EVERYDAY with PRACTICAL ELECTRONICS

JANUARY 1994

INCORPORATING ELECTRONICS MONTHLY

FULLY S.O.R. £1.95

10 PLUS 10 STEREO AMPLIFIER

TIMER AND NiCAD CHECKER

AUTOMATIC NIGHT LIGHT

CALCULATION CORNER 1

9 770262 361041 01

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

AMSTRAD DMP4000 Entire printer assemblies including printhead, platen, cables, stepper motors etc. Everything bar the electronics and case. Good stripper!! Clearance price just £5 REF: MAG5 or 2 for £8 REF: MAG8

VIEWDATA SYSTEMS Brandnew units made by TANDATA complete with 1200/75 built in modem, Infra red remote controlled keyboard. BT approved, Prestel compatible, Centronics printer port, RGB colour and composite output (works with any TV) complete with power supply and fully cased. Price is just £20 REF: MAG20 Also some customer returned units available at £10 each REF: MAG10

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

INFRA RED REMOTE CONTROLLERS Originally made for hi spec satellite equipment but perfect for all sorts of remote control projects.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

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

SINCLAIR C5 MOTORS We have a few left without gearboxes. These are 12v DC 3,300 rpm 6"x4", 1/4" OP shaft. £25 REF: MAG25

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

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

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

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

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

COMPOSITE VIDEO KIT. Converts composite video into separate H sync, V sync, and video. 12v DC operation. £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

PHILIPS LASER 2MW helium neon tube. Brand new full spec £40 REF: MAG40. Mains power supply kit £20 REF: MAG20P2. Fully built and tested unit £75 REF: MAG 75.

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

LED PACK of 100 standard red 5mm leds £5 REF: MAG5P4

JUG KETTLE ELEMENTS good general purpose heating element (about 2kw) ideal for all sorts of heating projects etc. 2 for £3 REF: MAG3

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

OZONE FRIENDLY LATEX 250ml bottle of liquid rubber, sets in 2 hours. Ideal for mounting PCB's, fixing wires etc £2 each REF: MAG2P2

***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. Transmits to any FM radio. 9v battery req'd. £5 REF: MAG5P5

***FM BUG BUILT AND TESTED** superior design to kit, as supplied to detective agencies etc. 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 we have generally have the locks missing and sometimes broken hinges. However they can be adapted for their original pupose 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 and 1 P channel, £3 a pair REF: MAG3P2

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

MAGNETIC AGITATORS Cosisting of a cased mains motor with lead. The motor has two magnets fixed to a rotor that spin round inside. There are also 2 plastic covered magnets supplied. Made for remotely stirring liquids! you may have a use? £3 each REF: MAG3P3 2 for £5 REF: MAG5P6

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

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

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

XT KEYBOARDS Mixed types, some returns, some good, some foreign etc but all good for spares! Price is £2 each REF: MAG2P6 or 4 for £6 REF: MAG6P4

PC CASES Again mixed types so you take a chance next one off the pile £12 REF: MAG12 or two identical ones for £20 REF: MAG20P4 component pack bargain 1,000 resistors +1,000 capacitors (all same value) £2.50 a pack. REF: MAG2P7

1994 CATALOGUE OUT SOON

BULL'S BULLETIN BOARD

MASSIVE

WAREHOUSE CLEARANCE

FANTASTIC £20.00 REDUCTION

REFURBISHED PC BASE UNITS
COMPLETE WITH KEYBOARD

FROM ONLY **£29.00**

AMSTRAD 1512 BASE UNITS

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PERFECT WORKING ORDER.

A LOW COST INTRODUCTION TO THE HOME COMPUTER MARKET.

AMSTRAD 1512SD

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

NOW ONLY **£29.00**

REF: MAG29

AMSTRAD 1512DD

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

NOW ONLY **£39.00**

REF: MAG39

SOLAR POWER PANELS

3FT X 1FT 10WATT GLASS PANELS
14.5v/700mA
NOW AVAILABLE BY MAIL ORDER
£33.95

(PLUS £2.00 SPECIAL PACKAGING CHARGE)

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

ALSO 1FT X 1FT GLASS SOLAR PANELS 12v 200mA ONLY £15.00. **REF: MAG15P3**

FREE SOFTWARE!

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

DSDD	PKT10 £2.99 REF: MAG3P7	PKT100 £16.00 REF: MAG16
HD	PKT10 £3.99 REF: MAG4P3	PKT100 £26.00 REF: MAG26P1

LARGER QANTITY PRICES AVAILABLE ON APPLICATION

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

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1994 CATALOGUE.

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MINIMUM GOODS ORDER £5.00 TRADE ORDERS FROM GOVERNMENT, SCHOOLS, UNIVERSITIES, & LOCAL AUTHORITIES WELCOME ALL GOODS SUPPLIED SUBJECT TO OUR CONDITIONS OF SALE AND UNLESS OTHERWISE STATED GUARANTEED FOR 30 DAYS. RIGHTS RESERVED TO CHANGE PRICES & SPECIFICATIONS WITHOUT PRIOR NOTICE ORDERS SUBJECT TO STOCK. QUOTATIONS WILLINGLY GIVEN FOR QUANTITIES HIGHER THAN THOSE STATED.

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PLEASE ALLOW 7 - 10 DAYS FOR DELIVERY
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TEL: 0273 203500
FAX: 0273 323077

VISA

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

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

HEADPHONES 15P These are ex Virgin Atlantic. You can have 8 pairs for £2 REF: MAG2P8

PROXIMITY SENSORS These are small PCB's with what look like a source and sensor LED on one end and lots of components on the rest of the PCB. Complete with fly leads. Pack of 5 £3 REF: MAG3P5 or 20 for £8 REF: MAG8P4

FIBRE OPTIC CABLE Made for Hewlett Packard so pretty good stuff! you can have any length you want (min5m) first 5m £7 REF: MAG7 thereafter £1 a metre (ie 20m is £22).REF: MAG1 Max length 250m.

SNOOPERS EAR? Originall 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.

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

MONO VGA MONITOR Made by Amstrad, refurbished £49 REF: MAG49

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

JUST A SMALL SELCTION of what we have- to see more get our 1994 catalogue (42p stamp) or call in Mon-Sat 9-5.30

HAND HELD TONE DIALLERS Ideal for the control of the Response 200 and 400 machines. £5 REF: MAG5P9

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

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

COMMODORE 64 Customer returns but ok for spares etc £12 REF: MAG12P2 Tested and working units are £69.00 REF: MAG69

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

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

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

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

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

PLUG 420? showing your age? pack of 10 with leads for £2 REF: MAG2P11

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. Comes with electronics but no information. £15 REF: MAG15P4

SUPER SIZE HEATSINK Superb quality aluminium heatsink. 365 x 183 x 61mm, 15 fins enamble high heat dissipation. No holes! £9.99 REF: MAG10P1P

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

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

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 30KeV to over 1.2M eV and a measuring range of 5-9999 UR/h or 10-99990 Nr/h. Supplied complete with handbook.

REF: MAG50

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EVERYDAY WITH PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

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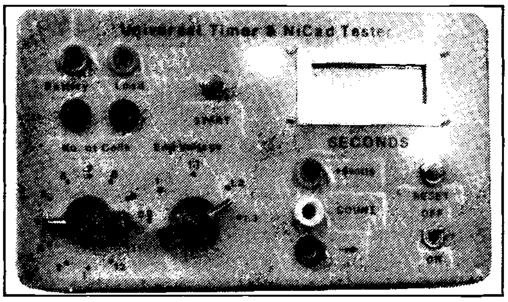
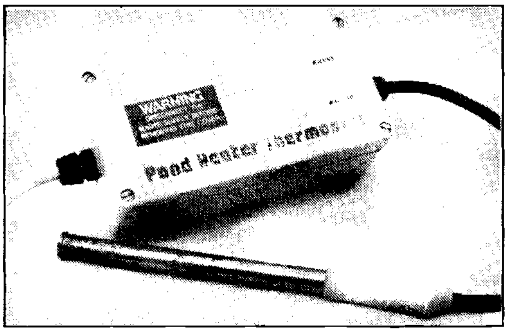
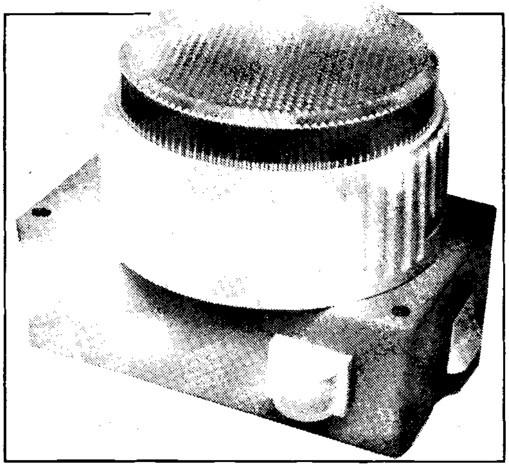
PROJECTS . . . THEORY . . . NEWS . . .
COMMENT . . . POPULAR FEATURES . . .







Projects

Series

Features

Our February '94 issue will be published on Friday, 7 January 1994. See page 3 for details.

NEXT MONTH

REVIVING THE VALVE SOUND

With a wiff of nostalgia and cooking valves, Jake Rothman rebuilds a pair of Quad II power-amps.

Quad II valve power-amplifiers made by the famous Acoustical Mfg. Co. of Huntingdon have had a loyal following for many years. They represent 1950s British technology typified by English Electric Locomotives and the Vulcan bomber.

With the current valve revival, it is worth rebuilding old Quads to enjoy their inherent beauty and sound quality, as well as for profit – as some hi-fi companies are now doing. There have been some articles about Quads in the hi-fi press but these did not deal much with the electronic side. Jake provides the missing technical data in this article.

WHISTLE CONTROLLED LIGHT SWITCH

Remote control of various appliances has enjoyed a great deal of popularity in the past few years, especially as the cost of adding such a facility to a product has decreased with the falling cost of integrated circuits. This can be seen in the proliferation of gadgets around for controlling the television, video, hi-fi and, if you are a keen electronics enthusiast, the curtains, the heating and any other gadgets which you can think of.

The TV is perhaps not a good example of where a remote control is of paramount importance as "getting up" may be the only excercise many viewers get in an evening! The light switch on the other hand would perhaps be more useful as one often enters a room carrying the shopping or a tray which makes it difficult to reach the switch to turn the lights on. In this case unfortunately, it would be no easier to operate your remote control handset even if this were to hand – this is where our Whistle Controlled Light Switch comes into its own!

BALANCED MIC. PRE-AMPLIFIER

A balanced microphone pre-amp is essential for high quality work since most higher priced microphones are of the balanced variety. This stereo pre-amp is designed to electronically unblanace the signal and raise it to "line level"; in other words make it suitable for any mixer or power amplifier input which is designed for tape recorders, CD players, tuners etc. It may be connected to the Mixer described in part 1 of our Multi Purpose Audio System *series and includes a 15V d.c. output which may be used to power the Mixer.*

The preamplifier is based on a new i.c. type SSM2017. This device boasts very low noise, wide bandwidth and low cost. It is particularly suitable for use as a balanced microphone amplifier, although it can be used with unblanaced microphones as well.

TIMEOUT

A quiet revolution is taking place in electronics today. It is almost as important as the replacement of valves by transistors and i.c.s in the 60's and 70's. This is the rise of the microcontroller. The increasing power and versatitity of the microcontroller at steadily decreasing prices is such that many of the simplest logic i.c. circuits may now be better designed using them.

Microcontrollers are a computer on a single chip – a central processing unit plus memory, clock, input/output and some sort of peripheral device.

Timeout is down-counter designed to introduce you to the world of microcontroller design and programming. It is preset to start from 60 or 90 seconds. Press any button to wake it up; there is no off/on switch. Press to start the countdown; during count down pressing again will pause the count. Timeout is a simple and inexpensive yet versatile (because it can be programmed) project. Get into this fascinating area of electronics.

EVERYDAY WITH PRACTICAL ELECTRONICS

FEBRUARY '94 ISSUE ON SALE FRIDAY, JANUARY 7th

SOME POPULAR BARGAINS

MOTORS – BATTERY 1-12V

3 DIFFERENT MODEL MOTORS, £1, Order Ref. 35.
SPIN TO START 3V DC MOTORS for model aircraft etc. 5 for **£1**, Order Ref. 134.
CASSETTE MOTOR 1·5-12V, powerful, speed increases with voltage, **£1**, Order Ref. 224.
MINI CASSETTE MOTOR, 6-9V working, **£1**, Order Ref. 944.
HIGH EFFICIENCY MOTOR for solar cell working, **£1**, Order Ref. 643.
12V MOTOR, ex BSR record player, **£1**, Order Ref. 687.
9V CASSETTE MOTOR, brushless, **£1.50**, Order Ref. 1.5P14.
1/10HP 12V DC MOTOR, Smiths, **£4**, Order Ref. 4P22.
1/8HP 12V MOTOR, Smiths, **£6**, Order Ref. 6P1.
1/6HP 12V MOTOR, Smiths, **£8**, Order Ref. 8P14.
1/3HP MOTOR, (Sinclair C5), **£15**, Order Ref. 15P8.

