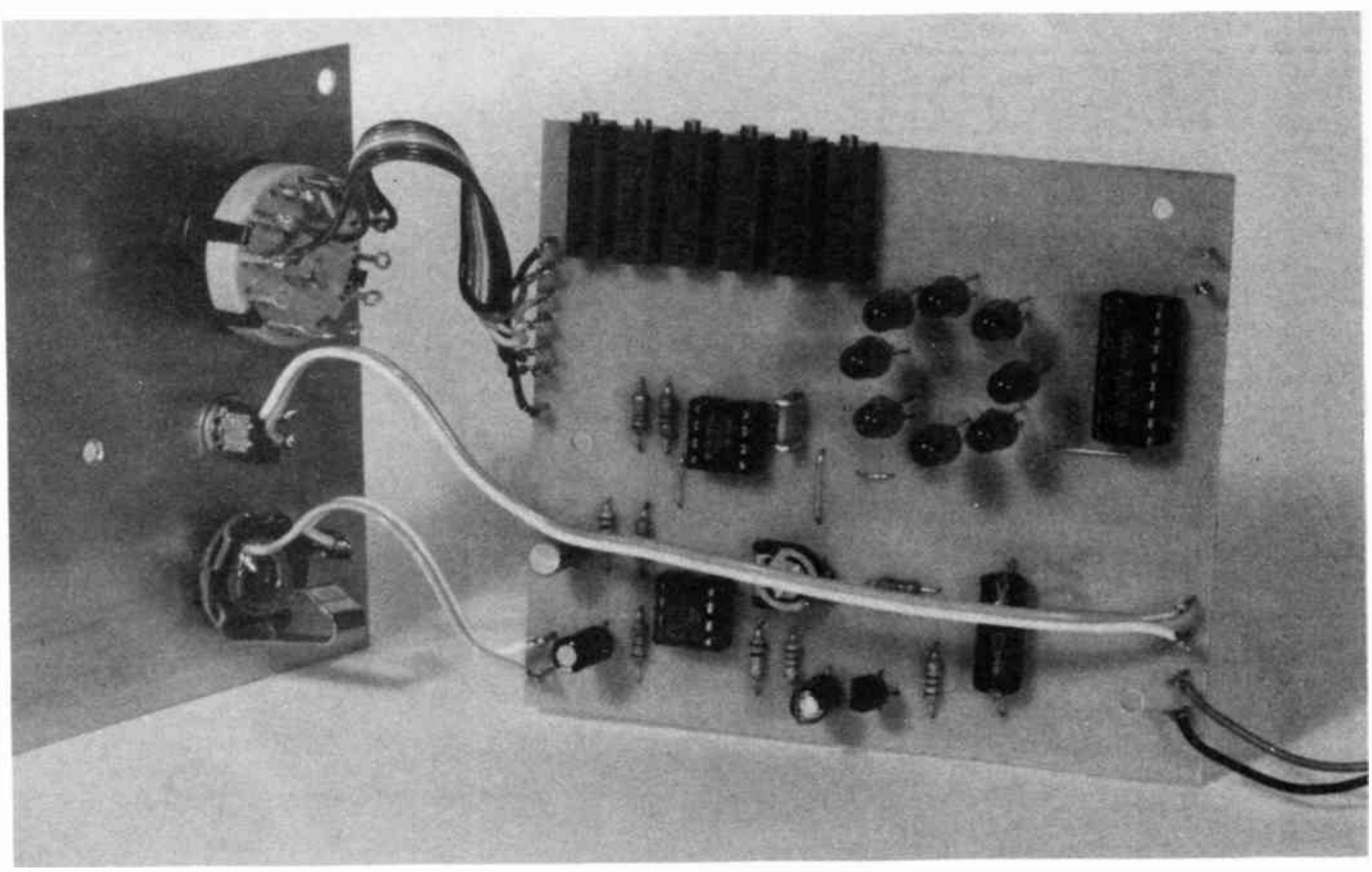
The printed circuit board is mounted on the rear of the aluminium front panel using 6BA or metric M3 fixings. Mount the board with its component side facing forward, and use spacers about 12mm long to hold the board well clear of the front panel. The l.e.d.s fit into holes drilled in the front panel, and their tops must therefore be about 15mm above the top surface of the circuit board.

This method of construction is reliant on the various mounting holes in the front panel being drilled with a fair degree of precision. Probably the best way of achieving this is to use a paper template traced from the printed circuit design. Mount the board on the right hand section of the front panel, leaving room for S1, S3, and SK1 on the left hand section of the panel.

The piezoelectric sounder LS1 and push switch S2 are mounted on the right hand side panel of the case. Most plastic cases have moulded-in guide rails which make it virtually impossible to mount LS1 on the rear surface of the panel. It must therefore be bolted on the outside of the case, using 8BA or metric M2 fixings. These are not normally supplied with the resonator, and must be purchased separately.

A small hole is needed to enable the leadout wires to pass through to the interior of the case. The resonator itself can be used as a printed template when marking the positions of the three mount-

Using coloured ribbon cable to wire the "tuning" switch S1 to the completed printed circuit board (p.c.b.).



ing holes. The sounder LS1 must be a ceramic resonator and not a moving coil loudspeaker. The available drive current is far too low to drive any form of moving coil loudspeaker.

To complete the unit the hard wiring is added. This is illustrated in Fig. 6. "Tuning" switch S1 is a standard 6-way 2-pole rotary type, but in this case one pole is left unused. It can be wired to the printed circuit using ordinary hook-up wire, but it is easier and neater if a piece of seven-way "rainbow" ribbon cable is used.

ADJUSTMENT AND USE

Setting up the unit requires the component board to be temporarily removed from the front panel to provide access to preset VR7. The initial settings of the preset resistors are not particularly important, but it is probably best to start with VR7 at a roughly middle setting.

At switch-on the l.e.d.s in the display will probably switch on to some degree, and it should be possible to control the brightness of the display using VR7. The exact setting of VR7 is far from critical, and any setting which gives fairly low display brightness under standby conditions should give good results. Once VR7 has been given a suitable setting the component board can be remounted on the front panel.

Multiturn presets VR1 to VR6 must be adjusted to give the correct reference frequencies. One way of doing this is to tune the unit by ear against a tuning fork, or any accurately tuned instrument. Pressing switch S2 enables the selected reference tone to be heard, and the appropriate preset resistor is then adjusted for the correct pitch. VR1 is the preset which controls the low "E", running through to VR6 which controls the top "E".

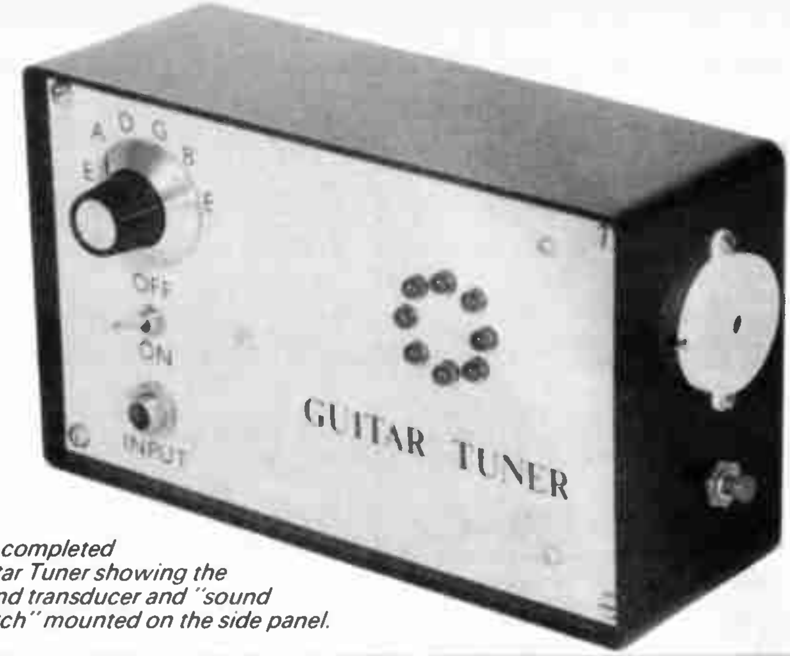
Alternatively, the unit can be tuned against an electric guitar, electronic keyboard instrument, etc. that is *accurately* in tune. It is just a matter of connecting the output of the instrument to the input socket SK1 using a normal jack lead, selecting the required preset using S1, playing the appropriate note, and then adjusting the preset for a stationary display.

OFF-TUNE

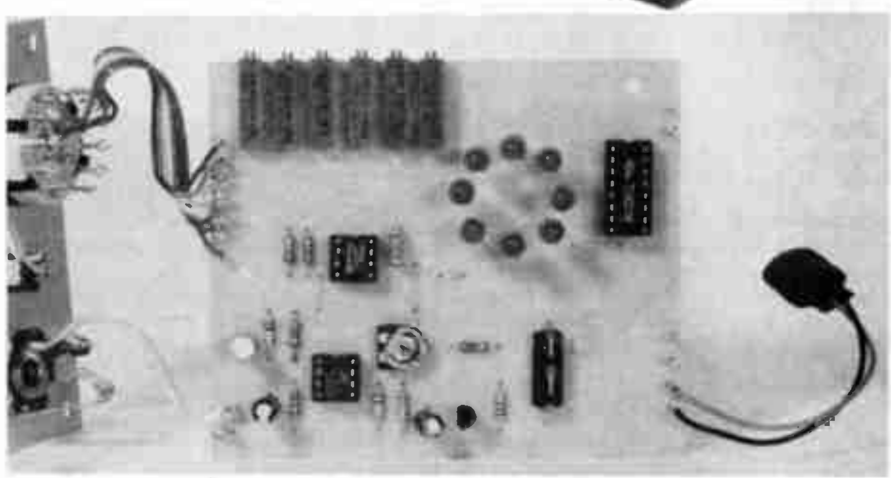
If the reference oscillator is well off-tune, either all the l.e.d.s will appear to light up continuously, or there will be some minor and rather random flashing of the l.e.d.s. For those with a good sense of pitch it might be quicker to use the audio output when getting the oscillator roughly in tune, and to then use the display for the fine tuning.

The input signal will not be a perfectly symmetrical waveform. In fact guitars produce some very odd waveforms during the course of each note. This means that the display might not always give perfect results with four l.e.d.s turned on and four switched off. However, guitar tuners that use l.e.d. displays are very tolerant of unusual input waveforms, and the display should give a perfectly clear indication while the input signal is strong enough.

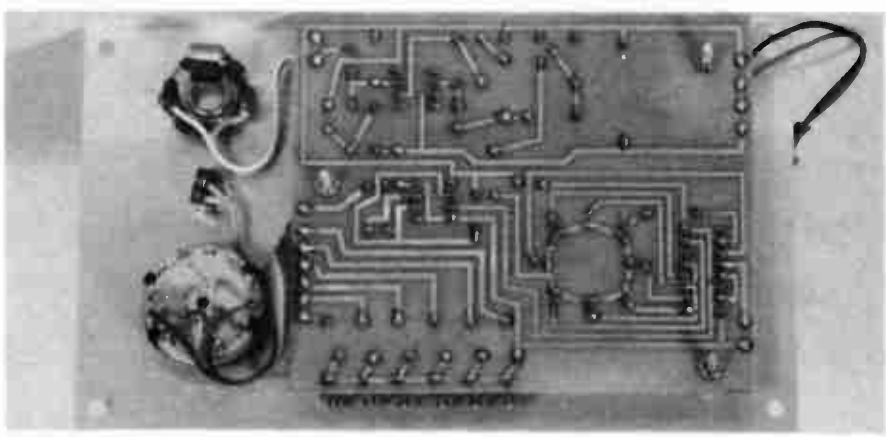
If the display invariably gives unusual results, such as having two sets of two l.e.d.s switched rather than a block of four, this probably means that the reference oscillator is one octave out. The unit is usable with the reference oscillator on the wrong octave, but the display will be clearer if the reference is re-tuned to the correct octave. □



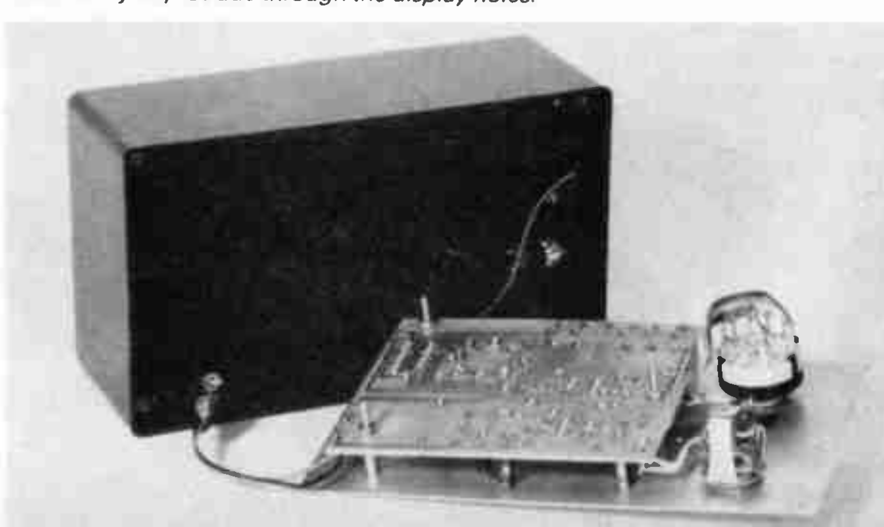
The completed Guitar Tuner showing the sound transducer and "sound switch" mounted on the side panel.



Completed circuit board showing positioning of the "tuning" presets (VR1 - VR6).



The p.c.b. must be positioned to one side to allow space for SK1, S3 and S1. (Below) The p.c.b. is mounted behind the aluminium front panel on spacers so that the l.e.d.s just protrude through the display holes.



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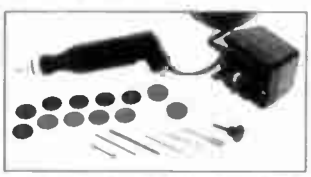

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steel brushes wheel (3)	R182-786	£3.30	£3.02
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brass brushes pencil (3)	R182-809	£3.30	£3.02
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Drive Shaft Diameter 2.4mm Nominal

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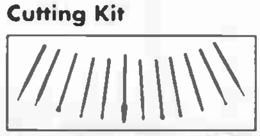
● Cutting Kit



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Mike Tooley, BA

Part 1

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The series has been written by a well known author and regular contributor to *Everyday with Practical Electronics*. Mike Tooley also has twenty-five years of experience in the teaching of electronics. He is Dean of Faculty at Brooklands College of Further and Higher Education in Surrey. His Faculty is responsible for the design and delivery of a wide range of electronics courses leading to NVQ, GNVQ, City and Guilds, and BTEC qualifications.

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Welcome to *Electronics From The Ground Up!* This nine part series aims to provide you with a thorough grounding in electronics and whilst it has been designed as a stand-alone series, it will also complement a formal course in Electronics. To this end, the series covers most of the under-pinning knowledge required for a study of Electronics at the following levels:

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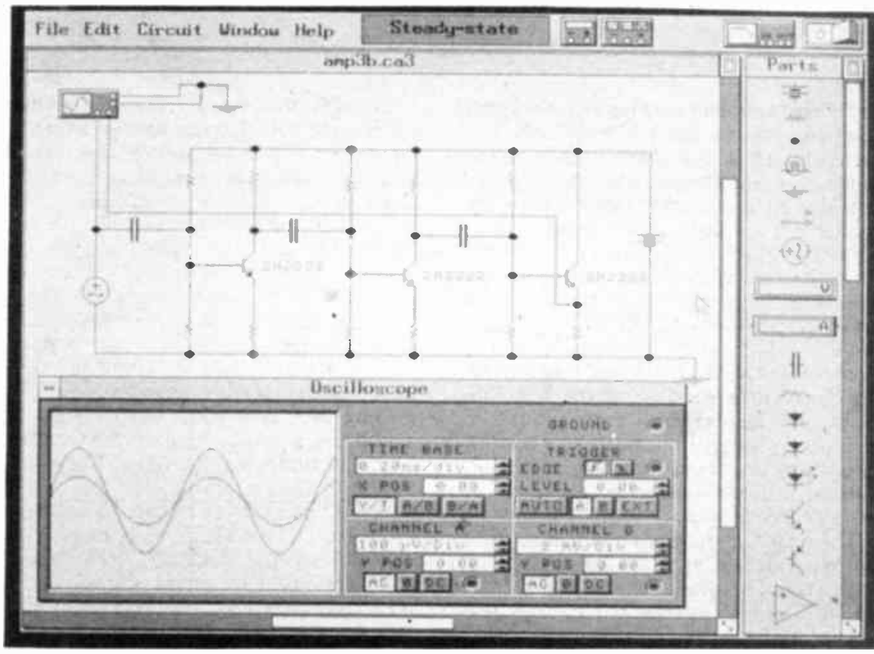


CONTENT

The series has been designed so that each successive part builds on material introduced in the previous parts. The practical assignments are designed to illustrate important concepts and re-inforce topics that may have appeared in earlier parts.

Part One provides a brief introduction to electricity and electronics. We explain how to use *Electronics Workbench* and introduce current, voltage and resistance. The five practical assignments in Part One should help to familiarize you with the techniques for constructing simple circuits and making measurements.

Part Two deals with d.c. and a.c. circuits. We will introduce capacitance and inductance and help you to investigate the behaviour of circuits containing combinations of capacitance, inductance and resistance. We also explain how to use the oscilloscope provided in the *Electronics Workbench* package.

Semiconductor diodes are introduced in Part Three. We investigate the behaviour of half-wave and full-wave rectifiers and develop these into complete power supply circuits incorporating smoothing and voltage regulation. Part Four is devoted to transistors. We explain transistor action and investigate simple amplifier circuits. We also show how transistors can be used in switching circuits.

Operational amplifiers are explained in Part Five. We look at a variety of circuit applications for operational amplifiers and design circuits to provide specific amounts of gain as well as a defined frequency response. We also investigate the use of operational amplifiers as comparators.

Oscillators are described in Part Six. We investigate the behaviour of a variety of oscillator circuits including sinusoidal, pulse and square-wave types. Part Seven is devoted to logic and digital circuits. We explain the basic logic functions and introduce truth tables and Boolean algebra. Digital circuits also feature in Part Eight. Here we introduce bistable elements, counters and shift registers.

Finally, Part Nine provides an opportunity to reflect on the previous eight parts. We explain how to use *Electronics Workbench* to simulate fault conditions and describe basic fault-finding techniques. An overview of the series topics is given in Table 1.1.

INTRODUCING ELECTRONICS WORKBENCH

Electronics Workbench (EWB) is a remarkable new software package that allows you to build and test a wide range of analogue and digital circuits. It is ideal for designing and verifying circuits *before* you reach for the soldering iron or breadboard. The software also makes an ideal learning aid – you can plug and play to your heart's content without ever having to sacrifice a single component.

If your circuit doesn't work first time, you can adjust the connections and component values until it does – without even having to make or break a soldered joint. If you don't happen to have a logic analyser,

TABLE 1.1 SERIES OVERVIEW

1. Introduction

Ohm's Law, current, voltage and resistance. Resistors in series and parallel. Voltage and current dividers. Power and energy.

2. D.C. and A.C. Circuits

Capacitance. Capacitors in series and parallel. Charge and energy. Inductance. Inductors in series and parallel. Induced e.m.f. C-R and L-R circuits. Waveforms. A.C. theory. Voltage and current in C-R and L-R circuits. L-C-R circuits. Resonance.

3. Diodes, Rectifiers and Power Supplies

Diode types and characteristics. Zener diodes. Rectification. Transformers. Half-wave and full-wave rectifiers. Smoothing. Regulators.

4. Transistors: Switches and Amplifiers

Transistor types and characteristics. Current gain. Transistors as saturated switches. Transistors as amplifiers. Common-emitter, common-base and common-collector connections. Single-stage amplifiers. Bias circuits. Gain and temperature stabilization. Two-stage amplifiers. Interstage coupling.

5. Operational Amplifiers

Operational amplifier types and characteristics. Ideal properties of operational amplifiers. Inverting, non-inverting and differential amplifiers. Gain setting. Tailoring the frequency response. Operational amplifier filters. Comparators.

6. Oscillators

Basic concepts. Sinusoidal, pulse and square-wave oscillators. Tuned L-C oscillators. Wien oscillator. Phase-shift (ladder and twin-T) oscillators.

7. Logic

Differences between analogue and digital circuits. Digital signals. Logic levels. Introducing the digital test equipment: word generator and logic analyzer. Logic functions: AND, OR, XOR, NAND, NOR, NOT. Truth tables. Boolean algebra. Logic conversion. Minimization. De Morgan's Theorem. Seven-segment displays.

8. Sequential Logic

Clocks. Bistables: R-S, D-type and J-K flip-flops. Counters and shift registers.

9. Putting it all together

Combining digital and analogue circuits. Using *Electronics Workbench* to simulate fault conditions. Basic fault finding techniques. Voltage measurements. Signal tracing. Analogue fault-finding. Digital fault-finding.

oscilloscope, function generator or digital voltmeter handy, don't worry, *EWB* has them all built in and ready for use at the touch of a key. Furthermore, the displays provided by the on-screen instruments are similar to those that you would get on real equipment.

Electronics Workbench simulates the work area in a real electronics lab. The large central work space works like a breadboard, the parts bin runs along the right-hand side, and the test instruments are stored in a shelf along the top. You build and test circuits entirely on the workbench using the mouse and menus. Everything you need, including a virtually limitless supply of reusable components of every conceivable type, is readily at hand.

There are two program modules, one for analogue circuits and one for digital. The modules are separate but similar and once you've become accustomed to one, you will quickly feel at home using the other.

Electronics Workbench is based on industry-standard SPICE (Simulation Program with Integrated Circuit Emphasis) models for components such as resistors, capacitors, inductors, diodes and transistors. You have complete control over the value of all parts in a circuit, as well as overall parameters of the models. Parameters are very easily changed and you can develop component models to suit your own individual requirements.

Unlike some simulation packages, the *EWB* package uses circuit diagrams rather than abstract netlists – the circuit diagrams look just the same as those you're already familiar with. With some other electronics simulators, you may have to type long lists of circuit nodes as text files. This is both tedious and error prone.

Menus and mouse usage conform to emerging GUI standards (GUI, pronounced "gooey," means "graphic user interface"). The simulated instruments add realism. At your disposal in the analogue version are a digital multimeter, a function generator, and an oscilloscope. For digital circuits you have a voltmeter and a digital word generator.

How to get the best out of the series

The following hints and tips should help you to get the best out of the series:

- When it comes to learning style, there is simply no hard-and-fast rule that can apply to everyone. A regular pattern of learning is, however, most effective. Whether this amounts to thirty minutes a day or three hours at the weekend is purely a matter of personal inclination. It is more important to set a target for the amount of material that you will cover within the time available. Then review this on a regular basis to see what you have *actually* achieved.
- Try to set aside a regular time for study and ensure that this is uninterrupted. Thirty minutes of highly focussed activity can be worth more than a whole day of spasmodic and haphazard study.
- Read *around* the the subject. Visit your local library (or the library in your school or college) and refer to several books rather than just one. Several different explanations of a particular concept will nearly always help to improve your understanding.
- Always make sure that you have read the text *before* attempting to carry out the assignment that relates to it. If you have problems with the assignment, re-read the preceding text.
- Finally, don't give up if you encounter a topic or concept that you don't understand or haven't met before. Inevitably there will be concepts that you might have to take "on trust". After all, you can't see an electron but you witness the effect of a stream of them whenever you sit in front of a TV screen!

THE FULL PACKAGE

The full *Electronics Workbench* comes with a range of support materials, "on-line" help, and a greatly expanded range of components. There is an excellent User's Guide which includes tutorials, a reference section and troubleshooting information. A Quick Reference Card is also supplied. You can use this to get started, or simply keep it by your system as a reference.

Interactive demonstrations (included on the disk) give you a quick overview of the software package and show you how to build and test circuits. Sample circuits (also supplied on the disk) include approximately 80 typical analogue and digital circuits. You can examine, test and modify them or use them as building blocks for your own circuits.

Tutorials are included within the User's Guide. These are invaluable for those who may be unfamiliar with a graphical user interface or who may have had little or no experience of building and testing electronic circuits. For registered users, there is the User Support "help-line". A Bulletin Board Service (BBS) is also available to provide the latest product information. Users can leave questions for answer via the BBS and circuits may be down or up-loaded for sharing with other users.

Ordering information for the full package is given at the end of this article.

START-UP OPTIONS

When you start *EWB* you have a number of options available apart from selecting either the analogue or the digital environment. If your computer has at least two megabytes of RAM, you can make the most of the extra memory by running the software in "protected" mode. Note, however, that it may run slowly in protected mode if your computer's extra memory is in the form of an expansion card. If so, you may prefer to force *EWB* to use real mode.

Another start-up option allows you to specify which set of schematic symbols (either ANSI or DIN) to use with the package. This then becomes the default symbol set, used whenever you start *EWB*.

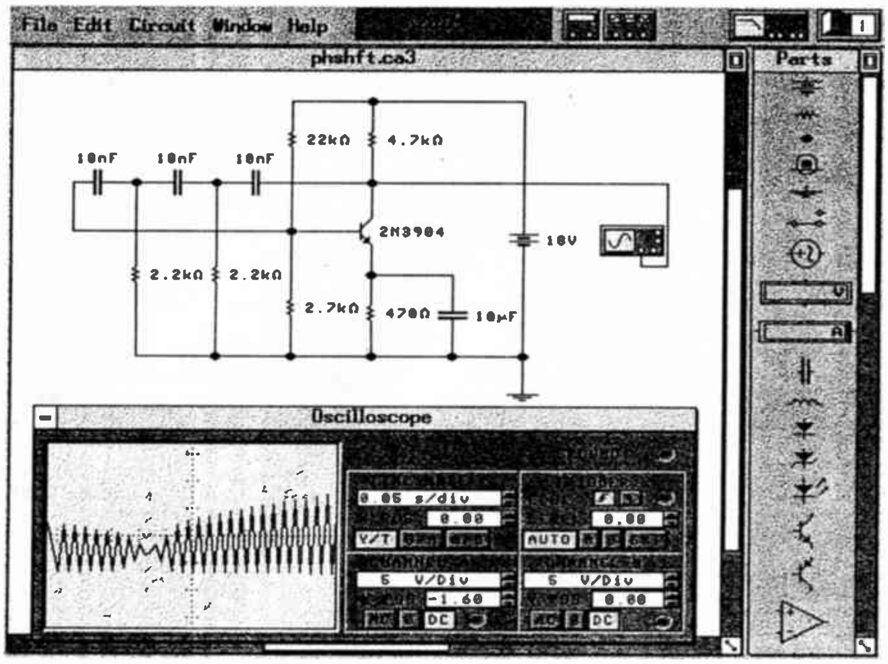


Fig. 1.1. A typical Electronics Workbench display.

POINT AND SHOOT...

EWB has a first class context-sensitive help system which, like most of today's GUI software packages, can be accessed using pull-down menus and windows. Even more useful, however, is the ability to move the mouse pointer over a component, click the left button (the selected component turns red), press F1 and, hey presto, a window will appear telling you about the component. As with the main help system, further options can be selected by simply clicking on the highlighted keywords. This simple yet elegant help system makes the software a joy to use and is perfect for the newcomer to electronics.

Having found out about the component, you might want to alter its parameters. You do this by double clicking the left mouse button. When you do this, a small window appears which allows you to set component values, voltages, frequencies, etc, as appropriate to the item concerned.

A wide choice of printing facilities is offered in the full version. You can print the current display (exactly as it appears on your computer's screen) or print out circuit descriptions, component lists, parameters associated with the component models, circuit diagrams, and test equipment displays. You can also convert your display into a PCX file for loading into one of many popular paint, graphics, CAD or DTP packages.

Electronics Workbench is copy protected and must be uninstalled if you wish to move the software to a different platform. However, if you want to use it at two different locations (for example, at work and at home), you need not delete all the files when uninstalling, just the authorization code.

SYSTEM REQUIREMENTS

To install and run *EWB*, you will require an IBM PC-AT, PS/2, or compatible with a 286 or higher processor. The PC should have a hard disk, at least 1MB of RAM and a Microsoft compatible pointing device (e.g., a mouse). You will require EGA or VGA graphics and DOS 3.3 or later. The software will make use of a maths co-processor, where available.

The full version needs a minimum of 4MB of hard disk space (more if you are using the MS-DOS 6.x double-space utility). You will also require a minimum of 550K RAM to run the program and you may have to modify your configuration files (CONFIG.SYS and/or AUTOEXEC.BAT) to release more base memory. Most good books and manuals on using DOS will tell you how to do this.

INSTALLING THE SOFTWARE

In order to get you off to a quick start (and to allow you to evaluate the package), Robinson Marshall and Interactive Image Technologies have kindly agreed to make a cut-down version of their software available to readers, this is contained on the disk presented FREE with this issue. This version is fully functional but only contains a sub-set of the features of the full package. In particular, the number and variety of components has been limited to just those devices needed to support the first two parts of our series. For a minimal outlay readers can upgrade the package to cover the whole series – see the order form at the end of this article.

To install the software, you should start up your system from DOS (not Windows), insert the distribution disk in the A: drive and type:

a:install

followed by <ENTER>. Then follow the directions on the display. *Electronics Workbench* will be placed in a directory called ELECT in the root directory of drive C: (unless you specify a different drive or directory).

When you install the program, you will be asked to specify either ANSI or DIN symbols. We recommend that you select the ANSI symbols.

To start Electronics Workbench you should move to the directory in which the program has been installed and then type:

elect

followed by the <ENTER> key.

As an example, let's assume that you have installed *Electronics Workbench* in a directory called ELECT on drive C:. You can start the program by typing:

c:<ENTER>
cd elect<ENTER>
elect

FINDING THE RIGHT PATH...

If you want to run *EWB* from anywhere in your system, you should specify its directory path in your AUTOEXEC.BAT file. You can do this by using the DOS PATH command. For example, to direct DOS to look for *EWB* in the ELECT directory on drive C:, add the following statement to your AUTOEXEC.BAT file:

path c:\ elect

If your AUTOEXEC.BAT file already has a PATH statement, you can simply add the appropriate directory, editing AUTOEXEC.BAT from a text editor or word processor operating in ASCII mode. Simply add a semicolon (;) to the end of the PATH statement and then type the directory after it, as shown in the following example:

Unmodified path statement:
path c:\ ;c:\ dos;c:\ util
Modified path statement:
path c:\ ;c:\ dos;c:\ util;c:\ elect

SCREEN LAYOUT

When you first load *Electronics from the Ground Up* you will be presented with a screen which contains the following items:

- Menu Bar (running along the top of the screen and starting from the top left-hand corner). The Menu Bar contains three drop-down menus accessed by pointing and clicking the mouse. These menus are entitled; Assignment, Circuit and Help.
- A window containing a brief description of the currently loaded assignment. If you need more workspace you can close this window by clicking on the "close window" icon in the top left hand corner of the "Description" window.
- The on/off Rocker Switch positioned in the top right-hand corner of the screen. This switch is operated to activate your circuit.
- The Parts Area. This is a storage area for the parts that you use to assemble your circuits. The parts area also contains power sources, voltmeters, ammeters, and other test instruments.
- The Breadboard Area (or "work space"). This forms the major part of the screen and it comprises an area in which you construct your circuits. The work space is, in fact, larger than the displayed area on your screen and you can scroll left and right or up and down by activating the relevant scroll bars with your mouse.

Note that the full version of *Electronics Workbench* has numerous refinements and added facilities including a Parts Bin and Test Instrument "Shelf". A typical *EWB* display, complete with a circuit and "virtual test instrument" is shown in Fig. 1.1.

BUILDING AND TESTING CIRCUITS

One of the most important features of *EWB* is the ease by which circuits can be assembled on the breadboard. There are several stages to this process:

1. Selecting the required components from the parts bin

2. Placing the components within the breadboard area
3. Changing component values (from their default values to those that are required by the circuit under investigation). This facility is *only* available in the full *EWB* package
4. Making connections between components
5. Placing test instruments (as required)
6. Refining the layout (i.e., moving the components and test instruments so that the symbols, component legends, and wiring all fit neatly and logically within the breadboard area)
7. Testing, refining and evaluating your circuit.

THE PARTS AREA

The parts area is your source of components. Unlike a real parts bin, you can use components over and over again. Furthermore in the full package, when you have selected a particular component type you can *allocate a value* to it – you are not restricted to the particular values that just happen to be available at the time. If you choose a value but decide that you need to change it, you don't have to go back to the parts bin!

In the evaluation package, the parts bin does not appear as a separate entity. Instead, the parts you need are pre-loaded into the breadboard area for each individual practical assignment. The components provided are sufficient for you to get familiar with using *EWB* and they will allow you to carry out all of the practical assignments.

SELECTING AND PLACING COMPONENTS

Selecting and placing components couldn't be easier once you've got the hang of it. Changing component values is also very straightforward.

It may take you a little while to become familiar with the techniques for laying out your circuits neatly. This doesn't matter too much at first but as your circuits get more complex it becomes increasingly important to ensure that your layout is clear and logical. This can avoid all sorts of problems associated with what is rather aptly described as "rat's nest" construction!

To select a component (prior to placing it) you simply need to move the mouse pointer over it. As you do this the mouse pointer arrow will change to a pointing finger. When this happens, simply press the left mouse button and drag the symbol of the component within the breadboard area.

You can "drop" the component at any point within the breadboard area by releasing the left mouse button. The component will remain fixed at the point that you released the mouse button but will have turned red, indicating that it is "selected". The component will remain selected until you next click the left mouse button.

Having placed a component, the following operations can be performed when the component is in its selected (red) state:

- Pressing <CTRL> <R> (i.e., first press and hold down the "Control" key and then press the "R" key) will rotate the selected component symbol through 90 degrees
- Pressing the left, right, up or down arrow keys will produce a corresponding movement in the position of all of the currently selected components.

MAKING CONNECTIONS TO COMPONENTS

Each of the components has two or more connecting points. These points (or terminals) comprise short wires that protrude from the component's symbol.

When a component has been dragged into position, you can attach connecting wires to the terminals by selecting a terminal with the mouse (the terminal will become highlighted), pressing the left mouse button and dragging the mouse. As you do this, a connecting wire will be drawn in the breadboard area.

LINKING COMPONENTS

In order to link two components together, you should drag the end of the connecting wire and locate it with the appropriate terminal of another component. However, if you leave the wire unconnected (i.e., you fail to locate the wire with a terminal point on another component or a four-way connector) the connection *will not be drawn* (an unconnected wire will not serve any useful purpose and thus it will not be treated as valid).

DISCONNECTIONS

If you wish to disconnect a wire, you need only point to the terminal in question, drag the wire away, and leave it unconnected. It will automatically be erased from the screen.

MULTIPLE CONNECTIONS

Simple circuits can be wired using simple wire connections that link one component to the next. More complex circuits may require multiple connections to a single component and *EWB* provides you with a junction connector to help in this task. The junction connector looks like a small round blob in the parts bin. You can use it to join together up to four wires (think of it as a terminal post with several wires clamped to it).

HELP

Remember that you can press F1 for help at any time or select from the "Help" dropdown menu. You can then simply point and click on the blue highlighted help topics for detailed information.

ELECTRONICS FUNDAMENTALS

Current, Voltage and Resistance

Electrical current is the name given to the flow of negative charge carriers called electrons. Electrons orbit around the nucleus of an atom just as the earth orbits around the sun (see Fig. 1.2). Electrons are held in their orbital paths by their attraction to the positive nucleus, which contains the positive charge carriers called protons. Since like charges repel and unlike charges attract, negatively charged electrons are attracted to the positive nucleus. This same principle can be demonstrated by observing the attraction between two permanent magnets; the two north poles of the magnets will repel each other, while a north and south pole will attract. In the same way, the unlike charges of the negative electron and the positive proton attract one another.

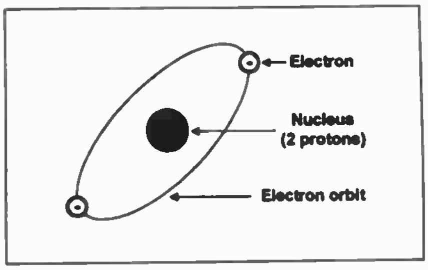


Fig. 1.2. An atom of helium showing electrons in orbit around the nucleus.

The ability of an energy source (e.g. a battery) to produce a current within a conductor is a measure of its electromotive force (e.m.f.). Whenever an e.m.f. is applied to a circuit a potential difference (p.d.) exists. Both e.m.f. and p.d. are measured in volts (V). In many practical circuits there is only one e.m.f. present (the battery or supply) however a p.d. will be developed across each component in the circuit.

The conventional flow of current in a circuit is from the point of more positive potential to the point of greatest negative potential (note that electron movement is in the opposite direction!). Direct currents result from the application of a direct e.m.f. (derived from batteries or d.c. supply rails). An essential characteristic of such supplies is that the applied e.m.f. does not change its polarity (even though its value may be subject to some fluctuation).

Fig. 1.3 shows a simple electric circuit in which a single source of e.m.f. (the battery) produces a current which flows in a resistor. The conventional flow of current is from the positive battery terminal through the connecting wire and the resistor, ending at the negative terminal of the battery.

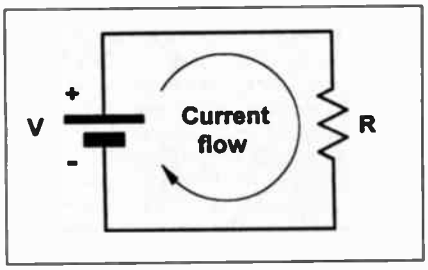


Fig. 1.3. A simple electric circuit.