MAINS MOTORS WITH GEARBOXES

5RPM 60W, £5, Order Ref. 5P54.
40RPM 100W, £6, Order Ref. 6P21.
50RPM 60W, £5, Order Ref. 5P168.
60RPM 60W, £5, Order Ref. 5P171.
110RPM 60W, £5, Order Ref. 5P172.
150RPM 60W, Order Ref. 5P169.
200RPM 60W, £5, Order Ref. 5P216.
500W MOTOR with gearbox & variable speed selector, 100rpm upwards, **£5**, Order Ref. 5P220.
1 REV PER 24 HRS 2W MOTOR, £1, Order Ref. 89.
1 REV PER 12 HRS 2W MOTOR, £1, Order Ref. 90.
1 REV PER 4 HRS 2W MOTOR, £2, Order Ref. 2P239.
1 REV PER HOUR 2W EXTRA SMALL MOTOR, 2 for **£1**, Order Ref. 500.
½RPM MINI MOTOR, £3, Order Ref. 3P64.
1RPM MINI MOTOR, £2, Order Ref. 2P328.
4RPM 2W MOTOR, £1, Order Ref. 446.
15RPM 2W MOTOR, £2, Order Ref. 2P321.
25RPM 2W MOTOR, £2, Order Ref. 2P322.
200RPM 2W MOTOR, £1, Order Ref. 175.
250RPM 2W MOTOR, £1, Order Ref. 750.

MAINS MOTORS

¾ STACK MOTOR with ¼" spindle, **£1**, Order Ref. 85.
MOTOR 1½" STACK with good length spindle from each side, **£2**, Order Ref. 2P55.
MOTOR 1¼" STACK with 4" long spindle, **£2**, Order Ref. 2P203.
MOTOR BY CROMPTON ·06HP but little soiled, **£3**, Order Ref. 3P4.
JAP MADE PRECISION MOTOR balanced rotor reversible, 1500rpm, **£2**, Order Ref. 2P12.
TAPE MOTOR BY EMI, 2 speed & reversible, **£2**, Order Ref. 2P70.
¼HP 1000RPM, £8, Order Ref. 8P7.
VERY POWERFUL MAINS MOTOR, with extra long (2½") shafts extending out each side. Makes it ideal for a reversing arrangement for, as you know, shaded pole motors are not reversible, **£3**, Order Ref. 3P157.

MOTORS – STEPPER

MINI MOTOR BY PHILIPS, 12V-7·5 degree step, quite standard, data supplied, only **£1**, Order Ref. 910.
MEDIUM POWERED Jap made 1·5 degree step, **£3**, Order Ref. 3P162.
VERY POWERFUL MOTOR by American Philips 10-14V 7·5 degree step, **£5**, Order Ref. 5P81.

LOUDSPEAKERS

2" ROUND 50 OHM COIL ¼W, 2 for **£1**, Order Ref. 908.
2¼" 8 OHM, 2 for **£1**, Order Ref. 454.
2½" 35 OHM, 2 for **£1**, Order Ref. 514.
3½" 8 OHM, 2 for **£1**, Order Ref. 682.
6½" 4 OHM WITH TWEETER, £1, Order Ref. 895.
6½" 6 OHM, £1, Order Ref. 896.
6½" 8 OHM WITH TWEETER, £1, Order Ref. 897.
8" × 4" 4 OHM, £1, Order Ref. 242.
5" × 5" 15 OHM, £1, Order Ref. 906.
5" × 3" 16 OHM, £1, Order Ref. 725.
6" × 4" 16 OHM, 2 for **£1**, Order Ref. 684.
8" 15 OHM AUDAX, £1, Order Ref. 504.
9" × 3" 8 OHM 5", £1, Order Ref. 138.
3" 4 OHM TWEETER, £1, Order Ref. 433.
GOODMANS 6½" 10W 4 OHM, £2, Order Ref. 2P27.
HORN SPEAKER, 4½" 8 OHM, £3, Order Ref. 3P82.
20W 5" BY GOODMAN, £3, Order Ref. 3P145.
20W 4" OHM TWEETER, £1.50, Order Ref. 1.5P9.
AMSTRAD 8" 15W 8 OHM with matching tweeter, **£4**, Order Ref. 4P57.
CASED PAIR OF STEREO SPEAKERS BY BUSH, 4 ohm, **£5** per pair, Order Ref. 5P141.
DOUBLE WOUND VOICE COIL, 25W ITT, with tweeter and crossover, **£7**, Order Ref. 7P12.
BULKHEAD SPEAKER metal cased, **£10**, Order Ref. 1043.
25W 2 WAY CROSSOVER, 2 for **£1**, Order Ref. 22.
40W 3 WAY CROSSOVER, £1, Order Ref. 23.

MONITORS AND BITS

PHILIPS 9" HIGH RESOLUTION MONITOR, £15, Order Ref. 15P1.
METAL CASE for the above Philips monitor, **£12**, Order Ref. 12P3.
PHILIPS 9" HIGH RESOLUTION TUBE, ref. M24 306W, **£12**, Order Ref. 12P7.
6" ELECTROSTATIC MONITOR TUBE, ref. SE5J31, **£10**, Order Ref. 10P104.
MINI SCOPE TUBE face size, 2" × 2½", electrostatic 3V heater, 1KV, in mu metal shield, **£10**, Order Ref. 10P73.

LCD 3½ DIGIT PANEL METER, this is a multi range voltmeter/ammeter using the A-D converter chip 7106 to provide 5 ranges each of volts and amps. Supplied with full data sheet. Special snip price of **£12**, Order Ref. 12P19.
12V-0-12V 6VA PCB MOUNTING MAINS TRANSFORMER, normal 230V primary and conventional open winding construction, **£1**, Order Ref. 938.
AMSTRAD 3" DISK DRIVE brand new. Standard replacement or why not have an extra one? **£20**, Order Ref. 20P28.
THIS COULD SAVE YOU EXPENSIVE BATTERIES, an in car unit for operating 6V radio, cassette player, etc. from car lighter socket, **£2**, Order Ref. 2P318.
MEDICINE CUPBOARD ALARM, or it could be used to warn when any cupboard door is opened, built and neatly cased, requires only a battery. **£3**, Order Ref. 3P155.
FULLY ENCLOSED MAINS TRANSFORMER, on a 2M 3-core lead terminating with a 13A plug. Secondary rated at 6V 4A. Brought out on a well insulated 2-core lead terminating with insulated push on tags, **£3**, Order Ref. 3P152, Ditto but 8A, **£4**, Order Ref. 4P69.
DON'T LET IT OVERFLOW, be it bath, sink, cellar, sump or any other thing that could flood. This device will tell you when the water has risen to the pre-set level. Adjustable over quite a useful range. Neatly cased for wall mounting, ready to work when battery fitted, **£3**, Order Ref. 3P156.
DIGITAL MULTI TESTER MG3800, single switching covers 30 ranges including 20A AC and DC, 10 MEG input impedence, 3½ LCD display. Complete with lead. Currently advertised by many dealers at nearly £40, our price only **£25**, Order Ref. 25P14.
ANALOGUE TESTER, input impedence 2K ohms per volt. It has 14 ranges, AC volts 0-500 DC volts 0-500, DC current 500 micro amps at 250 milliamp, resistance 0-1meg-ohm, decibels 20 56dB. Fitted diode protection, overall size 90 x 60 x 30mm. Complete with test prods, **£7.50**, Order Ref. 7.5P8.
LCD CLOCK MODULE, 1·5V battery operated, fits nicely into our 50p project box, Order Ref. 876. Only **£2**, Order Ref. 2P307.
SENTINEL COMPONENT BOARD, amongst hundreds of other parts this has 15 ICs all plug in so don't need desoldering. Cost well over £100, yours for **£4**, Order Ref. 4P67.
AMSTRAD KEYBOARD MODEL KB5, this is a most comprehensive keyboard, having over 100 keys including of course full numerical and qwerty. Brand new still in maker's packing, **£5**, Order Ref. 5P202.
SOLAR PANEL BARGAIN gives 3V at 200mA. **£2**, Order Ref. 2P324.
ULTRA SONIC TRANSDUCERS, 2 metal cased units, one transmits one receives. Built to operate around 40kHz, **£1.50** the pair, Order Ref. 1·5P4.
INSULATION TESTER WITH MULTIMETER, internally generates voltages which enable you to read insulation directly in megohms. The multimeter has four ranges, AC/DC volts, 3 ranges DC milliamps, 3 ranges resistance and 5 amps. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, yours for only **£7.50** with leads, carrying case **£2** extra. Order Ref. 7.5P4.
MAINS ISOLATION TRANSFORMER stops you getting "to earth" shocks, 230V in and 230V out. 150 watt upright mounting, **£7.50**, Order Ref. 7.5P5 and a 250W torroidal isolation, **£10**, Order Ref. 10P97.
MINI MONO AMP, on pcb. Size 4" × 2" with front panel holding volume control and with spare hole for switch or tone control. Output is 4W into 4 ohm speaker using 12V or 1W into 8 ohm using 9V. Brand new and perfect, only **£1** each, Order Ref. 495.
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READER POWER

I have often made the point in this column that this is *your* magazine and that *you* can influence what we publish, either by simply asking for a certain project or feature, or by expressing views on what we presently publish. The start of *Calculation Corner* represents "reader power".

Back in the September '93 issue we asked if you wanted to see more on the maths used in electronics. We also published a small feature called *Working It Out* in that issue to give a feel for the idea. Your response to the request to let us know what you want on this subject was very positive; *Calculation Corner* is a direct result of that response. So to all those readers that wrote in, our thanks, we hope you find the series helpful and interesting.

THANKS AGAIN

While on the subject of "reader power" it seems an appropriate time to thank you all for making EPE the best selling independent hobby electronics title in the UK for another year. Our research indicates that no other independent title comes anywhere near our UK sales figures, which of course pleases us no end.

This also results in bigger and better issues for you. Our advertisers find that EPE generally gives them a good response from readers which leads to more advertisement pages and, in turn, more editorial pages – this issue is 88 pages plus the covers and the free catalogue, I doubt if you will find that sort of value for money in any rival title.

Thank you for your support and may I wish you on behalf of all the EPE staff all the best for 1994

Mike Kenward

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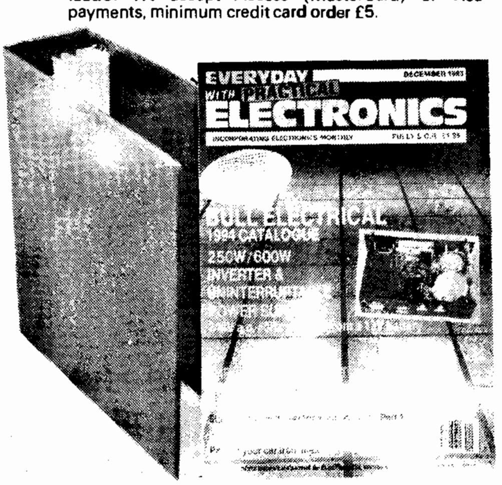

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Certain back issues of EVERYDAY ELECTRONICS, PRACTICAL ELECTRONICS and EVERYDAY with PRACTICAL ELECTRONICS (from Nov '92 onwards) are available price £2.20 (£3 overseas surface mail) inclusive of postage and packing per copy – **£ sterling only please,** Visa and Access (MasterCard) accepted, minimum credit card order £5. Enquiries with remittance, made payable to Everyday with Practical Electronics, should be sent to Post Sales Department, Everyday with Practical Electronics, 6 Church Street, Wimborne, Dorset BH21 1JH Tel: 0202 881749. In the event of non-availability **one** article can be photostatted for the same price. *Normally sent within seven days but please allow 28 days for delivery.* **We have sold out of Jan, Feb, Mar, Apr, May, June, Oct, & Dec 88, Mar, May & Nov 89, Mar 90, April, Aug & Sept 91 Everyday Electronics, and can only supply back issues from Jan 92 to Aug 92 (excluding Mar 92) of Practical Electronics. Dec 92, Jan, Feb and March 93 Everyday with Practical Electronics are also unavailable.**

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READERS' ENQUIRIES

We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply must be accompanied by a **stamped self-addressed envelope** or a **self addressed envelope and international reply coupons.** Due to the high cost we cannot reply to overseas readers queries by Fax.

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We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

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

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We would like to advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before using any transmitting or telephone equipment as a fine, confiscation of equipment and/or imprisonment can result from illegal use. The laws vary from country to country; overseas readers should check local laws.

PORTABLE AUTOLIGHT

T. R. de VAUX-BALBIRNIE

An automatic night-light – useful for children and the elderly.

LIGHT switches can be difficult to locate in the dark, especially by the young and by those who are not as agile as they used to be. This system avoids switches and operates a light without conscious effort on the part of the user.

By making sure that a light comes on when a person gets out of bed, accidents are avoided. Autolight switches on for a preset time – in the prototype this is for one minute approximately but it could be easily increased or reduced as required.

Although this circuit was designed as an automatic night-light, there is no doubt that readers will have ideas of their own and find alternative uses for the basic design. This could be the basis for numerous automatic control systems in and around the home.

Constructors are warned, however, that by the nature of this circuit, some false operation is inevitable. This is not of much consequence for the intended purpose but the device as it stands would not make a reliable basis for a burglar alarm.