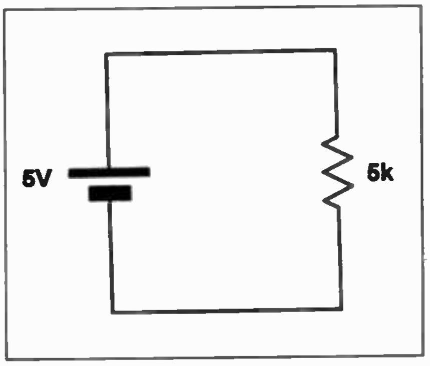


Fig. 1.4. Circuit for assignment 1.1

Practical assignment 1.1: Finding your way around

In this first assignment, you will build a simple circuit with just two components; a battery and a resistor (as shown in Fig. 1.4).

Objectives:

1.1.1 To introduce students to the techniques used for selecting and placing components

1.1.2 To introduce students to the techniques for changing component values
1.1.3 To introduce students to the techniques for wiring and laying out circuits
1.1.4 To introduce students to the use of a voltmeter and ammeter.

Instructions:

1. Selecting and placing the components

Start *Electronics Workbench* in the normal way by typing ELECT at the DOS prompt. The assignment will start automatically. View the parts that appear pre-loaded in the breadboard window and use the mouse to select the battery symbol. Drag the battery and place it slightly to the left of the centre of the breadboard area. When you have placed the battery, return to the parts area and select a resistor. Drag the resistor and place it slightly to the right of the centre of the breadboard area. Whilst the resistor is selected, press <CTRL> <R> to rotate it through 90°.

2. Moving the components

Point to the centre of the battery symbol using the mouse pointer. The battery symbol should turn red and should move as you move the mouse pointer within the breadboard area. Use this technique to increase the spacing between the battery and the resistor, at the same time keeping them aligned in the horizontal plane.

3. Changing component values

NB: This facility is only available if you are using the full *Electronics Workbench* package.

Once again point to the centre of the battery symbol. This time, click the left button on the mouse. A dialogue box will appear on the screen. The default battery voltage (12V) will appear within a text window in this box. Use the keyboard to edit the text and reduce the battery voltage to 5V (see Fig. 1.5).

Now point and click on the resistor symbol. A dialogue box will again appear. This time, change the default value of 1Ω to give a value of 5kΩ. To do this, enter "5" in the left-hand text box and use the scroll arrows in the right-hand box to select "kΩ".

4. Connecting the components

Move the mouse pointer so that it points to the positive terminal of the battery. When you have located this "hot spot", the terminal will become highlighted. When this happens, press and hold down the left button of the mouse and drag out a connecting wire. Move this wire (keeping the left mouse button held down) and locate it with the upper terminal of the battery.

Once again, the "hot spot" on the battery terminal should become highlighted. When this occurs, release the left mouse button. *Electronics Workbench* will re-draw the connection between the battery positive terminal and the resistor using neat right angles at each end. Using a similar technique, link together the negative terminal of the battery to the lower terminal of the resistor. When you have completed this process your breadboard area should look something like that shown in Fig. 1.6.

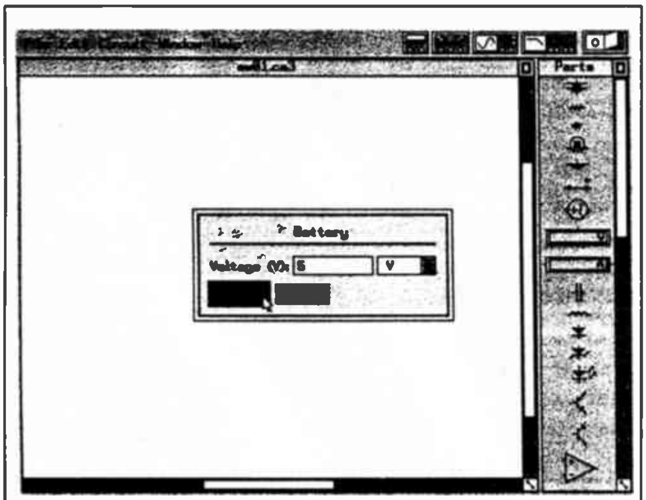


Fig. 1.5. Dialogue box to set the battery voltage.

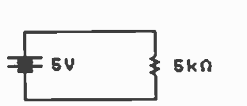


Fig. 1.6. Part completed circuit for assignment 1.1.

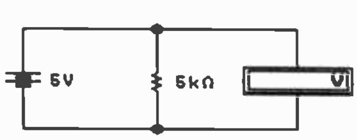


Fig. 1.7. Circuit for assignment 1.1 with a voltmeter added.

Table 1.2 Electrical units and symbols

Unit	Abbrev.	Symbol	Notes
Ampere	A	I	Unit of electric current (a current of 1A flows in a conductor when a charge of 1C is transported in a time interval of 1s).
Coulomb	C	Q	Unit of electric charge or quantity of electricity.
Farad	F	C	Unit of capacitance (a capacitor has a capacitance of 1F when a charge of 1C results in a potential difference of 1V across its plates).
Henry	H	L	Unit of inductance (an inductor has an inductance of 1H when an applied current changing uniformly at a rate of 1A/s produces a potential difference of 1V across its terminals).
Hertz	Hz	f	Unit of frequency (a signal has a frequency of 1Hz if one complete cycle occurs in a time interval of 1s).
Joule	J	E	Unit of energy.
Ohm	Ω	R	Unit of resistance.
Second	s	t	Unit of time.
Siemens	S	G	Unit of conductance (reciprocal of resistance).
Tesla	T	B	Unit of magnetic flux density (a flux density of 1T is produced when a flux of 1Wb is present over an area of 1 square metre).
Volt	V	V	Unit of electric potential (e.m.f. or p.d.).
Watt	W	P	Unit of power (equal to 1J of energy consumed in a time of 1s).
Weber	Wb	Φ	Unit of magnetic flux.

5. Adding a voltmeter

The basic circuit is complete but we can't find out what's going on without adding some simple instruments. We will start by adding a voltmeter to the circuit in order to read the voltage drop across the resistor. To do this, we will have to add two junction connectors to the circuit. To make things a little easier, we will first remove the two connecting wires.

Use the mouse pointer to select the hot spot at the top end of the resistor. When you have located it, press the left mouse and move the end of the connecting wire away from the resistor. Then release the left mouse button so that the connection is removed from the screen. Repeat this process at the lower end of the resistor. This should leave the breadboard containing only the symbols for the battery and the resistor.

Now return to the parts area. Use the mouse to select and place two junction connectors, one at either end of the resistor. These should be separated from the resistor terminals but vertically aligned with the resistor symbol. Now place connections from each end of the resistor to its respective junction connector. Next connect the positive terminal of the battery to the upper connector and the negative terminal to the lower connector. In each case, make use of the left-hand terminal (hot spot) of the connector.

Finally, select the voltmeter and drag this to the right of the resistor. Connect the voltmeter to the right-hand terminal (hot spot) of the connector. (Note that the negative terminal of the voltmeter is at the slightly thicker end of the symbol). Your circuit should now look like that shown in Fig. 1.7.

6. Testing

To test the circuit you must operate the switch that appears on the right-hand side of the menu bar. You can operate this switch by clicking the mouse pointer on it. When the switch is operated, the circuit will become 'live' and the voltmeter should indicate the voltage drop that appears across the resistor. The meter should read "5V" (if it doesn't you should check carefully that your circuit conforms to that shown in Fig. 1.7).

ELECTRICAL UNITS AND SYMBOLS

The units and symbols shown in Table 1.2 are commonly encountered in electrical circuits:

Example

In a time interval of 10s, a charge of 5C moves past a point in a circuit. What current (in A) is flowing?

In this example the charge is expressed in Coulombs (C) and the time is in seconds (s). Table 2 tells us that a current of 1A flows in a conductor when a charge of 1C is transported in a time interval of 1s. Hence, if 5C move past a point in 10s, the current will be equivalent to 5C/10s or 0·5A.

MULTIPLES AND SUB-MULTIPLES

Unfortunately, many of the derived units are somewhat cumbersome for everyday use. We can make life a little easier by making use of a standard range of multiples and sub-multiples (see Table 1.3).

Table 1.3 Multiples and sub-multiples

Prefix	Abbrev.	Multiplier
tera	T	1000000000000
giga	G	1000000000
mega	M	1000000
kilo	k	1000
(none)	(none)	1
deci	d	0·1
centi	c	0.01
milli	m	0.001
micro	µ	0.000001
nano	n	0.000000001
pico	p	0.000000000001

Example

An amplifier requires an input signal of 0·25V. Express this in mV.

We can express the voltage in mV (rather than V) by simply moving the decimal point three places to the right. Hence 0·25V is the same as 250mV (note that we have introduced a trailing zero).

Example

A light emitting diode requires a supply current of 15mA. Express this in A.

We can express the current in A (rather than in mA) by simply moving the decimal point three places to the left. Hence 15mA is the same as 0·015A (note that we have introduced zeros before and after the decimal point).

Example

An oscillator produces an output at 425kHz. Express this frequency in MHz.

To express the frequency in MHz rather than kHz we need to move the decimal point three places to the left. Hence 425kHz is equivalent to 0·425MHz (note, once again, that we have introduced a leading zero).

EXPONENT NOTATION

Exponent notation is frequently used in order to simplify the manipulation of very large or very small quantities. Any number may be expressed in exponent form by separating it into two parts comprising a number (often in the range 1 to 10) and a multiplier consisting of ten raised to an appropriate power. Here's how it works:

Consider the number 3765. This can be expressed as 3.765 × 1000. Now 1000 is

Table 1.4 Exponent notation

Quantity	Exponent
1,000,000	1×10^6
100,000	1×10^5
10,000	1×10^4
1,000	1×10^3
100	1×10^2
10	1×10^1
1	1×10^0
1/10 (=0.1)	1×10^{-1}
1/100 (=0.01)	1×10^{-2}
1/1,000 (=0.001)	1×10^{-3}
1/10,000 (=0.0001)	1×10^{-4}
1/100,000 (=0.00001)	1×10^{-5}
1/1,000,000 (=0.000001)	1×10^{-6}

the same as 10^3 (i.e. ten multiplied by itself three times, or 10 × 10 × 10). Hence 3765 = 3.765 × 10^3. Note that the exponent is 3 (or more strictly +3).

Now consider the number 0.00245. This is the same as 2.45/1000. Now 1/1000 is the same as 10^{-3} (i.e. one divided by ten multiplied by itself three times, or 1/(10 × 10 × 10)). Hence 0.00245 = 0.00245 × 10^{-3}. Here the exponent is −3.

·Table 1.4 shows the exponent notation for some common quantities in decade steps.

Example

A current of 0.07A flows in a resistance of 390,000Ω. Express both quantities in their exponent forms.

The current is expressed in exponent form as follows:

$$0.07\text{A} = \frac{7}{100}\text{A} = 7 \times 10^{-2}\text{A}$$

The resistance is expressed in exponent form as follows:

$$390{,}000\Omega = 3.9 \times 100{,}000\Omega = 3.9 \times 10^5\Omega$$

MULTIPLYING AND DIVIDING USING EXPONENTS

Exponents really become useful when you have to perform calculations based on very large or very small numbers. Two rules are worth knowing:

(a) Multiplication using exponents

When multiplying two values which are expressed using exponents, it is simply necessary to add the exponents. As an example:

$$(2 \times 10^2) \times (3 \times 10^6) = (2 \times 3) \times 10^{(2+6)} = 6 \times 10^8$$

(b) Dividing using exponents

When dividing two values which are expressed using exponents, it is simply necessary to subtract the exponents. As an example:

$$(4 \times 10^6) \div (2 \times 10^4) = 4/2 \times 10^{(6-4)} = 2 \times 10^2$$

Note that, in either case it is essential to take care to express the units, multiples and sub-multiples in which you are working.

OHM'S LAW

For any conductor, the current flowing is directly proportional to the e.m.f. applied. The current flowing will also be dependent on the physical dimensions (length and cross-sectional area) and material of which the conductor is composed.

The amount of current that will flow in a conductor when a given e.m.f. is applied is inversely proportional to its resistance. Resistance, therefore, may be thought of as an opposition to current flow; the higher the resistance the lower the current that will flow (assuming that the applied e.m.f. remains constant).

Provided that temperature does not vary, the ratio of potential difference (or voltage drop) across the ends of a conductor to the current flowing in the conductor is a constant. This relationship is known as Ohm's law and this leads us to the conclusion that:

$$V/I = \text{a constant} = R$$

where V is the p.d. in volts (V), I is the current in amps (A), and R is the resistance in ohms (Ω) (see Fig. 1.8).

The formula may be arranged to make V, I or R the subject, as follows:

$$V = I \times R \quad I = V/R \quad \text{and} \quad R = V/I$$

The triangle shown in Fig. 1.9 should help you to remember these three important relationships. It is important to note that, when performing calculations of currents, voltages and resistances it is seldom necessary to work with an accuracy of better than ±1% simply because component tolerances are invariably somewhat greater than this. Furthermore, in calculations involving Ohm's Law, it is sometimes convenient to work in units of kΩ and mA (or MΩ and µA) in which case potential differences will be expressed directly in V.

Example

A 12Ω resistor is connected to a 6V battery. What current will flow in the resistor?

Here we must use I = V/R

(where V = 6V and R = 12Ω):

I = V/R = 6V/12Ω = 0.5A (or 500mA)

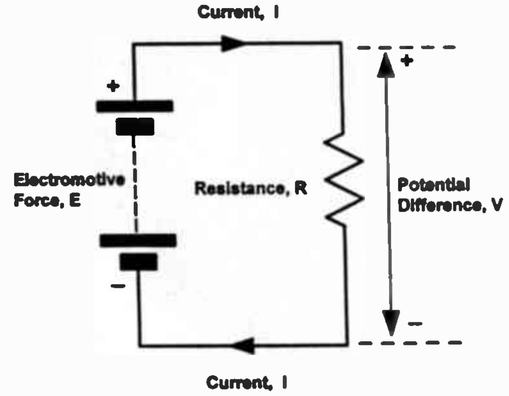


Fig. 1.8. Voltage, current and resistance in a simple electric circuit.

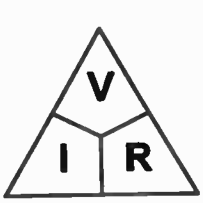


Fig. 1.9. The Ohm's Law triangle.

Hence a current of 500mA will flow in the resistor.

Example

A current of 100mA flows in a 56Ω resistor. What voltage drop (p.d.) will be developed across the resistor?

Here we must use V = I × R and ensure that we work in units of volts (V), amps (A), and ohms (Ω).

V = I × R = 0.1A × 56Ω = 5.6V

(Note that 100mA is the same as 0.1A)

Hence a p.d. of 5.6V will be developed across the resistor.

Example

A voltage drop of 15V appears across a resistor in which a current of 1mA flows. What is the value of the resistance?

R = V/I = 15V/0.001A
= 15000Ω = 15kΩ

Note that it is often more convenient to work in units of mA and V which will produce an answer directly in kΩ, i.e.,

R = V/I = 15V/1mA = 15kΩ

INTERNAL RESISTANCE

In most electronic circuits, resistances are clearly marked as individual (discrete) components. In some cases, however, resistances are present that are *not* marked on a circuit diagram. This is particularly true in the case of measuring instruments. For example, the voltmeter used in assignment 1.1 has a resistance. Its resistance is so large (in comparison with the circuit to which it is connected) that we can usually ignore it. In some cases, however, the resistance of the meter can become significant, as we shall see in the next assignment. Fig. 1.10 shows how we can represent the internal resistance of a meter as a component for inclusion in a circuit diagram.

Practical assignment 1.2:
Ohm's Law

This assignment will give you some practice in making measurements and plotting graphs. You will also confirm Ohm's

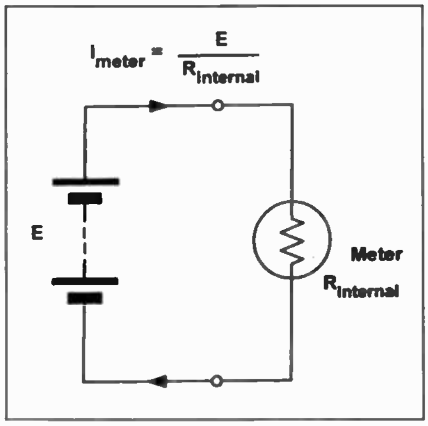


Fig. 1.10. Representing the internal resistance of a meter.

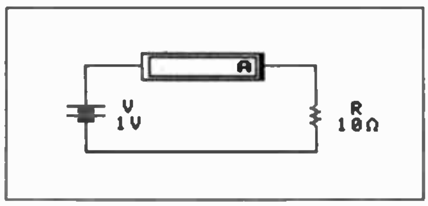


Fig. 1.11. Circuit for assignment 1.2.

Law and be introduced to the effects of voltmeter internal resistance when making measurements. This practical assignment can be completed in about one hour.

Objectives:

1.2.1 To investigate Ohm's Law in a simple d.c. circuit

1.2.2 To demonstrate the effects of the internal resistance of measuring instruments

Instructions:

Load *Electronics Workbench* and then click on assignment 1.2 from the Assignment drop-down menu.

1. Connect the circuit shown in Fig. 1.11. Note that the ammeter is connected *in series* with the resistor.
2. Select a 1V battery "1V" and a resistance value of "10Ω". Switch the circuit "on" and note down the measured value of the current supplied (this should be "100mA").
3. Now use values of voltage from "1V" to "10V" in 1V steps. At each step, measure and record the current supplied to the 10Ω resistor using Table 1.5.
4. Repeat steps 2 and 3 using resistance values of "5Ω" and "20Ω". Again, record your results in Table 1.5.

Table 1.5. Measured values for assignment 1.2

Supply voltage	Current supplied (mA)		
	R = 10Ω	R = 20Ω	R = 5Ω
0	0	0	0
1	100mA	50mA	200mA
2			
3			
4			
5			
6			
7			
8			
9			
10			

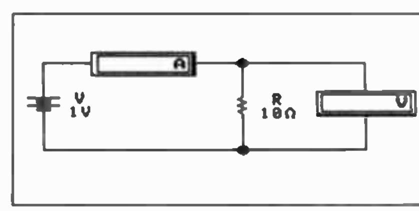


Fig. 1.14. Adding a voltmeter to the circuit.

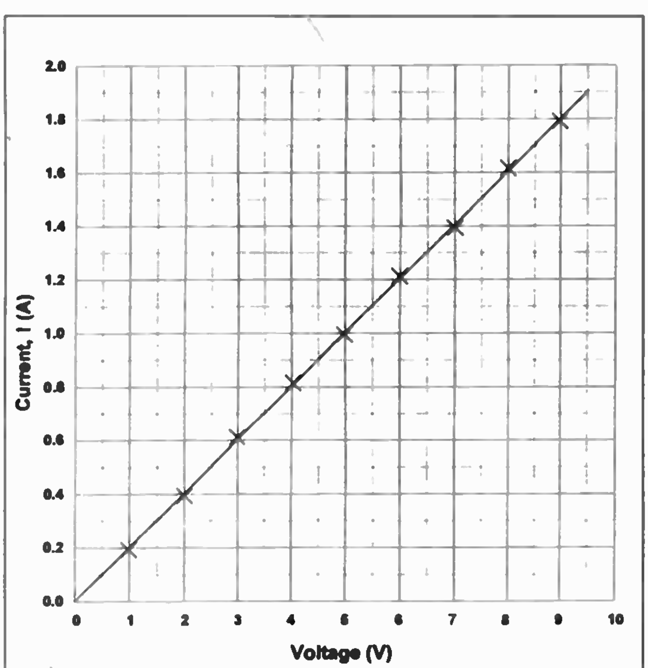


Fig. 1.12. How to plot the graph for assignment 1.2.

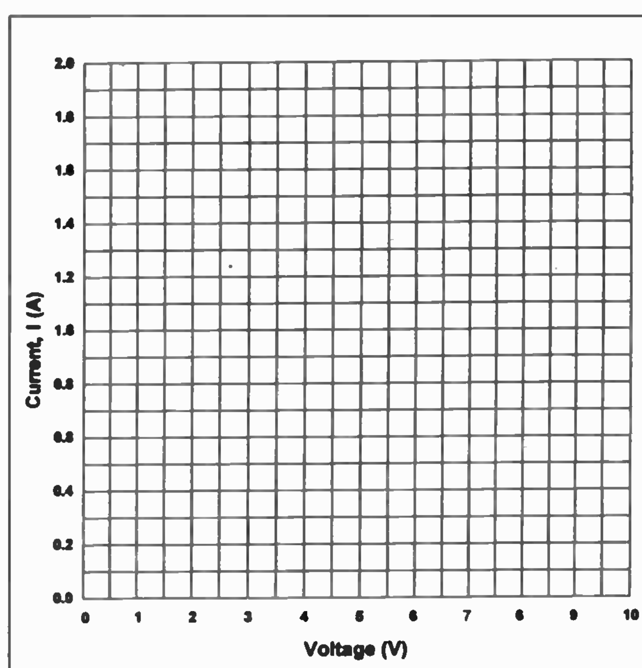


Fig. 1.13. Results graph for assignment 1.2.

5. Plot a graph (using a common set of voltage and current axes) showing the results for all three resistor values. Fig. 1.12 shows how to plot the graph whilst Fig. 1.13 is provided for you to plot your own values.
6. Now modify the circuit to include a voltmeter (as shown in Fig. 1.14). Set the resistance value once again to "10Ω" and the battery voltage to "1V".
7. Switch "on" and check that the current is 100mA. Confirm the Ohm's Law relationship (V = I × R) by determining the voltage drop across the resistor (this should be the same as the applied voltage, 1V):

   Voltage drop = I × R = 100mA × 10Ω = 0.1A × 10Ω = 1V
8. Repeat step 6 with resistance values of 10kΩ, 100kΩ, and 1MΩ. You should find that an increasingly large error appears as the value of resistance is increased. Ohm's Law should still be obeyed but the results indicate that something is causing a larger amount of current to flow than would be expected.
9. Remove the voltmeter and repeat step 8. What do you notice about the results?

Conclusions:

To what extent have the three objectives for this assignment been met? Comment on the shape of the graphs. What can you say about the *slope* of the graph? Comment on the errors that you observed when confirming Ohm's Law. What caused these errors? Why did the errors become more significant with larger values of resistor?

CIRCUIT THEOREMS

A number of basic theorems help us to understand the behaviour of electronic circuits. In the previous section we considered a simple electric circuit in which a source of e.m.f. (a battery) was connected to a single resistor. In this circuit we showed that:

Voltage (V) = Current (I) × Resistance (R)

Practical circuits can involve very large numbers of components. Components can be connected to other components in one of two basic ways; *series* and *parallel*, as shown in Fig. 1.15.

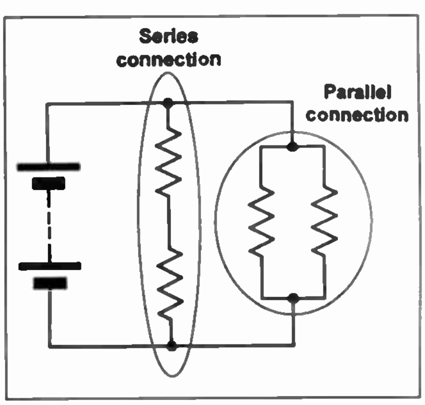


Fig. 1.15. Series and parallel connections.

Series and parallel combination of resistors

Fixed resistors may be arranged in either series or parallel combinations in order to obtain particular values of resistance. Some representative arrangements are shown in Fig. 1.16 and Fig. 1.17. The effective resistance of the series networks is simply the sum of the individual resistances. Hence, for Fig. 1.16a:

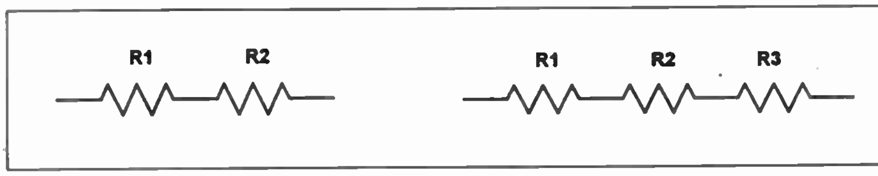


Fig. 1.16. Series resistors: (a) two resistors in series (b) three resistors in series.

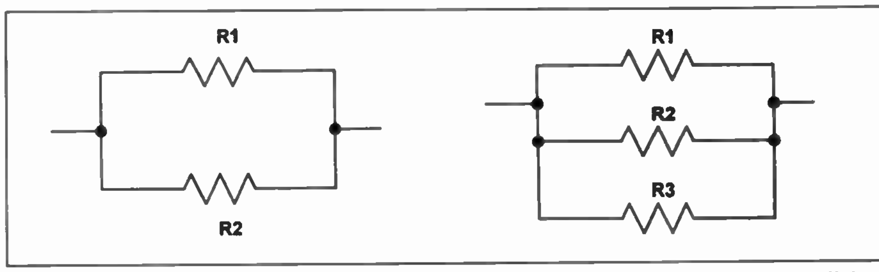


Fig. 1.17. Parallel resistors: (a) two resistors in parallel (b) three resistors in parallel.

$$R = R_1 + R_2$$

whilst in Fig. 1.16b:

$$R = R_1 + R_2 + R_3$$

In the case of the parallel connected resistors in Fig. 1.17, the reciprocal of the effective resistance of the combination is equal to the sum of the reciprocals of the individual resistances. Hence, in Fig. 1.17(a):

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

whilst in Fig. 1.17b:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Where only two resistors are connected in parallel (as in the case of Fig. 1.17(a)) the formula can be re-arranged as follows:

$$R = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{\text{product of individual resistances}}{\text{sum of individual resistances}}$$

Example

A resistance of 400kΩ is required. If a 180kΩ resistor is available what additional resistor should be connected in series with it?

The total value of resistance, R, is given by:

$$R = R_1 + R_2$$

Hence the value of the additional resistor, R_2, can be found from:

$$R_2 = R - R_1 = 400\text{k}\Omega - 180\text{k}\Omega = 220\text{k}\Omega$$

Example

Two 22kΩ resistors are connected in parallel. What will the resistance of this combination be?

The parallel combination will have a resistance given by:

$$R = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{22\text{k}\Omega \times 22\text{k}\Omega}{22\text{k}\Omega + 22\text{k}\Omega}$$

$$= \frac{484\text{k}\Omega}{44\text{k}\Omega} = 11\text{k}\Omega$$

From the foregoing example it is worth noting that, whenever two resistors of identical value are wired in parallel, the resistance of the combination will be equal to half that of each individual resistor.

THE AUTORANGING MULTIMETER

Electronics Workbench provides you with a versatile test instrument for measuring voltage, current and resistance. You will find the autoranging multimeter amongst the virtual test instruments on the equipment shelf at the top right-hand side of the screen display.

You can use the multimeter to measure a.c. or d.c. voltage or current, resistance, or decibel loss between two points in a circuit. The multimeter is auto-ranging so you don't have to specify a measurement range each time you use the instrument. The multimeter display is shown in Fig. 1.18.

The multimeter function (*"A", "V", "Ω", or "dB"*) is selected by means of the row of push buttons. In addition, the a.c. and d.c. buttons (symbolically marked) select alternating or direct current measurements on the current (A) and voltage (V) ranges.

To measure current, the multimeter must be switched to the current ("A") range and connected *in series* with the circuit. This simply means that you must break the circuit by open-circuiting one of the connections and then insert the meter in its place just as you did with the ammeter. When used as an ammeter, the meter offers a very low resistance and thus does not affect the current flowing at the point at which measurement takes place.

To measure voltage, the multimeter must be switched to the voltage ("V") range and connected *in parallel* with the component across which you are measuring. You may have to introduce one or two junction connectors in order to do this. When used as a voltmeter, the meter offers a very high resistance and thus it does not divert a significant amount of current from the circuit whilst it is connected.

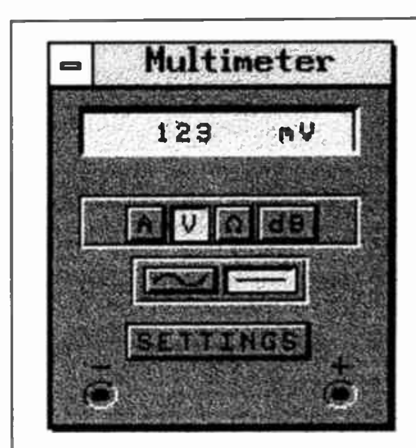


Fig. 1.18. Electronics Workbench's autoranging multimeter.

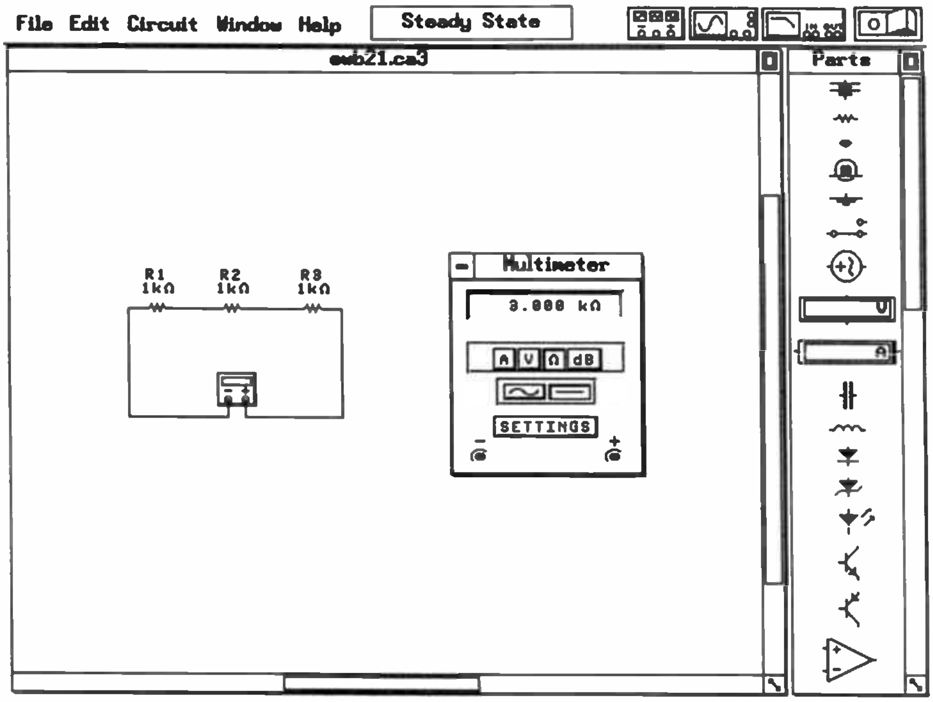


Fig. 1.19. Circuit for assignment 1.3 (measuring series resistances).

Note that *Electronics Workbench* allows you to configure the behaviour of the autoranging multimeter. In particular, you can determine the internal resistance of the meter. This is handy if you wish to investigate the effects of *loading* a circuit when a real meter is connected to it.

Practical assignment 1.3:
Measuring resistances

This assignment will give you some practice in using the autoranging multimeter to measure the resistance of a variety of series and parallel circuits.

Objectives:

1.3.1 To investigate series and parallel resistor networks.

1.3.2 To carry out resistance measurements using an autoranging digital multimeter.

Instructions:

Load *Electronics Workbench* and then click on assigment 1·3 from the Assignment drop-down menu.

1. Connect the circuit shown in Fig. 1.19. Set each resistor to a value of "1kΩ". You will have to drag the autoranging multimeter from its position on the test equipment "shelf" into the work space area.
2. Double click on the multimeter icon to open up its display. Drag the meter display to a clear area within the work space. Click on the "Ω" and "d.c." buttons (note that the d.c. button is marked with a straight line indicating a voltage or current that does not change with time).
3. Switch "on" to measure the resistance of the circuit. The meter should indicate "3.000kΩ" (as in Fig. 1.19). Now determine the resistance of the circuit with:

   (a) $R_1 = 1k\Omega$, $R_2 = 2k\Omega$, and $R_3 = 3k\Omega$
   (b) $R_1 = 2k\Omega$, $R_2 = 5k\Omega$ and $R_3 = 10k\Omega$

   In both cases, check that the effective resistance of the series combination is equal to the sum of the individual resistances.
4. Connect the circuit shown in Fig. 1.20. Set each resistor to a value of "3kΩ". Set the multimeter to read "Ω" and "d.c.".
5. Measure and record the resistance of the circuit (this should be 1kΩ). Now determine the resistance of the circuit with:

   (a) $R_1 = 1k\Omega$, $R_2 = 2k\Omega$, and $R_3 = 3k\Omega$
   (b) $R_1 = 2k\Omega$, $R_2 = 5k\Omega$ and $R_3 = 10k\Omega$

In both cases, check that the reciprocal of the effective resistance of the parallel combination is equal to the sum of the reciprocals of the individual resistances.

Conclusions:

To what extent have the two objectives for this assignment been met? Comment on the use of the autoranging multimeter. How do the controls on this instrument compare with the controls on a conventional instrument? What are the advantages of an autoranging meter?

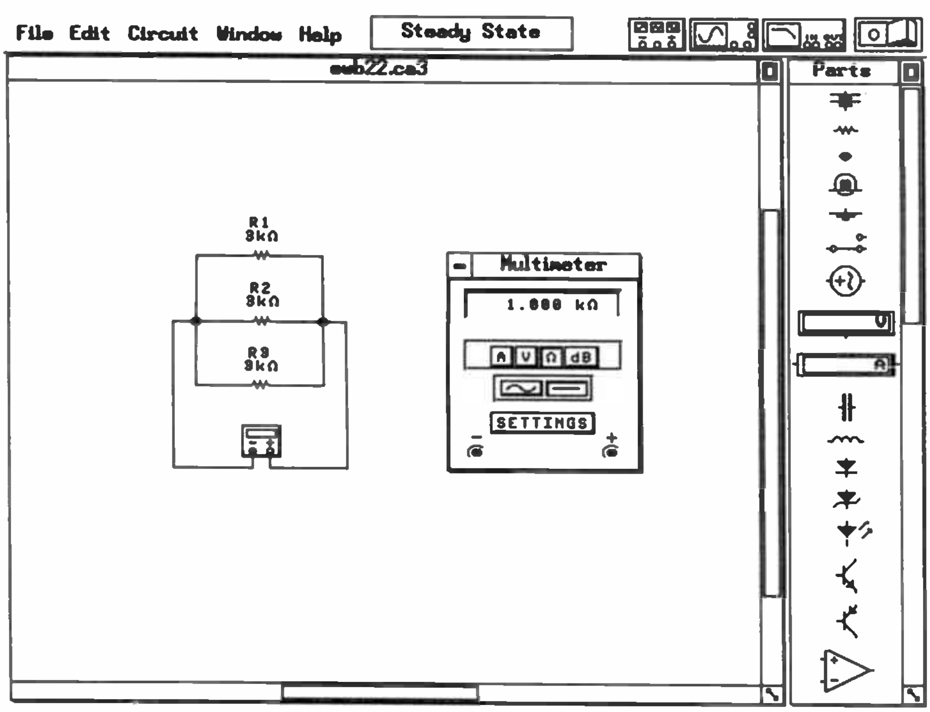


Fig. 1.20. Circuit for assgnment 1.3 (measuring parallel resistance).

THE VOLTAGE DIVIDER

A common application of resistors is that of providing a fixed division of potential using a voltage divider (or "potential divider") of the form shown in Fig. 1.21. The input voltage is divided by a factor which is determined by the values of the resistors present. The output voltage produced by the circuit of Fig. 1.21 is given by:

$$V_{out} = V_i \times \frac{R_2}{R_1 + R_2}$$

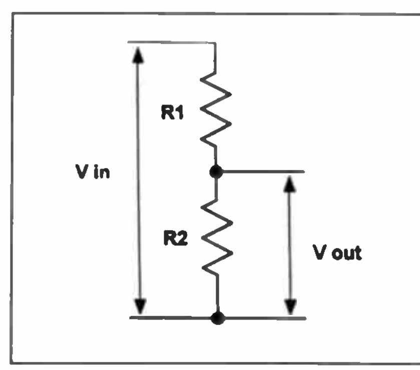


Fig. 1.21. Potential divider circuit.

Where accuracy of voltage division is important, a general rule of thumb is that the resistance of the load (ideally infinite) should be at least ten times greater than the value of R_2. In order to minimize the effects of an imperfect load, it is important to ensure that the resistance of the circuit to which the current divider is connected is ten (or more) times larger than the value of R_2. Furthermore, when selecting a value for R_2 in precision applications it is wise to choose a value which is at least 100 times lower than the expected load resistance.

Example

An item of test equipment requires an accurate 1V d.c. test voltage. Design a suitable voltage divider arrangement which can make use of an existing regulated 5V d.c. supply rail. (Assume that the input resistance of the equipment connected to the test point is greater than 100kΩ.)*

The required voltage division is 1V/5V = 0.2 (or 20%).

Hence $R_2/(R_1 + R_2) = 0.2$

or $R_2 = 0.2\,(R_1 + R_2)$

$R2 = 0.2\,R_1 + 0.2\,R_2$

Hence $R_2 - 0.2\,R_2 = 0.2\,R_1$

$0.8\,R_2 = 0.2\,R_1$

$$R_2 = \frac{0.2\,R_1}{0.8}$$

Thus $R_2 = R_1/4$

or $R_1 = 4\,R_2$

Taking a "worst case" value for the load of 100kΩ, this would suggest that R_2 should be 1kΩ and R_1 should be four times this value (i.e., 4kΩ). Note that the total resistance seen at the input of the voltage divider will be 5kΩ (i.e., 4kΩ + 1kΩ) and it will thus place a 1mA demand on the 5V supply. See Fig. 1.22.