TOTALLY SAFE

The Autolight is entirely self-contained so may be carried anywhere and used wherever the need arises. Being battery-powered, it is entirely safe in operation and could even be used in a damp environment.

The lamp used in the prototype unit was a ready-made "cupboard light" with integral batteries. This needs a simple modification to make it suitable for use with the Autolight circuit. A ready-made lamp gives a better appearance to the finished project than a home-made one (see photograph) and although not particularly bright, the light will be found adequate for the purpose.

A light sensor prevents the circuit from operating when there is sufficient light in the room already – either mains lighting or daylight. This is important to save the batteries from unnecessary drain. The sensitivity of the light-sensing section is adjustable and will be set at the end of construction.

The supply may be switched off completely so that no power is used – when the user is away from home, for example. However, it will normally be left on in *standby* mode – the current requirement being 200µA approximately which may be regarded as negligible.

The specified batteries operating the main unit should provide at least one year of service and the life of those in the lamp (two D-size cells), should be several months depending on how often the light is used and how long the operating time is set for.

PIR DETECTOR

The circuit operates when a detector senses a moving source of *infra-red radiation*. Such radiation is emitted by a warm object such as a person – the same principle as used in many modern burglar alarms of the so-called *Passive Infra-Red* (PIR) type.

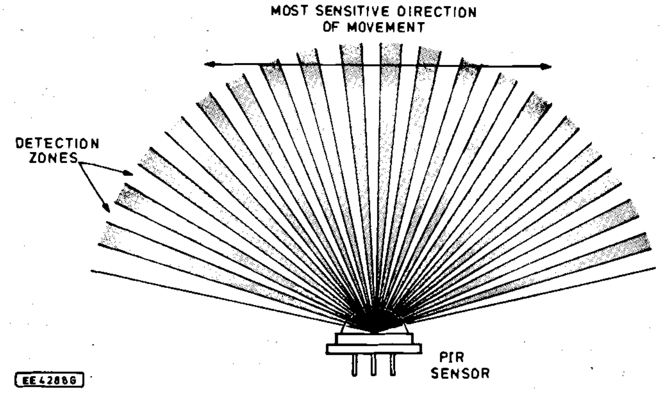


Fig. 1. Detection zone "fan" showing the 20-zones making up the 160 degree coverage.

Infra-red is a type of *electromagnetic radiation* akin to visible light but of a longer wavelength. Whereas light has a wavelength of less than 1µm, infra-red covers the range from 1µm until it blends into the *radio waves* at around 1mm.

For readers who are unfamiliar with these units, one micron (1µm) is defined as one millionth of a metre – that is, one thousandth of a millimetre. The detector used in this project detects infra-red in the band 4µm to 20µm.

The detector itself uses a special pyroelectric detector element situated behind a plastic lens. The lens focuses the infra-red radiation on to the sensitive surface. This is built into a ready-made hermetically-sealed module which also contains some of the essential circuitry.

While nothing is being detected, the output from the detector remains substantially high with a few very short random low pulses. When an infra-red emitting object is detected, the output provides a regular chain of square-wave pulses each going low for some random time but typically around 10ms. It is this change which triggers the rest of the circuit.

MOVING TARGET

The principle on which the detector is based is that of *multiple-zone detection*. Thus, triggering occurs only when the infra-red radiation passes from one detection zone to another fairly quickly. Steady sources such as light bulbs or the sun will therefore have no effect.

The detector used in this circuit has 20 detection zones each having an angular spacing of eight degrees (see Fig. 1). It thus covers an angle of some 160 degrees. Since it needs a movement of at least half a zone to activate the circuit, an angular movement of four degrees is required for triggering to occur.

At a distance of 3m (10ft. approx.) – a likely working distance – the target will need to move 20cm approximately to operate the unit. Note that the performance is most efficient when the detector directly faces the target and when the object moves *across* the detection field rather than backwards and forwards in line with the sensor.

The characteristics of the sensor are optimized for an object approximately the size of a person. A pet cat, for example, is less likely to operate it. The useful range is about 10m (33ft approx.). Although this is unlikely to be of value for the intended purpose, it may be appropriate for certain alternative applications.

Extra care will be needed when positioning the unit if a large pet is likely to enter the detection zone or where other warm objects pass nearby. Despite the operating characteristics mentioned above, small objects may still cause triggering depending on exactly how they move. Although of little significance, the incidence of false triggering may be greatly reduced by taking care over the final position of the unit.

CIRCUIT DESCRIPTION

The complete circuit diagram for Autolight is shown in Fig. 2. The PIR sensor, PIR1, needs a stable supply and the only successful way of providing this is to use a separate dedicated battery pack. Attempts to use the same supply as the rest of the circuit tend to cause false triggering when the relay operates with a consequent voltage drop at the supply.

sufficiently high to be interpreted as *Logic 1* ("high") by IC2 trigger input, pin 2, to which it is connected and has no further effect.

ON THE MOVE

When an object is detected, the regular chain of *low* pulses produced by PIR1 pin 3 allows capacitor C1 to discharge more deeply. The relatively low value of resistor R1 in comparison with R2 allows a fairly rapid discharge of C1. The voltage developed across it then falls to only a fraction of a volt. This is sufficiently low to be interpreted as Logic 0 ("low") by IC2 pin 2 and so supplies a trigger pulse. It is a characteristic of this particular type of i.c. that triggering takes place on the arrival of a *low* pulse rather than a *high* one as may be expected

A CMOS 555 timer, IC2, is used in this application and is configured as a *monostable multivibrator*. Thus, providing it is enabled by making the reset input, pin 4, high (assume this is the case for the moment), on the arrival of the trigger pulse, the output, pin 3, will switch on (become *high*) for a certain time then revert to *low*.

The time during which the output remains high is related to the value of resistors R10 (ignore the wire link), R11 and capacitor, C4. With the appropriate choice of resistor, R10, this may take anything from only a few seconds to several minutes.

With IC2 output high, current enters transistor TR1 base through current-limiting resistor R12. Collector current then flows from the supply through relay RLA coil. The normally-open contacts (RLA1) of the relay then "make" and operate lamp LP1, from the independent 3V battery supply B1, housed within its case.

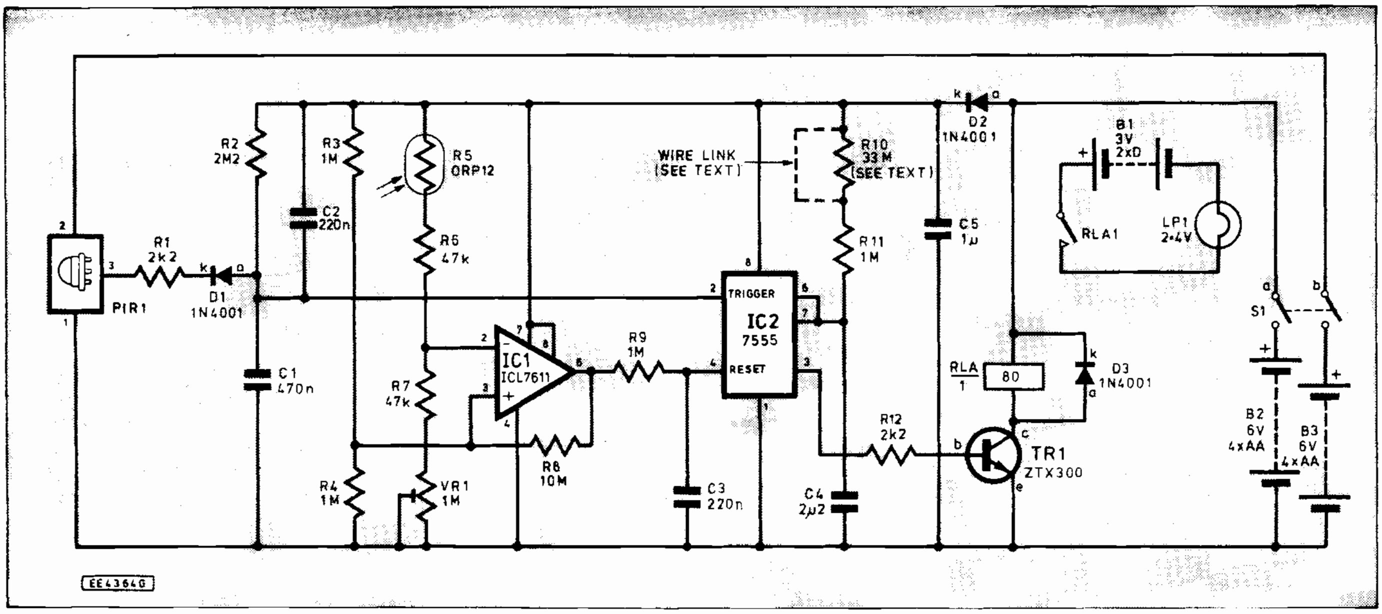


Fig. 2. Full circuit diagram for the Portable Autolight.

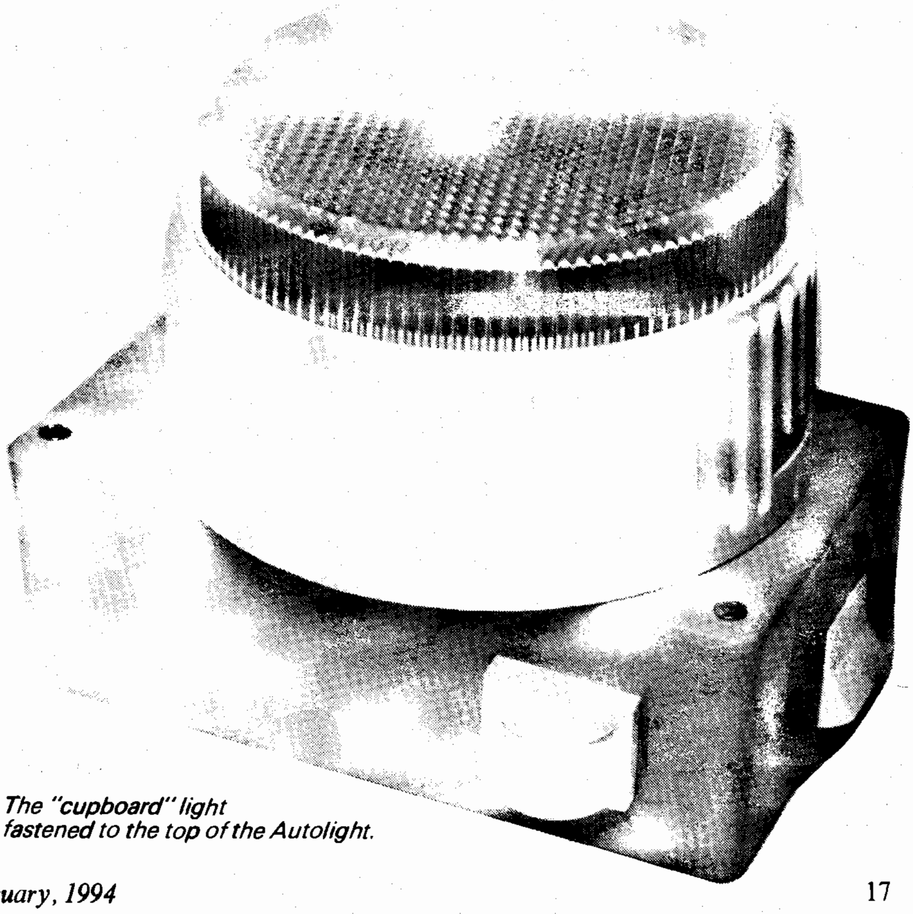
Two similar 6V battery packs, B2 and B3, are used. B2 is responsible for the control circuit while B3 is responsible for the PIR unit itself. Each battery pack consists of four AA-size cells in a suitable holder.

The current drawn from them is roughly balanced with each one providing around 100µA under quiescent conditions. Switch S1 is a double-pole on-off type, with pole S1a being responsible for B2 and pole S1b for B3.

Ignore the section of the circuit centred on IC1 for the moment – this is the light-sensing part and will be discussed presently. With switch S1 *on*, current flows from B2 through S1a and diode D2. This charges capacitor C1 through fixed resistor, R2, taking a few seconds to do so.

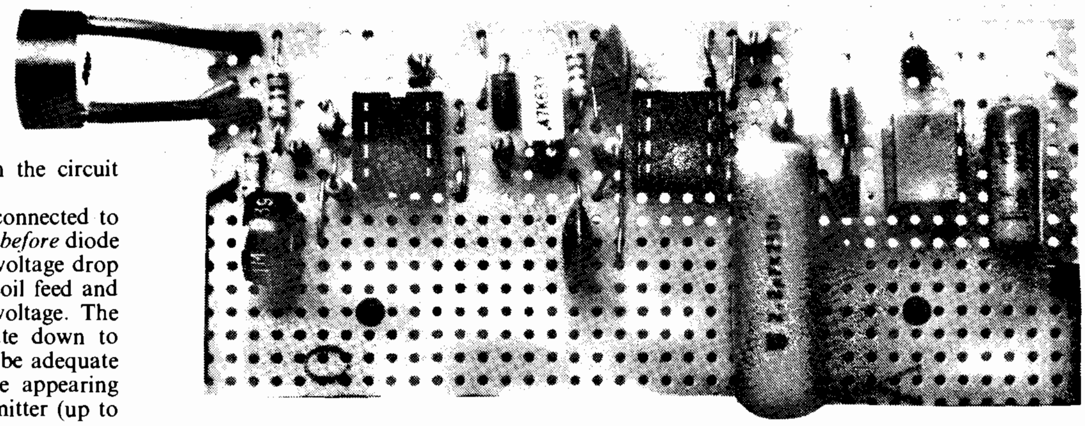
In the absence of sensor PIR1, the voltage across capacitor C1 would rise to that of the supply – nominally 6V. The connection of PIR1 to the system, however, modifies its behaviour. With the occasional *low* transition of the output, pin 3, C1 is allowed to discharge to some extent through diode D1 and fixed resistor R1 by allowing the PIR to *sink* current (that is, to allow current to *enter* it rather than flow from it).

Capacitor C1 has a large enough value to smooth out the individual variations and this results in a steady voltage of near 6V being developed across it under quiescent conditions – that is, while no infra-red is being detected. This voltage is


The "cupboard" light fastened to the top of the Autolight.

Diode D3 by-passes the reverse high-voltage "spike" which occurs when the magnetic field in the relay core collapses on switching off. Without this precaution, semiconductor components in the circuit could be destroyed.

Note that the relay coil is connected to supply positive *direct* – that is *before* diode D2. This avoids the forward voltage drop of D2 (0·7V approx.) in the coil feed and so maximizes the operating voltage. The nominal 6V relay will operate down to 4·8V so the battery pack will be adequate even allowing for the voltage appearing between TR1 collector and emitter (up to 1V approximately).



Layout of components on completed board.

INHIBITIONS

It is necessary to prevent the lamp from operating if the room is light already. This is the purpose of IC1 and associated components. IC1 is a micropower operational amplifier which is connected here as a *voltage comparator*.

If the non-inverting input voltage (pin 3) exceeds the inverting one (pin 2) the device will be *on* with the output (pin 6) *high* (positive supply voltage). In other situations, it remains *low*. While high, the output makes IC2 reset input (pin 4) high so enabling it.

Light-dependent resistor (l.d.r.) R5 is the light detector – its resistance falls with increasing light intensity reaching its sensitive surface. This component, in conjunction with fixed resistor R6 forms the upper limb of a potential divider.

The corresponding lower limb comprises fixed resistor R7 and preset potentiometer VR1, connected as a variable resistor. Thus, as the light falling on R5 becomes *brighter*, the voltage appearing across it *falls* and the voltage at IC1 pin 2 *rises*. Meanwhile, ignoring feedback resistor R8 for the moment, a fixed voltage of approximately one-half that of the supply exists at the non-inverting input, pin 3, due to the potential divider action of equal-value resistors R3 and R4.

While R5 is dark enough, the voltage at IC1 inverting input will be near-zero. The non-inverting input voltage will exceed this so IC1 will be *on* with its output *high* – the monostable section based on IC2 will therefore be enabled.

At a certain brightness level, the voltage at IC1 inverting input will rise above that at the non-inverting one. The output will then switch off and so disable IC2. Detection of any infra-red by PIR1 will then have no effect in triggering the circuit. By appropriate adjustment to preset VR1, the switching voltage level corresponding to the amount of light required can be controlled and the operating point set.

Resistor R8 applies a little positive feedback between IC1 output and the non-inverting input – this gives a Schmitt trigger action and ensures that the output switches *sharply*. This is necessary because light levels often change slowly and may even reverse temporarily as when a shadow is cast over the sensor. Resistor R8 builds some backlash into the system so that, once off, the light level would need to fall significantly for the op.amp to switch on again.

COMPONENTS

Resistors

R1, R12	2k2 (2 off)
R2	2M2
R3, R4, R9, R11	1M (4 off)
R5	ORP12 light-dependent resistor (photoconductive cell). Dark resistance 1M approximately.
R6, R7	47k (2 off)
R8	10M
R10	33M timing resistor – see text

All 0·25W 5% carbon, except R5 and possibly R10 (see text)

Potentiometer

VR1	1M miniature vertical skeleton preset, lin.

Capacitors

C1	470n ceramic
C2, C3	220n ceramic (2 off)
C4	2μ2 polyester
C5	1μ ceramic

See SHOP TALK Page

Semiconductors

PIR1	Sub-miniature passive infra-red sensor, type FIRM-287 size 33mm x 24mm x 29 mm
D1 to D3	1N4001 1A 50V rect. diode (3 off)
TR1	ZTX300 *npn* transistor
IC1	ICL7611 micropower op.amp
IC2	ICM7555 CMOS timer

Miscellaneous

RLA1	Miniature relay with 6V 80 ohm coil and s.p.s.t. contacts rated at 1A minimum.
B1	Two D-size alkaline cells or as appropriate for cupboard light.
B2, B3	AA cell holder and 4 AA cells to fit (2 off). Connectors as required (2 off)
LP1	Cupboard light – see text
S1	Miniature d.p.s.t. rocker switch

Plastic box, size 150mm x 90mm x 53mm external; stripboard, size 16 strips x 37 holes; 8-pin d.i.l. socket (2 off); 3-pin s.i.l. socket (or 8-pin d.i.l. cut to size, see text); stranded connecting wire; circuit board fixings; nuts and bolts; solder etc.

Approx cost guidance only **£20** *excluding batteries and lamp*

CONSTRUCTION

Construction of the Autolight project is based on a main circuit panel made from a piece of 0·1in. matrix stripboard size, 16 strips x 37 holes. Fig. 3 shows full topside component layout and details of the breaks required in the underside copper strips.

Commence construction by cutting the material to size and drilling the two mounting holes in the positions indicated. Make all track breaks and inter-strip links then add the soldered on-board components including the i.c. sockets and relay RLA.

Use the whole length of R5 end leads and sleeve them before soldering into position. Take care over the polarity of the three diodes.

TIMING RESISTOR

The value of resistor R10 will be determined by the required operating time – 10 megohms for each 20 seconds approximately. Since "10 megs" is the highest easily obtainable value it may be necessary to connect several similar resistors in series to achieve the required result.

An alternative method is to use a so-called "high voltage" resistor obtainable from certain suppliers. These are made in very high values – 33 megohms was used in the prototype unit. This provides about one minute of operation.

The wire link made between matrix positions *A22* and *C22* provides a short-circuit for resistor R10 and so allows a timing of only a few seconds due to the effect of resistor R11 alone. This is useful for setting-up purposes. Afterwards the link wire is cut through to allow the full timing period.

INTERWIRING

When the circuit panel is complete, adjust preset VR1 to approximately mid-track position and solder 20cm pieces of light-duty stranded connecting wire to

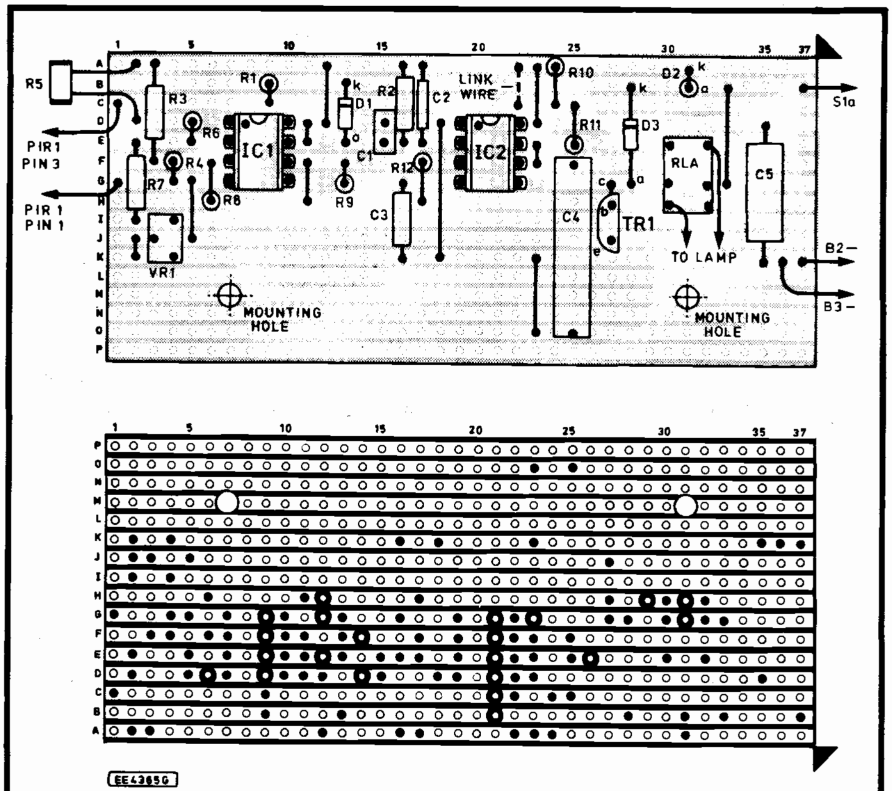


Fig. 3. Stripboard component layout and details of breaks required in the underside copper tracks. Note the leads to the relay contacts are soldered directly to the relay tags.

strips *C* and *G* on the left-hand side and to strip *B* on the right. Solder the negative wires for *both* battery connectors to strip *K* as shown. Solder similar pieces of wire *direct* to the relay normally-open (n.o.) contacts on the underside of the panel. *Make sure these cannot touch any other connections.*

Insert both i.c.s into their sockets taking care over the orientation. These are CMOS components and, in theory at least, vulnerable to damage by static charge which may exist on the body. It is a wise precaution to either avoid touching the pins when inserting them or to touch something which is earthed (such as a water tap) first. Bend the l.d.r. leads at right angles to the panel to the position indicated.

BASIC TEST

It is convenient at this stage to perform a basic test on the circuit panel before proceeding further since any minor problems will be easier to solve. This test is made without the PIR sensor or its supply being connected.

Tape over the l.d.r. window with some opaque material to simulate operation under dark conditions and so enable the timing section. Insert the batteries, B2, into their holder. Connect the positive wire of the battery connector to the wire leading to strip *B* on the circuit panel.

Often the unit self-triggers when powered-up – listen for a click from the relay and a further click "off" a few seconds later. Touch the wire leading to strip *C* momentarily on to the wire leading to strip *G* (this simulates the action of the PIR unit) – the relay should click and after a short delay, click off again. If there is any problem with hearing the relay, make a simple battery and bulb circuit with the wires leading to the relay normally-open contacts.

BOXING UP

If all is well, the box may be prepared to receive the circuit panel and other components and the light unit modified and fitted to the lid. Start with the box itself.

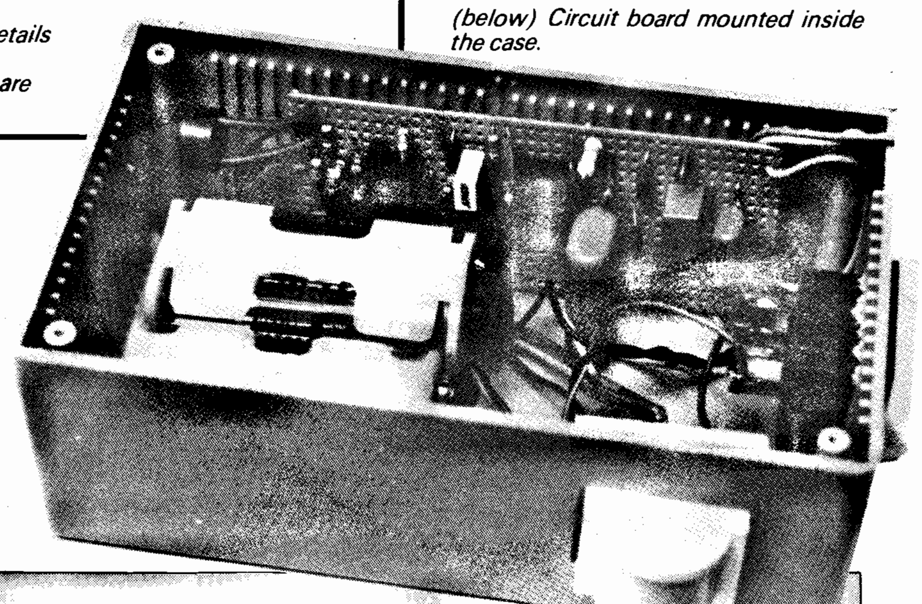
The hole for the PIR sensor is best made by carefully measuring its size and drawing the outline on the side of the case. Drill several holes on the inside of this line then join them together using a small hacksaw blade. Finish by smoothing off the work with a file. The hole should be made a tight push fit for the PIR unit. Make the hole for switch S1.