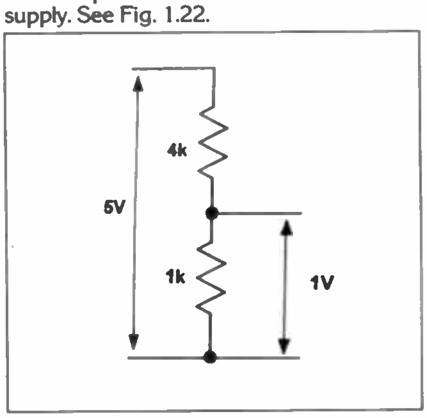


Fig. 1.22. A practical potential divider circuit (see example).

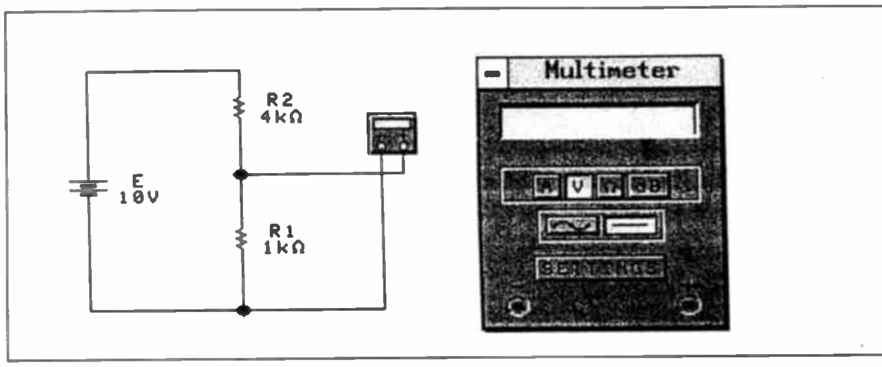


Fig. 1.23. Circuit for assignment 1.4 (measuring voltage drops).

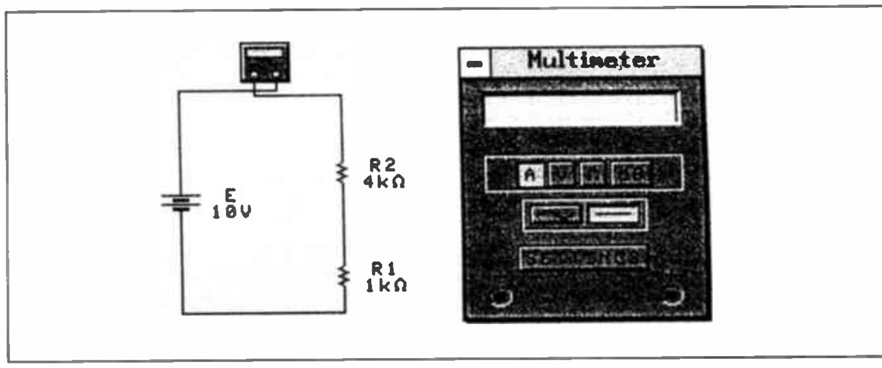


Fig. 1.24. Circuit for assignment 1.4 (measuring current).

Practical assignment 1.4:
The potential divider

In this practical assignment you will carry out measurements on a simple potential divider.

Objectives:

1.4.1 To investigate the behaviour of a simple potential divider circuit.
1.4.2 To carry out voltage and current measurements using an autoranging multimeter.
1.4.3 To investigate the effects of loading a potential divider circuit.

Instructions:

Select 1.4 from the Assignment drop-down menu.

1. Assemble the circuit shown in Fig. 1.23 (with the meter connected *in parallel* with R1). Select "V" and "d.c." on the multimeter's push buttons. Then click the mouse on the "Settings" button. Change the settings so that the ammeter resistance is "1Ω" and the voltmeter resistance is "10MΩ". These values are reasonably typical of a real instrument. Now click on the "Accept" button to return to the circuit and switch the power "on". Note down the indication produced by the meter.
2. Now reconnect the meter so that it is *in parallel* with R_2. Again note down the meter reading. Once again, note down the meter reading.
3. Reconnect the multimeter so that it is *in series* with R_1 (as shown in Fig. 1.24). Select "A" and "d.c." on the multimeter's push buttons and then switch the circuit on once again again. Note down the indication produced on the meter.
4. You should now have values for the voltage drops (V1 and V2) across R_1 and R_2 and also for the current flowing (I) in the resistors. Use these values to confirm Ohm's Law for each resistor and also confirm the operation of the circuit as a potential divider.
5. Repeat steps 1 to 4, this time using values of 10kΩ for R_1 and 40kΩ for R_2.
6. Finally, repeat steps 1 to 4 using values of 100kΩ for R_1 and 400kΩ for R_2.

Conclusions:

To what extent have the three objectives for this assignment been met? Comment on the readings that you obtained with two different sets of resistor values. Why was there a greater error with the larger resistance values? Can you suggest an application for the potential divider circuit?

THE CURRENT DIVIDER

Resistors may also be used to divert a known proportion of the current from one branch of a circuit to another. In this case, the input current is divided by a factor which is determined by the resistor values present. The current produced by the circuit of Fig. 1.25 is given by:

$$I_{out} = I_{in} \times \frac{R_1}{R_1 + R_2}$$

A common application of the current divider is found in ammeters where an appreciable proportion of the applied current is diverted through a "shunt" resistor (see Fig. 1.26). As an example, let's assume that we wish to indicate current up to a maximum (full-scale indication) of 1A using a meter movement which requires only 1mA for full-scale deflection. The difference (999mA) must be diverted by the shunt resistor (R_S).

Example

A moving coil meter operates with a 1mA d.c. full-scale deflection current. If the meter has a coil resistance of 100Ω, devise a suitable current divider arrangement which will provide full-scale deflection when 10mA is applied. Calculate the required value of parallel (shunt) resistor.

The required current division is 1mA/5mA = 0.2 (or 20%).

Hence $R_1/(R_1 + R_2) = 0.2$.

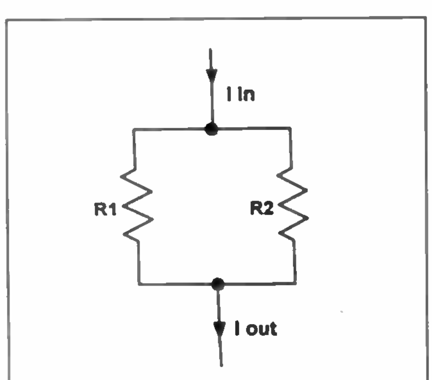


Fig. 1.25. Current divider circuit.

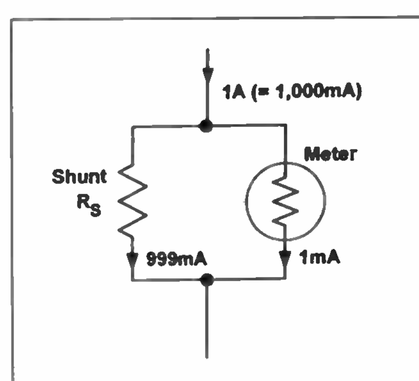


Fig. 1.26. A meter shunt.

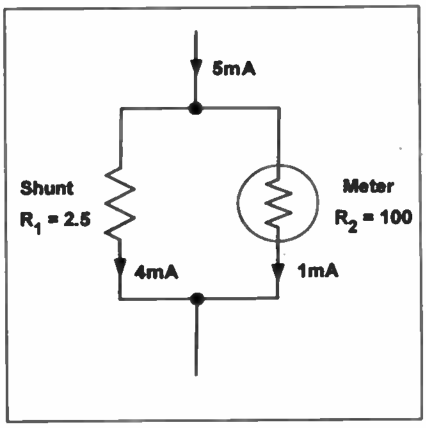


Fig. 1.27. Practical current divider circuit.

The value of R_2 is simply that of the meter coil (i.e., 100Ω) as shown in Fig. 1.27.

$$\text{Now } \frac{R_1}{R_1 + 100} = 0.2$$

or $$R_1 = 0.2\,(R_1 + 100)$$

$$R_1 = 0.2R_1 + 20$$

Thus $$R_1 - 0.2\,R_1 = 20$$

$$0.8\,R_1 = 20$$

or $$R_1 = 20/8 = 2.5$$

The required value for R_1 can be achieved by connecting 3.3Ω and 10Ω resistors in parallel across the terminal of the meter. The resistors used for R_1 should ideally be 2% 0.25W thick film metal glaze resistors. Note that, in this case, R_2 is the internal resistance of the meter – not a discrete component!

As with the case of the voltage divider, close tolerance (e.g., ± 1%) resistors should be used in order to obtain accurate values of current division. Furthermore, a notable disadvantage of simple current dividers is that the output current (I_{out}) will fall, when the load connected between the output terminals has any appreciable resistance, thus impairing accuracy.

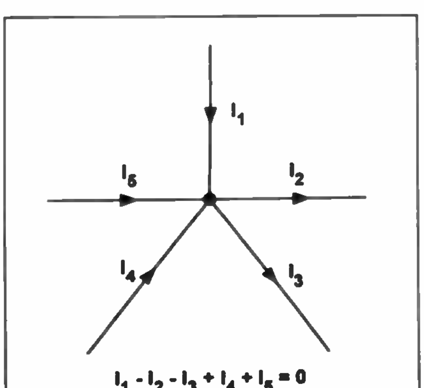
Where accuracy of current division is important, a general rule of thumb is that the resistance of the load (ideally zero) should be no more than one tenth of the value of R_2.

KIRCHOFF'S LAWS

Kirchhoff's Laws relate to the algebraic sum of currents at a junction (or node) or voltages in a network (or mesh). The term "algebraic" simply indicates that the polarity of each current or voltage drop must be taken into account by giving it an appropriate sign, either positive (+) or negative (−).

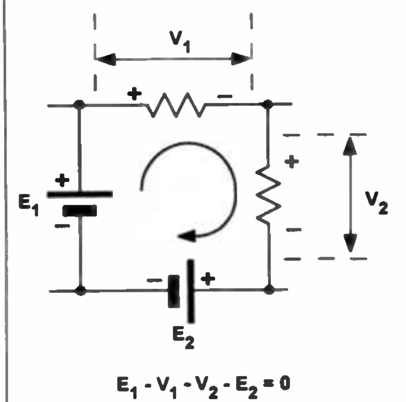
Kirchhoff's Current Law states that the algebraic sum of the currents present at a junction (node) in a circuit is zero (see Fig. 1.28).

Kirchhoff's Voltage Law states that the algebraic sum of potential drops in a closed network (mesh) is zero (see Fig. 1.29).



Convention:
Currents flowing towards the junction are positive (+). Currents flowing away from the junction are negative (−).

Fig. 1.28. Kirchhoff's Current Law.



Convention:
Move clockwise around the circuit starting with the positive terminal of the largest EMF. Voltages acting in the same sense are positive (+). Voltages acting in the opposite sense are negative (−).

Fig. 1.29. Kirchhoffs Voltage Law.

Example

The d.c. power supply in an audio system is required to deliver the following outputs:

800mA for a power amplifier
150mA for a pre-amplifier
250mA for an FM tuner

What is the total current required from the power supply?

We can determine the total current required from the power supply by simply adding together the current demands of each of the system components (see Fig. 1.30). Thus:

$$I_T = 800\text{mA} + 150\text{mA} + 250\text{mA} = 1{,}200\text{mA} = 1.2\text{A}$$

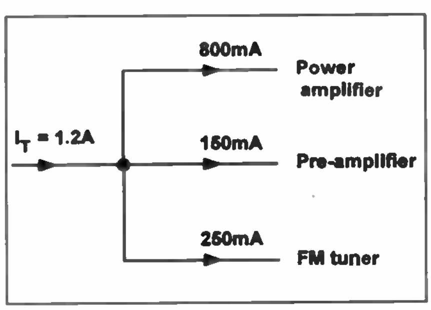


Fig. 1.30. Example of Kirchhoffs Current Law.

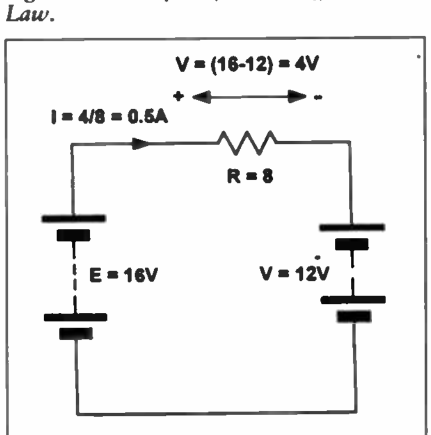


Fig. 1.31. Example of Kirchhoffs Voltage Law.

Example

A battery charger delivers an output of 16V. If the charger is connected to a 12V battery via a ballast resistor of 8Ω. What voltage drop will appear across the ballast resistor and what current will flow in it?

Fig. 1.31 shows the arrangement. The voltage dropped across the resistor can be calculated by applying Kirchhoff's Voltage Law:

$$E - V_R - V = 0 \text{ or } E - V = V_R$$

thus:

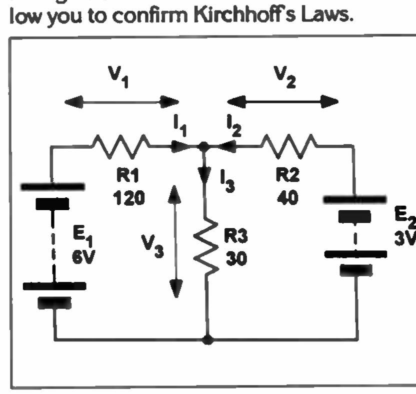
$$V_R = 16 - 12 = 4V$$

The current flowing in the resistor can be calculated from:

$$I = V_R / R = 4V/8\Omega = 0{\cdot}5A = 500mA.$$

Practical assignment 1.5: Using the digital multimeter

This assignment involves making current and voltage measurements on the network of two batteries and three resistors shown in Fig. 1.32. These measurements will allow you to confirm Kirchhoff's Laws.



Fig, 1.32. Circuit for assignment 1.5.

Objectives:

1.5.1 To verify Kirchhoff's Laws.
1.5.2 To carry out voltage and current measurements on a complex network of resistors and batteries.

Instructions:

Select and load assignment 1.5.

1. Connect the circuit shown in Fig. 1.32. The corresponding Electronics Workbench layout is shown in Fig. 1.33. Set the batteries, E_1 and E_2, to "6V" and "3V" respectively and the resistors, R_1 to R_3, to "120Ω", "40Ω", and "30Ω" respectively. (Please note that the negative terminal of the meter is adjacent to the thicker end of the rectangular symbol. You will have to use the rotate facility (using the <CTRL> and <R> keys) to align the meters as shown in Fig. 1.33.
2. Switch "on"; measure and record the indications on the meters using Table 1.6.
3. Verify Kirchhoff's Current Law by substituting values in the equation:
$$I_3 = I_2 + I_1$$
(where I_3, I_2 and I_1 are the currents flowing in R_3, R_2 and R_1 respectively)
4. Verify Kirchhoff's Voltage Law by substituting values in the equations:
(a) $E_1 = V_1 + V_3$

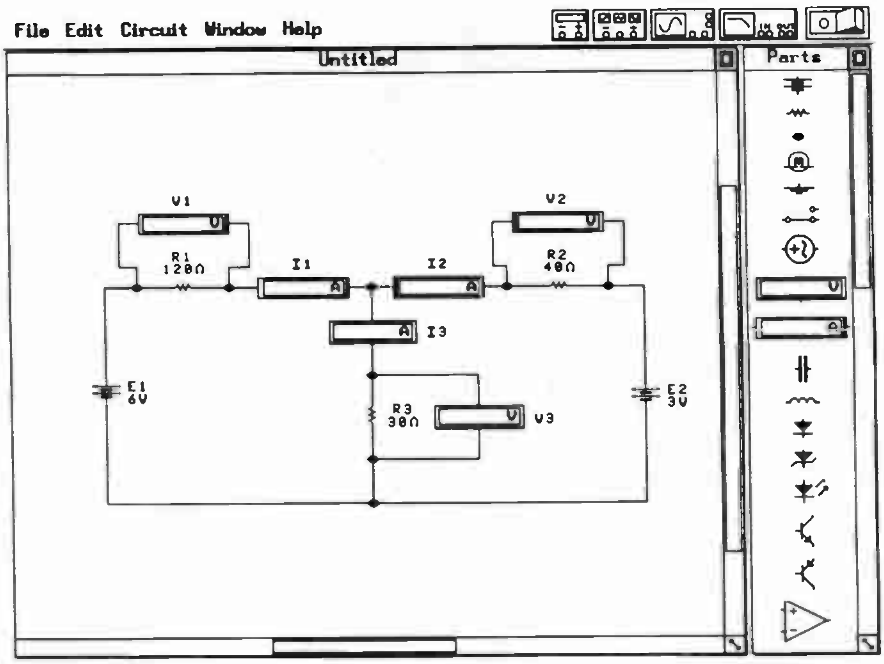


Fig. 1.33. Electronics Workbench layout for Fig. 1.32.

Table 1.6 Measured values for assignment 1.5

E_1 (V)	E_2 (V)	V_1 (V)	V_2 (V)	V_3 (V)	I_1 (mA)	I_2 (mA)	I_3 (mA)
6	3						

(where E_1 is 6V, V_1 and V_3 are the voltage drops appearing across R_1 and R_3 respectively)

(b) $E_2 = V_2 + V_3$

(where E_2 is 3V, V_2 and V_3 are the voltage drops appearing across R_2 and R_3 respectively)

Conclusions:

To what extent have the two objectives for this assignment been met? Are Kirchhoff's Laws obeyed? What differences would have been noticed if (a) both of the batteries had been connected with opposite polarity and (b) if just one of the batteries had been connected with opposite polarity?

POWER AND ENERGY

In simple terms, energy is the capacity to perform work whilst power is the rate at which that work is done. In electrical circuits, energy is supplied by batteries or generators but it may also be stored in components such as capacitors and inductors. Electrical energy is converted into various other forms of energy by components such as resistors (producing heat), loudspeakers (producing sound energy), light emitting diodes (producing light).

The unit of energy is the joule (J). Power is the rate of use of energy and it is measured in watts (W). A power of 1W results from energy being used at the rate of 1J per second. Thus:

$$P = E/t$$

where P is the power in watts (W), E is the energy in joules (J), and t is the time in seconds (s).

The power in a circuit is equivalent to the product of voltage and current. Hence:

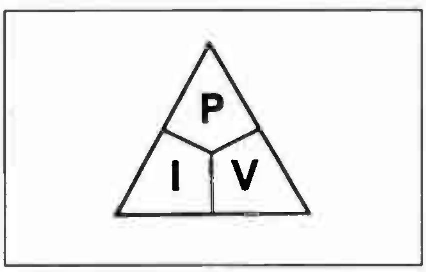


Fig. 1.34. Power, current and voltage triangle.

$$P = I \times V$$

where P is the power in watts (W), I is the current in amps (A), and V is the voltage in volts (V).

The formula may be arranged to make P, I or V the subject, as follows:

$$P = I \times V \quad I = P/V \quad \text{and} \quad V = P/I$$

The triangle shown in Fig. 1.34 should help you to remember these relationships.

V	I	R	P
IR	$\frac{V}{R}$	$\frac{V}{I}$	$\frac{V^2}{R}$
$\frac{P}{I}$	$\frac{P}{V}$	$\frac{V^2}{P}$	I^2R
$\sqrt{PR}$	$\sqrt{\frac{P}{R}}$	$\frac{P}{I^2}$	IV
VOLTS	AMPS	OHMS	WATTS

Fig. 1.35. Some important electrical formulae.

The relationship, $P = I \times V$, may be combined with that which results from Ohm's law ($V = I \times R$), to produce several further relationships which are summarized in Fig. 1.35.

Example

A current of 1.5A is drawn from a 3V battery. What power is supplied?

Here we must use $P = I \times V$ (where $I = 1.5A$ and $V = 3V$):

$$P = I \times V = 1.5A \times 3V = 4.5W$$

Hence a power of 4.5W is supplied.

Example

A voltage drop of 4V appears across a resistor of 100Ω. What power is dissipated in the resistor?

Here we use $P = V^2/R$ (where $V = 4V$ and $R = 100\Omega$):

$$P = V^2/R = (4V \times 4V)/100\Omega = 0.16W$$

Hence the resistor dissipates a power of 0.16W (or 160mW).

Example

A current of 20mA flows in a 1kΩ resistor. What power is dissipated in the resistor?

Here we use $P = I^2 \times R$ but, to make life a little easier, we will work in mA and kΩ (in which case the answer will be in mW):

$$P = I^2 \times R = (20mA \times 20mA) \times 1k\Omega = 400mW$$

Thus a power of 400mW is dissipated by the resistor.

PROBLEMS

These problems have been included for you to check your understanding. You can treat them as theoretical exercises and solve them using appropriate formulae then use *Electronics Workbench* to construct the circuits and check your answers! You will find all of the components that you need in the file, 1-PROBS.

1. A 9V battery is connected to a 27Ω resistor. Determine the current supplied by the battery and the power dissipated in the resistor.
2. A current of 15mA flows in a resistor when 3V is applied to it. Determine the value of resistance.
3. A 45V battery is made up of a series arrangement of 1.5V cells. How many cells are required?
4. A 56Ω resistor is rated at 1W. What is the maximum voltage that can be safely applied to it?
5. Resistors of 22kΩ and 68kΩ are connected (a) in parallel and (b) in series. Determine the resistance of each of these combinations.
6. A 10V nickel cadmium battery is connected, via a 22Ω resistor to a charger delivering 12V. Determine the charging current.
7. Three 15kΩ resistors are connected in parallel across a 50V d.c. supply. Determine the current taken from the supply and the current flowing in each resistor.
8. A potential divider consisting of a 4.7kΩ resistor in series with a 3.3kΩ resistor is connected across an 24V d.c. supply. Determine the voltage appearing across each resistor.
9. A current divider consists of 10Ω resistor connected in parallel with a 100Ω resistor. If a current of 20mA flows in the 100Ω resistor, determine the

current in the 10Ω resistor and the total current supplied to the circuit.

10. Two 1kΩ resistors are connected in series across a 12V supply. A third resistor of 1.5kΩ is connected in parallel with one of the two 1kΩ resistors. What current will be taken from the supply and what voltage will be dropped across the 1.5kΩ resistor.

Answers to these problems will be given in next month's instalment.

BRAIN TEASER

Each month we shall leave you with a more complicated problem that you can solve with the full version of *Electronics Workbench*. This month's Brain Teaser involves the circuit arrangement shown in Fig. 1.36.

Assuming that all of the resistors have the same value (10Ω), determine the resistance measured across any pair of opposite corners (e.g., A and B in Fig. 1.36).

The solution will be given in next month's instalment.

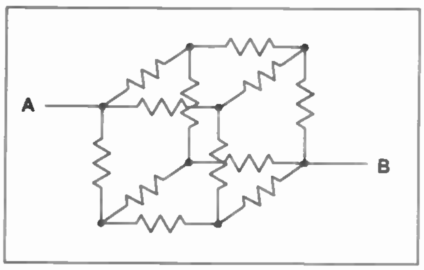


Fig. 1.36. Brain Teaser problem.

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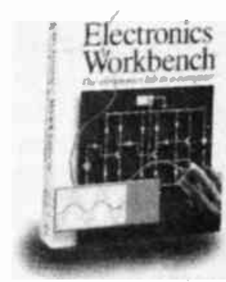

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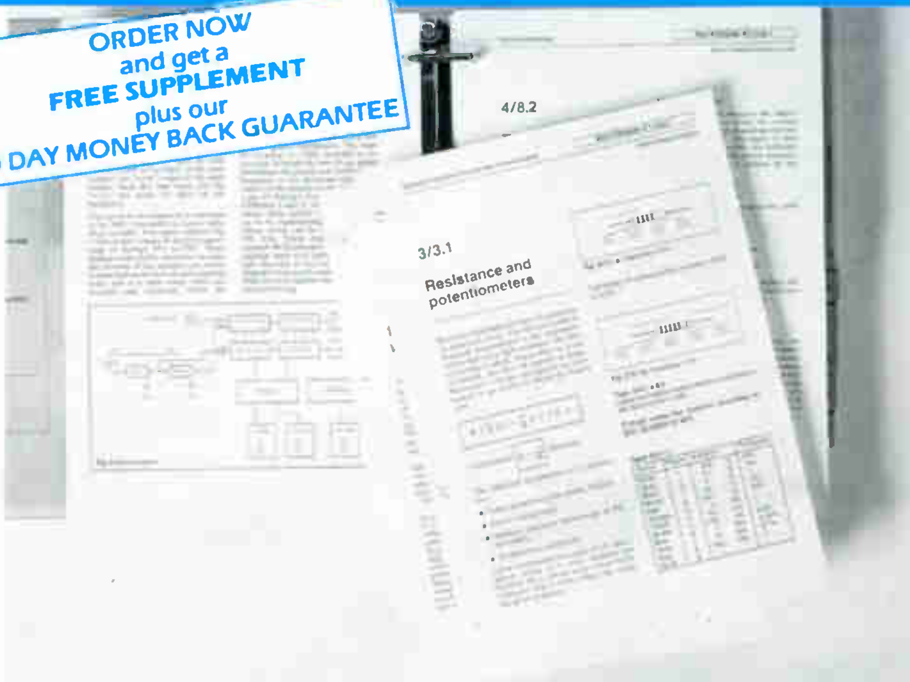

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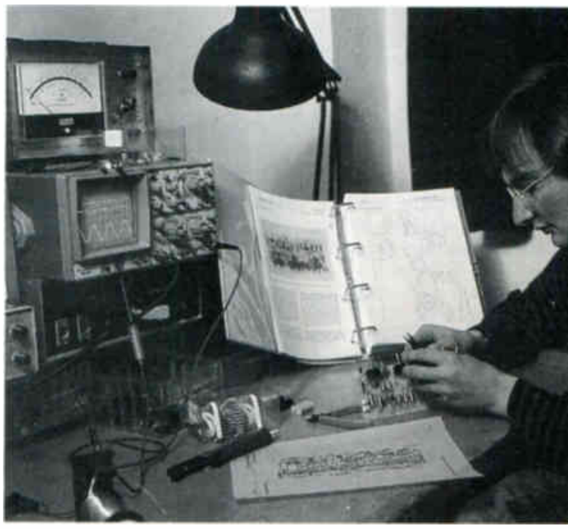

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New Technology Update

Ian Poole investigates developments in the opto-electronics field and reports on the latest research into organic electronics.

OPTO-ELECTRONICS is a fast growing area of electronics. In the next few years it is likely that it will play an increasing role in data transfer. In addition to this there will be many new uses which will be found as the technology develops and improves.

Lasers

Lasers are being used increasingly. One of their major uses is in domestic CD players where many millions are in everyday use around the world. Apart from this application they find uses in many other areas. One of these is for optical communications enabling data to be sent at high speeds over fibre optical links.

One of the limitations encountered in this area is that the unmodulated laser signal has a finite bandwidth. Existing narrow-band lasers have a bandwidth of about 10MHz and this limits the rate at which data can be sent.

To overcome this problem and increase the rates of data transmission, Hitachi have developed a new laser diode which has an unmodulated signal bandwidth of just a few kilo-Hertz. Using this diode it is expected that data rates of up to 200Gbits/sec will be achieved.

The secret to the new device lies in its structure. The basic diode is built on a substrate of InP. On top of this Hitachi have fabricated a stack of InGaAsP layers in a strained layer multiple quantum well structure – see Fig. 1. This enables the diode to emit 55mW of infra-red radiation at a wavelength of 1·55μm.

Normally the narrow-band lasers have a set of laser diodes with a diffraction grating etched onto the structure. Using the interference pattern generated only allows through a narrow band of radiation.

To achieve the very narrow bands, Hitachi have modified this basic design. They have altered the pitch of the grating to be slightly shorter at either end. In this way a 4kHz bandwidth can be achieved.

With the requirements for ever faster methods of transmitting data, optical forms of data transmission will be used increasingly in the years ahead. This new development is likely to be of great importance, especially as the devices become more widely available.

High Speed

Using the new laser diodes it will be possible to increase the speed at which data is transmitted. Work is also progressing on methods of increasing the speed of reception as this is equally important.

In one new development being undertaken at the University of Minnesota a new diode is being developed which should be capable of operating at frequencies up to 100GHz. This is a marked improvement over any other devices which are currently available.

The key to this new development is the miniaturisation of the structure within the diode. To manufacture the diodes a new electron lithography machine has been developed and this is capable of producing line widths of only 0·01μm.

Unlike many other high speed photodetectors which use gallium arsenide, this one is fabricated from silicon. This has the additional advantage that it is easy to incorporate other circuits onto the same substrate. By doing this delays can be reduced to the absolute minimum, thereby ensuring that the full potential of the diode itself is maintained.

The main increase in speed has been achieved in the diode itself. It consists of interleaved fingers of gold deposited onto a silicon substrate. When the light hits the silicon, electrons are freed, giving a small current which can be picked up by the gold electrodes.

The size of the fingers is critical. The smaller the spacing the quicker the freed electrons can be picked up and the faster its speed of operation. The fingers also need to be kept as thin as possible otherwise the efficiency of the device falls very rapidly making it much less sensitive.

The new diode is so fast that a number of unexpected effects were noticed during development. It was found that red light produced a slower response than violet. This was traced to the fact that red light penetrated further into the silicon. This resulted in it taking longer for the electrons to reach the fingers. It also emphasised the critical nature of the minute geometries to the research team.

The team are delighted with the performance of the device in fulfilling its primary function. However they have also discovered that it can be used to generate a microwave signal if the operating conditions are altered suitably.

It will be interesting to see where their work leads. What is certain is that this new diode will be instrumental in increasing the speed of optical data networks.

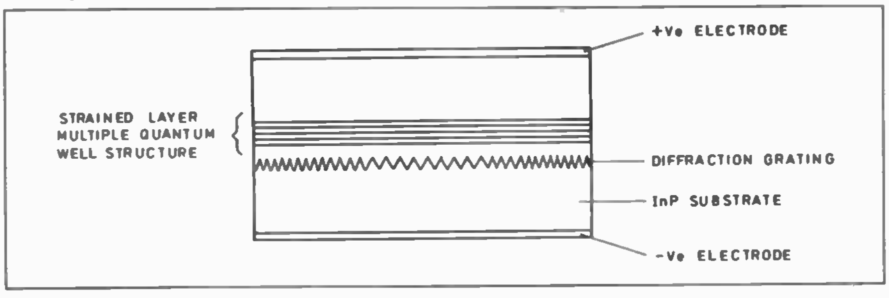


Fig. 1. Cross section of the Hitachi narrow-band laster l.e.d. structure.

Organic Electronics

Organic materials are finding uses in a wide variety of areas these days. Originally confined to fields related to chemistry and materials, organic compounds are now entering new spheres.

Organic superconductors have been available for some while. Although still very much in their research phase these new compounds are proving to be very promising for the future.

Another area where organic compounds are beginning to be developed is in semiconductor research. Here organic polymers have been successfully used to make l.e.d.s. Although the first devices which were announced back in 1990 only had an efficiency of 0·01 per cent, research at Cambridge University has raised this figure to around four per cent.

To achieve this figure the group have used a substance called phenylene vinylene. A film of the material has electrodes deposited and emits a green/yellow light when 15V is applied.

It has not been easy to increase the efficiency of these l.e.d.s. A number of measures have had to be employed, each contributing to raising the overall efficiency.

Initial studies showed that very few electrons entering the structure actually caused light emission. Much of the energy in the system was dissipated in a non-radiative manner.

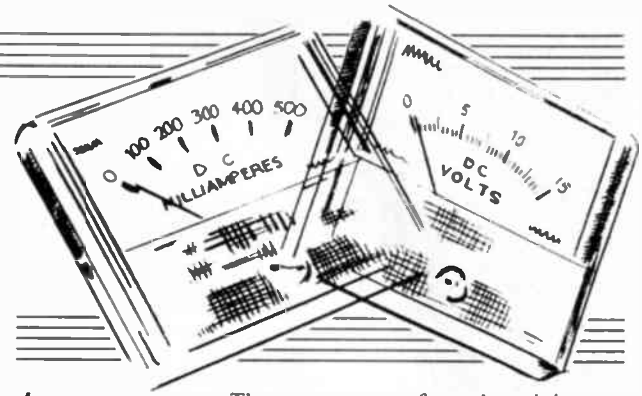
The cause of this was investigated and as a result it appeared that a co-polymer should be used instead. This gave a thirty fold increase in the level of emission.

Despite this the efficiency was still only 0·3 per cent. Another layer was introduced into the structure and this gave a rise in efficiency to three per cent. Now a new material containing cyano structures has been introduced into the material with the effect that efficiencies of around four per cent are being seen.

For the future it appears likely that many more organic semiconductor materials may become available. If this happens then not only will silicon and gallium arsenide become materials of the past, but a whole new field of organic semiconductor components may appear.

Constructional Project

HOBBY PSU



T.R. de VAUX-BALBIRNIE

A no-frills power supply for the experimenter. 3V to 12V in 1V steps at 350mA max.

THE serious electronics enthusiast soon comes to realize that certain pieces of equipment are near-essential while others are little more than gimmicks. A bench power supply unit (PSU) definitely comes into the former category. The Hobby PSU is a compact mains-operated unit providing a regulated output from 3V to 12V in 1V steps and with a maximum current of 300mA.

While it is possible to operate experimental circuits from batteries, doing so has several disadvantages – the chief of which is cost. The price of batteries is quite high and if a large current is drawn over several hours – as will be required for some tests – they will soon be drained.

Another point about batteries is that their *regulation* is poor – that is, the terminal voltage falls quite severely as increasing current is drawn. This can cause problems when experimenting with new designs.

UNNECESSARY GOODIES

Commercial power supply units are available from many suppliers but tend to be expensive – even a "cheap" one appears to cost between £60 and £80. For occasional use this expense may need some justifying. Also, commercial units tend to have facilities which will rarely, if ever, be needed by the average constructor. For example, for many purposes a maximum output of 12V is adequate – perhaps for setting-up automotive circuits. Commercial units typically provide an output up to 30V.

For many purposes, a maximum current of 300mA will be found sufficient. A rating of up to 2A or more, as provided by many commercial units, increases costs and makes the unit heavy and bulky on account of the requirement for a larger mains transformer. The Hobby PSU does not have fixed output voltages – usually 5V and 12V – found on many commercial units. Again, this reduces costs. Other facilities omitted from this design are a "split" supply and an a.c. output facility.

OUTPUT METERS

On a commercial power supply unit there are often instruments – a voltmeter and an ammeter – mounted on the front panel. These may be found useful at times but including them adds considerably to constructional costs.

Since the output voltage of the Hobby PSU is switched and accurate to around 0·1V, a voltmeter is not really essential. If the current needs to be measured, most experimenters will have access to a multitester which may be used for the purpose.

For readers wishing to add a built-in voltmeter and/or ammeter, it is a straightforward matter to include these. Details for doing this are given later.

The photographs and diagrams show the prototype unit with meters included. If no such meters are to be used, it will be desirable, although not essential, to have a multitester available at the end for testing purposes. Note that the total cost given in the "Cost Box" does not include any meters.

The output current from the unit is automatically limited. A two-way switch on the front panel may be used to select a limit of either 50mA or 300mA. The smaller value will be appropriate for low-powered circuits.

IMPORTANT SAFETY NOTE

Constructing this unit involves making mains connections. Any reader who is unsure of being able to make a safe job, must seek the help of a qualified electrician.

In particular, the following safety points must be followed. Firstly, the unit must be built in an *Earthed METAL box* – a plastic case is unsuitable and must not be used. Also, there must be a switch in the live mains input wire and a neon indicator to warn of the *ON* state (in the prototype the neon indicator was part of the switch itself – see components list).

Fuses must be included in both transformer primary and secondary circuits – note that fuse FS1 must be of the special mains (ceramic) type. Some further safety notes are given later.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Hobby PSU is shown in Fig. 1. The principle component is IC1 – an L200CV integrated circuit regulator. This is a practically indestructible device which provides on-chip voltage regulation and current limiting.

It is fully protected against any abuse causing overload or overheating. Although capable of providing a full 2A output, here it is used much more conservatively. The metal case itself can then provide an adequate heatsink.

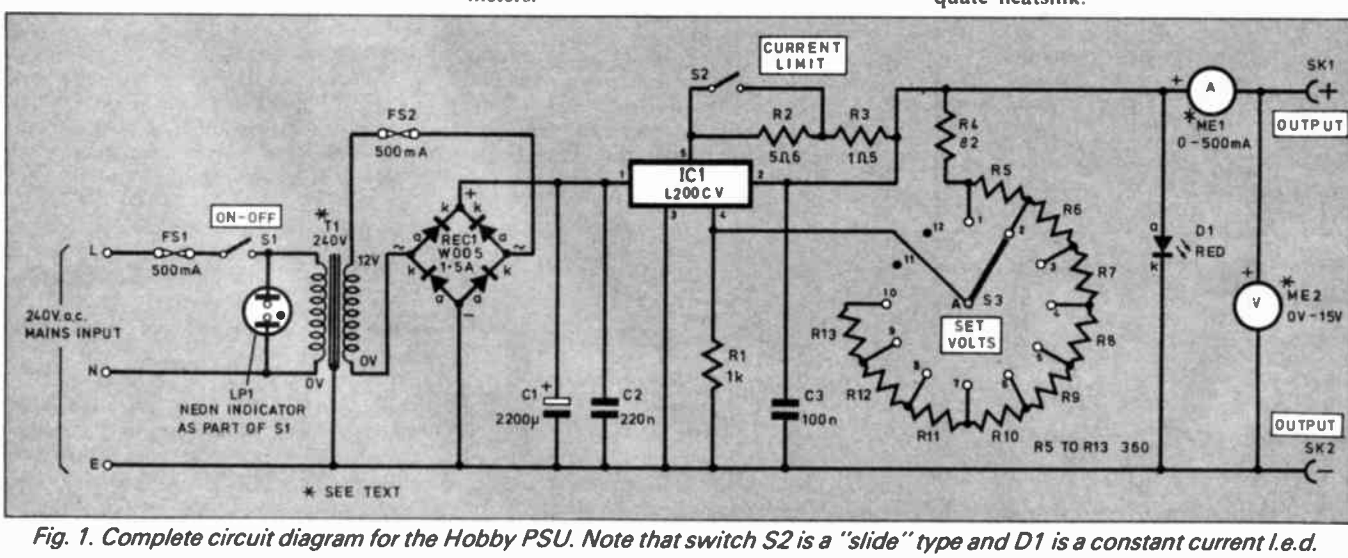


Fig. 1. Complete circuit diagram for the Hobby PSU. Note that switch S2 is a "slide" type and D1 is a constant current l.e.d.