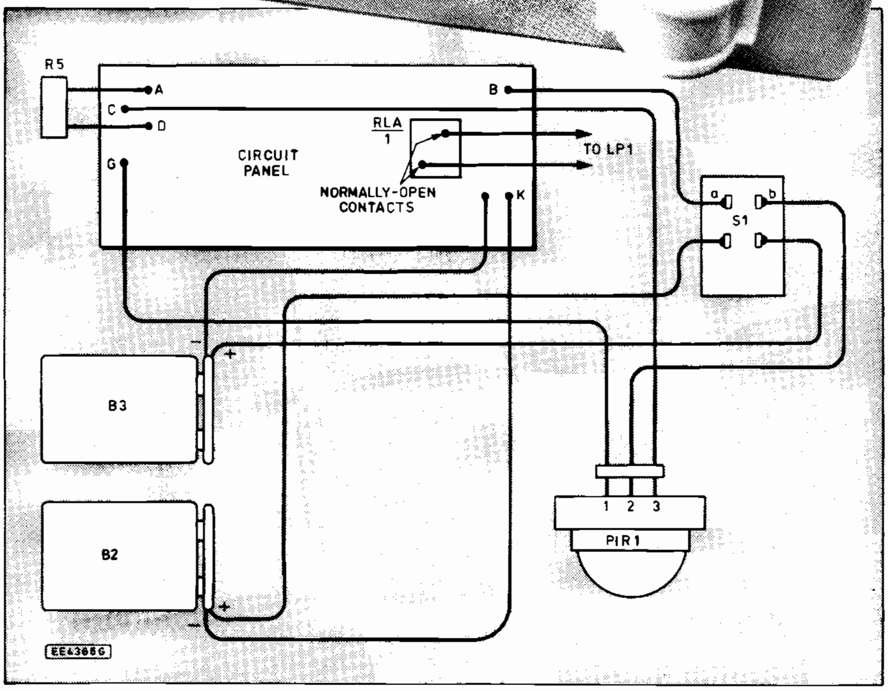
Hold the circuit panel in place and mark the position of the mounting holes. Mark also the position directly opposite the l.d.r. R5. Remove the circuit panel again and drill holes in the case to correspond with the markings. The hole through which light reaches the l.d.r. should not exceed 5mm diameter.

Referring to Fig. 4 complete the internal wiring shortening any wires as necessary. Mount the circuit panel using two small fixings and short plastic spacers. Bend the l.d.r. leads as necessary so that this component stands approximately 5mm behind the hole drilled for the light to pass to it.

Fig. 4. (bottom). Interwiring to off-board components.

(below) Circuit board mounted inside the case.





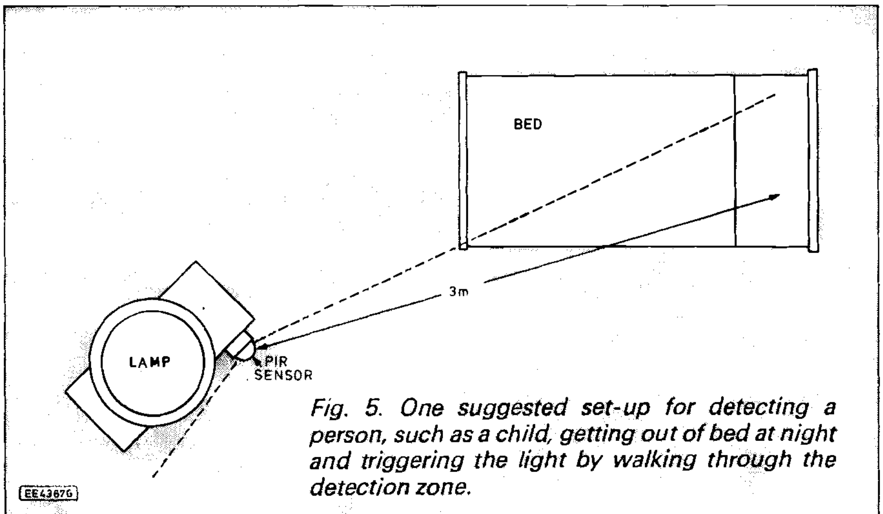


Fig. 5. One suggested set-up for detecting a person, such as a child, getting out of bed at night and triggering the light by walking through the detection zone.

PIR CONNECTIONS

Do not be tempted to solder the connections on to the PIR tags direct. Excessive heat from the soldering iron could ruin internal components. Instead, use a 3-pin single in-line (s.i.l.) socket. If this is not available make one by cutting down an 8-pin d.i.l. socket.

Solder the connecting wires leading to strip *G*, S1b and strip *C* to tags 1, 2 and 3 respectively on the socket. *Make certain that the numbering of the pins (as marked on the sensor plastic body) is correctly followed.* There is no room for error here – *incorrect polarity is likely to cause permanent damage.* Push the socket gently into position on the sensor pins and press the unit into place.

CUPBOARD LIGHT

Attention may now be given to modifying the cupboard light unit. Exactly how this is done will depend on the particular lamp being used.

The important point is that the existing circuit wiring, between batteries and bulb should be broken at some point and the new ends "bridged" with the wires leading to the normally-open contacts of the relay. A convenient method is to remove the internal switch and solder the wires to each side of the gap so formed.

Drill a small hole in the lamp base and in the lid of the components case for the wires to pass through. Drill two further holes to mount the lamp on the lid.

The bulb fitted in the light unit will probably be a 2·5V 300mA type. It may be possible to upgrade it using a cycle light type 2·4V 500mA lamp. This was checked in the prototype unit but the additional light output was found to be hardly worthwhile especially since it puts an additional load on the batteries.

Note that it is correct for a 2·4V or 2·5V lamp to be used with the 3V nominal battery supply. This allows for the voltage drop which occurs when the cells deliver the rather high current required especially as they age somewhat.

Mount the lamp on the lid of the box. Note that, in service, *no significant light from the unit must enter the l.d.r. hole in the side.* This is important – if it does, there will be triggering problems later. Also, direct light from the lamp should not reach the PIR sensor. Secure both battery holders to the base of the box – Velcro fixing pads would be a good method.

FINAL TESTING

With construction complete, a final test should be made and the timing set. Leave the opaque tape over the l.d.r. for the moment.

Stand the unit on a horizontal surface, point the PIR unit away from any moving infra-red emitting source and switch on. The light may self-trigger and go off a few seconds later.

There may follow a period of instability and re-triggering for no apparent reason. This is due to the PIR unit stabilizing. Once it has done so, the light should remain off. When the sensor is subject to large environmental changes, it can take up to 30 minutes to stabilize. However, under normal household conditions it will be only a minute or so.

If a person now walks into the detection zone, the unit should trigger. Some thought should be given as to the best position for the unit and some tests made. Fig. 5 shows a successful arrangement tried with the prototype unit. When satisfied, remove the tape from the l.d.r. window.

With preset VR1 adjusted as it is (mid-track position) and with a reasonable amount of light in the room, it should be found that the unit will not operate. The operating point may then be adjusted – clockwise rotation of VR1 sliding contact (as viewed from the left-hand edge of the circuit panel) *decreases* the light level at which the circuit is inhibited. A form of course adjustment may also be made by moving the l.d.r. nearer or further from the light entry hole.

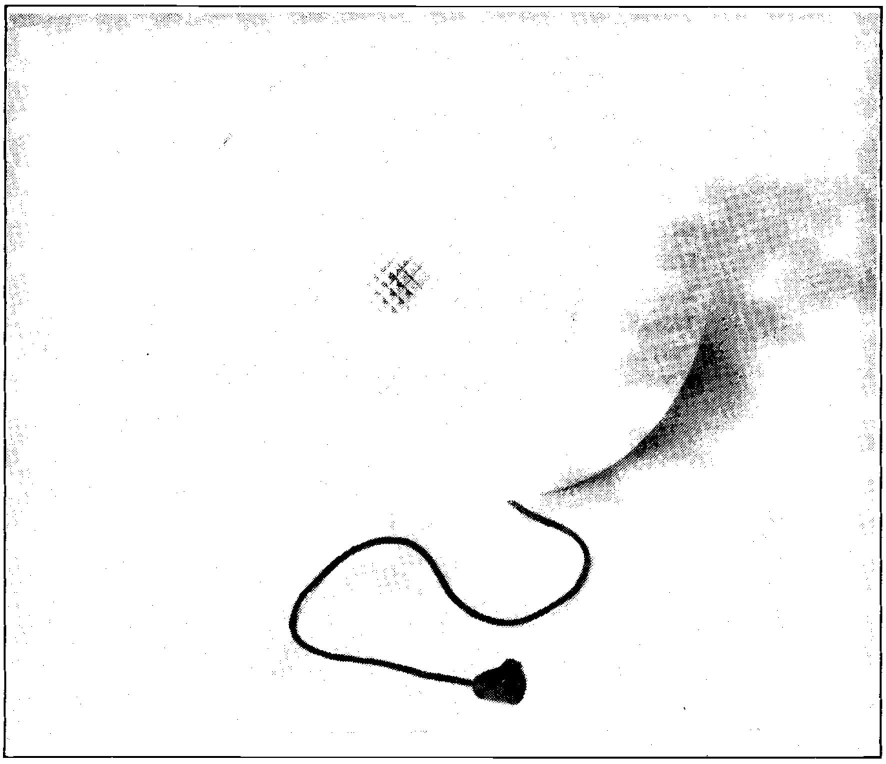
CORRECT OPERATION

Correct operation is obtained when *very little* light reaches the l.d.r. For this reason, if the hole faces direct light such as a window, it may need to be covered over to some extent.

Operation cannot be checked with the lid of the case removed since the extra light reaching the l.d.r. would completely alter the triggering point. After any adjustment to VR1, the lid must therefore be replaced. Note that the presence of a warm hand making adjustments even from *behind* the PIR unit may cause a period of instability when the unit is tested.

If the light switches on and off rapidly, this is a sign that a small amount of light from the lamp is falling on the l.d.r. – possibly by reflection from a wall. This may usually be cured by re-positioning the unit or by making a cardboard shield. Do not point the sensor at a flickering flame such as an open fire or false triggering may result.

The best orientation for the PIR sensor will provide reliable triggering without excessive false operation. It is probably as well to leave the timing as it is until the unit has undergone a period of trial. After that, the link wire on the circuit board should be cut through and the ends bent apart. This will provide the correct timing as set previously. Autolight may then be put into permanent service. □



The recommended battery-operated wall light for use in cupboards, under stairs, cellars and lofts prior to modification for the Autolight.

Innovations

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

NEW CONCEPT OF 'VIRTUAL REALITY'

British Industry Gives a Lead to Europe – by Hazel Cavendish

ONE can be forgiven for posing the question: Just what IS Virtual Reality and Telepresence?

Although certain parts of British industry are becoming increasingly aware of the value of this new scientific approach as a means of visualising data and applications, the general public is still in a mist of confusion. The man in the street is likely to link the technology with arcade and TV games – particularly if he has teenage children – and wonders how this can be usefully employed in the hard world of commerce. In fact this new scientific development has come a long way from amusement arcades in five years, and offers great earning potential to British industry. Meanwhile Western Europe is more than a little interested.

The Virtual Reality and Telepresence was set up in the U.K. in 1988 by the Advanced Robotics Research Centre in Salford near Manchester. Since then their experimental testbed – the most advanced of its kind in Europe – has been used to evaluate the interaction between operators and semi-autonomous robots. Equipped with head-mounted or area projection stereoscopic displays and intuitive input devices such as gloves, 3D "mice", speech recognition and synthesis, operators are tested controlling either a robot vehicle or an enhanced Puma Robot Arm. "Virtual" models of architectural and hazardous environments are constructed using a range of VR toolkits, although ARRC was the first to demonstrate the feasibility of converting objects and surfaces into 3D images by using a scanning laser range-finder system, so that they could be viewed on a stereo headset.

BUZZ WORDS

Teleoperation is the extension of a person's sensing and manipulation capability to a remote location; a teleoperator uses all the aids to communicate through channels to the human operator.

Telepresence is the ideal of sensing sufficient information about the teleoperator and task environment to communicate this to the human operator in a sufficiently natural way so that the latter feels physically present at a remote site.

Robotics is the science and art of performing functions normally ascribed to human beings through an automatic apparatus or device, which assumes almost human intelligence.

Telerobotics is a form of teleoperation in which a human operator acts as a supervisor, intermittently communicating to a computer information about goals, constraints, plans, contingencies, assumptions, suggestions and orders relative to a limited task, receiving in return information about accomplishments, difficulties and sensory data, while the subordinate telerobot executes the task based on information received from the human operator plus its own artificial sensing and intelligence. [One may be permitted to wonder: with such powers, will the robot learn to argue with its boss?]

Nanopresence. The concept of telepresence can be readily extended to providing the human with an experience of presence in 3D worlds which are *invisible* to the naked eye. The implications of using *Nanopresence* for non-destructive testing and inspection of materials in the offshore, aerospace and medical industry are enormous, as is its use in assisting people in the assembly of future micro-devices, such as motors, pumps and actuators. 1994 is likely to see interesting developments in this sphere.

In order to understand this fascinating new development it is necessary to know some of the buzz-words connected with it, otherwise one flounders in a sea of jargon (see the list above).

In the mid-80s only a few European researchers were aware of the significant developments in telepresence for robotic space application that were occurring in human factors laboratories of NASA's Ames Research Centre at Moffat Field, California. Advanced Robotics Research Ltd based on the campus of Salford University near Manchester was the first European establishment to exploit the new technology as a means of achieving telepresence, under the British Government's "Advanced Robotics Initiative", backed by investment from a group of industrial companies including British Nuclear Fuels, Hunting Engineering and the National Nuclear Corporation.