The Live mains input wire is fused using FS1 then connected to switch S1. With S1 *on* current is supplied to the primary winding of transformer T1. A nominal 12V a.c. output is then provided at the secondary. This is fused using FS2, full-wave rectified by bridge rectifier REC1 and smoothed using capacitor C1.

Capacitor C1 charges to the peak voltage of the a.c. available at T1 secondary – about 17V – less the voltage drop of some 1·4V due to the effect of the diodes inside REC1. This leaves about 15V to 16V which is necessary to provide a full 12V output. This is because up to 3V is effectively "lost" between IC1 input and output terminals.

The nominal 15V d.c. supply is applied to IC1 input pin 1. An output voltage is then developed at pin 5 whose value is accurately determined by resistor R1 and the resistance appearing between pins 2 and 4.

In this circuit, R1 is fixed in value and rotary switch S3 (Set Volts) selects the appropriate resistor(s) in the series chain R5 to R13 together with resistor R4 which is always present. With S3 in its lowest position, the output voltage is determined by R4 alone – that is, 3V. In the tenth position, S3 connects all resistors in the chain – this provides 12V.

COMPONENTS

Resistors
R1 1k
R2 5Ω6
R3 1Ω5
R4 82
R5 to R13 360 (9 off)
All resistors 0·6W 1% carbon film.

See SHOP TALK Page

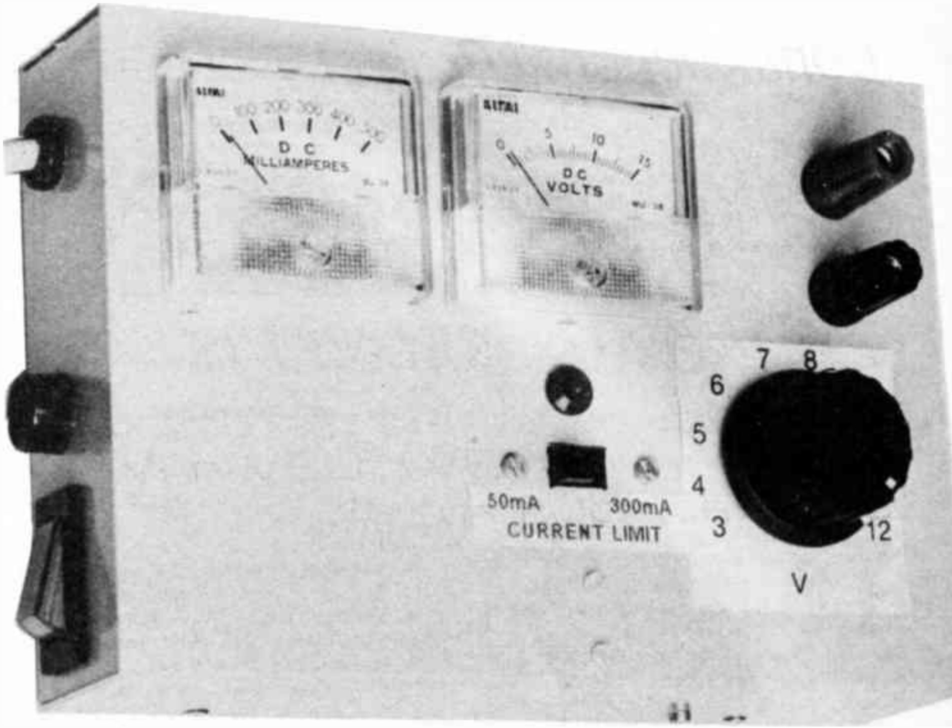
Capacitors
C1 2200µ radial p.c.b. elect. 35V
C2 220n disc ceramic
C3 100n disc ceramic

Semiconductors
D1 Red constant current l.e.d. 3V to 12V operation with no series resistor required
IC1 L200CV voltage and current regulator
REC1 W005 1·5A 50V bridge rectifier.

Miscellaneous
T1 Mains transformer with 240V primary and 6V-0-6V secondary or twin 6V secondaries rated at 500mA (6VA)
S1 Mains rocker switch with inbuilt neon indicator (or separate mains neon).
S2 Miniature on/off slide switch
S3 12-position rotary switch, make-before-break action.
ME1 Miniature 0 to 500mA ammeter, face size 45mm x 51mm – if required
ME2 Miniature 0 to 15V voltmeter, face size 45mm x 51mm – if required
SK1, SK2 4mm terminal post/socket – one red, one black
FS1 20mm panel fuseholder, with 500mA *mains-type* ceramic fuse to fit.
FS2 200mm chassis fuseholder with 500mA quick-blow fuse to fit

Printed circuit board available from *EPE PCB Service*, code 902; aluminium case size, 175mm x 125mm x 45mm; solder tags (3 off); stand-off insulators (4 off); small fixings; strain relief bush; l.e.d. mounting clip; stranded wire; 3A mains wire; solder, etc.

Approx cost guidance only **£26** *excluding meters*



The completed power supply showing front panel layout. The meters are optional.

CURRENT LIMITING

The resistor connected between IC1 output pin 5 and *limiting* terminal, pin 2, determines the output current limit. With Current Limit switch S2 in the *open* position, this is set by resistors R2 and R3 connected in series providing about 63mA. This allows for 50mA output current in addition to the 13mA required for the l.e.d. D1 (a constant current device).

With S2 *closed*, resistor R2 is short-circuited and limiting is set by R3 alone. This corresponds to about 300mA. Readers wishing to make changes to the current output (subject to a maximum of 300mA to 350mA) should choose resistors according to the formula:

$$R = 450/I$$

Where *R* is the resistance connected between pins 2 and 5 and *I* is the current limit required in milliamps.

Capacitors C2 and C3 are necessary for the internal stability of IC1. Meters ME1 and ME2 are the optional ammeter and voltmeter respectively connected in the output circuit. While switched on light-emitting diode, D1, glows to show that the output circuit is working. If any fuse fails, the l.e.d. will not operate.

CONSTRUCTION

Construction of the Hobby PSU is straightforward but the following points must be noted. Fuseholder FS1 should be of the panel variety. Transformer T1 must be adequately rated – it will be described by the supplier as a 6W or 6VA unit – that is, it should be rated at *500mA minimum*.

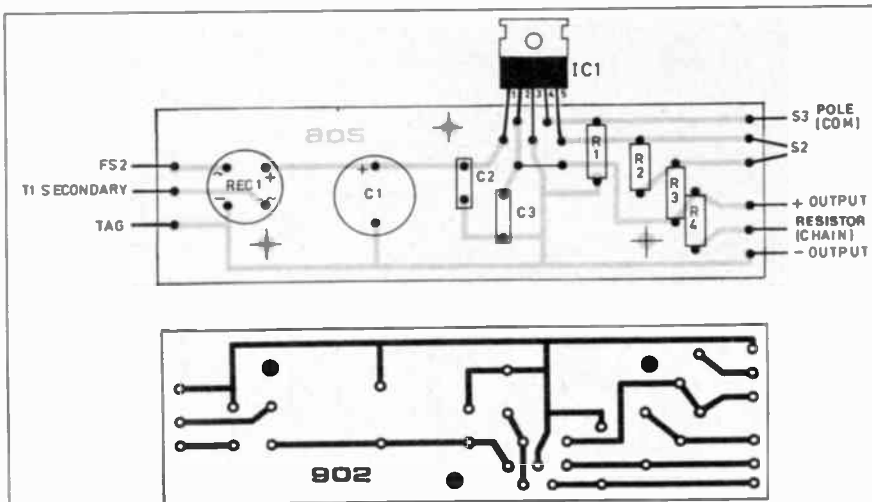


Fig. 2. Printed circuit board component layout and full size copper foil master pattern.

The l.e.d. indicator in the output, D1, must be of the *constant current* type requiring no series resistor. It should be capable of operating over the range 3V to 12V.

Rotary switch S3 must be of the ***make-before-break*** type. These are readily available but perhaps less commonly used than the break-before-make variety. If the latter type is used, there will be no resistor connected between IC1 pins 2 and 4 between switch positions. Under such conditions, the output would repeatedly rise to 12V or more as the switch was rotated and this could be damaging to certain circuits.

Construction is based on a small printed circuit board (p.c.b.) and the topside component layout and full size underside copper foil master pattern is shown in Fig. 2. This board is obtainable from the *EPE PCB Service*, code 902.

Begin construction by drilling the three mounting holes in the positions indicated. Solder the link wire into position. Follow with the on-board components in the following order: all resistors (flat with the board) and capacitors noting the polarity of C1, then REC1 (note the lettering on top indicating the orientation) and then IC1. The bridge rectifier REC1 should be soldered so that it stands 5mm clear of the board.

Solder 20cm pieces of stranded connecting wire to the solder pads, at each end of the board, marked FS2, T1 secondary, tag, − output, chain, + output, S2 (2 off) and S3 common. The use of different colours – for example, rainbow ribbon cable – is advised to avoid wiring errors later.

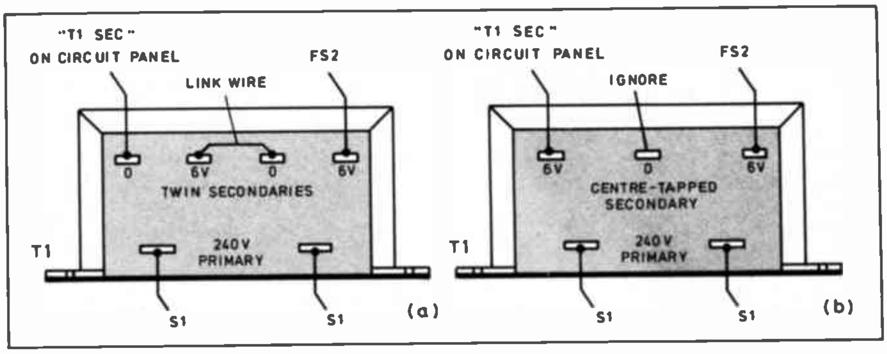


Fig. 4. Wiring details for the transformer secondary windings: (a) twin and (b) centre-tapped secondaries.

CASE ASSEMBLY

All components, apart from transformer T1, switch S1 and fuse FS1, are mounted on the *lid* section of the metal case. Make holes in the lid for switches S2 and S3, for fuseholder FS2, l.e.d. D1 clip and for the output terminals SK1 and SK2. If meters are to be incorporated, make the holes for these also. (See photographs for component position guide).

A cardboard template is usually provided with the meters. Measure the positions carefully and tape the template in place. Draw round the outline and mark the fixing centres. Drill a circle of small holes around the outline then join them together using a small hacksaw. Finally, file the edge of the hole smooth and drill the fixing holes.

Hold the circuit panel temporarily 5mm clear of the lid in the position shown – see photograph. Mark the position of the hole in IC1 tab on the side panel and drill this. Using this hole, secure the i.c. temporarily and mark the position of the circuit panel mounting holes on the lid of the box. Remove the panel and drill these through.

Drill holes in the base section to mount the transformer, switch S1, fuseholder FS1 and for the strain relief bush to be used on the mains input lead later. Mount these components using a solder tag on one of the transformer fixings. ***Note that this solder tag will be used to Earth the case and transformer core and is essential for safety reasons.***

Attach fuseholder FS2 and slide-switch S2. Mount the output terminals/sockets SK1 and SK2 using the plastic bushes supplied to insulate them from the metalwork. Use solder tags for the connections to be made later. In fact, SK2 (negative) may make metallic contact with the case because this is at supply negative voltage anyway. Mount the meters if these are used.

NYLON FIXINGS

Attach the circuit panel using short plastic stand-off insulators on the bolt shanks and thin ***nylon*** fixings. Note that it is essential for the underside of the panel to remain well clear of the base with no possibility of any protrusions on the underside touching the metalwork. Secure IC1 using a *metal* fixing. There must be no strain on IC1 pins when the circuit panel is bolted into position.

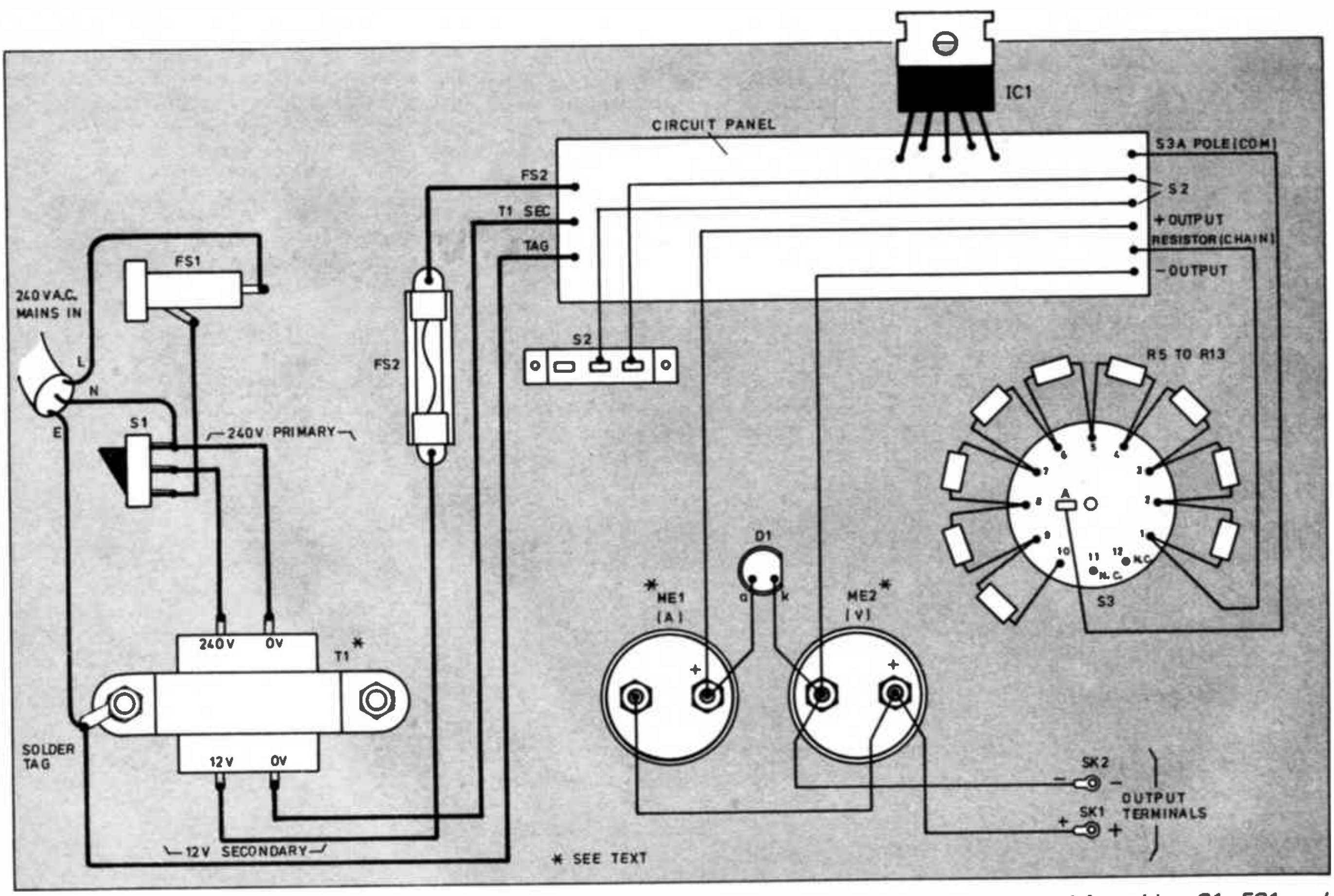


Fig. 3. Interwiring details from the p.c.b. to off-board components. Mains rated wire must be used for wiring S1, FS1 and transformer T1.

Prepare rotary switch S3 in the following way. First, remove the mounting nut, serrated washer and tab washer – a circle of holes will be revealed. Replace the tab washer with the protrusion engaging with the correct hole so that only *ten* positions are provided (the hole will probably be marked with the number ten – otherwise use trial and error).

Bend the component tags outwards and, referring to Fig. 3, solder resistors R5 to R13 around those marked 1 to 10 as indicated. Mount S3 and, again referring to Fig. 3, complete the internal wiring shortening any wires as necessary. The wires may be neatly grouped using cable ties.

When connecting the output terminals, note that the *positive* is the *red* one. If the mains transformer is of the type having *twin* 6V secondaries refer to Fig. 4a. If it has a 6V-0V-6V (centre-tapped) secondary, refer to Fig. 4b.

If no voltmeter is to be used, this is ignored on the diagram. If no ammeter is used it is simply by-passed. If meters are present, note that they are *polarity sensitive* – there will be a plus (+) inscribed on the body next to the positive terminal.

ADDITIONAL SAFETY

The mains input wire must be of 3-core *mains* type of 3A rating minimum. It must be firmly secured using a proper strain relief bush through the hole drilled for the purpose with a little slack left inside the case.

Mains-type wire must also be used for all FS1, S1 and T1 transformer primary connections and these must be secured so that they cannot dislodge in service. The Earth wire must be soldered securely to the solder tag at T1 fixing.

Note that the specified switch needs both a mains Live and Neutral feed because of its internal neon indicator. This is convenient because the switch then acts as an anchorage point for the mains neutral wire.

If the mains plug is of the UK pattern, fit it with a 2A or a 3A fuse. Insert FS1 and FS2 into their holders and fit switch S3 control knob. Make a cardboard shield for the mains connections at FS1, S1 and T1 primary windings.

Fit the lid of the case checking that no wires are trapped and no short-circuits are formed with the metalwork or anything else. Fit the base with self-adhesive plastic feet to protect the work surface.

TESTING

For safety reasons, it is essential for all testing to be carried out with the lid of the case in position.

No adjustment to the circuit is normally needed – testing is simply a matter of checking for correct operation. With the lid of the case on, set switch S3 for minimum (3V) output. Plug the unit into the mains and switch on. Note that the mains neon indicator lights and the l.e.d. operates.

If there is an inbuilt voltmeter, check that this reads 3V approximately. Rotate S3 control knob and note that the output increases in approximately 1V steps to 12V. If this check is made using a multitester, set it to a suitable voltage range and apply it *directly* to the output terminals observing the polarity.

OVER THE LIMIT

If an ammeter has been fitted, the output current limit is checked by simply short-circuiting the terminals using a piece of connecting wire. The voltmeter will read zero and the l.e.d. indicator will go off. The meter should indicate 300mA approximately (with switch S2 closed) or around 50mA (with S2 open). Any current up to 350mA is satisfactory for the upper limit. The current should remain substantially constant whatever the selected output voltage.

If a multi-tester (multimeter) is used, set it to an appropriate current range and apply the probes to the output terminals *direct*. The results should be as above.

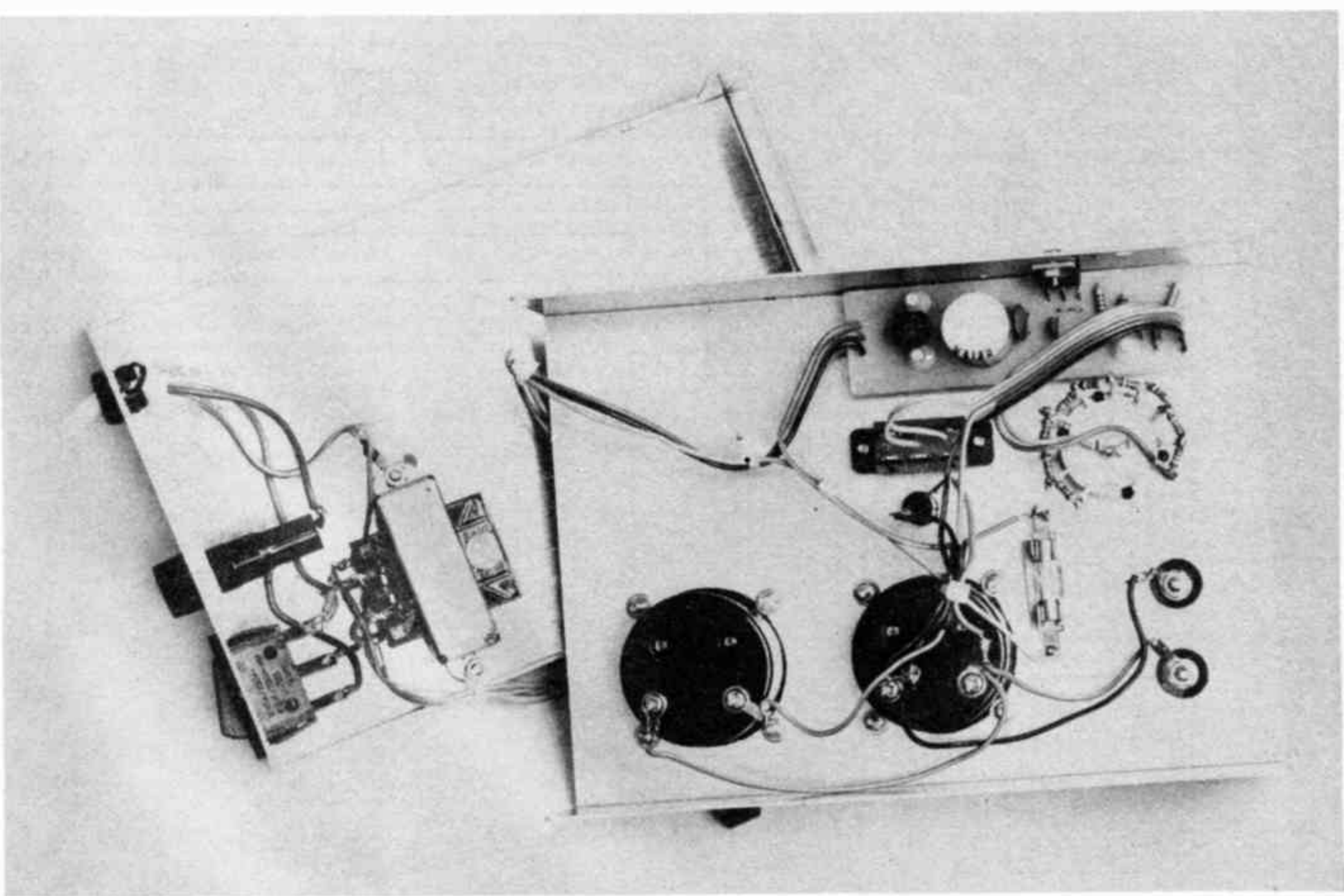
If an output limit is unacceptably high, increase the value of resistor R3 slightly and *vice-versa*. Similarly, to reduce the lower current limit increase the value of R2 slightly and *vice-versa*. In the absence of any meters, correct operation will have to be taken on trust.

Short-circuit the output again so that the maximum current is drawn. Under these conditions, the greatest amount of heat is produced by IC1 and a check should be made to see that it is dissipated adequately.

The case in the region of IC1 will become warm – check after an hour or so that it is not excessively so. It will be found that a low output voltage combined with a high current will produce the greatest amount of heat. Make a scale for rotary switch S3 and a label for S2.

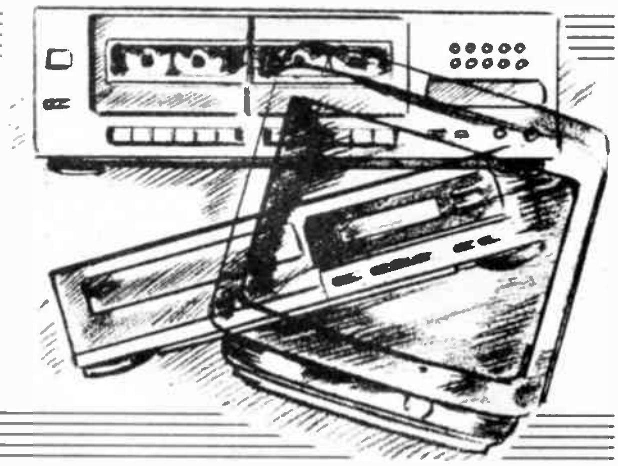
When testing a circuit requiring less than 50mA, it would be wise to get into the habit of setting the current limit accordingly. There will then be less chance of damage in the event of there being a circuit fault such as that due to a short circuit.

You will always be powered-up with the Hobby PSU! □



Layout of components in the base and lid of the aluminium metal box – using meters.

AUDIO AUXIPLEXER



WILLIAM E. CHESTER

Ease the hassle of plugging in extras to your hi-fi equipment with this audio multiplexer and optional remote control.

If, like the author, you continually expand your hi-fi set-up by adding audio separates and so make greater demands on the input capability of the existing amplifier, this project will be of interest to you.

The circuit described here is a four plus one channel stereo analogue switch. The extra channel is used for tape to tape recording. Its use, though, is not limited to stereo audio for it can be used wherever analogue signals need to be switched with minimal disruption.

One feature which should prove particularly appealing is the option for remote control. An infra-red receiver is described, having a typical range of 10 metres. However, a transmitter unit is not described – simply use an existing television or video remote control keypad.

Many remote control keypad units have "redundant" buttons whose transmitted code is not normally used. One such button is ideal for operating the Audio Auxiplexer if the television or video deck is on and within range at the time.

The name for this project came about because of the auxiliary input of the hi-fi amplifier. This was the only general purpose input available for connection of the Nicam TV sound decoder, compact disc player or hi-fi video sound outputs. The phono plugs had to be frequently changed at the back of the amplifier, depending on which source was to be listened to. By subjective standards, the design's noise performance standard is extremely good.

DESIGN CONSIDERATIONS

Since for the original application the author had stereo sources in mind, the design is based on the 4052B analogue multiplexer integrated circuit. Being a four-position double-pole switch, one 4052 chip will deal with all four stereo channels.

Switch control is achieved digitally by presenting a 2-bit binary code to two control pins of the 4052B chip. Additionally, placing logic 1 on an inhibit input will mute the signal output. This feature is made use of by the remote control receiver. Sound is muted until the user has stopped flicking through the four channels.

Purists may wonder why an LM1037 chip was not used as the audio multiplexer. There are at least two reasons. Firstly, the author does not find the LM1037 technical specification to be very awe inspiring, especially when a lot of audio anomalies in hi-fi are tested by the subjective qualities of the end user.

For instance, the LM1037 total harmonic distortion at 1V r.m.s. is around 0·04 per cent, with a maximum of 0·1 per cent. The 4052B offers a typical 0·04 per cent sine wave distortion at 1kHz. Putting aside the slight technical difference here, who could tell the difference between 0·04 and 0·1 per cent harmonic distortion? *(Specification figures may vary slightly between manufacturers. Ed.)*

Channel separation in the 4052B is quoted as −50dB at 3MHz for a 5V peak-to-peak input waveform. Down at audio frequencies this figure should become nearer to the LM1037 figure of −95dB at 1kHz.

Certainly, in listening tests on the prototype, signal breakthrough onto a quiet channel was inaudible at two feet from a loudspeaker and the volume set on 75 per cent of its potential 20W r.m.s. output.

Secondly, the LM1037 is over ten times more expensive, and perhaps there is something to be said for the sense of achievement that comes from making the most of alternatives. Simply dismissing the 4052B based on its apparent cheapness may not be doing it justice. Let's face it, if you blow one up during your exploits, they don't cost a bomb to replace either!

Of course, in analogue multiplexers there are little parasitic nasties such as on-resistance and feedthrough capacitance.

INSIDE A 4052B

A simplified diagram of just one switch within a 4052B chip (half a stereo channel) is shown in Fig.1. Metal oxide (MOS) field effect transistors are used throughout. The on-resistance, R_{ON} of the switch is a consequence of the series and parallel combination of the f.e.t. channel resistances within transistors TR1 to TR6. Each channel resistance is inversely proportional to the supply voltage.

In other words, the higher the supply voltage (V_{DD}-V_{SS}), the greater the gate to source voltage differential and thus the lower the channel resistance when the control level is at logic 1.

A supply range of 9V to 12V for the Audio Auxiplexer was chosen to allow operation from a battery and to keep the variation of on-resistance between the limits 75 ohms to 100 ohms. In the 4052B itself, steps have been taken in the design to linearise the transfer characteristics due to changes in R_{ON}.

Feedthrough capacitance between each switch input and output for the 4052B is

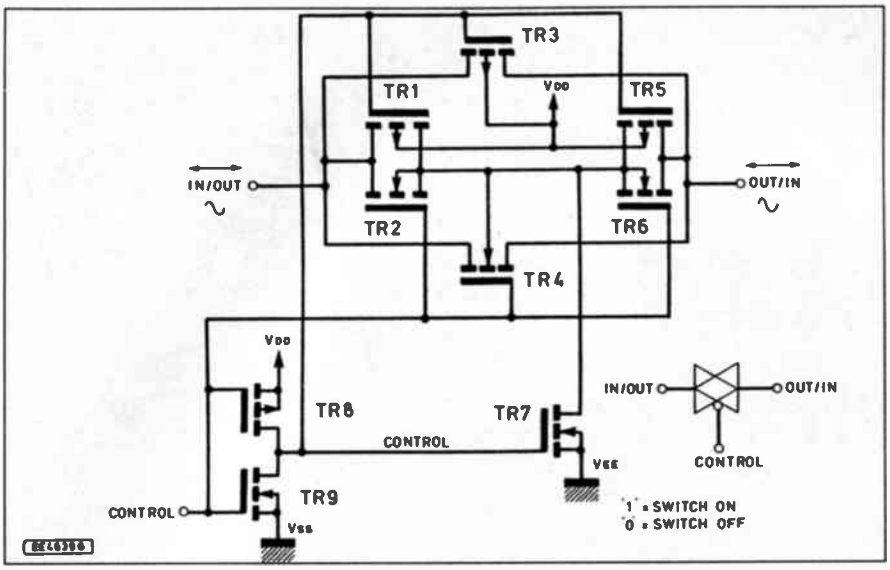


Fig. 1. Simplified 4052 multiplexer switch element.

C_f reactance at 30MHz $= 1/2\pi fc$
$= 1/(6{\cdot}28 \times 30{\cdot}10^6 \times 0{\cdot}12 \times 10^{-12}) = 44{\cdot}2\,k\Omega = X_c$
Feedthrough attenuation at 30 MHz $= 20 \log (R_L/(R_L + X_c)) = -33dB$
(neglecting C_L) for $R_L = 1k\Omega$

C_f reactance at 20kHz $= 66{\cdot}3M\Omega = X_c$
Feedthrough attenuation at 20kHz $= 20 \log (R_L/(R_L + X_C)) = -96{\cdot}4dB$ for $R_L = 1k\Omega$
For a realistic R_L of 47kΩ this figure becomes: $-63dB$ for $(R_L = 47k\Omega)$
At mid-band audio frequencies the feedthrough attenuation is around
$-75dB (R_L = 47k\Omega)$
Example: If the switch is off and V_{in} is 1V r.m.s. then V_{out} at a signal frequency of 5kHz will be 0·5mV pk-pk.

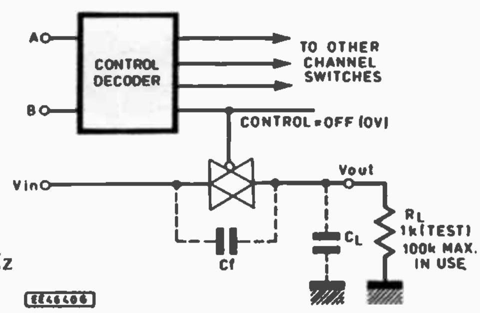


Fig. 2. Calculating signal feedthrough in an unselected (off) 4052 switch path.

tors R7 and R8. The transistors operate at economical display.

Two light emitting diodes (l.e.d.s D1 and D2) instead of four have been employed: they simply echo the binary representation of the selected stereo source, indicating which audio channel is active. The circuit has been designed so that both D1 and D2 glow dimly when audio Source 1 is selected.

Having the l.e.d.s glowing dimly instead of being turned fully off obviates the need for a power-on indicator and allows the display to be read in the dark. Very much like cat's-eyes, you can tell exactly which eye the cat is blinking. The brightness of the dim glow, if you see what is meant, is determined by the value of supply filter resistor R1, which is shown in the power supply circuit diagram of Fig. 5.

Because of the inclusion of resistor R1, the power line voltage fed to TR1 and TR2 is slightly higher than that supplied to the rest of the circuits. Consequently, the output high voltages from IC2 pins 1 and 14 do not quite manage to cut-off the base-emitter junctions of the transistors.

given at around 0·12pF; quite small by audio standards. This capacitance, if high enough would be the route for an unselected signal to breakthrough to the output terminal.

The specified feedthrough attenuation of -50dB at 30MHz with an input of 5V peak-to-peak is quoted for an output load of one kilohm. However, only a 20kHz bandwidth is needed for this Audio Auxiplexer application. A value of 0·12pF equates to a reactance of 1330 megohms at a frequency of 1kHz. An idea of the calculations needed to quantify feedthrough for a 4052B switch that is turned off is given in Fig. 2.

Note that transistor TR7 shown in Fig.1 is turned on when the switch is unselected (control voltage at logic 0). The low channel resistance of TR7 takes the mid-point of the switch to ground thereby minimising signal feedthrough via TR1, TR2 or TR5, TR6.

The 4052B requires three power supply lines, namely V_{DD}, V_{SS} and V_{EE}. The supply power for this device is taken to V_{DD}-V_{SS}, so the digital control inputs are referenced to V_{SS}. The analogue inputs and outputs are referenced to V_{EE}, which must be less than or equal to V_{SS}.

CHANNEL SELECTION

The circuit diagram for the channel selection controller of the Audio Auxiplexer is shown in Fig. 3.

Digital selection of the audio signal source is made by IC1 and IC2 in conjunction with switches S1 to S4. IC1 is an 8-bit priority encoder, although only four of its eight inputs are actually used.

Since the select switches S1 to S4 are inexpensive pushbutton switches, it is possible that two might be pressed simultaneously by mistake. However, IC1 conveniently outputs a two-bit code, from pin 7 and pin 9, which corresponds only to the highest priority input line taken high by the switches.

The logic 1 voltage level at IC1 pin 14 (gate select) returns to logic 0 when all inputs (IC1 pins 10 to 13) are released. This action causes the 4-bit latch, IC2, to capture input data at its pins 2 and 3. The data appears at the Q0 and Q1 outputs of IC2 and it is this binary code which determines the 4052B (IC3 and IC5 in Fig.4) analogue switch selection.

An inversion of the control code is applied by IC2 pins 1 and 14 to the bases (b) of transistors TR1 and TR2 via resistors R7 and R8.

MULTIPLEXING STAGE

The circuit diagram details for the audio multiplexing stage are shown in Fig. 4.

Transistors TR3 to TR12 are connected as unity gain emitter-followers. They offer an approximate impedance of 45 kilohms to audio input signals and a very low output impedance to drive signal tracking into the analogue switches, IC3 and IC5.

Due to the nature of each base-emitter junction, the d.c. voltage at each signal input to IC3 and IC5 will be about 0·8V below the V_{SS} supply voltage. Capacitors C4 to C17 are used to block d.c. voltages which may be inadvertently connected to the input and output terminals.

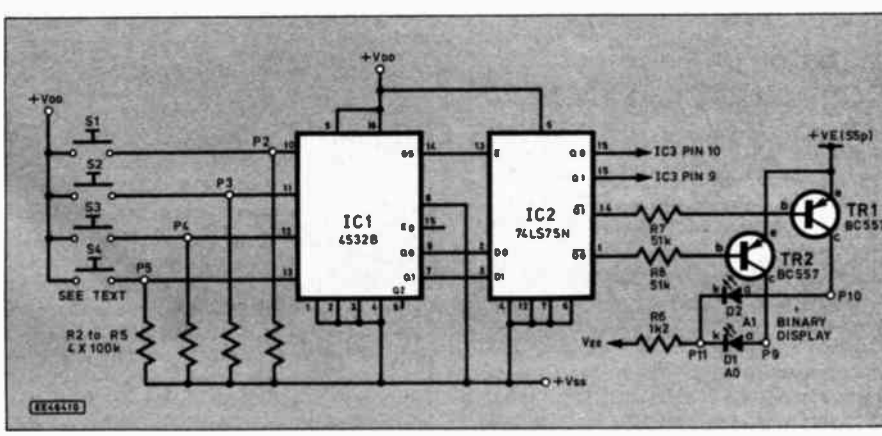


Fig. 3. Circuit diagram for the channel select section of the Auxiplexer.