VIRTUAL WORLDS

Led since 1989 by Bob Stone, Technical Manager and visiting Professor of Virtual Reality at the University of Salford, the company is definitely going places. The building of virtual worlds using sensory data is a key element in their research. A prime requirement for the sensory system is that it can produce enough 3D information to build a useful representation of the environment in which it operates. Work at ARRL has focussed on an approach which uses an infra-red scanning laser rangefinder. Such a system is capable of producing extremely dense range information.

It was soon realised that if virtual technologies were to become accepted throughout industry as a standard for future human-system interfaces, they must support, in a cost-effective manner, the involvement of a team of users – not just a single operator equipped with a headset and gloves. A prime example of the need to involve a team of users was found in the nuclear and offshore industries, where many specialists need to rehearse the decommissioning of radioactive facilities or platform structures. To achieve this ARRL established a remote Studio where stereoscopic images from the Company's VR computer were relayed for 3D display on a special silvered screen, using a pair of liquid crystal video projectors with polarising filters. Team observers experienced a full image by wearing polarised filter spectacles, complimentary to those used on the projectors.

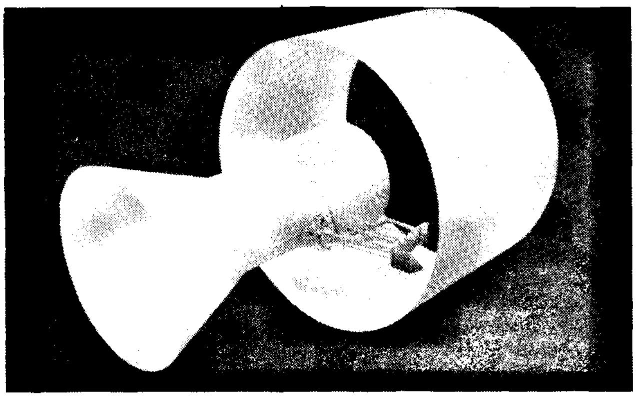
MICROSCOPIC WORLDS

The concept of telepresence was not to be restricted to hazardous environments originally designed for intervention by humans but had to be extended to providing the human with an experience of presence in 3D worlds *invisible* to the human eye. Successful developments in the new and exciting field of nano and micro-technology could well depend on providing researchers with the means of visualising materials at, for example, an atomic level.

In pursuit of this aim Salford University and the Company demonstrated that VR could be used to visualise new surface features previously undetectable when using conventional display techniques. VR was used to allow virtual "flight" over materials at the right level. To do this, a device known as a scanning tunelling microscope – one of the University's key development facilities – was used.

Selling the vision and technical potential of VR to a sceptical and money-conscious market proved a highly challenging and sometimes frustrating exercise, says Professor Stone. There had been so much "hype" about it that many potential industrial users declared they would never contemplate procuring a "child's game" for serious commercial application.

The first important breakthrough came when Rolls-Royce approached the Company to investigate using VR as a means of



Rolls Royce Trent aero engine model as displayed on a high-resolution screen, hosted on a Silicon Graphic Onyx Graphics 'Supercomputer'. The model shows the fan casting and part of the lower bifurcation assembly.

radically changing its design and maintenance procedures. After a feasibility study VR was used to simulate the Trent 800 aero-engine, currently being developed for the new breed of twin-engine airliner such as the Boeing 777. (The engine had its running tests last month). A fitter wearing a VR headset and gloves was able to interact with the virtual representation in much the same way as he would have done with a physical model. The pipework assembly was found to generate excellent stereoscopic images, and additional routines were written in to colour-code individual pipe routes selectively and to segment pipes into groups of objects, allowing detail switching and their removal and manipulation by engineers.

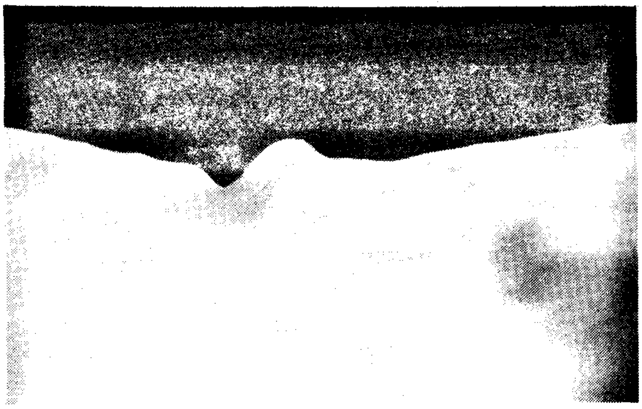
The feasibility study culminated in a demonstration of the virtual Trent engine to senior Rolls-Royce personnel, using both immersion and stereoscopic projection displays. Later the Rolls company was to become one of the founder members of ARRL's Virtual Reality and Simulation Initiative in May this year, entirely funded by the industrial sector, to inform and assist industry in introducing VR technology into their businesses. Thirteen British companies have now joined the initiative, which is steadily gaining members.

VR ACTIVITY

As early as 1991 there were four main centres of VR activity in Britain: W Industries of Leicester, British Aerospace in North Humberside, Dimension International of Aldermaston and Division Limited of Bristol.

W Industries developed a range of "Virtuality" products primarily for the leisure and entertainment market, expending considerable sums in packaging and marketing the technology to secure a lucrative early market in excess of £11 million. Since then it has sought to open out its product range to more serious applications such as engineering design. In Humberside British Aerospace's Brough Division spearheaded UK efforts in advanced fighter aircraft cockpit design, using VR technology. This advance was led by Professor Roy Kalawsky, Britain's first Professor of VR, who holds a visiting chair at Hull University.

Dimension International pioneered the concept of "Desktop" VR in the South of England, and worked with the TV Company Broadsword on *Cyberzone* – claimed to be the world's first VR TV Game Show. In Bristol, Division Limited pioneered the use of transputer technology in their development of the Vision, ProVision and Supervision Systems – modular and high speed graphics engines which avoid the processing bottlenecks associated with previous approaches to generating.



Virtual Environment fly-through of a sample of platinum measuring 14,500 Ångströms square. This model was reconstructed using real data obtained using Salford University's Scanning Tunnelling Microscope and revealed such features as stylus impact damage, diamond polishing irregularities and surface characteristics when bombarded with helium ions.

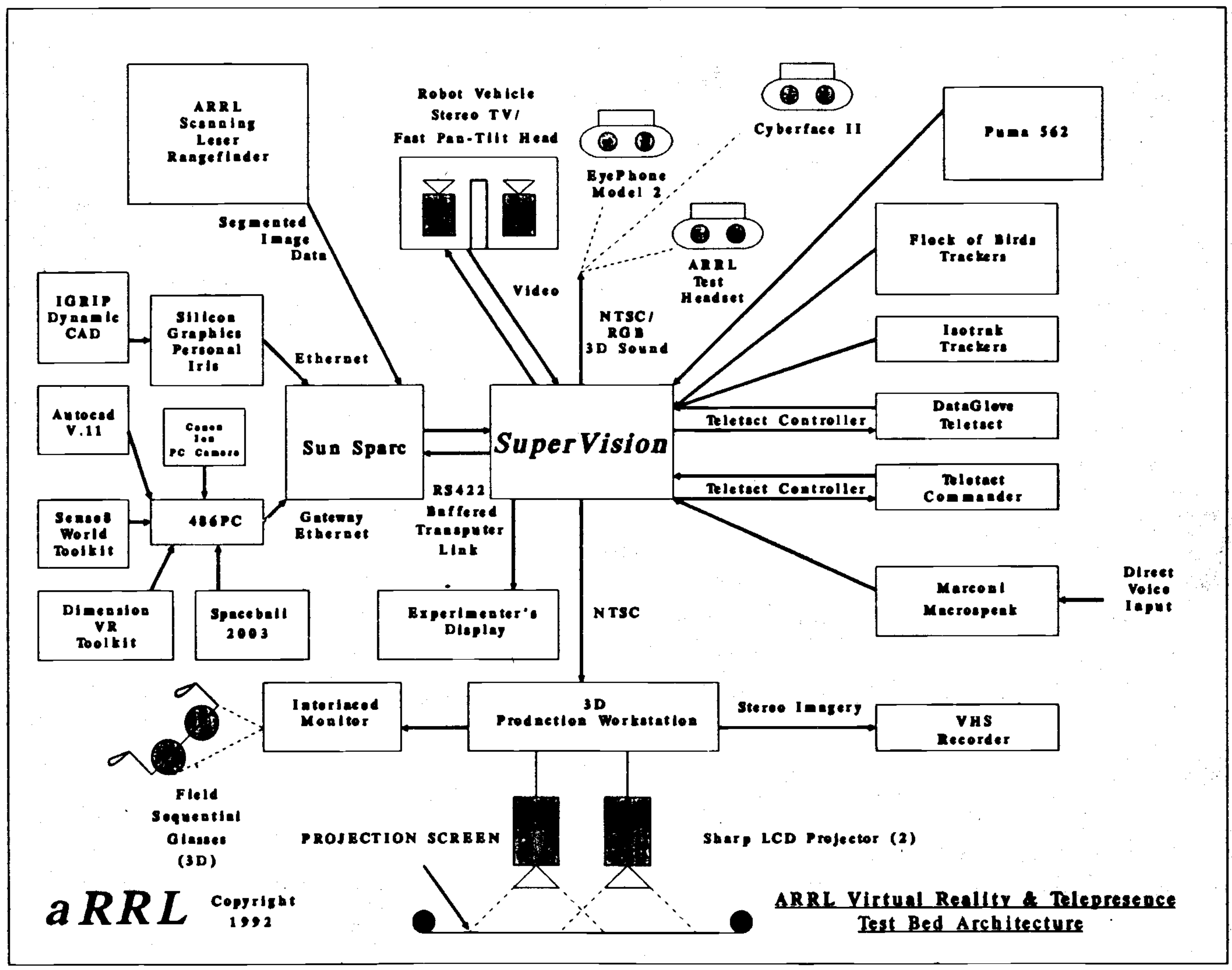
More recently Nottingham University's VR Application Research Team has been working closely with the nearby Shepherd School to introduce Desktop VR technology into the educational lives of children with learning difficulties and severe physical handicaps.

A very important contract, still shrouded in secrecy, was the first one to be industrially-funded in Britain and related to the development of a virtual model of the Deep waste Repository currently being considered for the safe and cost-effective disposal underground of low and intermediate level radioactive wastes at Sellafield.

UNSUNG HEROS

Professor Stone pays tribute to many "unsung" heroes and inventors engaged in developing systems which are likely to find their way into VR in the not-so-distant future. Willie Johnson's "Goggle Vox" (described in *Everyday with Practical Electronics* last January) is cited as a breakthrough in head-mounted displays brought about by the diffusion film *Microsharp* developed by Johnson and his team at Loughborough University, and currently the subject of a patent application.

Stone regrets the necessity for Johnson and many others to seek development funding in countries other than Britain. "One can only guess at how often this state of affairs actually results in the UK and other European countries losing valuable inventions and personalities" he says.



New Technology Update

Ian Poole investigates battery management i.c.s.

BATTERY management is becoming increasingly important. In the August 1993 issue of *Everyday with Practical Electronics* a look was taken at the new Nickel Metal Hydride (NMH) cells which are beginning to appear on the market in various pieces of equipment. However the major drawback with these cells is that they must not be overcharged otherwise their performance will be greatly impaired. This is true not only of NMH cells but also of the more familiar NiCads which are in widespread use. These cells rarely live up to their expected life chiefly because they are rarely charged properly.

In addition to this fast charge facilities are being increasingly required. In many professional applications it is not possible to wait 12 hours or more for the battery to be recharged. However fast charging needs to be very carefully monitored. Even a few minutes of overcharge can have a disastrous effect, even if the cells are designed for fast charging.

Battery Monitoring I.C.s

To overcome these problems a number of battery management i.c.s are appearing on the market. Using these i.c.s it is possible to manage fast charging of NiCad and NMH cells in as little as 15 minutes. This can be done whilst still being able to monitor the state of charge, ensuring that the correct charging conditions are met so that battery life is not impaired.

The major problem encountered in battery management is that both NiCad and NMH cells give little information to the outside world about their state of charge. Matters are further complicated by the fact that any indicators are often several stages removed from the original property which needs to be monitored. Furthermore the these indicators are often the result of the interaction of several properties within the battery.

Despite all of these problems battery management i.c. designers have homed in on three main properties which are able to give the vital information about the battery state. The voltage is probably the most obvious one. It can be seen that when a cell is fully charged its voltage peaks as shown in Fig. 1. Also when the cell is nearly discharged the voltage falls away rapidly. This information combined with the charge/discharge current and the cell temperature are all that is needed directly from the cell.

A forth and final item is the time for which the various activities have been taking place. By using a knowledge of the time it is possible for the management i.c. to build up an almost exact picture of the state of the cell. From this it is then possible to control the charge and discharge of the battery.

NiCad and NMH

Although NiCad and NMH cells exhibit slightly different characteristics they are sufficiently similar that the same techniques can be used. In fact many i.c.s can be used for both types.

Obviously there are some differences which need to be taken into account. In the first case NMH cells have a less pronounced rise in output voltage when the cell is fully charged. As NMH cells are less tolerant to overcharge than their NiCad counterparts this is very important.

Fast charging is also different. This is mainly because of the low tolerance of the NMH cell to overcharge. Normally the maximum rate for NMH cells is limited to only 1·3C whereas NiCads can often be charged at a rate of as much as 4C and sometimes more. (To charge a cell or battery at 1C, a 700mA hour cell would be charged at 700mA).

Types of I.C.

There are two main types of battery management i.c. The first is the monitor and the second is the charge controller. Often the two types are available as separate items. However, as they are generally used together they are also available in combined packages.

The controllers contain an internal register. This contains the chip's representation of the state of charge of the battery. To update the i.c. all the relevant information is fed into it. By combining this information with a timer on the chip it is then possible to calculate the amount of charge in the battery. However to be able to achieve this the controller must remain connected to the battery all the time and as a result, these chips are usually an integral part of the battery pack.

When it comes to charging, great care has to be taken to ensure that the batteries cannot become overcharged. To avoid this most charger i.c.s use more than just one indication to signal the right time to stop charging. This has to be done because the i.c.s will have to be used for batteries of all makes. Although they will all perform in basically the same way there will naturally be some variations between manufacturers and even between different batteries made by the same company.

Full Charge

One of the major triggers used to signify full charge is the fall in output voltage. For fast charge rates the controller i.c. will sample the voltage every few seconds to monitor whether voltage is falling. For lower rates it will be every few minutes. When a distinct fall in voltage is measured over successive samples the charging will cease.

The other indicator of full charge is the battery temperature. In many ways this is better because it is more closely linked to the state of charge than the voltage. Once the battery is charged its temperature will start to rise steadily. It is then fairly easy to detect this change. However changing room temperature can cause this method to fail, and therefore it is best used in conjunction with the voltage detection method as a fail safe.

One additional feature which these controllers include is an automatic switch to a trickle charge once the main charging is complete. For NiCad cells a rate of C/10 is quite acceptable. However NMH cells are far less tolerant of trickle charging and a lower rate must be employed. This trickle charge will equate to the self discharge rate of the battery.

The Future

As battery management technology becomes more established costs will fall and it is likely that most new battery packs will include management chips. Unfortunately this will mean that the battery management circuitry is most likely to have to be discarded with the rest of the battery when it reaches the end of its life. However when its cost is balanced against the initial cost of the battery and the increased life there will still be a significant saving. There will also be the added advantage that batteries can be made even more reliable than they are today.

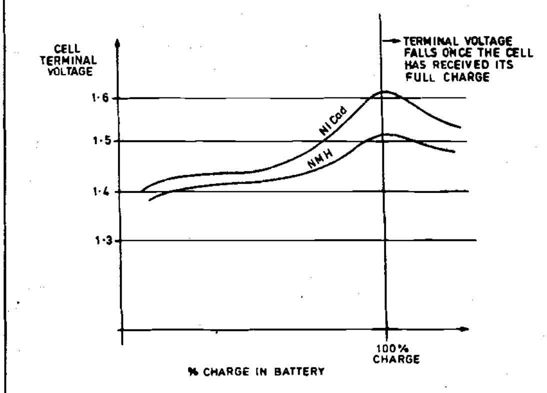
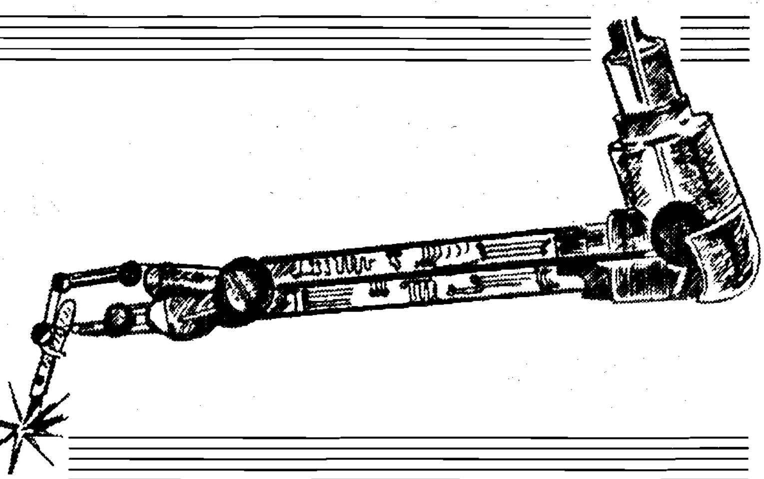


Fig. 1. Charge characteristics of NiCad and NMH cells.

Regular Clinic



CIRCUIT SURGERY

ALAN WINSTANLEY

Welcome to our monthly forum to discuss readers' requests and to help out with puzzling projects.* Circuit Surgery *is here to try and lend a hand with general electronic topics, so if you think you have a query which might be of interest to others, then write in! We're also keen to pass on any useful hints or tips, so drop me a line if you have any suggestions to share with your fellow readers.

This month, I start with a topic which follows on from our very successful educational series *Teach-In '93* (published Nov '92 to Oct '93) which was specially designed to support students of GCSE and GCE "A" Level Electronics. Then we investigate a voltage detection chip – the ICL8211 – which is useful as an over or under-voltage alarm or monitor. First, a question from a *Teach-In '93* follower, ***A.J. Granger*** of Brighton:

Teach-In: Zener Diodes

"I haven't worked with Zener diodes before and wondered if you could clarify how you calculate the value of a series resistor and also the current and power ratings of the components. Please can you explain?"

I'll try! Mr. Granger was referring to our explanation of *Zener diodes* given in *Teach-In '93* (Part 3). One or two other letters also asked for further clarification, so here goes. The Zener diode is a component which is capable of providing a reasonably stable voltage even if the voltage supplied to it, varies. Basically, if you supply it with a higher (steady or varying) voltage, a stable *lower* voltage appears across it! You can use this steady voltage for several purposes: as part of a power supply (called a "stabilised" or "regulated" supply) or as a "reference" voltage for other circuitry perhaps.

A *series limiting resistor* is needed with the Zener diode. Take a look at Fig. 1

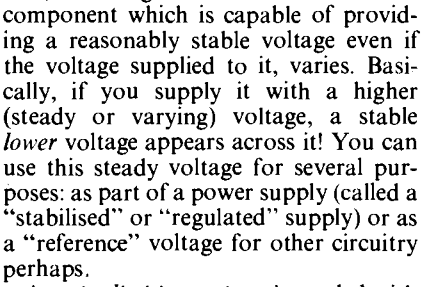


Fig. 1. Simple Zener diode aplication.

which depicts a 10V d.c. voltage connected to a resistor R1 and a Zener diode D1. Note how the Zener diode is "reverse biased" to produce a steady voltage, the value of which depends on which Zener diode you pick. They have a tolerance on their values, too, typically ±5%.

The Zener diode we chose was a 5·1V type (e.g. a **BZY88C5V1** which is rated at 500mW maximum power dissipation) – which means that it will produce a 5·1V reference voltage under suitable conditions. A load is shown which could perhaps be a 5V logic circuit.

The resistor R1 limits the total current flowing, in order to prevent destruction of the Zener. The current I_{IN} which flows through the resistor, then splits into two paths. I_Z is the current flowing through the Zener diode, and I_L is the current flowing into the load. It follows that $I_{IN} = I_Z + I_L$. Let's assume that the load draws a constant 25mA i.e. $I_L = 0{\cdot}025$A.

Before calculating the required series resistor, we need to bear in mind that a nominal current needs to flow through the Zener too. We can decide this figure ourselves and we have to pick a reasonably small value for I_Z to ensure that the Zener's power rating is not exceeded. Let's say that $I_Z = 5$mA. So with 5·1V appearing across the Zener and 5mA flowing through it, the power dissipated by the Zener diode is ($P = I \times V$) 0·0255 Watts or **25mW**, well within its 500mW rating.

By Ohm's Law, the resistor value is then equivalent to the required voltage drop across it (which is 10V – 5·1V = 4·9V) divided by the *total* current I_{IN} flowing through it – which is 5mA + 25mA = 30mA. So in this simple circuit you could use a series resistor of 163 ohms (4.9/0·03), if one existed. You would use the nearest preferred value down instead, say **150 ohms**.

Now double check. Using a 150 ohm resistor means that more current than we originally intended will flow through the resistor, although the voltage across the resistor won't change because the Zener maintains a steady 5·1V. How much current flows through R1?

Again, from Ohm's Law, the current will be $I = V/R$ so $I_{IN} = 4{\cdot}9V/150$ which gives us a current of **32mA**. Because the load still faithfully draws 25mA, the rest of the current flowing will be consumed by the Zener, which draws **7mA** (instead of the 5mA we intended) and therefore will dissipate about **36mW** (5·1V × 7mA). Still very safe.

The power dissipated by the *resistor* could be worked out using either of two formulae: $P = I \times V$ or $P = I^2R$. It's roughly **160mW** so a 250mW (¼W)type is fine. By reducing the resistance even more, the Zener current will increase accordingly. The maximum current which we may allow the Zener to draw is determined by its power rating. A 5·1V 500mW Zener diode may pass no more than **98mA** maximum ($I = P/V$).

Surprise Supplies

Suppose the supply rises to 25V. The current flowing through the resistor will now be (19·9V/150 ohms) = 133mA. R1 will dissipate 2·6 Watts and will soon bite the dust. The Zener will dissipate 550mW so is now over-rated too. Yikes!

The picture's more complicated when the supply voltage and/or the load current varies. Designers have to take into account "worst case conditions" when specifying the components. The resistor's power rating is peak when the supply voltage is at its *maximum* – but choose a resistor value low enough for the required peak load current to flow when the supply's at its *minimum* voltage.

The Zener's power figure is peak when the supply rail is maximum voltage and the load is at minimum current. For instance, take a 5V Zener, and if the supply varies between 10 to 15V, the load varies between 20mA and 100mA. Assuming a nominal Zener current of 5mA, I reckoned that the resistor would need to be 47 ohms 2·2 Watts and the Zener would need to be rated at 0·96 Watts minimum to cope with the varying load and supply. See if you agree!

Low Voltage Monitor

Talking of voltage references, ***Clifford Beck*** of Co. Offaly, Ireland, wrote:

"I have an experimental rechargeable lighting circuit which is charged by a wind charger, and I run a few lights from it. Could you design a circuit to switch the lights off when the battery drops below 11·5V, so when the battery is fully charged the lights can come on again? I was thinking of using the 8211 integrated circuit."

Thanks for the suggestion, Mr. Beck. Presumably the idea is to prevent the lighting from flattening the battery until it has recharged again. It occurred to me that this might also appeal to caravanners, boating enthusiasts or campers, and the device concerned – the 8211 programmable voltage detector – is a really easy i.c. to use and is a neat way of monitoring the supply voltage level, or any other d.c. level for that matter.

There are actually two 8-pin d.i.l. devices available – the ICL8211 and the ICL8212. I'll describe both. They are almost identical except that the 8212 functions in the opposite manner to the 8211. Firstly Fig. 2 shows a basic under-voltage alarm using the ICL8211. The chip monitors the supply by comparing

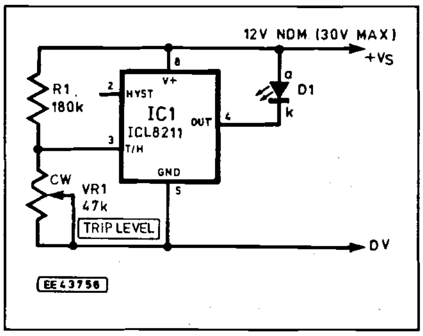


Fig. 2. Low voltage alarm.

it against an accurate internal 1·15V reference or "threshold". With the 8211, when the voltage at pin 3 is *less than* the 1·15V reference, the output (pin 4) goes low and **sinks** typically 7mA in this state – it's current limited by the i.c. so I added an l.e.d. D1 as shown, with no series resistor being necessary.

Hence, when pin 3 is less than 1·15V, the l.e.d. lights. A potential divider is needed (R1 and VR1) and is calculated so that the voltage at pin 3 will fall below 1·15V when the supply voltage itself drops to the required level. In our case, the rail is assumed to be 12V d.c. or more but an alarm/cut out is required when it falls to 11·5V or so, the exact alarm point being set by VR1.

The i.c. only consumes 20µA typically and the potential divider resistance can be set for 50µA current flowing through it, or even less, hence the circuit itself has negligible loading on the supply rail. The supply voltage can be up to 30V absolute maximum.

Sister Chips

The complementary ICL8212 device has two major differences: its output is **not** current limited (35mA sink, maximum), and the output goes low when pin 3 is *higher* than 1·15V. This is probably more suitable for our application because we could just add a *pnp* transistor driver to the output, see Fig. 3.

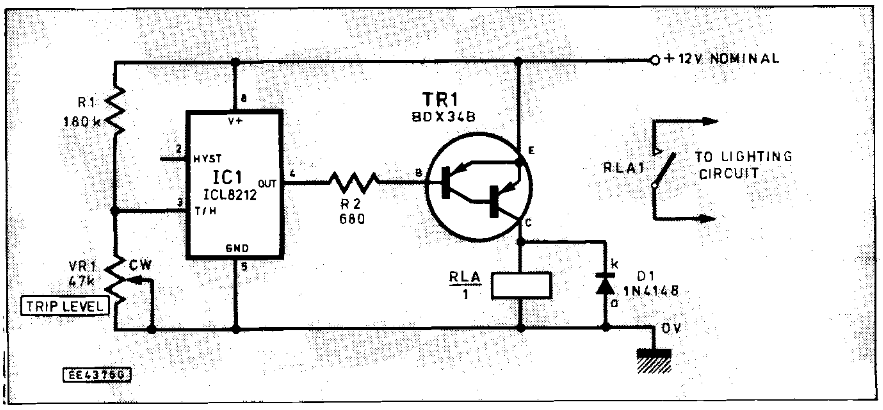


Fig. 3. Low voltage trip circuit using ICL8212. RLA only operates when supply rail exceeds trip level. TR1 can provide up to 10A drive.