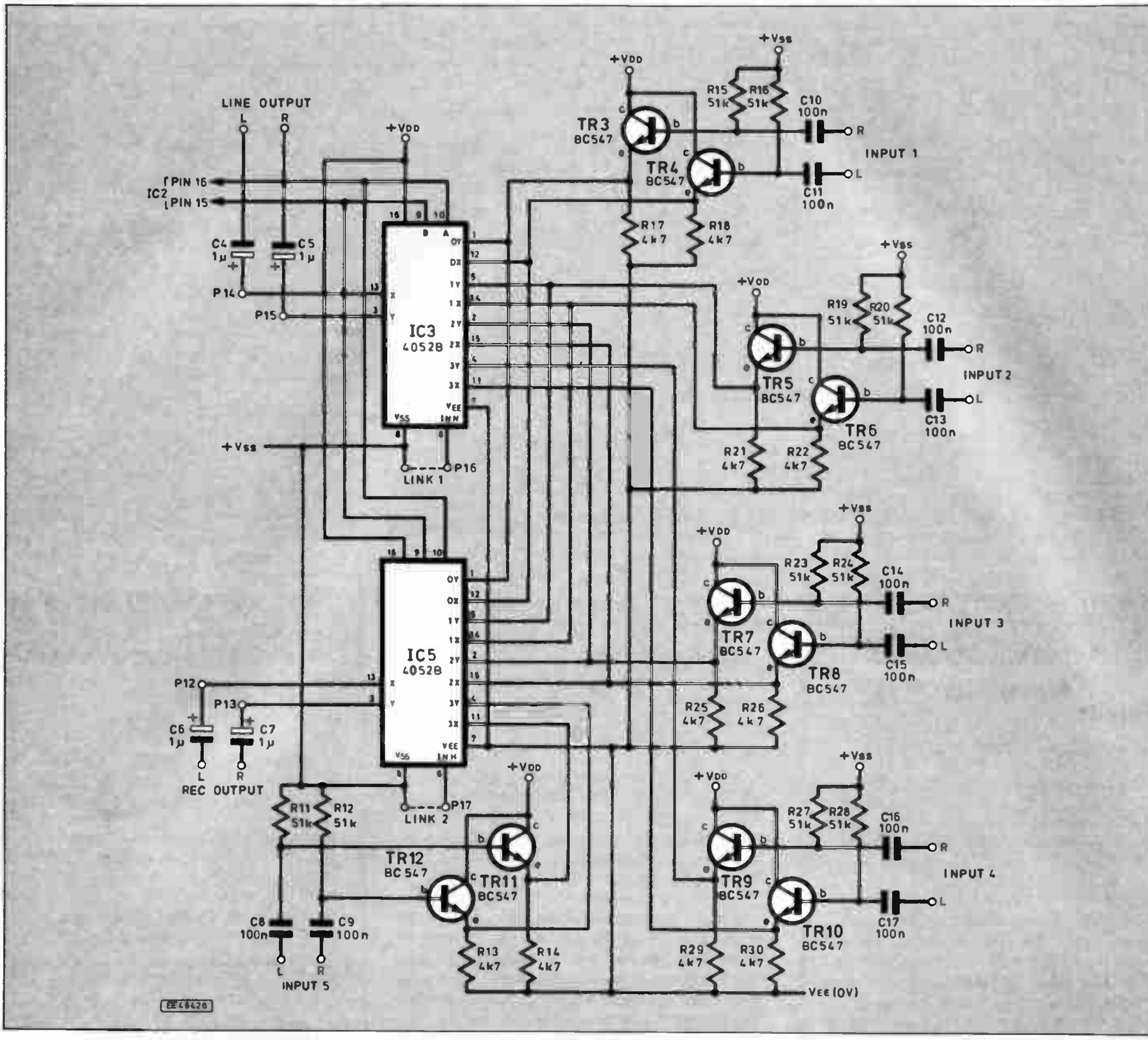


Fig. 4. Circuit diagram for the Audio Multiplexing stage.

The idea of using ten transistors at the signal source inputs is to buffer the high impedance input lines and to provide a low impedance feed to the analogue switch inputs. The length of the printed circuit board tracking to these latter inputs could provide the opportunity for cross-talk from adjacent "other channel" tracking, especially if two high impedance signal tracks were to be run closely parallel for any appreciable length.

As well as preserving good channel separation, an added benefit of low impedance may be an ability to minimise the small control voltage transients (of around 30mV) fed into the analogue switch channels by control voltage changes on the 4052B control inputs A and B, as supplied by IC2 in Fig. 3.

On a practical note, the low impedance LINE-OUT output is desirable where the Auxiplexer is used some distance from the main amp. Noise susceptibility can be a problem on long, higher impedance feed and cabling systems.

The possibility of signal cross-talk and transient breakthrough was borne in mind when designing the printed circuit board. High impedance tracking is kept short while other signal tracking is distanced away from, or placed at right angles to different channel tracking. Additionally, placing power-rail tracking or large areas of power-plane copper in proximity to the signal tracks helps lower their impedance and susceptibility to picking up radio frequency (r.f.) noise.

POWER SUPPLY

Details of the power supply circuits are shown in Fig. 5. Power may be supplied at any d.c. voltage between 9V and 12V. Resistor R1 and capacitor C1 filter the supply voltage to prevent false triggering of IC1 and IC2 in respect of mains-borne interference.

A current drain of 8mA to 12mA causes a voltage drop of about 0·25V across resistor R1. This voltage effectively appears across the base-emitter junctions of transistors TR1 and TR2, thus causing l.e.d.s D1 and D2 to glow dimly when audio input Source 1 is selected.

The power supply voltage for the V_{SS} inputs of IC3 and IC5 (pin 8) is derived via a 741 op.amp, IC4, which is used to buffer a split level reference voltage as set by resistors R9 and R10.

Total circuit current drain, with both display l.e.d.s turned on, is around 18mA

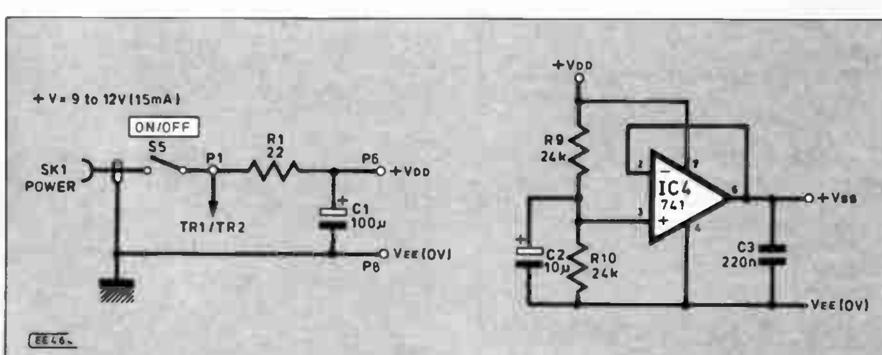


Fig. 5. Power supply circuit diagram details.

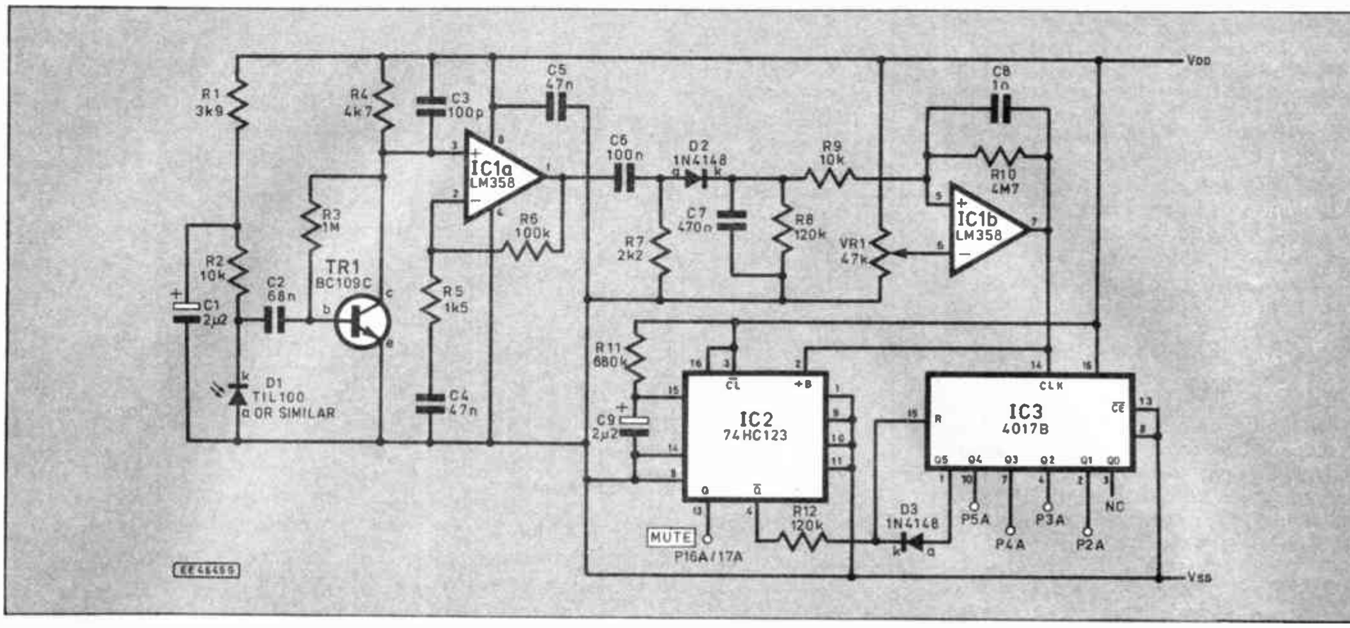


Fig. 6. Circuit diagram for the Infra-Red Receiver.

COMPONENTS

MAIN CIRCUIT

Resistors

R1	22	
R2 to R5	100k (4 off)	
R6	1k2	
R7, R8, R11, R12, R15, R16, R19, R20, R23, R24, R27, R28	51k (12 off)	
R9, R10	24k (2 off)	
R13, R14, R17, R18, R21, R22, R25, R26, R29, R30	4k7 (10 off)	

All 0·25W 2% carbon film or better.

See SHOP TALK Page

Capacitors

C1	100µ radial elect. 25V
C2	10µ radial elect. 16V
C3	220n ceramic minidisc 16V
C4 to C7	1µ tantalum 35V (4 off)
C8 to C17	100n polyester (10 off)

Semiconductors

D1, D2	3mm green l.e.d.
TR1, TR2	BC557 *pnp* transistor (2 off)
TR3 to TR12	BC547 *npn* transistor (10 off)
IC1	4532B 8-bit priority encoder
IC2	74LS75N dual 2-bit latch
IC3, IC5	4052B dual 4-way audio multiplexer (2 off)
IC4	741 op.amp

Miscellaneous

S1 to S4 push-make switch (see text)
S5 s.p.s.t. min. slide switch

Printed circuit board available from *EPE PCB Service* code 903 (Control); 8-pin d.i.l. socket, 16-pin d.i.l. socket (4 off); SK1 to SK14; panel mounting phono sockets (14 off); twin screened audio cable (1 metre); plastic case, 175mm x 130mm x 58mm; battery and battery clip to suit; terminal solder pins; connecting wire; solder, etc.

Approx cost guidance only **£24**

maximum so exclusive operation from a battery could give a useful life.

REMOTE CONTROLLING

Operation by remote control may or may not be a good idea, depending on how many "couch-potatoes" are already resident in your household. Then again, the main emphasis is on convenience if you have to be operating something else in another part of the room.

It was decided not to increase the population of remote control transmitter units. You may already possess two or even three of these, so accessing the right one in a hurry can be a bit of a hectic operation. The Infra-Red Receiver circuit (referred to from now on as just the Receiver) shown in Fig. 6 should work well with most TV and video remote transmitter units.

Photo-diode D1 is reverse biased in the photo-voltaic mode. Light falling on its flattened, sensitive side causes the usually tiny "dark" leakage current (of about 30nA) to increase. The small change in current causes a voltage change across resistor R2, which is fed via coupling capacitor C2 into the common-emitter amplifier stage formed around TR1.

The value of capacitor C2 affects the sensitivity of the receiver since, in combination with the input impedance of TR1, it determines the low frequency roll-off (the −3dB point). A capacitance value of less than 68n may reduce sensitivity but, in experiments, a value greater than this did not give any further increase in sensitivity.

The −3dB point is no less than 2·5kHz, so very low frequency changes, caused, for example, by changes in ambient light levels or by the 50Hz flickering of tungsten filament lamps, will usefully be rejected. Collector load resistor R4 sets the stage gain around TR1 to about 120 and a good strong signal will present more than 50mV to the second stage around op.amp IC1a. Resistor R1 and capacitor C1 act as a power line filter to ensure the signal detected by photo diode D1 is not modulated by noise on the positive supply.

Capacitor C3 rolls-off the upper frequency response beyond 300kHz, whilst C4 gives unity gain at d.c. and maintains the lower signal frequency cut off at 2·5kHz.

COMPONENTS

RECEIVER

Resistors

R1	3k9
R2, R9	10k (2 off)
R3	1M
R4	4k7
R5	1k2
R6	100k
R7	2k2
R8, R12	120k (2 off)
R10	4M7
R11	680k

All 0.25W 2% carbon film or better.

See SHOP TALK Page

Potentiometer

VR1 47k min. preset horiz.

Capacitors

C1, C9	2µ2 radial elect. 25V (2 off)
C2	68n polyester 100V
C3	100p polystyrene 5 per cent
C4, C5	47n polyester 100V (2 off)
C6	100n polyester 100V
C7	470n polyester 100V
C8	1n ceramic

Semiconductors

D1	TIL100 or similar photo-diode
D2, D3	1N4148 signal diode (2 off)
TR1	BC550 or BC109C *npn* transistor
IC1	LM358 dual op.amp
IC2	74HC123 dual re-triggerable monostable
IC3	4017B decade counter

Miscellaneous

Printed circuit board available from *EPE PCB Service* code 904 (Rec.); 8-pin d.i.l. socket; 16-pin d.i.l. socket (2 off); ribbon cable to suit; terminal solder pins and/or 5-way connector (see text); connecting wire; solder, etc.

Approx cost guidance only **£12**

Resistors R5 and R6 set the gain of the second stage around IC1a to about 84, giving an overall voltage gain through stages one and two which approaches 10,000.

Passing through d.c. blocking capacitor C6, the output signal from IC1a pin 1 is half-wave rectified by diode D2. A symmetrical load for capacitor C6 is provided by resistor R7. In this application, the LM358 used for IC1 seemed happier operating with this resistive load rather than having the more usual load of a diode with its anode connected to the bottom supply rail.

Capacitor C7 smooths the rectified positive voltage pulses and the resultant average d.c. voltage appears at IC1b pin 5. Op.amp IC1b is wired as a comparator, resistor R10 giving it a hysteresis factor of about 10mV.

Preset potentiometer VR1 adjusts the switching threshold and is set for the maximum that maintains a low level output at IC1b pin 7 when no input signal is present. Output pulses from IC1b swing closely between near ground potential and the high level saturation voltage.

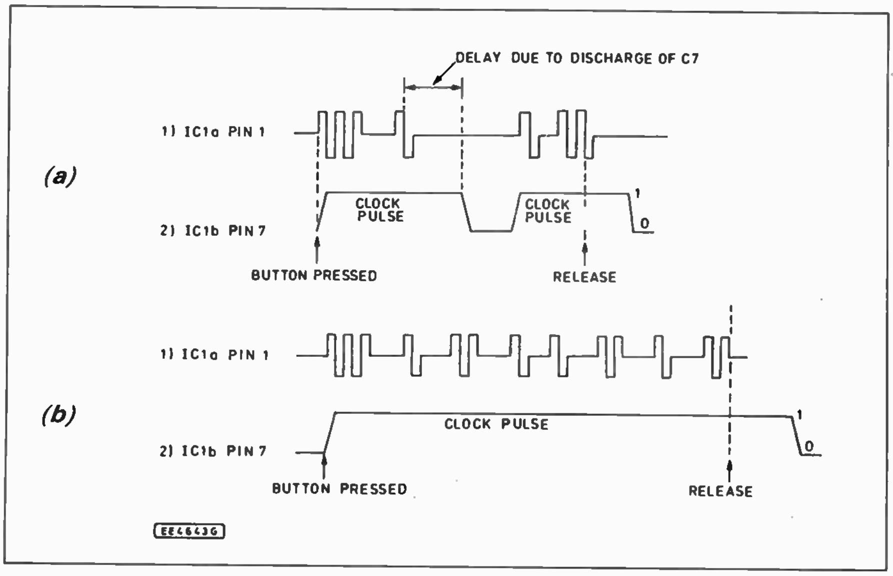


Fig. 7. Typical remote controller waveform responses.

SOUND MUTING

One function of the remote control Receiver, and which is very desirable and currently used on many remote controlled TVs, is a sound mute action. On the rising edge of each output pulse from IC1b a re-triggerable monostable, IC2, is triggered. The Q output of IC2 is connected to the inhibit control inputs of the 4052B multiplexing chips IC3 and IC5 (see Fig. 4). When IC2 is triggered its Q output is set to logic 1, a level which inhibits IC3 and IC5.

Trigger pulses received before the time constant of approximately 1·5 seconds expires, as set by capacitor C9 and resistor R11, will cause the monostable to remain triggered. Consequently, sound from all input sources is effectively disconnected until a remote control pulse has not been received within the preset period of 1·5 seconds. This delay is easily changed by adjustment of the values of C9 and R11.

COUNTER STAGE

The principal function of the Receiver circuit is to switch between the four audio channels. For this, the trigger pulses from IC1b also control a type 4017B decade counter, IC3.

Basically, the counter is clocked on by one place each time an input pulse, originating from the remote controller, is detected at the comparator output, IC1b pin 7. Four outputs of the counter are used, which quite simply replace the four push button switches S1 to S4.

The counter does not respond to the first pulse from IC1b since at this time its reset pin 15 is held high by IC2 pin 4. The *CR* network formed by resistor R12 and the reverse capacitance of D3 plus that of IC3's reset input ensures that the reset condition persists until the second clock pulse is received. The next four pulses cause IC3's outputs one to four to go high in sequence.

A sixth successive press of a remote transmitter button causes IC3 to be reset through D3. Another press causes IC3 output one to go high again, and so on.

Three successive presses of the transmitter button followed by a 1·5 second pause will give:

1) sound mute
2) audio Source 1 select
3) audio Source 2 select

then mute-off (after 1.5 seconds) and IC3 reset. To subsequently select Source 3, the button will then have to be pressed four times.

REMOTE CONTROLLERS

The way in which remote controller button presses relate to clock pulses sent to the 4017B counter depends to some extent on the manufacturer of the remote controller and on the value of the *CR* network formed by capacitor C7 and resistor R8. Fig. 7 illustrates the situation more clearly.

Pulse trains with gaps between them will produce continuous clock pulses while the transmitter button is held down, as in Fig. 7a. Conversely, transmitted data codes which have no distinguishable pause between them will give a single clock pulse, as in Fig. 7b. In this latter case, each press of the transmitter button will give a single clock pulse and advance counter IC3 to the next output.

In tests, three makes of remote controller were tried by the author, Philips, Hitachi and Granadacolour. They all operated the receiver decoder correctly. The Philips and Granadacolour gave continuous pulses (at a rate of about two per second) as in Fig. 7a when a button was held down. Short presses advanced the counter to the next sequential output.

RECEIVER POWER FACTORS

The Receiver circuitry chosen, as shown in Fig. 6, has a very low current drain. This was intentional since operation from a battery was required. Note that the supply for this circuit is sourced from V_{DD} and V_{SS} supply of the main Auxiplexer circuit.

The LM358 used for IC1 requires around 1·5mA and the total current may be less than 4mA on a 4·5V supply. Half of the LM358 is used as the pulse-shaping comparator.

Apart from its low supply current, the LM358 is also capable of taking its output down to the V_{SS} supply potential. This provides an ideal logic 0 for the inputs of the CMOS chips IC2 and IC3.

The logic 1 output level is not quite so ideal since the maximum on the LM358 output at saturation is about 1·5V less than the positive supply voltage on its pin 8. Nevertheless, an input voltage greater than 70 per cent of the supply voltage will normally be presented and be acceptable to the CMOS inputs as a logical 1.

The unity gain bandwidth for the LM358 is only about 1MHz but the gain factor of 84, as set here by R5 and R6 (1 + (R6/R5)), gives a usable range up to 40kHz. This is perfectly adequate in this application.

CONSTRUCTION

Details of the component layout and life size copper foil track pattern for the Main printed circuit board (p.c.b.) are shown in Fig. 8. The equivalent details for the Receiver p.c.b. are shown in Fig. 9. Both boards are available from the *EPE PCB Service*, codes 903 and 904 respectively.

Assemble components on the main p.c.b. in order of on-board link wires, i.c. sockets, capacitors, and then the transistors. Capacitors C1 and C2 are electrolytic types, so observe the correct polarity as shown in the component layout diagram. The transistors should also be correctly orientated according the same diagram.

Only fit link wires marked LK1 and LK2, which take the respective inhibit pins of IC3 and IC5 to their V_{SS} supply points, if the optional Receiver circuit is not required.

Terminal solder pins or flying leads can be used for connection points P1 to P17, depending on personal preference. They were also used on the prototype for input pairs RT1, LT1 to RT5, LT5. Alternatively, if you use pin and plug connectors instead they may be found to be more convenient, although more costly.

Additionally, link points A1 and A2, then A2 to A3, similarly link B1 to B2 and B2 to B3. If the l.e.d. display is required then link point Q1 to Q2, and point Q3 to Q4. These links and the wiring diagram are shown in Fig. 10.

Points P2 to P6 are grouped to allow connection to either the four pushbutton switches S1 to S4, or to the Receiver circuit board.

It is advisable to "earth" yourself before handling CMOS chips IC1, IC3 and IC5 in order to reduce the possibility of damage to them by static electricity discharge.

RECEIVER

With the Receiver p.c.b. fit the two link wires first, and then insert and solder all resistors. Fit diodes D2 and D3 making sure that they are correctly orientated. Solder in d.i.l. sockets for all the i.c.s. The capacitors are next, noting that C1 and C9 are polarised. Now correctly fit transistor TR1 and then solder in preset VR1.

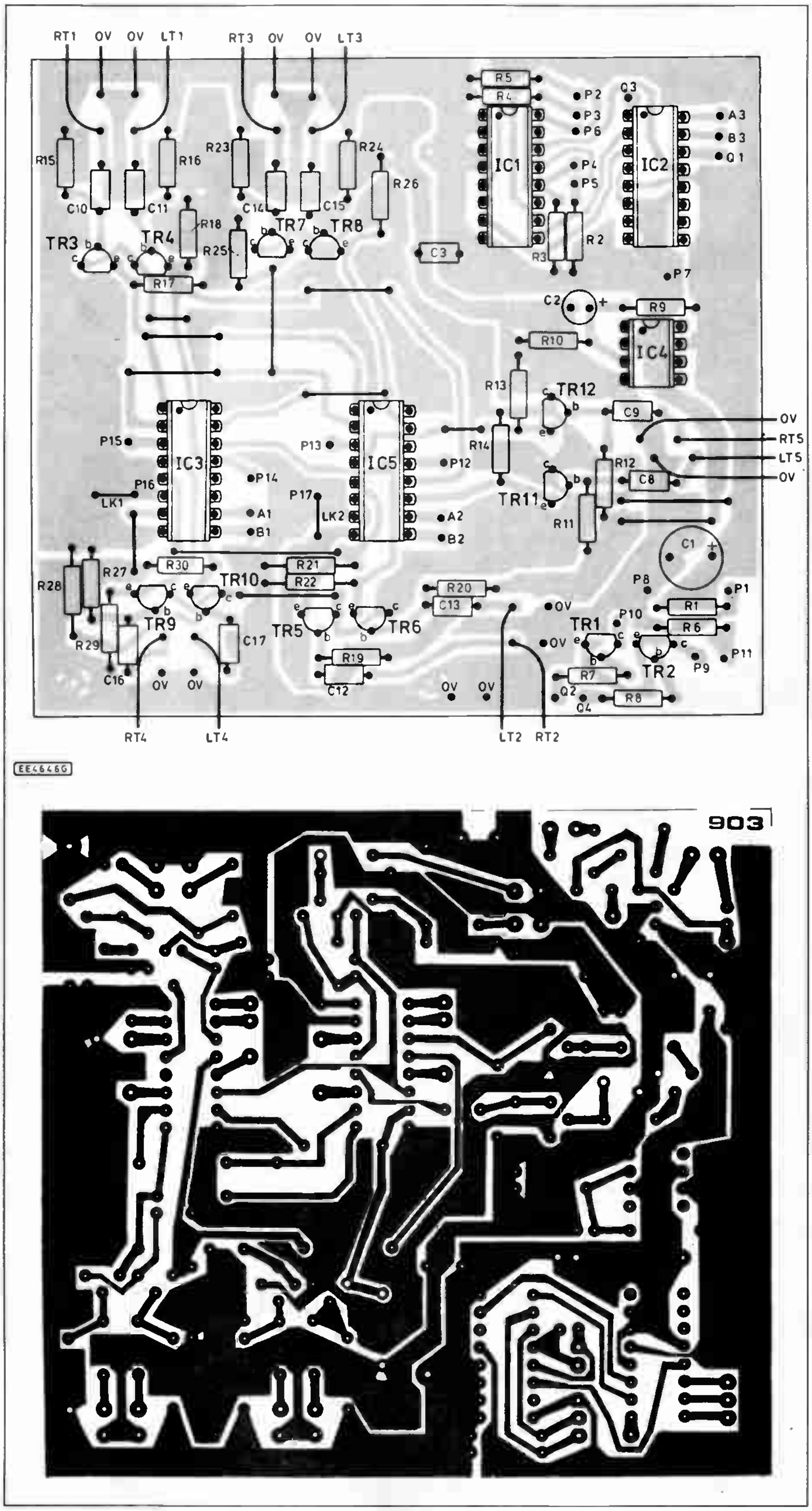


Fig. 8. Printed circuit board component layout and full size copper foil master pattern for the Main Control Board.

In the wiring diagram Fig. 10, the connection point numbering scheme, e.g. P2A, P7A reflects the terminal point to which connections should be made on the Main Auxiplexer p.c.b. For instance, P16A/17A of the Receiver board should be wired to points P16 and P17 on the Main p.c.b. A length of 6-way ribbon cable could be used for points P2A to P7A. The use of terminal pins is again up to personal preference.

TESTING AND SETTING-UP

Before connecting power to either p.c.b. do a thorough scan of the solder side to check for poorly soldered joints, and for solder splashes, particularly between the power planes, that could cause short-circuits. For test purposes without the Receiver p.c.b. ensure that links LK1 and LK2 are fitted.

Connect a battery or d.c. power supply of between 9V and 12V across points P1 (positive) and P8 (0V). Check the current drain by placing multimeter probes across resistor R1 and measure the voltage drop. A reading of 0·2V to 0·3V is normal and indicates a supply current of around 10mA.

Assuming a basic power supply voltage of 12V, the voltage at pins 16 of IC1, IC3 and IC5 should be about 11·8V, as will be the potential on IC2 pin 5 and IC4 pin 7 (about 8·8V with a 9V supply voltage). All readings are referenced to 0V at p.c.b. point P8. Check that the V_{SS} supply at point P7 is half the voltage on point P6.

Correct biasing of the input stages can be checked by measuring each transistor emitter voltage. Each base resistor will drop about 0·2V and each base-emitter junction drop about 0·6V (the latter being irrespective of power supply voltage).

The status of the l.e.d.s D1 and D2 is likely to be random at this time. With a pair of pliers or a short length of wire, short together points P2 and P6. If all is well, the l.e.d.s will both glow dimly. Try shorting points P5 and P6: both l.e.d.s should now light fully.

At this stage, the Main p.c.b. can be assembled into the case. However, if remote operation is required, links LK1 and LK2 should be removed and the following procedure carried out;

REMOTE CONTROL TESTING

Temporarily solder photo-diode D1 in place. Its final position may change according to the type of case or box used. Having already ascertained that the Main p.c.b. is functioning it is safe to complete all the interconnections. Switch on the supply and check that the P6A voltage appears at IC1 pin 8, IC2 pin 16 and IC3 pin 16.

Using P7A as the 0V reference, take voltage readings at various places. The cathode of diode D1 should be very close to the V_{DD} voltage at point P6, as should IC2 pin 4. In this state, IC3 will be reset: proof is given by a logic 1 (V_{DD} voltage level) on IC3 pin 3.

A d.c. voltage of about 1·5V to 3V should be present at IC1 pin 3. This is not critical but it should also appear at IC1 pin 1. A very high or very low voltage indicates that R3 or TR1 are not well.

Connect the measuring probe to IC1 pin 7 and turn the wiper of preset potentiometer VR1. For most of the wiper's rotation, the meter should show a very low voltage (less than 100mV) but at a particular point the meter reading should jump up to about (V_{DD}-1·5) volts. The correct setting is achieved by slowly turning back from the present position until the output at IC1 pin 7 drops down to about 0V again.

Using a remote transmitter handset, correct operation of the Receiver can now be confirmed. Direct the transmitter beam at photo-diode D1 and press a remote control button. Simultaneously, observe the voltage at IC2 pin 13. This output will go high (V_{DD}) and remain so if the transmitter is of the type shown in Figure 7a. If, however, the transmitter beam behaves more like the one represented in Fig. 7b, IC2 pin 13 will return to 0V within two seconds.

In either event, the high voltage level at P16A/P17A will return to 0V within two seconds of the transmitter button release. If it does not and appears "latched" then

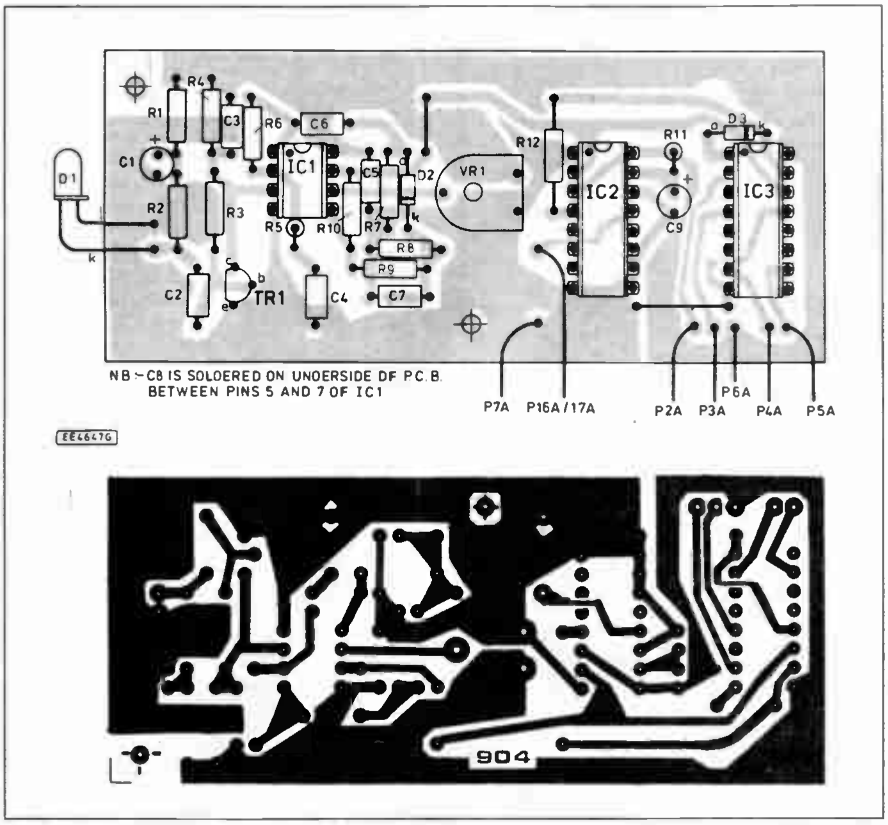


Fig. 9. Printed circuit board component layout and full size copper foil master pattern for the Receiver board.

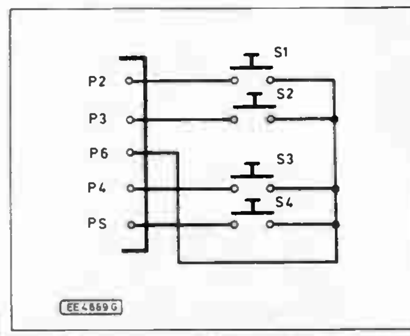
back off preset VR1 a little further. Capacitor C8 is used to damp any tendency for IC1b to oscillate so check that you have the correct value for this capacitor if problems persist.

Continuous short presses of the transmitter button will cause IC3 to sequentially step through its outputs. The voltage appearing at points P2A to P5A will confirm this.

A final inter-working check is completed when the l.e.d. display of D1 and D2 has been cycled through according to Table 1 in response to transmitter button action.

CASE CONSTRUCTION

The case used for the prototype is a plastic ABS type, external dimensions 175mm x 130mm x 58mm. It also features ventilation grills at the top and bottom, though these are not needed in normal use.



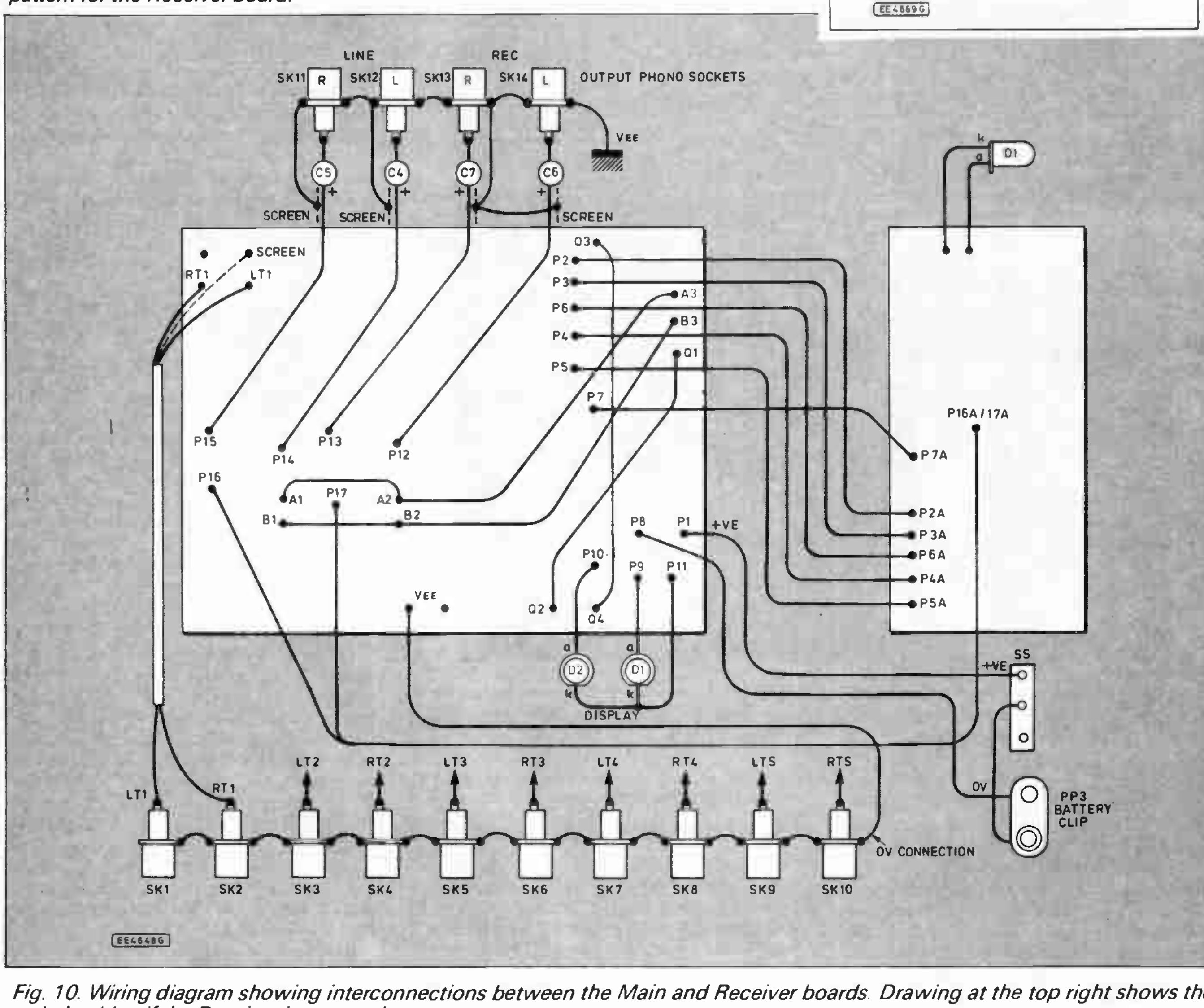


Fig. 10. Wiring diagram showing interconnections between the Main and Receiver boards. Drawing at the top right shows the switch wiring if the Receiver is not used.

Table 1: L.E.D. Display Truth Table

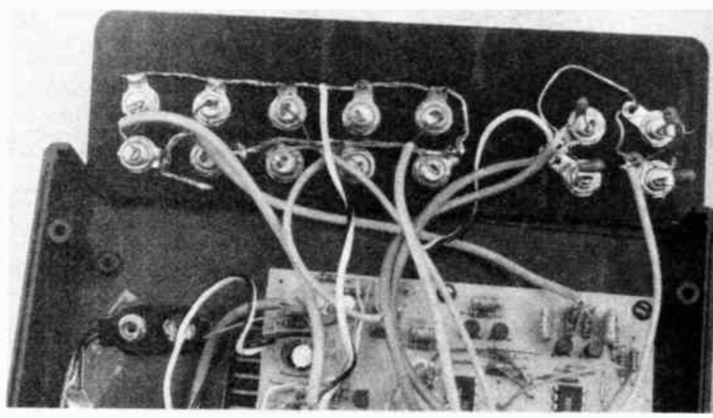
CONTROL INPUTS			L.E.D. STATUS	
B	A	SOURCE SELECTED	2	1
0	0	1	DIM	DIM
0	1	2	DIM	ON
1	0	3	ON	DIM
1	1	4	ON	ON
1	1	5	ON	ON

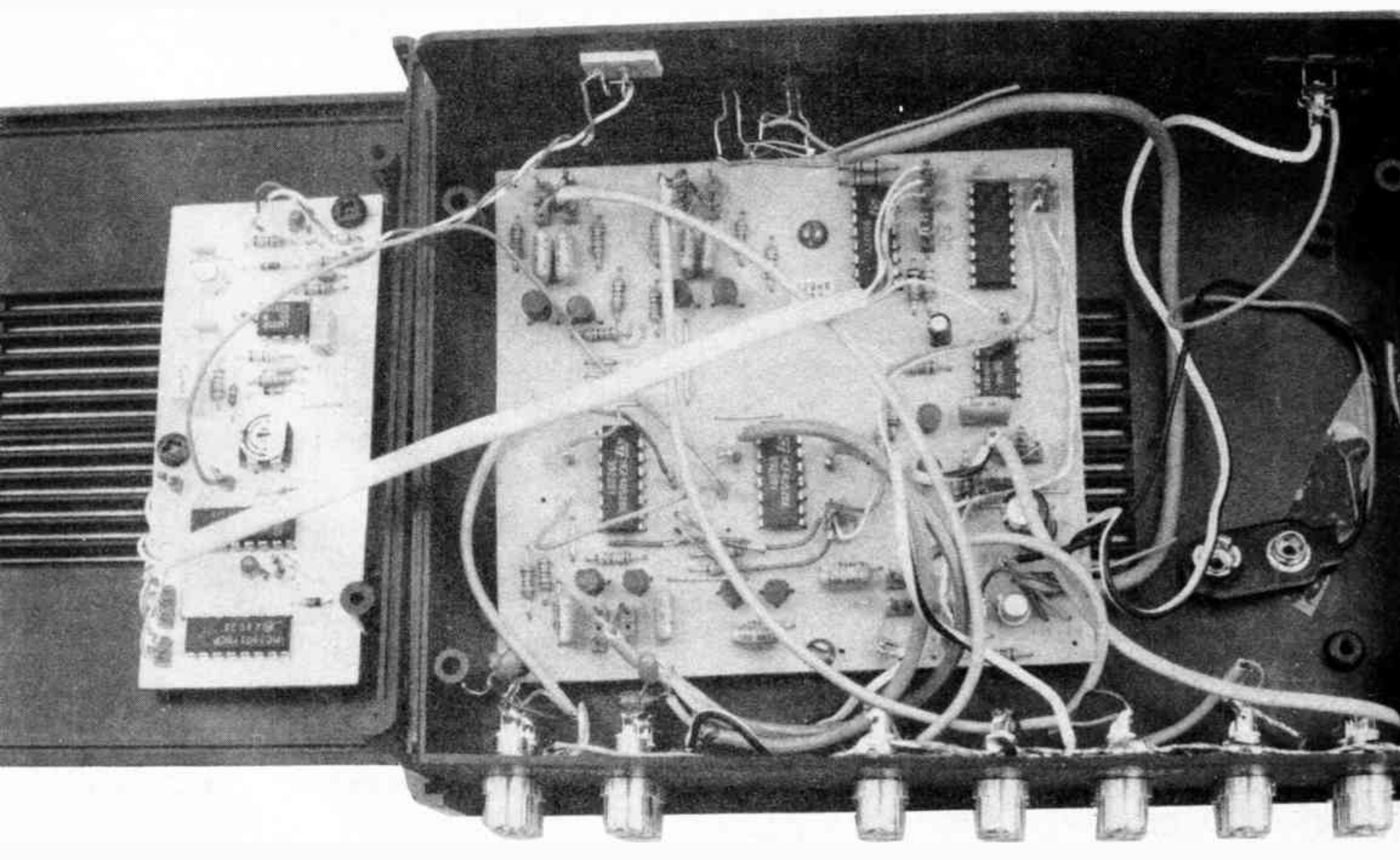
For the full complement of inputs and outputs, 14 holes each 6·5mm diameter were drilled into the back panel to take the audio input and output sockets. The front and back panels fit snugly in rebates in the upper and lower halves of the case.

The front panel is drilled to take the on/off switch, the two l.e.d.s and the four pushbutton switches. The prototype case was modified solely for remote operation, so a 5mm square aperture was needed for the photo-diode window.

Moulded bosses are provided inside both top and bottom halves of the case. These allow the Main p.c.b. to be fixed in the bottom and the Receiver p.c.b. in the top, using self-tapping screws.

Two 4·5mm holes accommodate the l.e.d. holders. Using three wires, connect p.c.b. points P9, P10 and P11 to the l.e.d.





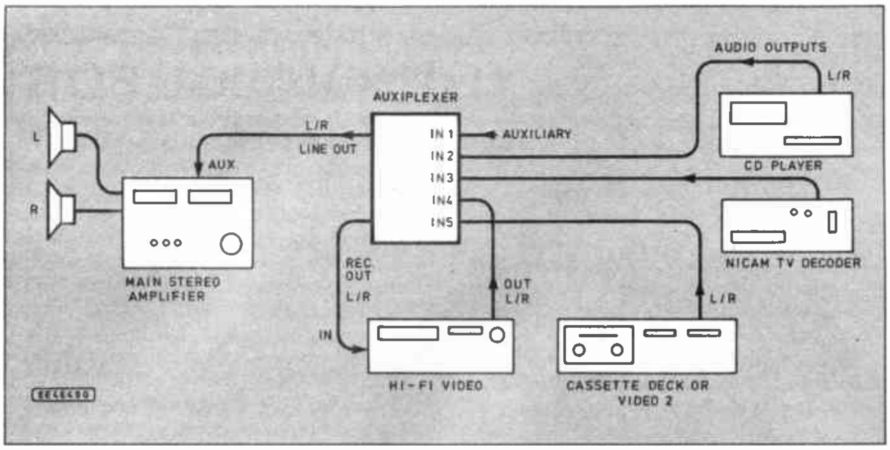


Fig. 11. Suggested use of the Audio Auxiplexer

wires. Clipping l.e.d. D2 into the left holder will ensure the display makes sense.

If a 9V battery is used, this can be fitted inside. Take the battery clip black wire to point P8 and the red wire to the pole of switch S1. One side terminal of S1 is then taken to p.c.b. point P1.

To hold the photo-diode D1 in place, it is useful to glue a small piece of copper stripboard (two tracks wide – 12mm x 8mm) just above the aperture on the back of the front panel. The diode leads can be cropped and soldered to these intermediate solder pads so that the diode's light-sensitive side is over the aperture. A short twisted pair not longer than 100mm is then taken to the diode connections on the Receiver p.c.b.

The remaining wiring concerns the audio inputs and outputs. Screened single- or twin-core cable is recommended for these. As shown on the interconnection diagram of Fig. 10, the outer connections of the phono sockets are strung together, by copper braid for instance, and taken to V_{EE}. Ensure that cable screens are terminated only at one end to prevent "earth-loops" and possible noise problems. *(Remember, though, that there must be a 0V connection between the Audio Auxiplexer and the equipment to which it is connected. Ed.)*

Note that capacitors C4 to C7 are mounted by soldering one lead of each to the output sockets.

IN USE

The prototype Audio Auxiplexer, complete with the remote control Receiver, functioned satisfactorily from a rather run-down PP3 battery at 7·5V even though a 9V to 12V supply is recommended. Dead battery syndrome is indicated when the Auxiplexer ignores any infra-red activity!

As already mentioned, the audio inputs should be treated as "general purpose". That is to say, the unit is meant to switch the full bandwidth of signals at a moderate amplitude.

The maximum input amplitude in mind at the time of design was one volt r.m.s., but there is no reason why anything up to 2·2V r.m.s. (6V peak-to-peak) cannot be handled when a 12V supply is provided. A typical normal input level might be as low as 250mV r.m.s.

By way of example, Fig. 11 shows a suggested set-up. The Audio Auxiplexer is interposed between each audio source and the stereo amplifier.

The REC-OUT output was provided since some amount of "tape-to-tape" recording use was envisaged. An input on socket IN5, for instance, could be taped by a machine connected to the REC-OUT socket. The line output of this same machine can be monitored during the recording by its connection to input socket IN4.

SENSITIVITY

Remote control transmitters having a nine volt power source gave a significantly longer reception range compared to those using two 1·5V cells. A glass lens (expensive) will boost the range but this is not essential. The expected range of four to ten metres should be more than adequate for most normal room dimensions.

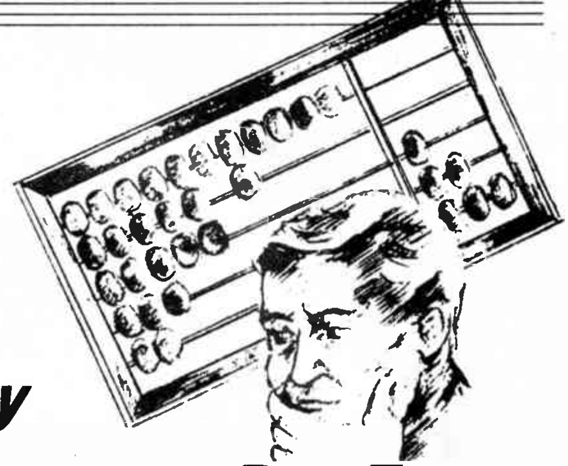
A supplementary infra-red filter was also tried in front of the photo-diode but again was found to be superfluous for normal circumstances. Besides which, the photo-diodes available usually have some form of integral filter.

If the counting action for a single button press seems sensitive and it is difficult to set the Auxiplexer to a particular input, then the time constant set by capacitor C7 and resistor R8 may need increasing. Increasing the value of R8 in steps of 10 to 20 kilohms should give the required result.

A handy feature provided by remote control facility is that switching to a silent (or unconnected) source effectively provides continuous sound mute. □

Special Series

CALCULATION CORNER



An introduction to A.C. theory

STEVE KNIGHT

Part Ten

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. We conclude the series this month by looking at phasor diagrams, reactance and impedance.

LAST month we saw how a phasor is simply a straight line of a length which represents the peak magnitude of an alternating current or voltage, rotating in an anti-clockwise direction at an angular velocity $\omega = 2\pi f$ rad/sec. If two such phasors are concerned, the angle between them shows the phase angle ϕ existing between the generated a.c. waveforms.

We will now work through some examples that will illustrate how we can use such diagrams to solve, by scaled drawing, a.c. problems, particularly in adding or subtracting sinusoidal currents or voltages, and finding circuit impedances where resistance, inductance and capacitance come into play.

To do this, you will need plenty of plain paper, a ruler and a protractor, plus a bit of stamina.

PHASOR ADDITION

We start with an example illustrating phasor addition.

1. Two alternating voltages are represented by $v_1 = 25 \sin \omega t$ and $v_2 = 20 \sin(\omega t + \pi/3)$ volts. Draw a scaled phasor diagram and from it find the resultant sum of these voltages.

Always try and draw your phasor diagrams at the instant $t = 0$ which for the above gives $v_1 = 0$ and $v_2 = 20 \sin \pi/3$. This gives us a **reference phasor** (v_1 in this case) which can be drawn horizontally on the paper. Fig. 10.1 shows the procedure which now follows.

Draw phasor v_1 horizontally and of a scale length (say, 1cm = 5V) equal to the peak amplitude of 25V. Phasor v_2 leads v_1 by $\pi/3$ rad (or 60°), so draw a line of scaled length equal to a peak amplitude of 20V at 60° to the reference phasor v_1.

If these two phasors are now considered to be rotating, they will generate two sinusoidal voltage waves exactly as Fig. 9.6 in last month's instalment illustrated, the phase angle between the waves now being 60°.

By adding these two waves we obtain a single **resultant** wave which is also sinusoidal and at a phase angle leading or lagging on the reference phasor.

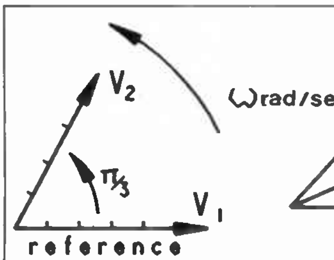


Fig. 10.1. Setting up the basic phasor diagram

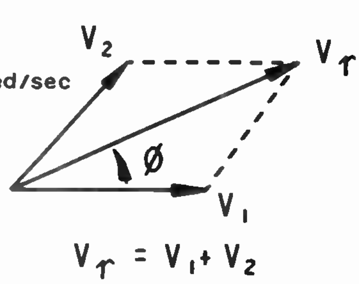


Fig. 10.2. Phasor addition.

This resultant, v_r, is found from the diagram by drawing the diagonal of the parallelogram as Fig. 10.2 shows. Those of you who have worked on force problems will recognise this as the same technique used in finding resultants from a number of forces acting at a point. The *length* of the resultant is now measured (to the chosen scaling) and this provides the peak value of the resultant wave; while a measure of angle ϕ tells us the phase angle by which v_r leads v_1.

From a scaled diagram (do this for yourself) we find

Length of the resultant = $v_r = 39\hat{V}$ peak

Phase angle relative to $v_1 = \phi = 27°$ or $\frac{3\pi}{40}$ rad.

Hence the resultant equation

$$\mathbf{v_r = 39 \sin(\omega t + \frac{3\pi}{40})} \text{ volts}$$

It is acceptable to write this equation in the form

$$v_r = 39 \sin(\omega t + 27°) \text{ volts}$$

but strictly this is a hybrid expression and to avoid any confusion the degree symbol must be clearly shown.

Notice that the peak value of v_r is *not* the simple addition of the peak values of v_1 and v_2 i.e. $25 + 20 = 45\hat{V}$ as it would be in a d.c. circuit, but here comes out at $39\hat{V}$.

PHASOR SUBTRACTION

Subtraction of phasor quantities can be treated by scaled diagrams if the phasor line for the quantity being subtracted is drawn in the opposite sense. This next example will make this method clear.

2. Two alternating currents are expressed by $i_1 = 4 \sin \omega t$ and $i_2 = 2 \sin(\omega t - \pi/4)$mA. From the circuit shown in Fig. 10.3 find the current i_3.

Here $i_1 = i_2 + i_3$ and so $i_3 = i_1 - i_2$. Kirchhoff's current law applies to current phasors just as it does for d.c. currents.

The phasor diagram of Fig. 10.4a shows us the two given

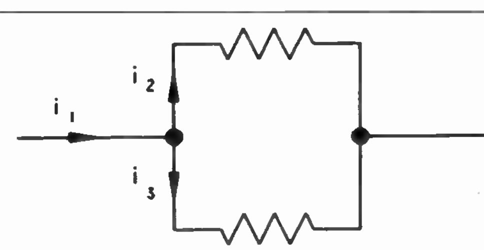


Fig. 10.3. Applying Kirchoff's current law to an a.c. circuit.

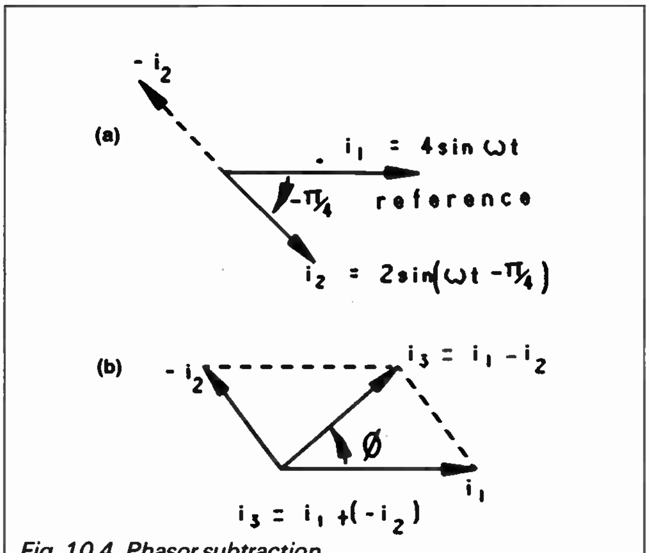


Fig. 10.4. Phasor subtraction.

currents i_1 and i_2 where i_2 is seen to lag i_1 (the reference) by $\pi/4$ or 45°. To perform the subtraction we reverse i_2 to give us $-i_2$ as shown by the broken line and *then* add i_1 to $-i_2$. The resultant $i_3 = i_1 + (-i_2)$ is then obtained as indicated in Fig. 10.4b. Here clearly i_3 leads i_1 by angle ϕ.

By making a scaled diagram we find by measurement:

Peak magnitude (length) of $i_3 = 2{\cdot}95$mA

Phase angle $\phi = 28°$ with i_3 leading reference i_1

The equation of i_3 is therefore

$$i_3 = 2{\cdot}95 \sin(\omega t + 28°) \text{ or } \mathbf{2{\cdot}95 \sin(\omega + \frac{28\pi}{180})mA}$$

The phasor triangle can, of course, be solved by the Cosine Rule for those who are familiar with trigonometry, but a large, carefully scaled phasor diagram can give quite accurate results. You will find a number of such examples in the self-assessment problems at the end of this article. Give yourself plenty of practice in resolving them.

PEAK OR R.M.S?

When we draw phasor diagrams to scale, there is no need (as we have so far done) to make the various phasor lengths equal to the peak values. Since for all sinusoidal waveforms r.m.s. = 0·707 peak values, we may scale all values by $\sqrt{2}$ and directly add or subtract phasors with their r.m.s. values.

REACTANCE

In a *linear* circuit consisting of resistors, inductors and capacitors, singly or in any combination, if any voltage or current has a sinusoidal waveform, *all* voltages and currents will be sinusoidal of the same frequency.

When an alternating voltage is applied to a complete circuit an alternating current will flow. The magnitude of this current will depend upon the amount of opposition presented by the circuit.

These quantities, as always, are related by Ohm's law: V(volts) = I (amperes) × opposition (ohms), but you will have noticed that the usual term "resistance" has been replaced by "opposition". This does not mean that ohms do not appear in a.c. circuit calculations, but in inductive and capacitive circuits the term we use is **reactance**. We shall consider the effect of a.c. conditions on resistance, inductance and capacitance individually.

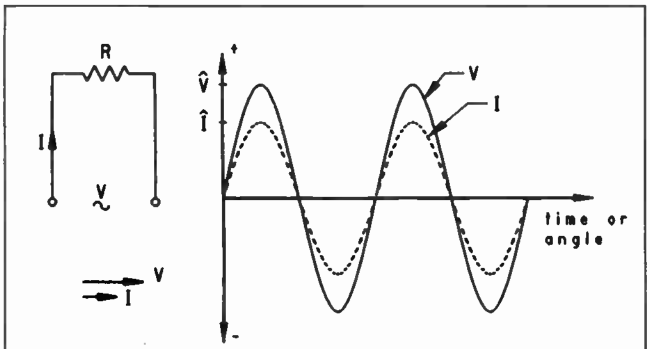


Fig. 10.5. In a purely resistive circuit V and I are in phase and I = V/R.

RESISTANCE

When a circuit consists only of pure resistance, then at any instant of time the current must be directly proportional to the voltage – Ohm's law must be obeyed. Then for a sinusoidal voltage, the current and voltage waveforms must be in step or **in phase** with each other at every instant. Fig. 10.5 shows us the phasor diagram and the in-phase condition existing in a resistive circuit.

Using r.m.s. values, I = V/R just as for a d.c. circuit. Phase angle ϕ is, of course, 0° and has no particular significance.

INDUCTIVE REACTANCE

When a circuit consists only of pure inductance, the alternating current induces an alternating back e.m.f. in the coil which acts in such a direction (remember Lenz's law?) that it *opposes* the applied voltage at every instant of time. This effectual opposition to the flow of current becomes greater as the frequency increases since the rate at which the current changes increases and the induced back e.m.f. becomes greater.

This opposing effect of inductance (which must *not* be confused in any way with the ordinary resistance of the material from which the inductor is wound) is known as the **inductive reactance**; this is denoted by X_L and is measured in ohms.

Applying Ohm's law, we then have

$$X_L = \frac{V}{I} \text{ where } X_L = \omega L \text{ or } 2\pi fL \text{ ohms}$$

V and I are r.m.s. values and L is in henries. X_L is therefore directly proportional to inductance L and frequency f.

What is the phase relation between V and I? This time they are *not* in phase; in a purely inductive circuit, the **current lags the voltage by 90°** or $\pi/2$ radians. Fig. 10.6 shows the phasor diagram for this situation. Keep this relationship in mind.

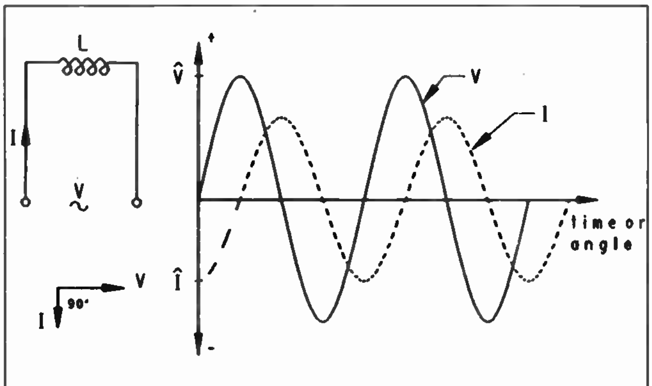


Fig. 10.6. In a purely inductive circuit I lags V by 90° and $I = V/X_L$.

Here are a couple of worked examples about inductive resistance.

3. A coil has an inductance of 0·3H. What current will flow in the coil when it is connected to a 10V, 500Hz supply?

   We need to find first the reactance of the coil:

   $$X_L = 2\pi fL = 2\pi \times 500 \times 0{\cdot}3 \text{ ohms}$$
   $$= 942\Omega$$
   $$\text{Current } I = \frac{V}{X_L} = \frac{10}{942} = 0{\cdot}0106\text{A}$$
   $$= \mathbf{10{\cdot}6mA}$$

In all such problems, simply replace resistance with reactance and apply Ohm's law.

4. A coil has a reactance of 1250Ω in a circuit where the supply frequency is 3kHz. What is the inductance of the coil?

   Again, $X_L = 2\pi fL$ from which, by rearrangement, we get

   $$L = \frac{X_L}{2\pi f} = \frac{1250}{2\pi \times 3000} = 0{\cdot}066\text{H}$$
   $$= \mathbf{66mH}$$

CAPACITIVE REACTANCE

When a capacitor is used in an a.c. circuit, it experiences a periodic process of charge and discharge as it attempts to make the voltage across its terminals equal to the voltage of the supply. Consequently, an alternating displacement current flows in the circuit just as though the capacitor was behaving merely as a resistance, though in reality, no current actually passes *through* the capacitor.

This resisting effect is known as the **capacitive reactance** X_c and is measured in ohms. Its actual magnitude depends upon the capacitance and the supply frequency and is expressed by

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C} \text{ ohms}$$

where C is in farads. Notice in this case that as C or f become *larger*, the reactance becomes *smaller*.

Now the current flow will be a maximum when the capacitor is uncharged, that is, at the instant the applied voltage is zero, and will be zero when the capacitor is fully charged, that is, at the instant the applied voltage is a maximum. Interpreting this on a phasor diagram, we find that the **current will lead the voltage by 90°**. Fig. 10.7 shows the condition this time.

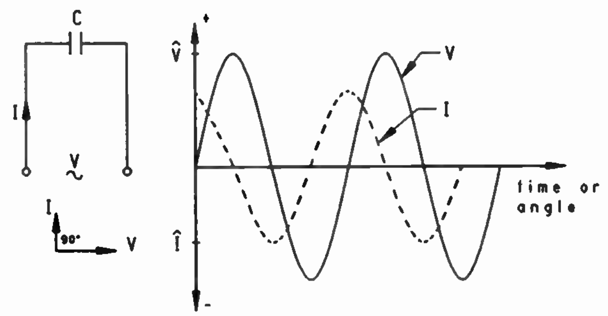


Fig. 10.7. In a purely capacitive circuit I leads V by 90° and $I = V/X_c$.

5. Find the reactance of a 10µF capacitor when connected to a supply of frequency (a) 50Hz, (b) 5kHz.

   Here the capacitance $C = 10 \times 10^{-6}$ farads.

   (a) $$X_c = \frac{1}{2\pi f C} = \frac{10^6}{2\pi \times 50 \times 10}$$
   $$= \frac{10^3}{\pi} = \mathbf{318{\cdot}3\Omega}$$

   (b) $$X_c = \frac{10^6}{2\pi \times 5000 \times 10} = \frac{10}{\pi} = \mathbf{3{\cdot}18\Omega}$$

   Hence, as the frequency *increases* from 50Hz to 5kHz, the reactance *decreases* from 318·3Ω to 3·18Ω.

6. Find the value of the capacitor which takes a current of 0·1A from a 10V, 2kHz supply.

   We first need to find the reactance:

   $$X_c = \frac{V}{I} = \frac{10}{0{\cdot}1} = 100\Omega$$

   Then since $X_c = \frac{1}{2\pi f C}$ we have by rearrangement

   $$C = \frac{1}{2\pi f X_c} \text{F} \quad \text{or} \quad \frac{10^6}{2\pi f X_c} \mu\text{F}$$

   $$\therefore \quad C = \frac{10^6}{2\pi \times 2000 \times 100} = \frac{10}{4\pi} = \mathbf{0{\cdot}8\mu F}$$

   Get into the habit of setting 10^6 into the expression for X_c; the capacitance can then be entered in µF.

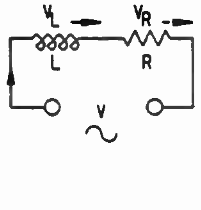


Fig. 10.8. The series L-R circuit.

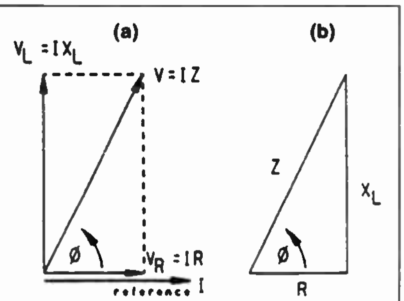


Fig. 10.9. Phasor diagram and impedance triangle for an L-R series circuit.

IMPEDANCE

The voltage-current relationship for any a.c. circuit having non-ideal components is known as the impedance Z. Impedance is the *combined* effect of resistance *and* reactance, both of which are present in any real life circuit.

Let us look at the practical inductor, which not only has inductance but an effective resistance built into its windings. This can be considered in the form of the circuit shown in Fig. 10.8, where a pure inductance is taken to have a resistor in series with it. This resistance may be solely the resistance of the coil winding or it may include any additional external resistance.

To find out what happens in such a L-R circuit we turn to the phasor diagram which will show us the actual relationship existing between the applied voltage V and the circuit current I. We are now working in r.m.s. values.

Since we have a series circuit, we take the current I as the reference phasor. Now looking at Fig. 10.9a we draw V_R *in phase* with the current reference, and V_L *leading the current* by 90° (current lags, remember). The supply voltage must be the phasor sum of V_R and V_L obtained by addition, that is, the diagonal of the parallelogram made up from V_R and V_L. This resultant voltage V *leads* the current by phase angle ϕ.

From the triangle containing phase angle ϕ we see that the sides are made up from the phasors $V_R = IR$, $V_L = IX_L$ and $V = IZ$. By eliminating the common current I from these, we can draw a similar triangle with sides R, X_L and Z. This **impedance triangle** as it is called is seen in Fig. 10.9b; since it is a right-angled triangle, the relationship between the sides can be readily found from Pythagoras, and so

$$|Z| = \sqrt{R^2 + X_L^2} \quad \text{and} \quad \tan\phi = \frac{X_L}{R}$$

$|Z|$ means that this is the "modulus" of the impedance, that is the actual numerical value in ohms.

These simple relationships enable us to find the impedance and the phase angle of any series L-R circuit.

7. A coil having a resistance of 85Ω and an inductance of 45mH is connected to a 1kHz, 5V supply. Find the circuit impedance, the phase angle, and the current drawn from the supply.

   Here $R = 85\Omega$, $L = 45 \times 10^{-3}$H, $f = 10^3$Hz, $V = 5$V

   Find the reactance of the coil first:

   $$X_L = 2\pi f L = 2\pi 10^3 \times 45 \times 10^{-3}\Omega$$

   The 10^3 and 10^{-3} terms cancel out, hence $X_L = 2\pi \times 45 = 283\Omega$

   Then $|Z| = \sqrt{R^2 + X_L^2} = \sqrt{85^2 + 283^2} = \sqrt{87314} = 295\Omega$

   $$\tan\phi = \frac{X_L}{R} = \frac{283}{85} = 3{\cdot}33$$

   $$\therefore \quad \phi = \arctan 3{\cdot}33 = \mathbf{73{\cdot}3° \text{ lagging}}$$

   The current drawn $I = \frac{V}{|Z|} = \frac{5}{295} = 0{\cdot}017\text{A}$ or **17mA**

The solution of the impedance and phase angle could be expressed as $Z\angle\phi$ or $295\angle 73{\cdot}3°$. This is known as the **polar form**. We can also express Z in the form $Z = R + jX_L$ which is the **complex** interpretation. You will no doubt meet these methods in due course. They are very powerful mathematical ways of solving complicated circuit problems.

C AND R IN SERIES

It should be no great problem at this stage for you to derive the impedance and phase angle expressions for a series C-R circuit as shown in Fig. 10.10.

Again, current is the reference phasor, with V_R in phase with I and V_c lagging I by 90°. (I leads V_c by 90° in a capacitor). The phasor diagram of Fig. 10.11a then follows, the addition of V_R and V_c giving the resultant supply voltage V. The impedance triangle of Fig. 10.11b is then found exactly as it was for the inductive circuit above; it is similar to the L-R triangle except that the capacitive reactance X_c is in the opposite direction to the inductive reactance X_L. Then, as before, we find

$$|Z| = \sqrt{R^2 + X_c^2} \quad \text{and} \quad \tan\phi = \frac{X_c}{R}$$

Now follow the next example carefully and then attempt the self-assessment problems for yourself.

8. A series circuit is made up of a 2µF capacitor and a 330 ohm resistor. The circuit supply is 30V, 250Hz. What is the circuit

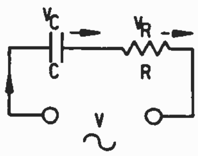


Fig. 10.10. The series C-R circuit.

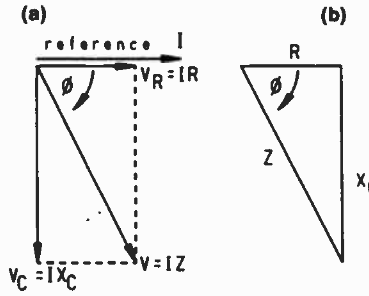


Fig. 10.11. Phasor diagram and impedance triangle for a C-R circuit.

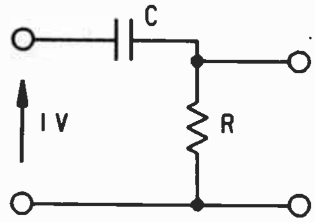


Fig. 10.12. A coupling problem.

impedance, the current drawn from the supply and the voltage across the resistor and the capacitor?

$$C = 2\times10^{-6}\text{F},\quad R = 330\Omega,\quad f = 250\text{Hz},\quad V = 30\text{V}$$

Working as we did for the previous example we have

$$X_c = \frac{1}{2\pi fC} = \frac{10^6}{2\pi\times250\times2} = \frac{10^3}{\pi} = 318\Omega$$

Then $|Z| = \sqrt{330^2+318^2} = \sqrt{210024} = \mathbf{458\Omega}$

$$I = \frac{V}{|Z|} = \frac{30}{458} = 0{\cdot}0655\text{A or } \mathbf{65{\cdot}5mA}$$

$$\tan\phi = \frac{X_c}{R} = \frac{318}{330} = 0{\cdot}964$$

$$\therefore\quad \phi = \arctan 0{\cdot}964 = \mathbf{44^\circ\ leading}$$

Voltage across $R = IR = 0{\cdot}0655\times330 = \mathbf{21{\cdot}6V}$

Voltage across $C = IX_c = 0{\cdot}0655\times318 = \mathbf{20{\cdot}83V}$

This brings us to the end of the present series. I hope you have all gained something from it, perhaps useful revision for those who have already gone through the mill, and more confidence for those who are making a first attempt to get to grips with a bit of electronic-orientated mathematics.

PROBLEMS

1. A 5mH coil has a reactance of 125·7Ω. What is the frequency of the supply?
2. At what frequency will a 100μF capacitor have a reactance of 6·37Ω? What will be its reactance if the frequency is doubled?
3. A resistor of 48Ω is in series with a capacitor of reactance 64Ω. What is the circuit impedance and phase angle?
4. The circuit of Fig. 10.12 shows the coupling between two transistor stages of an oscillator. If 1V is present across the input of this circuit at that frequency when $X_c = R$, what will be the voltage across R?
5. Plot a graph of reactance X_L (vertical axis) against frequency (horizontal axis) for a coil of inductance 50mH over the range 0 to 1kHz in 200Hz steps. On the *same* axes plot the graph of reactance X_c for a 2·5μF capacitor over the same frequency range.
   What comments can you make about the shapes of the curves? At what frequency does $X_L = X_c$? (This is known as the **resonant** frequency).
6. The impedance |Z| of a certain coil is measured as 500Ω at a frequency of 796Hz and as 800Ω when the frequency is doubled. What is the inductance and resistance of the coil?
7. Use scaled phasor diagrams to add together the following voltages or currents, expressing the resultant in the form $\hat{V}\sin(\omega t\pm\phi)$ or $\hat{I}\sin(\omega t\pm\phi)$:

   (a) $v_1 = 50\sin\omega t,\quad v_2 = 50\sin(\omega t + \frac{\pi}{2})$

   (b) $v_1 = 20\sin\omega t,\quad v_2 = 12\sin(\omega t - \frac{\pi}{2})$

   (c) $i_1 = 10\sin 500t,\quad i_2 = 15\sin(500t - \frac{\pi}{3})$
8. Subtract $80\sin(628t - \frac{\pi}{4})$ from $120\sin 628t$. What is the frequency of these signals? What is the r.m.s. value of the resultant?

Last Month's Answers

1. 9·56V, 10·6V. **2.** 909kHz, 1·1μs. **3.** 100Hz.
4. 25V; 17·7V; 25Hz, 0·04s.
5. $\frac{\pi}{12}, \frac{\pi}{6}, \frac{\pi}{3}, \frac{5\pi}{12}, \frac{2\pi}{3}, \frac{5\pi}{6}, \pi, \frac{5\pi}{4}, \frac{3\pi}{2}, \frac{11\pi}{6}, 2\pi$

This Month's Answers

1. 4kHz. **2.** 250Hz, 3·18Ω. **3.** 80Ω, 53° lagging.
4. 0·707V **5.** About 450Hz **6.** 72mH, 346Ω.
7. (a) $70{\cdot}7\sin(\omega t+\frac{\pi}{4})$ (b) $23{\cdot}3\sin(\omega t-31^\circ)$
(c) $21{\cdot}8\sin(500t-37^\circ)$.
8. $8{\cdot}86\sin(628t+43^\circ)$, 100Hz, 6·26.

SHOP TALK
with David Barrington

Digilogue Clock

Apart from the printed circuit board, the only other items required to build the *Digilogue Clock* that could be classed as non-standard are the one inch high digital displays. These are the common cathode types and were purchased through **Maplin** code FA04E. Other displays can, of course, be used but check the pinout details first as the line-up can differ from device to device.

The click switches (code FF87U), caps (code FF94C) and red filter sheet (code FR34), to cover the digital displays, were also obtained from the above source. The crystal should be readily available and is usually found listed under "Timing Crystals" sections in catalogues. They are certainly listed by **Cirkit** and **Maplin**.

Finally, the printed circuit board will accept either 5mm or 8mm l.e.d.s. However, if you decide to use the 8mm types do not forget to upgrade the "mains adaptor" as recommended.

Visual/Audio Guitar Tuner

The only item you need to be careful about when stocking up parts for the *Visual/Audio Guitar Tuner* is to make sure you specify "high brightness" l.e.d.s when ordering.

Although the article calls for 18-turn cermet presets, it appears that 20-turn and 22-turn are the most popular ones stocked. Either way, 18-turn to 22-turn should be suitable for this circuit.

Hobby PSU

There are a few important points to note when selecting parts and building the *Hobby PSU* project. The most important being, that this unit involves making *mains* connections and any person unsure of being able to carry this out safely *MUST* seek help from a qualified person.

The l.e.d. used must be a "constant current" type with *no* series resistor required and be capable of 3V to 12V operation. Also the rotary switch must be a "make"-before-break action type.

Experimental Seismograph

The only items that are likely to cause concern when shopping for items contained in part two of the *Experimental Seismograph* are the hardware components. All the "electronic" parts appear to be off-the-shelf devices.

The lead weights will have to come from a Scuba Diving shop, or you could, of course, improvise. Your local bicycle shop or motor spares store should carry the stranded steel or alloy wire, i.e. bike brake cable. We have been reliably informed that "grape vine" wire is stocked by garden centres.

We cannot foresee any component buying problems arising for both the Main and Receiver boards of the *Audio Auxiplexer.*

The special full-bridge p.w.m. motor driver i.c. type UDN2953B used in one of the *Circuit Surgery* items is listed by Electromail (☎ *0536 204555*), code 653-547.

All printed circuit board prices and code numbers for this month's constructional projects can be found listed in the PCB Service, page 803.

FOX REPORT

by Barry Fox

Photo CD Goes Professional

For five years now Kodak has been taking space at consumer electronics shows to promote Photo CD as a domestic product. But Photo CD has now become what it always should have been, a valuable professional, business, and industrial tool that will eventually spin off down into some consumer applications. At the *Chicago Consumer Electronics Show* in late June (full report next month) Kodak pushed only industrial applications for Photo CD.

I have always wondered why Kodak made such obvious mistakes when launching Photo CD. People want paper prints of their snapshots, to carry around and show friends. They do not want to plug in electronics and switch on a TV set, or carry round a portable CD player with LCD screen.

But professional photographers want a more convenient way to store images, and industry needs a better way to search and display stored images. Photo CD provides the perfect way to access photographic quality images with a computer. As more people use personal computers in their homes, the idea of storing family snapshots on CD will follow logically.

Development

Visting Kodak's HQ in Rochester, NY (quite close to Canada and the Niagara Falls) I got the chance to ask Kodak's people how the company came to make the basic mistake of launching a stand-alone Photo CD player as a consumer product.

In 1980 Sony announced Mavica, the still picture camera that records on a floppy disk instead of film. "This", admits Kodak, "caused quite a stir, and we didn't like what we saw". The knee jerk reaction was a clumsy move into the consumer market with an NTSC 8mm camcorder sourced from Panasonic.

This was soon abandoned and the European launch of PAL system was cancelled. Kodak's still picture photographic disc camera was pretty unsuccessful too. How often do you see anyone shooting disc film today?

In the late eighties Kodak's laboratory in Rochester started looking at the idea of storing photographic images on CD. By 1989 they had a prototype system working and were talking to Philips about setting a standard, and making disc recorders and players. Photo CD was announced in autumn 1990 and went on sale two years later. Kodak admits that the format is not yet profitable.

Although Photo CD was launched as a consumer product, by 1993 half of all sales were commercial. The 1993 figure was a 60/40 split, with industrial applications ahead of consumer sales. Talking recently to high street photo dealers, who offer a Photo CD service, they are doing very little domestic business, my bet is that the industrial market share will very soon be 75 per cent and go on rising into the 90 per cents. Then PC users with ROM drives may create a new consumer base.

High Level Picture

Kodak's original place was for Photo CD to be a high level still picture format inside the CD-i standard. Philips vetoed this idea. So Kodak went off on its own, and developed the dedicated Photo CD player which Philips manufactured and Kodak sold alongside Philips' higher priced CD-i players. Philips had by then modified CD-i to play Photo CDs. But a PCD player will not play CD-i discs.

This confused the market. Stand-alone Photo CD only sold well in Germany, and certainly not in the US and UK. Kodak admits that it ordered too many table-top PCD players.

Stand-alone Photo CD players are now being virtually given away for the price of an audio CD player. This has let Philips reduce the price of CD-i players. While PCD prices were high Philips was barred by agreements with Kodak from selling PCD-capable CD-i players for less.

All the marketing thrust is now on industrial applications such as portable Photo CD players, which plug into a TV set, and access software that lets a PC with ROM drive read Photo CD discs. Kodak charges no royalty on the PCD name or logo, seeing the format as establishing the company's name in the electronic imaging field.

In a logical development, Panasonic has just demonstrated a notebook computer, with built-in ROM drive to take 8cm Photo CDs. These discs, the size of a CD single, have a third the storage capacity of a full size 12 cm disc, which is neatly the equivalent of one 36 exposure roll of film.

Hybrid System

Photo CD is of course a hybrid system which uses inexpensive "wet film photography" to capture the image, a high cost opto-electronic scanner to convert the analogue film image into digital code, industrial optical recording technology to store the code on a CD, and a low cost CD player technology to retrieve the image from the disc.

This hybrid approach makes sound sense when you consider the cost of opto-electronic imaging. Kodak has now developed an image sensor for a still picture camera that finally matches the resolution of film. The sensor has six million pixels and incorporates a red, green and blue mosaic filter to give colour. At this resolution there is only a nine micrometre space between individual pixels.

Forward Error Correction

The only way to make sensors of this complexity and precision is to assume that each and every one of them will have at least some defective pixels, and use forward error correction. Each sensor comes with its own defect map, which is downloaded into a ROM chip in the camera.

This map tells the electronics in the camera how to disguise defects, by blanking the faulty pixel, and replacing its signal with an average taken from the good pixels around it. Even so the cost is still between $25,000 and $30,000 per sensor.

Compare that with the cost of a respectable photographic camera (£100 or so), a roll of film (a few pounds) and processing (a few pounds more) and you see why the hybrid approach is the only practical way for most users to store full photographic quality images electronically.

The Way Forward

The forward error correction technique used for the new sensor gives an interesting pointer to the way consumer video camera and projection technology may move. If just one pixel in the LCD for a video camera or projector fails, the picture is forever blemished with a red, green or blue dot that becomes increasingly irritating the more the picture is viewed.

(You will often see this on airlines which use seat back LCD screens for inflight entertainment; the airlines have bought the LCDs cheap and most have visible defects.)

Might we perhaps see a consumer system which allows the user of an LCD screen or sensor to identify a faulty pixel, perhaps by moving a cursor over the screen, and then eliminate and replace its signal with an average of the remaining good pixels around it?

EXPERIMENTAL SEISMOGRAPH

JOHN BECKER

Tune in your computer to the seismic singing of intra-planetary rock and roll.

LAST month we described the circuits which detect seismic events and detailed their construction. This month we conclude the project by showing how a PC-compatible computer can be interfaced to the detectors.

COMPUTER INTERFACE

The block diagram for a PC-compatible computer interface circuit is shown in Fig.12. Its practical circuit is detailed in Fig. 13.

All processed signals from the sensor circuits are first brought into separate buffer stages formed around two quad op.amps which are both designated as IC15. Only the components associated with sensor channels 1 to 4 are shown in detail. Channels 5 to 8 are brought to an identical network shown only in block form.

Taking the network for Channel 1, the signal passes through R56 and C23 to the unity gain buffer IC15a. The inclusion of R56 and C19 helps to reduce higher-frequency signal noise levels. Resistor R60 provides a bias voltage of +2·5V as set by R64, R65 and C27. Except for having different identity numbers, components for signal Channels 2 to 4 have identical functions to their counterparts in Channel 1.

Both quad-buffer op.amps are powered at +12V/-5V so that their outputs can be swung fully between 0V and +5V, to suit the standard input range of the analogue-to-digital converter (ADC). If this circuit is used in other applications, the input voltage to the buffers must not allow their outputs to swing outside the 0V/+5V range.

From their respective buffers, the signals are routed to the 8-way analogue multiplexer IC11. The selection of which path is routed to IC11 output X at pin 3 is determined by the address code on IC11's control pins 9 to 11. The analogue voltage level on IC11 pin 3 is converted to a digital equivalent by ADC IC12.

IC12 is a 6-bit flash ADC whose digital outputs B1 to B6 and OFL (overflow) are connected to the D0 to D6 data lines of the computer. (The software listing ignores the OFL status.)

Presets VR7 and VR8 control the ADC's reference voltage levels, against which the conversion value is calculated. The ADC converts the analog input voltage to its equivalent decimal value each time the clock input pin 7 is taken high.

The clocked conversion, though, is not immediately transferred to the ADC data outputs. It is first stored in an internal register, and then transferred to the outputs on the next clock conversion pulse. It is important to note this point when the ADC is being fed from a multiplexed signal source. Although the multiplexer's output holds the analog signal for one channel, the ADC's outputs may hold the converted data for the previously selected channel. This is why in the software listing, two reads of the ADC data are made, with the data of the first read being ignored.

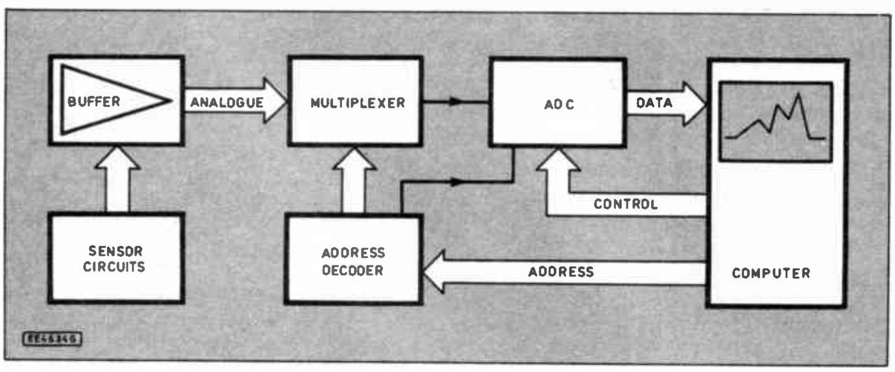


Fig. 12. Block diagram for the PC-compatible Interface.

Normally in this circuit, ADC outputs B1 to B6 and OFL are held in a high impedance state. For outputs B1 to B6 to become active, control pin CE must be high and control pin $\overline{CE}$ must be low. The OFL output can be read any time that pin CE is high, irrespective of the status of pin $\overline{CE}$.

INTERFACE ADDRESSING

For use with a PC-compatible computer, the controlling of the ADC clocking and output status has to be synchronised with address-decoded signals specific to the expansion socket of the computer.

With PC-compatibles, all expansion sockets can be accessed by read or write calls to addresses in the range &H300 to &H31F (decimal 768 to 799). With this interface circuit, address decoding has been simplified so that any read or write call to one of four blocks of addresses activates the ADC. The block chosen is &H300 to &H307, as determined by the address decoding circuit around IC9a and IC10.

Although the p.c.b. is hardwired for the above address block by the tracked connection to IC10 pin 14, the track could be cut and connected to any of IC10 pins 12, 10 or 7 to select one of the other three address blocks permitted, in ascending address order.

Multiplexer IC11's path selection is controlled by the outputs of the hex type-D flip-flop IC14, which in turn is controlled by the computer data lines and a write call to the address decoder block. Data from computer lines D0 to D2 is sent to the equivalent data inputs of IC14. On receipt of a clock signal on its pin 9, IC14 clocks the input data through to the Q0 to Q2 output registers. The clock signal is derived from the negative-going combination of the computer $\overline{WR}$ line and IC10 output pin 14 through OR gate IC9b.

OTHER COMPUTERS

It has not been verified, but it seems probable that some non-PC-compatible computers could make use of the interface circuit, with appropriate changes to the software, of course.

The likeliest circuit-changing route to pursue with a computer which has a User port, such as versions of the BBC or the C64 for example, is as follows. Omit IC10, connect the inputs of IC9a to the 0V line, and connect together pins 1 and 8 of IC9b. Then connect the $\overline{WR}$ track to computer line D7, and the $\overline{RD}$ track to computer line

COMPONENTS

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

PC-COMPATIBLE INTERFACE

See SHOP TALK Page

Resistors
- R56 to R59, R64, R65 — 1k (10 off) (see text)
- R60 to R63 — 220k (8 off) (see text)

Potentiometers
- VR7, VR8 — 2k sub-min cermet preset (2 off)

Capacitors
- C19 to C22 — 1µ radial elect 63V (8 off) (see text)
- C23 to C27 — 47µ radial elect 16V (9 off) (see text)
- C28 to C31 — 100n polyester (4 off)

Semiconductors
- IC9 — 74HC4075 triple 3-input Or gate
- IC10 — 74HC138 1-of-8 decoder
- IC11 — 74HC4051 8-way analog multiplexer
- IC12 — CA3306 6-bit flash analog-to-digital converter
- IC13 — 74HC04 hex inverter
- IC14 — 4174 hex type D flip-flop
- IC15 — LM324 quad op.amp (2 off) (see text)

Miscellaneous

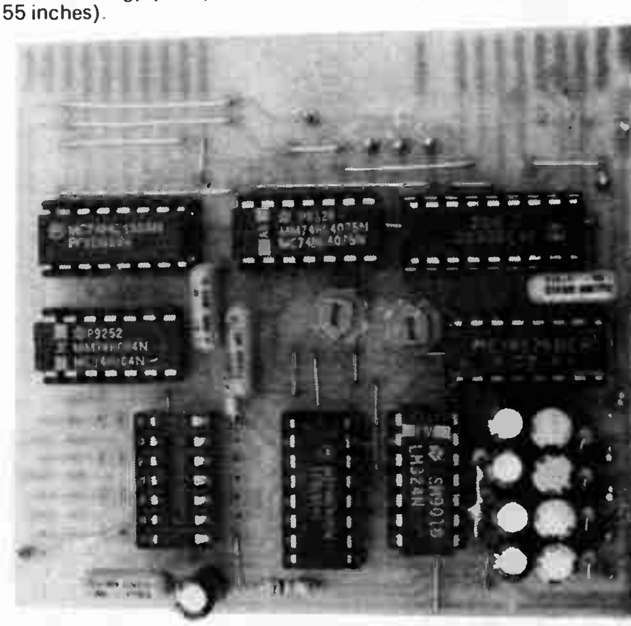
Printed circuit board (double-sided) available from *EPE PCB Service*, code 898; , 14-pin d.i.l. socket (4 off), 16-pin d.i.l. socket (3 off), 18-pin d.i.l. socket, 24 s.w.g. tinned copper wire for links, solder-braid for erroneous solder-short removal, 1mm terminal solder pins, solder, wall screws and Rawplugs (quantity, length and size to suit wall bracket), plastic food tray about 6 inches × 5 × 1.5 (L × W × H), any normal engine oil (to fill tray), insulating tape, about 12lbs (5·44kg) of weight (e.g. 3 off 4lb scuba diving lead weights).

GOLITSYN PENDULUM

Dexion type 140 slotted angle steel lengths: 60 inches (2 off), 36 inches minimum (2 off), about 15 inches for miscellaneous brackets, triangular bracket plate, nuts and bolts (9 off), hacksaw or loan of Dexion guillotine-type cutter. 4-way nylon 13 amp connector strip, shackles (approx 1.5 inches long) (2 off), stranded steel or alloy wire e.g. bicycle brake or gear cable (approx 55 inches).

VERTICAL PENDULUM

4-way nylon 13 amp connector strip, rigid steel wire e.g. gardener's grape vine support wire (length to suit application – see text), wall bracket (size about 4 or 6 inches), 6-inch round nail, 2-inch oval ferrous nail.



ATN (Attention) or its equivalent. Since computer line D6 is not actually used by the example software, its tracked connection to IC12 pin 2 could be cut, enabling the line to be used instead for $\overline{WR}$ control.

It is regretted that neither the author nor *EPE* can make suggestions for modifying the circuit, or software, to suit other computers.

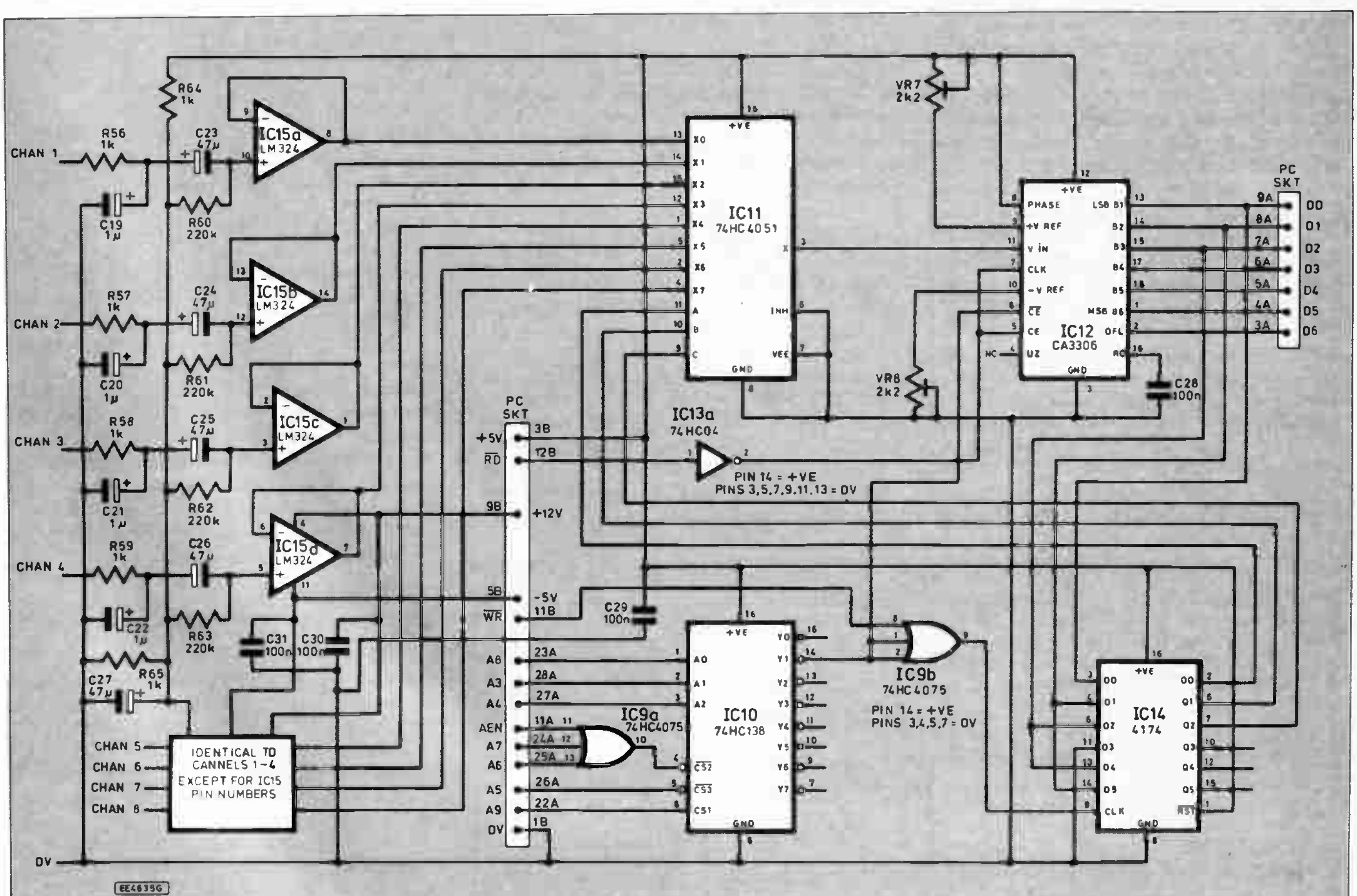


Fig. 13. Full circuit diagram for the PC-compatible Interface. Only Sensor channels one to four are shown in detail.

PENDULUM CONSTRUCTION

Details of the vertical and Golitsyn pendulums are shown in Fig. 16 and Fig. 17. As discussed earlier, the choice of which type to build will depend on the space available and which earth movement frequencies you wish to monitor.

An oil bath is used with both types of pendulum. This dampens the pendulum swing once the ground wave movement has passed. Both types should be shielded from draughts by, for example, an old curtain, sheets of cardboard, or stiff paper.

Scuba diving lead weights were used as the mass for the test models. They had the advantage of being heavy but small, and already owned! There are many scuba diving shops around the country as it is an increasingly popular sport. Any other compact weights could be used instead. The choice of using 12 lbs (5.44kg) was somewhat arbitrary, based only the fact the original *EE* seismograph used about the same weight.

It is essential to use rigid wire for the vertical pendulum since stranded wire could try to untwist, thus affecting the sensor alignment. Gardener's grape vine wire was used because a length was to hand. Bicycle gear cable was used for the Golitsyn pendulum support as it too was to hand. Stranded or rigid wire may be used with this pendulum since twisting is not an obvious problem.

Both types of wire, though, may tend to stretch over a period of several days after the pendulums have been installed, requiring realignment of the sensors. They will eventually settle-down.

Golitsyn's pendulum was made from Dexion type 140 slotted angle steel (another workshop spare!). Other strong rigid materials could be used instead, as shown in the original *EE* article. Purists may be correct in thinking that the horizontal swing beam should be made of a light weight material, such as aluminium, since the beam's weight will affect the actual centre of pendulum mass.

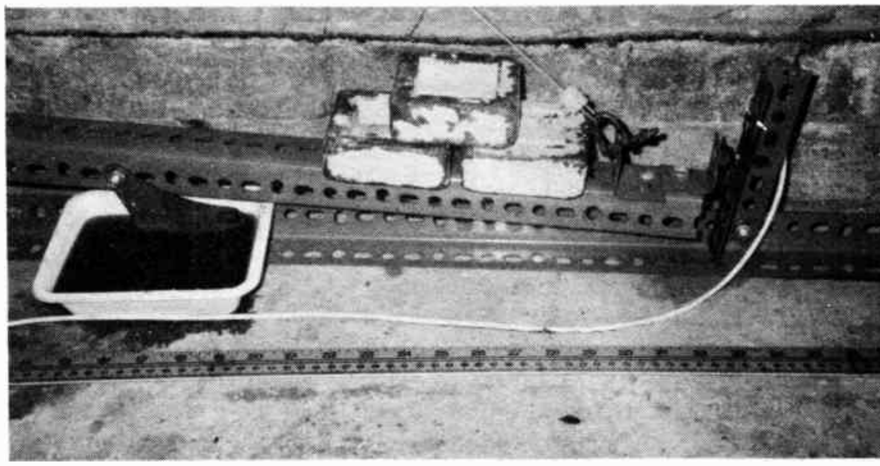
The vertical support beam was screwed to a thick supporting buttress of the garage wall as this was more solid than the wall itself. Thin walls may be subject to non-seismic vibration.

ALIGNMENT

If there is a choice of mounting position, it is suggested that the Golitsyn beam is aligned sideways facing West/East, which is the most likely direction from which the most powerful seismic waves will originate. If there is room, a second beam can be aligned in a North/South direction.

Beam and framework lengths may be changed to suit materials to hand and in respect of different frequencies to which the pendulum is to be tuned. Much retuning, though, can be done by moving the weights along the beam, so shifting the centre of mass. In retrospect, the author believes it might have been better had the swing beam been made somewhat longer.

The vertical support beam should be fixed to the wall first, loosely securing it by a single screw somewhere near the middle. Next bolt and fix the remaining parts. Do not screw the base beam to the floor. With the weights on the swing beam, adjust the support wire length until the beam swings freely. Carefully pivot the vertical beam about its screw until the swing beam is in line with the base beam.



Golitsyn type pendulum showing details of the improvised mass and oil damping bath.

A second pair of hands is useful at this time to dampen the erratic swinging of the beam. Tighten down the screw. Drill holes at other points in the wall behind the vertical beam through the slot holes and fix with screws. Make sure that the support is solidly secured.

For interest, the photograph shows part of the prototype's Golitsyn pendulum as squeezed into a crowded garage.

SENSOR AND MAGNET ATTACHMENT

Attach the sensor to its bracket using insulating tape and connect a cable between it and its circuit. Over 15 metres of signal cable were used to connect the three sensors in the garage, through the ceiling, to the circuits in the workroom upstairs.

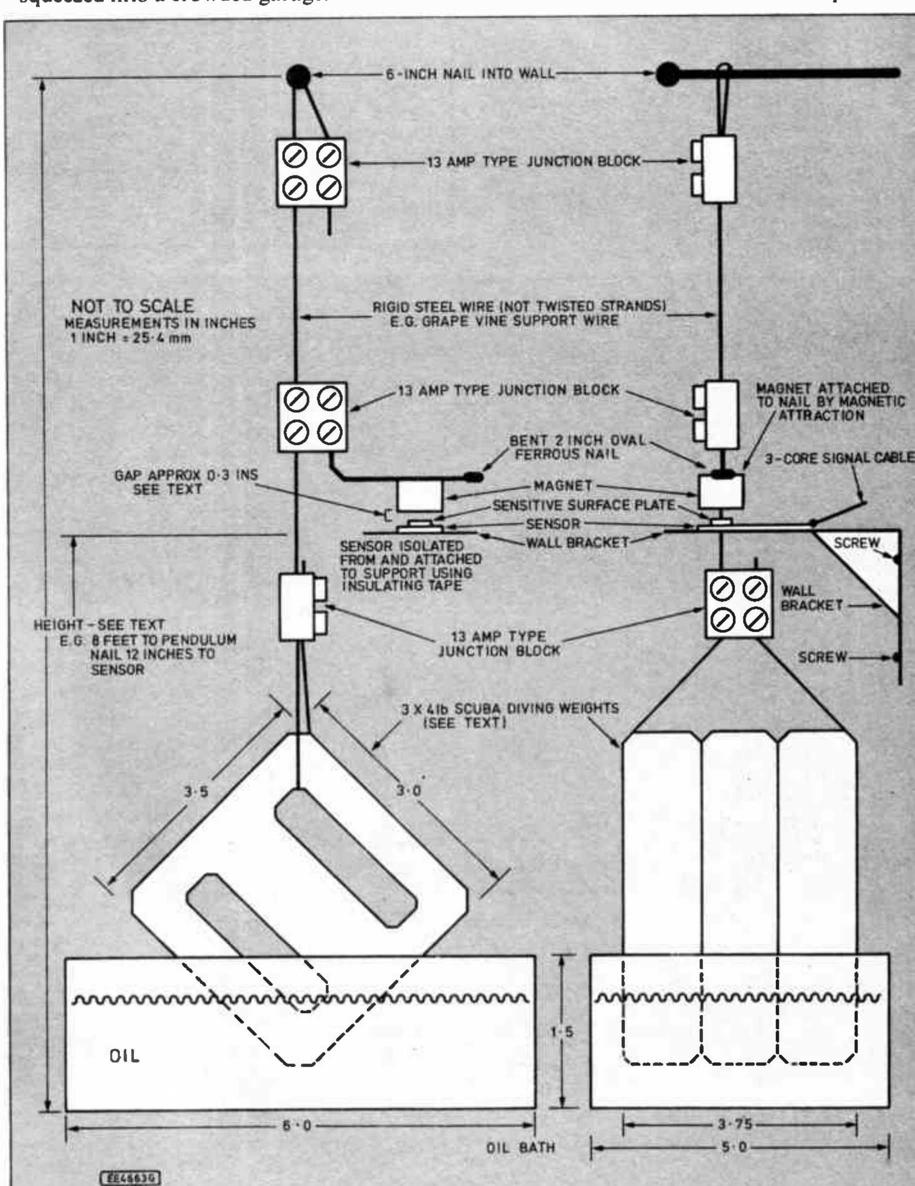
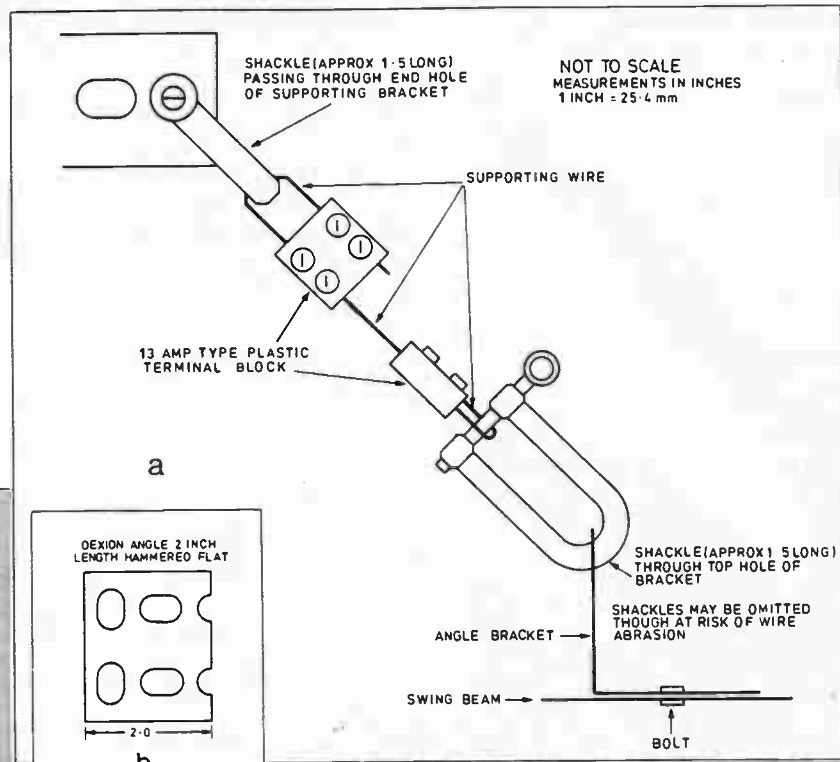


Fig. 16. Details and measurements for the vertical pendulum.

Two side-by-side lengths of 4-core cable were used, feeding to two sensors in parallel, and to one on its own. Probably, a single length of 5-core cable could have been used.

For the sake of drawing simplicity, and because pendulums may be considerable distances apart from each other, the wiring details in the p.c.b. layouts of Fig. 10 and Fig. 11 (last month) show each sensor connected to a 3-core cable. None of the cables or interconnecting wires in the seismograph were found to need screening.

The sensor is slightly light sensitive and its face should be covered with insulating tape.



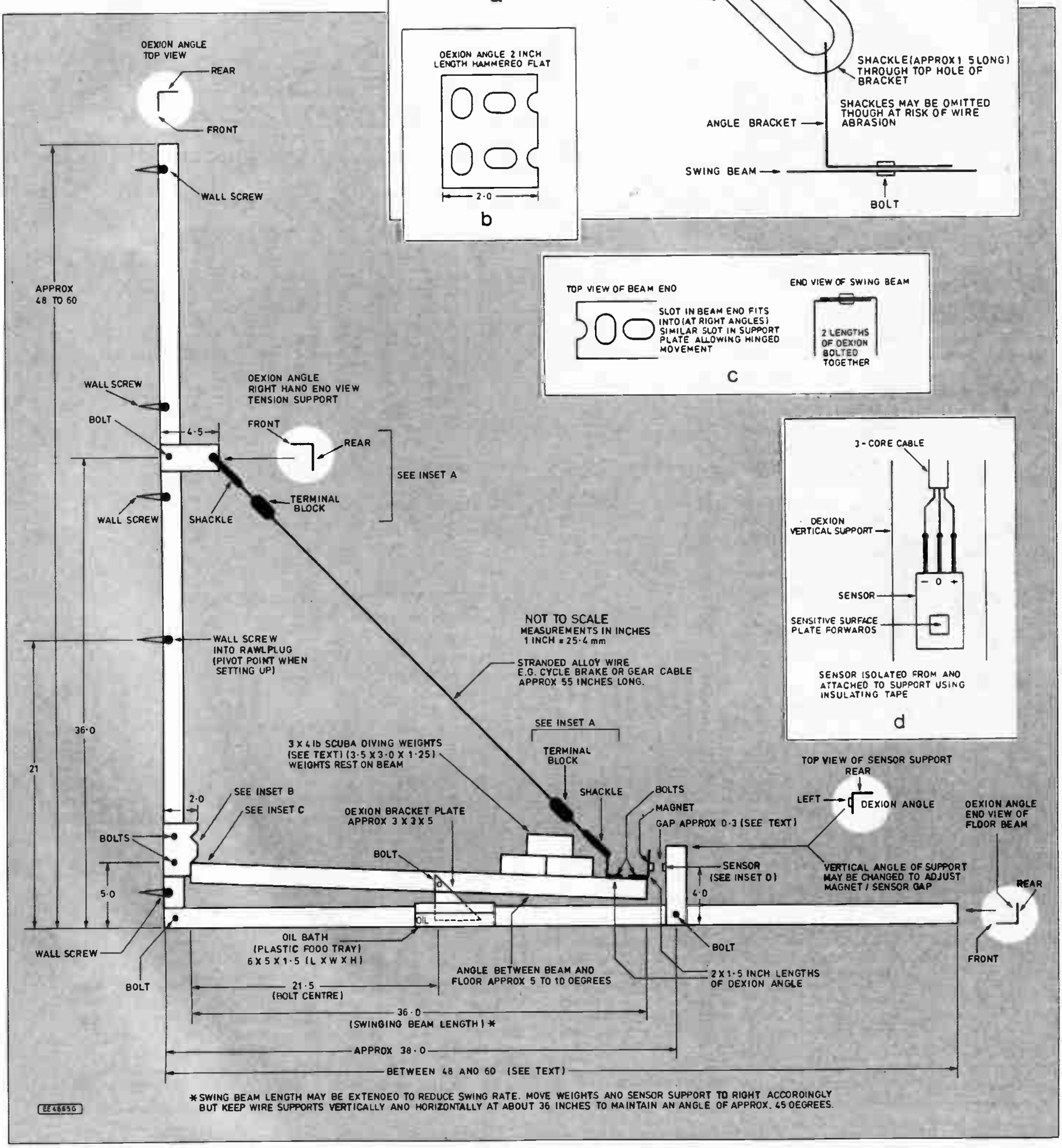


Fig. 17. Details and measurements for the Golitsyn type pendulum.

CONSTRUCTION

Component layout details for the computer interface board are shown in Fig. 14. Its double-sided track layouts are shown in Fig. 15.

Before assembling this board, insert it into one of the computer expansion sockets and check that the tracks line up with the socket terminals. If necessary, gently file down the board edges until it fits snugly into the socket.

The second side of the track layout in Fig. 15 is full of solder pads, but it is only the six tracks which plug into the computer socket which have any function. Terminal pins must be soldered in to the holes provided to connect these six tracks to their counterparts of the main track side. The board is not through-hole-plated. No soldering to the other pads on this side is necessary.

All the link wires on the component side must be inserted and soldered.

Because board design space was limited, both sets of resistors R56 to R63 need to be mounted vertically. Note the auxiliary drawing for R60 to R63 which shows the upper wires of the resistors commonly soldered together. Unwanted input-path components can be omitted.

The output socket to the computer should be chosen and wired to suit the number of sensors, plus one pin for the 0V line.

SOFTWARE PRELIMINARIES

The author has split his suggested software into three Listings, combined copies of which are available from the Editorial Office (see opposite page).

Listing 1 contains the main routines and has been written principally for use with GWBasic running on a computer having an EGA screen (screen mode 9). Additional routines, though, have been written into the software to make it compatible with QuickBasic and also with CGA screens (screen mode 1). It is believed that VGA screens will respond correctly to the EGA commands. The routines specifically for QuickBasic users only are shown in Listing 2.

For use with GWBasic only, three of the sub-routines have also been written in 8086 machine-code as well as in Basic. The code data (in a condensed format) and its loader routine are shown in Listing 3. It believed that the 8086 codes used are compatible with all members of the 86/88 processor family.

Listing 3 should be typed in as a separate program. When typing in the data lines, take care not to confuse numerals 0 and 1 with letters O and I. The decoding routine has a check-sum count for each line to help with typing error detection.

Two of the 8086 routines, the output-to-printer and the time-condense routines can be run with CGA and EGA screens. The 8086 routine for data playback, though, will not work with a CGA screen. None of the 8086 routines will run with QuickBasic.

All readers should note the REM statements at the head of Listing 1.

Readers who use GWBasic should omit the routines shown in Listing 2, and MUST run the routine of Listing 3 before Listing 1 can be run.

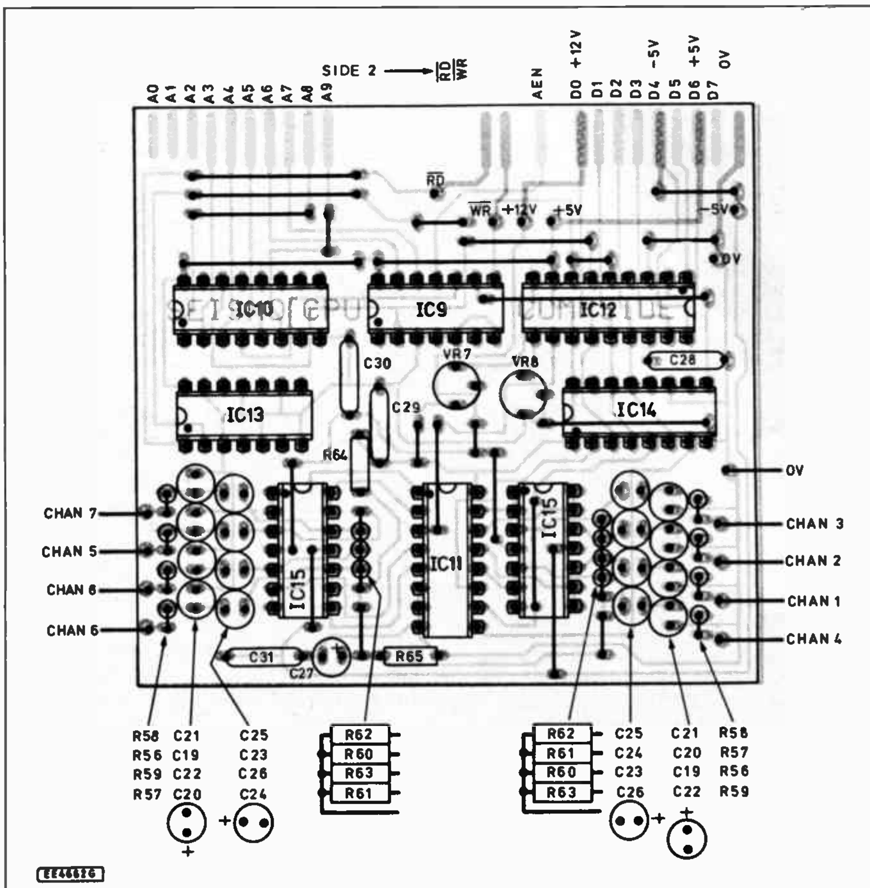


Fig. 14. Interface printed circuit board component layout. This board is available from the EPE PCB Service, *code 898.*

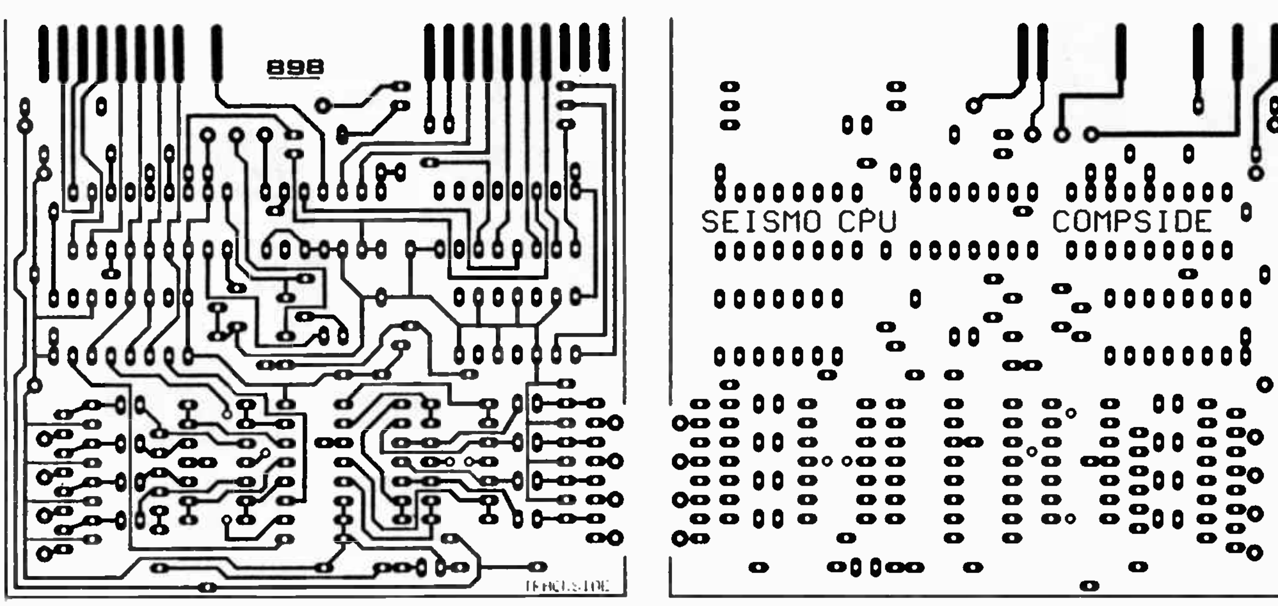


Fig. 15. Full size, top and bottom, copper foil master patterns for the double-sided Interface board.

QuickBasic users should omit Listing 3, and MUST also delete all lines in Listing 1 which commence with the statement "IF QB=0" and all routines stated as being for GWBasic only.

Experienced programmers will recognise that after lines specific to their Basic interpreter have been typed in, a variety of conditional (IF...THEN) statements can be simplified, or even deleted. QuickBasic users could also delete most line numbers except where they are associated with GOSUB and GOTO statements. All REM statements can be omitted.

The software has been written for monitoring up to eight sensors (seven for QB users due to memory space restrictions), as selected near the head of Listing 1. If any of the listings are rewritten or added to, any new variables used must be initialised amongst those near the start of Listing 1. Failure to do so could result in a complete system hang-up, requiring the computer to be switched off and then reloaded.

The reason for this is that in order to avoid a lot of string manipulation, which could result in a "garbage-collection" delay during an important recording sequence, data destined for the disk file or printer is poked into specific string locations. Any change to the addresses of these strings, as could happen by the introduction of uninitialised variables between calls for VARPTR values, will cause data to be wrongly located, even into the area reserved for the Basic or machine code software.

SOFTWARE OPERATION

There are four menu options provided by the software, constant recording, triggered recording, playback from disc, and time-condense. With the first three options, all sensor data is plotted to the screen. From an additional menu selection choice, plotted waveforms may also be output to the printer during the first three options.

During recording, screen space permitting, two additional composite traces of condensed waveforms can be displayed below the main sensor traces. Whereas the main traces show about five minutes of data, the condensed traces show 60 minutes and 12 hours respectively. The sensor count and screen mode determines which, if any, of the condensed traces are displayed (study the Listings for information). Screen trace timings may vary depending upon which computer and Basic language are used. The recording time per page can be extended by the inclusion of a delay loop.

With both recording modes, when first called from the menu, a random-access file is opened and automatically named with the current day's date (as YYMMDD – year, month, day). Should the file be closed and re-opened on the same day, recording will recommence from the previous end of the file. Files are updated with fresh blocks of data each time the waveform traces complete their course across the screen. Simultaneously, current time and date information is recorded as well. (No routine has been written to monitor the time-related sync pulse train from the tape recorder signal.)

When in constant record mode, each consecutive screen data block is recorded to disk without pause.

In triggered record mode, data is normally recorded into the latest, but unchanging, file address. Only if a triggered event is detected, when the waveform amplitude exceeds a preset level, will the file address be updated. It will then again be updated for a minimum of two additional data blocks, after which, if no further triggered event has occurred, current data will once more be written into the new static address.

The reasoning behind this process is that information about the waveform immediately prior to the event can be as important as the event itself, and this technique ensures that at least one full block of previous data is recorded.

Further updating of the file address for a couple of blocks beyond the event ensures that continuing seismic shocks below the trigger level are also recorded.

The trigger threshold level is not changeable as a menu option (although it could be made so) but is set by the value of variable TRIG in the initialisation sequence near the top of Listing 1. It may be given a different value if preferred.

Be warned that recording consumes just under 19K bytes of disk space per screen page of three-sensor data. The use of the triggered recording mode has obvious benefits in terms of disk space conservation.

At any time during either recording mode, a flag may be set which tells the software whether or not it should print the waveforms to the printer at the end of the current screen page. Pressing keyboard letter "p" (lower case) sets the flag, toggling it to the opposite high or low state at each key press. The flag status is permanently displayed on screen. It does not change the basic sampling rate.

Recording may be terminated and the file automatically closed at any time by pressing "*" on the keyboard. Data for an incomplete screen block will not be recorded.

PLAYBACK AND CONDENSING MODES

During playback mode, in which recorded data is recalled from disk, pressing key "p" causes a paper printout of the screen data to be produced, and pressing key "h" holds the screen until another key is pressed. The menu can be returned to by pressing the "*" key. The keyed requests will not be actioned until the waveform traces have completed a full screen-page crossing.

Time-condense mode recalls recorded data from disk, examines consecutive groups of 12 data samples and then records onto another file the resulting minimum and maximum sample levels, so shortening the time-scale by a factor of six. The condensed file may then be replayed to the screen. Condensed files can also be further condensed by the same process, ad infinitum! Recorded time and date information is correspondingly amended on the condensed file.

With both the playback and condensing modes, a sub-menu option allows selection of which file is to be viewed or condensed. A directory of files can be called for display.

The ability to examine selected records within a file by direct random access has not been provided, but readers familiar with programming should be able to insert this option.

Routines for the printer have been written to suit Epson protocols and should be compatible with any Epson 9-pin or 24-pin dot matrix printer. The line length required is 624 dots (the equivalent of 78 alphanumeric characters) in condensed spacing format, horizontally covering approximately 132mm of the page.

> **EXPERIMENTAL SEISMOGRAPH SOFTWARE LISTING**
>
> The author's software program listings are too long to permit publication here. However, we will be pleased to supply readers with a **FREE** photocopy of all three listings on request.
>
> Please send a medium/large sized stamped addressed envelope (S.A.E.) to: Everyday with Practical Electronics, Allen House, East Borough, Wimborne, Dorset BH21 1PF.

PROCESSING SPEEDS

Running the software complete with machine code on an Amstrad 1640, the playback routine can display waveform data at a rate of about one page per second. File condensing occurs at a similar rate. Formatting the data for printer output takes a fraction of a second per screen page, though the printout itself takes about five seconds with an Epson LQ-550.

Readers who cannot use the machine code will find that their equivalent Basic routines are slower. With a three-sensor display, per screen page it takes about 30 seconds to playback, 13 seconds to condense, and about another 90 seconds if a paper printout is requested during playback.

INTERFACE CHECKING

Type in the software listings as required and save them under file names of your choice. Most typing errors can probably be corrected by running the program without the interface connected. Resave and make back-up copies of the debugged programs.

Connect the sensor outputs to the computer interface board. Set presets VR7 and VR8 for minimum resistance, so setting the ADC range for maximum width. Plug the interface into one of the computer's expansion sockets and switch on. If the computer does not respond as normal, immediately switch off and re-inspect the interface assembly. (The computer manual will show the correct orientation of the board in its socket.)

Switch on the seismograph, load and run the software. From the menu, select constant record.

Moving the magnets slowly back and forth across the sensors, the screen traces should respond to the movements, though not yet with any degree of accuracy. Let the top three traces completely cross the screen and restart at the other side. The data should have been recorded to disk immediately the traces reached the right hand side. Press "*" to close the file and return to the menu. The recorded data can now be replayed. Try printing it to the printer, and also condensing it.

Assuming all is well, you are now in a position to set up the pendulums.

Disc and bar magnets have both been used with the sensors, the former removed from cheap plastic figures used for magnetically securing paper to a steel surface. The bar magnets came from inexpensive spare burglar alarm magnetic contact sensors, and were found to be more powerful than the disc types. Magnetic strength may be increased by putting two or more magnets together.

Place the magnet on its swing beam bracket, or on the bent nail of the vertical pendulum, as appropriate. Since Dexion and the nail are both magnetic materials, the magnet will hold itself in position without the help of adhesives, a fact which facilitates alignment.

The sensitivity of the sensors will depend on the magnet strength and the alignment distance. A distance of about 0.3 inches (8 mm) was used with the test pendulums. It is a matter for which trial and error applies.

It was found from practical experiment that placing the magnet very slightly to one side of the sensor increased the sensitivity response, and provided a certain amount of directional tuning.

Alignment of the vertical pendulum is done by shifting the position of the terminal block which holds the nail, and by sliding the magnet along the nail.

Fine positioning of the Golitsyn can be done in several ways. Parallel alignment of the swing beam with reference to the floor beam can be fractionally adjusted by sliding the far end of the floor beam sideways. Its weight should hold it in position. The angle of the sensor support can be changed to vary the magnet to sensor spacing. The angle that the swing beam subtends to ground can be changed by adjusting the support wire length by means of the terminal block connections and by changing the angle of the upper wire support. The weighted end of the swing beam must be below its pivot point.

The swing beam angle with respect to ground plays its part in setting the tuned frequency of the pendulum. Its best angle is found experimentally, by gently swinging the beam and timing the period between successive full swings. Slight shifting of the weight positions will also change the tuned frequency. It is suggested that, initially, a swing period of about ten seconds is selected.

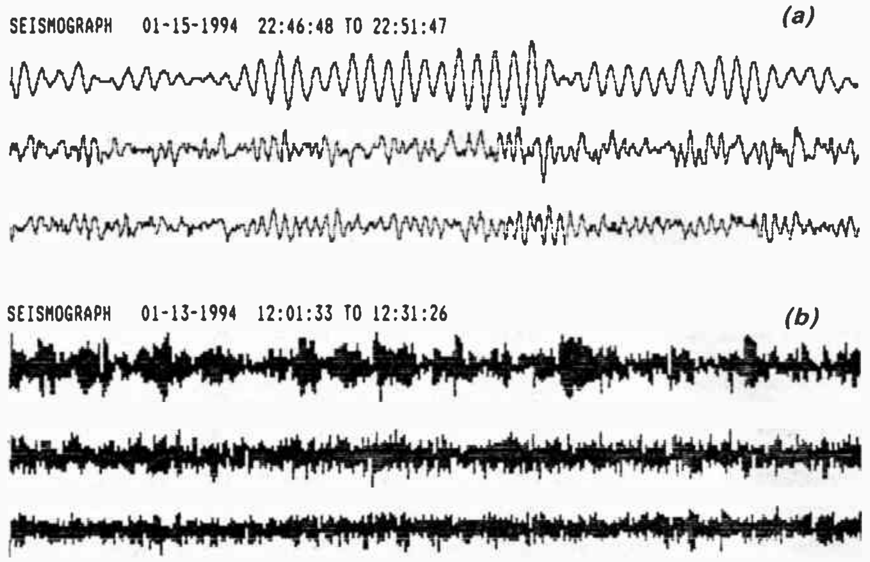


Fig. 18. Recorded amplified waveforms from three sensors. (a) continuous five minute period and (b) condensed waveforms for a 30 minute period.

FINE TUNING

Once the pendulums have been aligned, return to the circuit and computer. Fine tuning of the various preset controls discussed earlier can now be carried out in respect of the results observed. Note in particular that VR7 and VR8 can be adjusted to decrease the range of the interface ADC. This has the effect of amplifying the input signals. In the test model, the reference span range was eventually set for 2V to 3V as measured on the – V REF and + V REF pins of IC12, respectively.

Be prepared to have to make alignment corrections for some days after the pendulums have been installed, partly because of their settling time, and partly because of information gained in the light of experience. Note that the pendulum movements are normally only slight, and may not be apparent to the naked eye. However, you will probably be astonished at the amount of seismic activity, in the broader sense of the phrase, which is picked up by the sensors; described in one book as "a world-wide background of chaotic seismic noise".

So far, the author has not recorded a large earthquake and does not know just how large a signal would be produced by one. Ironically, at the time of the big San Francisco earthquake of 18th January 1994 (Richter 6.6), the author was in the middle of writing this article, did not have the seismograph switched on, and was unaware of the situation until too late. (The San Francisco earthquake of 1906 registered 8.25.)

Nonetheless, the author has reviewed many hours of interesting recorded earth movement patterns. Many are obviously related to traffic intensity (traces from the vertical pendulums over the Christmas period declined almost to zero), but other traces will definitely have been caused by other earth movements. Some of the results, recorded at quite high gain settings, are shown in Fig. 18.

When the next big seismic event occurs, hopefully we shall all have our seismographs running. It is also hoped, though, that examination of traces other than those caused by earthquakes, such as traffic patterns for example, will be of interest.

As a suggestion for additional research and experimentation, the use of a spring-mounted pendulum could prove interesting. Whereas the two pendulum types described essentially monitor sideways moving ground waves, a vertically-sprung pendulum monitors up and down movements. Professional seismic stations generally monitor vertical movements as well as horizontal ones.

HISTORICAL FRAGMENTS

The word *seismograph* comes from the two Ancient Greek words *seismos* – literally meaning earthquake, and *graphikos* – to write.

The earliest known seismograph was invented in China in A.D. 132 by Zhang Heng (78-139 A.D.). His Earthquake Weathercock consisted of four bronze dragons facing outwards from each other. Each had a ball in its mouth, one of which was supposed to drop into the mouth of a bronze frog below it when an earthquake occurred in that direction! (1, 2).

Although no further details have been found, it seems that in 1703 a certain Monsieur de la Hautefeuille designed an instrument which has been described as the first Western seismograph. (2).

John Mitchell (1724-93) originated the wave theory of earthquake transmission.

In 1855, Italian Luigi Palmieri (1807-1896) invented a device consisting of horizontal mercury filled tubes with turned up ends. The movements of small iron floats that were attached could be read off on an intensity scale. (3).

The first modern seismograph was invented in 1880 by British geologist John Milne (1850-1913). His invention used a horizontal pendulum and a pen which drew onto a turning drum. (2, 3).

Charles F. Richter devised his logarithmic earthquake peak intensity scale in 1935. (4).

Coming into prominence now, particularly in connection with oil prospecting seismology, are electronic stress sensors which, when mounted in widespread patterns, detect the strength and direction of ground wave movements. (4).

Boris Borisovich Golitsyn, after whom the Golitsyn pendulum is named, was born in St Petersburg on March 2nd 1862, dying in Petrograd on May 16th 1916. From about 1899 onwards, it was he who was responsible for laying down the foundations for modern scientific seismometry. (5).

Earthquakes of magnitude 8.6 have occurred on only three occasions in this century. The Chilean triple earthquake of 1960 peaked at 8.9. The average annual energy release from all earthquakes ranges from about 10^{25} to 10^{27} ergs, 80% of which is generated by major shocks. (4)

Shallow earthquakes are classified as having origins down to 60km, intermediate ones down to 300km, and deep quakes down to 700km. From records of 5605 shocks in Italy, 90% of the earthquakes originated at depths of less than 8km. (4).

Sources: (1) Cambridge Encyclopaedia of Earth Sciences. (2) Timetables of Science, ISBN 0-283-99926-8. (3) Asimov's Chronology of Science and Discovery. (4) Holmes Principles of Physical Geology, ISBN 0-442-30780-2.* (5) Dictionary of Scientific Biography, ISBN 0-684-16965-7.

Additional reading: Everyday Electronics October and November 1989.* Understanding the Earth, Open University set book, 1975, SBN 8514-308-0.* Earthquakes and Volcanoes, Mitchell Beazely, ISBN 0-85533-657-9. Publications marked with an asterisk contain more suggestions for further reading. □

INTERFACE

Robert Penfold

IN THE previous two *Interface* articles the basic principles of simple speech recognition systems were covered, together with some simple hardware. In this month's article we will consider the software side of speech recognition.

It is actually this aspect that represents the real difficulty when trying to produce a practical system. The human brain is very good at stripping away information that is irrelevant, and interpreting the parts of the data that are pertinent.

If the same word is spoken by a hundred different people, there will probably be a wide range of different pronunciations. Some strong accents might give difficulties, but in general there would be no difficulty in understanding the same word spoken by a hundred different people of mixed sex and from different parts of the country. Furthermore, subtleties in the way a word is spoken can convey different meanings, and most humans have no difficulty in interpreting differences in meaning due to changes in the intonation of the voice.

Stupid Computers

Some claim that computers are highly intelligent and capable machines, while others suggest that they are really quite stupid bits of electronics. Tasks such as number crunching show computers in a good light, but an application such as speech recognition tends to leave computers looking rather stupid.

The problem seems to be that there is no way of reducing speech recognition, or any similar application that involves complex pattern recognition, to a simple mathematical process that the average computer can handle in real-time. A few compromises therefore have to be accepted when using a simple speech recognition system.

The main one is that anyone using such a system must endeavour to always say each word in a reasonably standard fashion. Also, if a simple speech recognition system is used by several people, they must each use their own version of the software, and "teach" the system their renderings of the words that must be recognised.

The difference in the data produced by two people speaking the same word is often quite remarkable. The differences in the data can be quite small for two similar voices, but reliability is always likely to be better if each person uses a system based on their own word samples.

Teach-In

The system is "taught" a key word by repeating it five times so that the computer can work out a sort of average set of data.

Listing. 1: Experimental Speech Recognition Program
(Q Basic for IBM PC and compatible)

```
DECLARE SUB average (intake%(), accum%())
DECLARE SUB accumulate (intake%(), accum%())
DECLARE SUB again (intake%(), accum%())
DECLARE SUB clearscores (score%())
DECLARE SUB compare (store%(), score%())
DECLARE SUB printscore (score%(), words() AS STRING)
DECLARE SUB menu (intake%(), accum%(), store%(), score%(), words()
AS STRING)
DECLARE SUB sample (intake%())
DECLARE SUB storeit (element AS INTEGER, word AS STRING, intake%(),
store%(), words() AS STRING)
DECLARE SUB learn (intake%(), accum%(), store%(), words() AS STRING)
DECLARE SUB try (intake%(), accum%(), store%(), score%(), words() AS
STRING)
'
REM Speech Recognition Experimental Program
REM QBasic for IBM PC and compatible
'
'
'

DIM intake%(25, 2)
DIM accum%(25, 2)
DIM store%(25, 2, 5)
DIM score%(5)
DIM words(5) AS STRING
'
'
DO
    menu intake%(), accum%(), store%(), score%(), words()
LOOP UNTIL 0
'

SUB accumulate (intake%(), accum%())
FOR s = 1 TO 25
    FOR c = 1 TO 2
    accum%(s, c) = accum%(s, c) + intake%(s, c)
    NEXT c
NEXT s
END SUB

SUB again (intake%(), accum%())
FOR samples = 1 TO 5
    LOCATE 9, 5
    PRINT "Say the word now..."
    sample intake%()
    LOCATE 9, 5
    PRINT SPACE$(19)
    accumulate intake%(), accum%()
    LOCATE 11, 5
    PRINT SPACE$(18)
NEXT samples
END SUB

SUB average (intake%(), accum%())
FOR s = 1 TO 25
    FOR c = 1 TO 2
    intake%(s, c) = accum%(s, c) / 5
    accum%(s, c) = 0
    NEXT c
NEXT s
END SUB


SUB clearscores (score%())
FOR w = 1 TO 5
    score%(w) = 0
NEXT w
END SUB
```

```
SUB compare (store%(), score%())
clearscores score%()
FOR word = 1 TO 5
    FOR c = 1 TO 2
        FOR s = 1 TO 25
            IF ABS(store%(s, c, word) - store%(s, c, 0)) < 10 THEN
                score%(word) = score%(word) + 1
            END IF
        NEXT s
    NEXT c
NEXT word

END SUB

SUB learn (intake%(), accum%(), store%(), words() AS STRING)
DIM NewWord AS STRING * 10
'
CLS 0
LOCATE 3, 5
PRINT "Learn a word"
LOCATE 5, 5
PRINT "Please  type in the word"
DO
    LOCATE 7, 5
    INPUT NewWord
LOOP UNTIL NewWord <> ""
again intake%(), accum%()
average intake%(), accum%()
'
DO
    LOCATE 13, 5
    PRINT "Store as word no.(1 - 5)?"
    LOCATE 15, 5
    INPUT wordno
LOOP UNTIL (wordno > 0) AND (wordno < 5)
storeit wordno%, NewWord, intake%(), store%(), words()

END SUB

SUB menu (intake%(), accum%(), store%(), score%(), words() AS
STRING)
DIM Char AS STRING
'
CLS 0
LOCATE 3, 5
PRINT " PLEASE SELECT"
LOCATE 7, 5
PRINT "1. Learn a word"
LOCATE 9, 5
PRINT "2. Recognise a word"
LOCATE 11, 5
PRINT "3. Exit"
LOCATE 15, 5
PRINT "Press number key"

DO
    DO
        Char = INKEY$
    LOOP UNTIL Char <> ""
    c = VAL(Char)
LOOP UNTIL (c > 0) AND (c < 4)
IF c = 1 THEN learn intake%(), accum%(), store%(), words()
IF c = 2 THEN try intake%(), accum%(), store%(), score%(), words()
IF c = 3 THEN END
END SUB

SUB printscore (score%(), words() AS STRING)

FOR word = 1 TO 5
    LOCATE 12 + word, 5
    PRINT words(word)
    LOCATE 12 + word, 20
    PRINT score%(word)
NEXT word

END SUB

SUB sample (intake%())
DO WHILE STICK(0) = 0
LOOP
FOR s = 1 TO 25
FOR c = 1 TO 2
    intake%(s, c) = STICK(c - 1)
    NEXT c
NEXT s
BEEP
LOCATE 11, 5
PRINT "Sample complete"
END SUB

SUB storeit (element AS INTEGER, word AS STRING, intake%(),
store%(), words() AS STRING)
FOR s = 1 TO 25
    FOR c = 1 TO 2
    store%(s, c, element) = ABS(intake%(s, c) - intake%(s - 1, c))
    NEXT c
NEXT s
words(element) = word
END SUB

SUB try (intake%(), accum%(), store%(), score%(), words() AS STRING)
CLS 0
LOCATE 3, 5
PRINT "Recognise a word"
LOCATE 5, 5
PRINT "Say the word now..."
sample intake%()
storeit 0, "dummy", intake%(), store%(), words()
compare store%(), score%()
printscore score%(), words()
LOCATE 20, 5
PRINT "Press any key to continue..."
DO
    k$ = INKEY$
LOOP UNTIL k$ <> ""
END SUB
```

Hopefully, in use the data received each time the word is spoken will never deviate far from the averaged pattern stored in the computer's memory.

Over the years I have tried speech recognition systems based on several methods of pattern matching, and most failed to work at all. The demonstration program shown in Listing. 1 uses the only method I have found to work at all well, and this does not use the data in its raw form. Instead, each sample is compared to the previous one, and a series of differences are stored in memory.

These values are then compared with each of the averaged samples, value by value. A point is scored if the error is within acceptable limits. The averaged sample which achieves the highest score provides the best match.

As the accompanying program is largely self explanatory there is no point in giving a detailed description of its use. It is for Q BASIC, as supplied with any recent version of the MS/DOS operating system. The hardware must be connected to drive "Pos 0" and "Pos 1" of the games port (as described in last month's article).

The program is only intended to demonstrate the basic principles involved, but it could presumably be developed to the point where it could be used in a practical system. Unfortunately, integrating anything of this type into existing applications programs is probably not a practical proposition.

DOWN TO EARTH

George Hylton

GRAPHS SAVE MATHS

Drawing a graph can save a lot of calculation. Needing a ready-made 9V d.c. power source for battery operated equipment, I found in my junk box an old Sinclair ZX mains adaptor. Rated output: 9V at 1.2A. More than adequate for the average portable radio or tape recorder, which might draw around 25mA when idling, rising temporarily to a few hundred milliamps when playing loud music or rewinding.

However, a meter check showed that the off-load output voltage was 15V. Too high. Even when loaded with a 12V, 1A car bulb the voltage was still nearly 12V. For safety, some sort of voltage-reducing add-on was needed. The surplus voltage would be enough to operate an i.c. voltage regulator with a 9V stabilised output.

LM317 REGULATOR

The spares cabinet contained some LM317T voltage-regulator i.c.s mounted on small heat sinks, bought at bargain price from an *EPE* advertiser. (I knew they'd come in handy some day!) The LM317 is a variable regulator whose voltage can be set (in the simplest circuit, shown in Fig. 1) to anywhere in the range 1·25V to 37V, by selecting two resistances, R1 and R2. The regulator drops 3V minimum and this would be available from my adaptor even at fairly high outputs.

DISSIPATION

Ideally the i.c. should be fitted into the plastic case of the adaptor. Would it get too hot? In search of guidance I turned to the Texas Instruments data book on linear i.c.s. (The LM317 is a National Semiconductors type, but several makers list it, including T.I.). The data told me that the LM317 will dissipate up to two watts in free air at 25°C. The air inside the adaptor wouldn't be exactly free, but the dissipation wouldn't be as much as 2W.

At 15V input and 9V output the i.c. would drop 6V. To dissipate 2W at 6V would need a current of 333mA. But by then the voltage would be less than 15V. And anyway, 333mA would be unlikely to be needed for long periods, and then there was the small heat sink ... Worth a try! (In fact, when built the unit was left to run all day with a 60mA load, with no signs of trouble).

VOLTAGE SETTING

So far, so good, but what about R1 and R2? The various circuits in the Texas data show values of R1 from 120 to 1200 ohms, with a most frequent value of 240 ohms. The voltage drop across R1 is 1·25V for all values. This is the key to design, 1·25V is the reference voltage of the stabilizer.

Whatever current flows through R1 also flows through R2 and the sum of the voltage drops across R1 and R2 is the output voltage, V_{OUT}. Additional current I_d also flows in R2 but is so small (50µA typically, 100µA max.) that its effect on V_{OUT} is negligible provided that R1 and R2 pass a swamping current of a few milliamps.

The upshot is that if R1 = R2, each resistor drops 1·25V and the output is 2·5V. For larger values of R2, every R1-worth of resistance drops another 1·25V; e.g. if R2 = 10 times the value of R1, it drops 12·5V and so V_{OUT} = 12·5V + 1·25V = 13·75V.

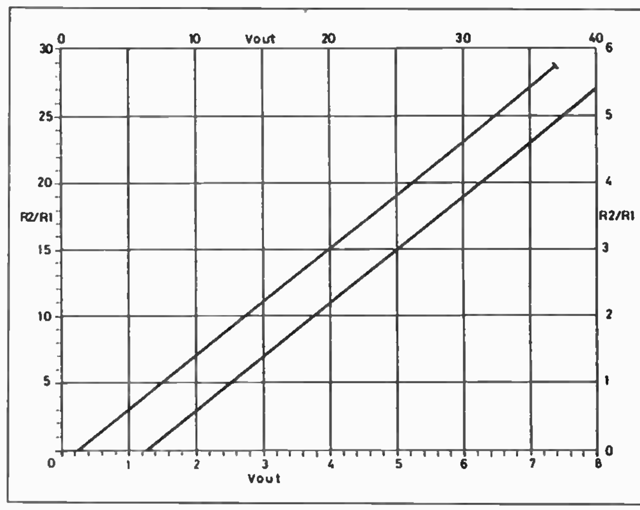


Fig. 3. Voltage outputs plotted against potential divider R2/R1 values.

DESIGN FORMULA

This behaviour leads to the formula given by the data:

$$V_{OUT} = 1{\cdot}25\,(1 + R2/R1)\text{ volts}$$

Fine, if you want to calculate V_{OUT}, but you don't. You choose V_{OUT} to meet your need. What you really want to know is how to choose R1 and R2 so as to get what V_{OUT} you need.

The formula can be manipulated to give:

$$R2/R1 = (V_{OUT}/1{\cdot}25V) - 1$$

This gives only the ratio of R2 to R1, not their actual resistances. However, the applications circuits suggest that it should be safe to choose R1 broadly around 240Ω. Once R1 is chosen R2 comes from the ratio.

Example: The required V_{OUT} is 5V. Make R1 = 270Ω. V_{OUT}/1·25 = 4, so, after deducting the 1 we have R2/R1 = 3; i.e. R2 = 3 × R1. With R1 = 270Ω, R2 = 810Ω, which is conveniently close to an E12 value, 820Ω.

GRAPHING THE FORMULA

It might be handy to be able to find R2/R1 for any output voltage, without doing any arithmetic. The solution is to draw a graph of the revised formula. It turns out that the "curve" is really a straight line, so any two known points (pairs of values for V_{OUT} and R1/R2) are all you need to plot it. For accuracy it's a good idea to use two points which are at opposite ends of the curve. If R2 = 0 then R2/R1 = 0 and V_{OUT} = 1·25V. This is the minimum output voltage with the circuit shown. The maximum, fixed by the voltage rating of the LM317, is 37V. This gives R2/R1 = 28·6. Our two key points are thus 1·25 horizontal, 0 vertical and 37 horizontal, 28·6 vertical. Joining these with a straight line (Fig. 3, upper curve) enables any intermediate values to be read off.

OPENING THE SCALE

Covering the full range of output voltage gives a scale which is a bit hard to read at lower voltages. To make things easier I have plotted a second curve (lower line) for V_{OUT} up to 8V. Using the appropriate scales you can see at a glance that for V_{OUT} = 5V, R2/R1 = 3, which is harder to read from the upper curve. It would be quite possible to plot only that segment of a curve which embraces values round about your chosen V_{OUT} and so obtain even greater reading accuracy, but there's not much point, because resistor and i.c. tolerances limit the precision by which V_{OUT} can be set. If a very precise V_{OUT} is needed then R1 or R2 must be presettable.

For the record, I used for my nominal 9V output R1 = 330Ω, R2 = 2200Ω, these being the nearest E12. values. They give a ratio of 6·7 instead of the required 6·2. The output should then be 9·6V. In fact it was 9·7V (because of tolerances). On the assumption that some 9V batteries can give voltages close to 9·7V when new I settled for that.

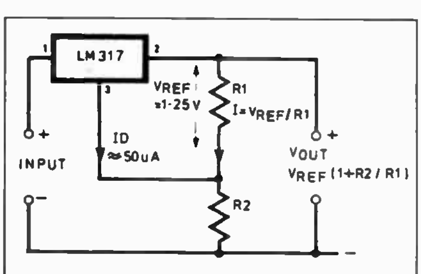


Fig. 1. Simple voltage regulator circuit using an LM317.

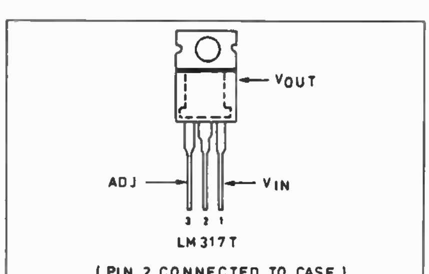


Fig. 2. LM317T pinout connections.

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Back numbers or photostats of articles are available if required – see the Editorial page for details.

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REPORTING AMATEUR RADIO

Tony Smith G4FAI

ENIGMA

In April 1993 we reported on the activities of Nils Schiffhauer, DK8OK, who tracked down a government "numbers station" sending groups of numbers from Germany to Spain. This was using an illegal Spanish callsign, and Nils cheekily reported this offence to his national licensing authority, causing the station to change to an official German call!

Although it was widely thought these transmissions originally came from behind the Iron Curtain, according to Nils some were broadcast by BND, West Germany's CIA, to agents in eastern Europe. Strangely, even though Germany was by then re-united, its numbers stations were still on the air as if nothing had happened on the political scene!

Such stations still exist today, and if you listen round the shortwave bands, you will hear men and women reading numbers or letters in English, German, Spanish, Russian, and other languages; and sometimes the numbers are sent in Morse code, the traditional mode for clandestine messages!

Now, a new organisation has been formed to bring together those who are interested in this aspect of shortwave listening. Appropriately called ENIGMA, the European Numbers Information Group and Monitoring Association, it is devoted to monitoring and gathering information about these mysterious stations.

Formed in January 1993, ENIGMA publishes a quarterly newsletter which acts as a forum for ideas and information about numbers stations, and carries features about them. It gives details of current transmissions, frequencies, times, etc., plus possible explanations on their purpose and/or origin based on experience and past monitoring by group members.

Having just read ENIGMA'S newsletter No. 5, I'm amazed at the amount of detail contained in it. There are 20 pages, A4 size, packed with frequencies, times, callsigns, commentary, letters, articles, and details of books on the subject.

The mind boggles when wondering about the purpose of stations labelled as the "Lincolnshire Poacher", "Ready Ready", "Nancy Adam Susan", "Cynthia Voice", "Nui Nochen", "Bulgarian Betty", "Bugle Station", and "Russian Counting Man". The newsletter reports that the longest voice message ever heard was from Russian Man who, in March, on 8074kHz at 1900 hours, sent 401 groups with transmission lasting over two hours.

MORSE STATIONS

Issue No. 5 includes the first of a two-part special feature on Morse numbers stations. It suggests that although they lack the distinctive characteristics of the voice transmissions, the absence of an identifiable language makes them even more anonymous and mysterious – features which greatly intrigue those engaged in this aspect of SW listening.

For those interested in monitoring these stations, but who do not know Morse, the article suggests that it is not necessary to learn the full code. Letters are rarely used, so only numbers need be learned. These are easier to copy than letters, especially when sent slowly.

There's good advice on getting started, and the feature recommends the "Three Long Dashes" station to beginners. Its entire transmissions are always slow and it uses short zeros (one dash instead of five).

There are 32 different frequencies listed, also 21 three-figure identifications which have been heard, presumably representing the numbers of the "agents" the messages are intended for. It has an irregular schedule, having been heard at all times of day and night. Interestingly it is never heard on a Friday, which perhaps narrows down the list of potential countries of origin.

The ENIGMA newsletter is published four times a year and costs £5 (overseas, £10), including postage. Write to *ENIGMA Newsletter, Dept EPE, c/o Bradford Resource Centre, 31 Manor Row, Bradford, West Yorks, BD1 4PS.* Cheques should be payable to "C.A. Midgley". A sample copy costs £1.00 or 4 x IRCs from the same address.

FIRST AMRED PUBLISHED

The first termly issue of *AMRED* (Amateur Radio in Education), the magazine of STELAR (Science & Technology through Educational Links with Amateur Radio) was recently published. As reported previously this is a group of educationalists who want to promote amateur radio in education to assist in the teaching of science and technology.

In his introduction to the first issue STELAR's Chairman, Richard Horton G3XWH (who has been personally involved with many educational amateur radio projects), comments that two needs have been largely unfulfilled in relation to such activities. There has been little dissemination of information on what has been happening; and there is a need to bring together the prime movers to share experiences and offer support to schools not yet aware of the potential of the hobby to aid good practice in science and technology teaching.

Since its formation last August, STELAR has contacted over 120 schools and colleges now known to participate in amateur radio and it is hoped that at least 80 of these will become affiliated.

In March, three members of STELAR addressed the annual workshop meeting of a similar organisation, "Amateurfunk in der Schule", in Germany where there are over 2000 teachers with amateur radio licences and over 300 schools active in the hobby.

In November this year, the two organisations will be co-hosting the first ever *International Conference on Amateur Radio in Schools* (ICARS). This will be in London and it is hoped to invite up to 30 international delegates from their parent organisations to take part.

The first issue of *AMRED* has explanatory articles on packet radio and amateur satellites, and details of the Amateur Novice licence. It has information on STELAR h.f. nets to be held each Wednesday in term time, and on STELAR h.f. activity days, the first of which was held over a 24 hour period on 23 and 24 June. There is also a list of overseas school stations who would like to receive packet contacts from UK schools.

The message is clear. Schools not using amateur radio are missing out, and they are invited to contact STELAR for information about the hobby and how it can benefit them. Teachers willing to study for the amateur licence can do so in a number of ways, including attendance at a STELAR residential crash course, financed by Trio-Kenwood UK, as described in this column last month.

Perhaps students who read this magazine and think their school should be involved in amateur radio could show this information to their teachers! Enquiries from schools should be addressed to the *Chairman of STELAR, Richard Horton G3XWH, 7 Carlton Road, Harrogate, North Yorkshire HG2 8DD.* Please mention that you read about STELAR in EPE!

IMPROVED OUTBACK RADIO

According to *Amateur Radio*, journal of the Wireless Institute of Australia, the 2·5 million residents of Australia's outback are to get improved communications. Many rely on shortwave radio to keep in touch with the outside world, and over 80,000 h.f. sets are used for this purpose. If they want to make a phone call they call a base station which connects them to the public phone service.

Now, Telstra (Telecom Australia) has introduced two services. One, Satcom-m, is satellite-based, and uses terminals the size of a briefcase, including the antenna.

The other, Radphone Direct Dial, uses h.f. and allows users to dial directly to almost any number in Australia. The service will have the facility to send faxes and digital data later this year.

The h.f. terminals cost about the same as top-line multiband h.f. amateur rigs, and the satellite terminals cost about five times as much, so one imagines that quite a lot of the existing h.f. radios will continue in service for some while yet.

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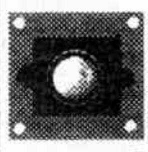

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