Transistor TR1 is a *pnp* Darlington power transistor which turns on when pin 4 is low (pin 3 > 1·15V). The load shown here is just a relay which in turn switches the lighting, but TR1 is rated at up to 10A and could easily drive a load directly. By adjusting VR1, when the supply rail is *higher* than the desired switching level (11.5V, Mr. Beck specified), then pin 4 is low – this is equivalent to the "alarm state" of the 8212 – therefore the transistor is *on*. When the supply rail falls, eventually dropping below 11·5V, the potential at pin 3 drops below 1·15V and thus the output goes high. TR1 turns off, switching off the lights!

The circuit consumes little current under these circumstances, preserving the battery. It's probably easier to use the 8212 this way since all it then needs is a single transistor to directly drive the load. Hence we're actually using the 8212 to detect not a fall but a *rise* in voltage – when the supply rail exceeds 11·5V this is deemed the "alarm" and is used to turn the lighting **on**.

It's possibly worth introducing some hysteresis – a difference in the switch-on and switch-off levels which prevents the load from constantly jittering. Pin 2 (hysteresis) can be used to introduce positive feedback by connecting it via a resistor to the potential divider. (The hysteresis pin is actually a complement of the output pin but it only sources some 20µA.) This means that the load won't forever be switching on and off when the circuit is *just* on the threshold level. Try it by adding a resistor – say 1M or 2M2 – between pins 2 and 3.

Finally, whilst the ICL8211/8212 are bipolar devices made by Harris, improved CMOS versions of both chips are produced by Maxim – the MAX8211 and MAX8212. They're only suitable for supply rails up to 16·5V though, the CMOS chips have much lower quiescent currents and the resistance of the potential divider network can be greatly increased to reduce the supply drain. Also the hysteresis pins source a useful 10mA. All four devices are available from Farnell (0532 636311) – Part Numbers are ICL821?CPA or MAX821?CPA2.

Suggestions for experimenters: design using an opto-isolator driven straight from the ICL8211 output, or maybe use the hysteresis pin of the MAX8212 (goes high when the threshold exceeds 1·15V) to drive an *npn* transistor or MOSFET to power the lights.

Soft Where?

D. Evans of Gwynedd asks if there is any suitable educational software to run on a PC. *Electronics Principles* from EPT Educational Software is now available from the EPE Direct Book Service and a demo disk costs £2 – see advert elsewhere in this issue. It's definitely worth checking out if you're looking for an imaginative and concise way of learning the basics of electronics using a computer as a learning aid.

C.L. Quay from Malaysia wrote to say he's delighted with the hi-fi 'speaker de-thump which worked a treat (see last month).

I read every letter but unfortunately I cannot guarantee an individual reply or advise on the repair or modification of commercial equipment. If you have a suggestion or idea which might interest other readers, then write to me at *Circuit Surgery*, Everyday with Practical Electronics, 6 Church Street, Wimborne, Dorset BH21 1JH. See you next month!

CIRCUIT SURGERY

Circuit Surgery is for your queries, hints and tips. If you think we can help with an interesting problem or if you have a tip worth passing on then write to Alan at *Circuit Surgery*, Everyday with Practical Electronics, 6 Church Street, Wimborne, Dorset BH21 1JH.

Special Series

SAFETY FIRST!

T.R. de VAUX-BALBIRNIE

Part two

Staying alive with electrical equipment

LAST month we discussed electric shock, some first-aid procedures and a little of the theory. This time we shall pursue the same topic.

By understanding this, it is more likely that we shall avoid electric shock or reduce its severity in an accident. Note that those working in industry and education must seek more specific guidance. Also, overseas readers should check their own national regulations since there may be differences in detail.

MAINS SUPPLY

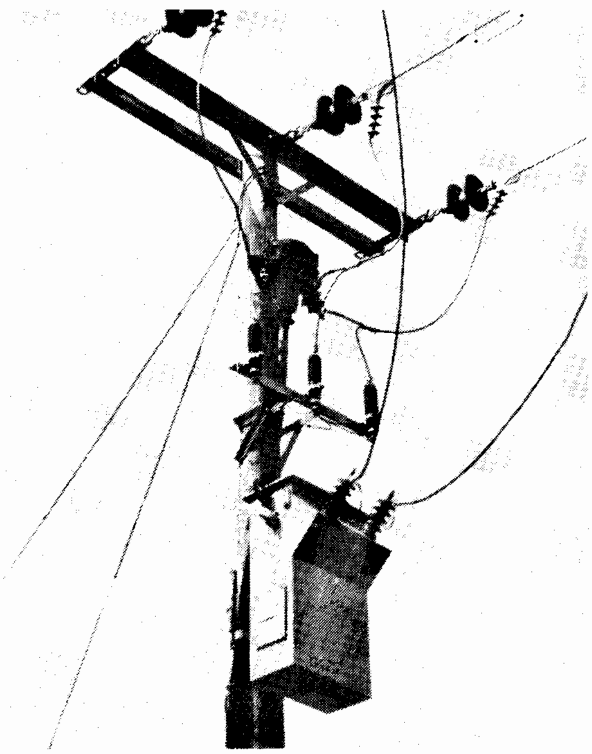
Before proceeding, it is necessary to have at least a simplified knowledge of how mains electricity is supplied to the consumer. The energy is transmitted from the power stations along the National Grid network at very high voltage (up to 400,000 volts – 400kV). It arrives at a local transformer (see Fig. 1a) which may be situated at ground level or may be a *pole transformer* of the type shown in the photograph opposite.

The transformer reduces the voltage to the household working level of 240V and the supply arrives in the house through two wires – *Live* (L) and *Neutral* (N). These, together with a third one connected directly to Earth (E), appear at each power socket in the house (see Fig. 1b). For technical reasons, the neutral wire is also connected to earth – this is an important point as we shall see presently.

To operate an appliance, a circuit is made by connecting it between the live (L) and neutral (N) wires. For simplicity, we refer to the current *entering* by the live wire and *returning* by the neutral one. However, in reality it pulses backwards and forwards through the circuit because the mains supplies *alternating current* (a.c.).

Imagine we have an electric shock situation where a person is holding both live and neutral wires at the same time – one in each hand (see Fig. 2). Current flows through the body completing a circuit.

However, holding both conductors in this way seems rather unlikely and it is difficult to see how it could easily happen by accident. It is more likely that a single bare wire – the live one – will be touched while the feet make contact with the ground. This may also produce an electric shock called an *earth-loop shock.*



Pole mounted local transformer.

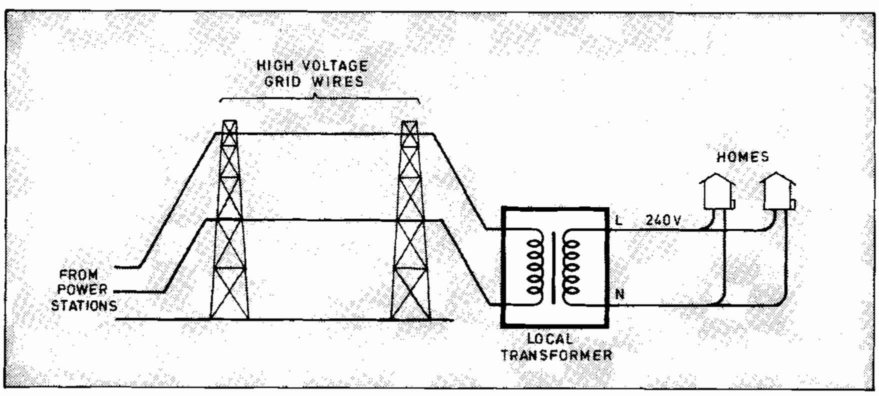


Fig 1a. Simplified Electricity distribution system.

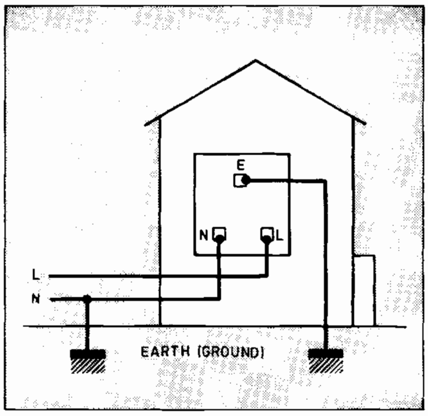


Fig. 1b. Connections in the house.

Fig. 2. Current flow through the body.

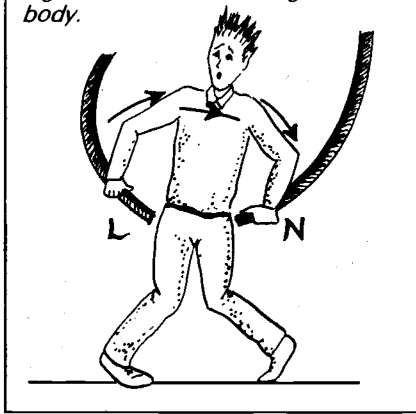
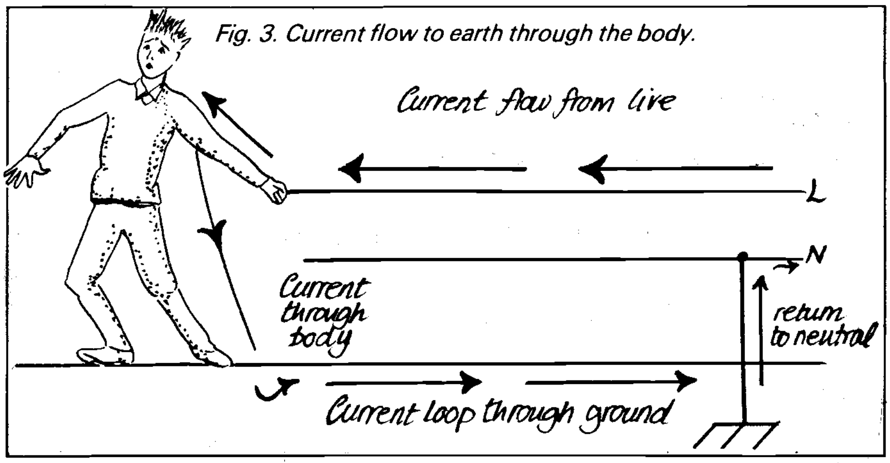


Fig. 3. Current flow to earth through the body.



DOWN TO EARTH

To understand this "loop", refer to Fig. 3. Suppose, due to some fault, the live wire is exposed and a person touches it. Sufficient electrical contact is made with the ground ("earth") through most shoes and, for example, a wooden floor. The earth conducts electricity due to the presence of moisture and various conducting substances. There is therefore a circuit formed through the body from live to neutral via the earth as shown by the arrows. Accidental touching of a live conductor can happen very easily if wires are pulled free, cut through or sufficiently worn so as to expose the copper beneath the insulation.

The severity of the shock depends on the strength of the current which, as well as the *skin contact resistance* with the live wire, is also related to the resistance between the person's feet and ground. This, in turn, is influenced by the type of footwear, if any, the material used for the floor and the amount of any moisture present. Note that an accidental brush with the *neutral* wire will not cause a shock because no circuit is formed from the live one.

Since touching the *live* wire is so dangerous, it is essential to distinguish it from the neutral one. This is done by using a colour code for the insulation. The live lead is usually *red* in fixed cable (that is, *permanent* wires) and *brown* in flexible ones.

The corresponding colours for the neutral are *black* and *blue* respectively. In fixed cables, the Earth wire is bare copper and in flexible ones the insulation on the earth wire has *green and yellow* stripes. It is obviously essential for everyone to follow this code.

AN INTERESTING CASE

Many pieces of electrical and electronic equipment are housed in a metal case. This may be to provide mechanical strength, electrical screening, to withstand high temperatures or for any other reason where plastic would be unsuitable. it is usual to connect *all* exposed metalwork to ground via the earth wire mentioned previously using the top pin of the 13A mains plug.

Refer to Fig. 4(a) which shows a familiar piece of equipment – an electric iron – operating from the mains with the element correctly connected between live and neutral and with the case earthed. Suppose the live (L) wire became detached and touched the metal case – see Fig. 4(b). There would now be a circuit formed from the live wire to the metal work, to earth and hence to the neutral of the supply as shown by the arrows.

Since the resistance of this circuit is low, the current would be correspondingly high and blow the fuse in the live wire at the plug or elsewhere. This would isolate the appliance from the mains live feed so if someone touched the case it would be safe.

If the earth (E) wire broke loose – perhaps inside the plug (see photograph) – the earth loop would be broken. In the event of the above fault developing, the fuse would fail to blow and the next person touching the case would receive an earth-loop shock. For this reason, the proper earthing of metal cases should be checked frequently.

This may be done using a multitester set to a low

Fig. 4a. Normal current flow.

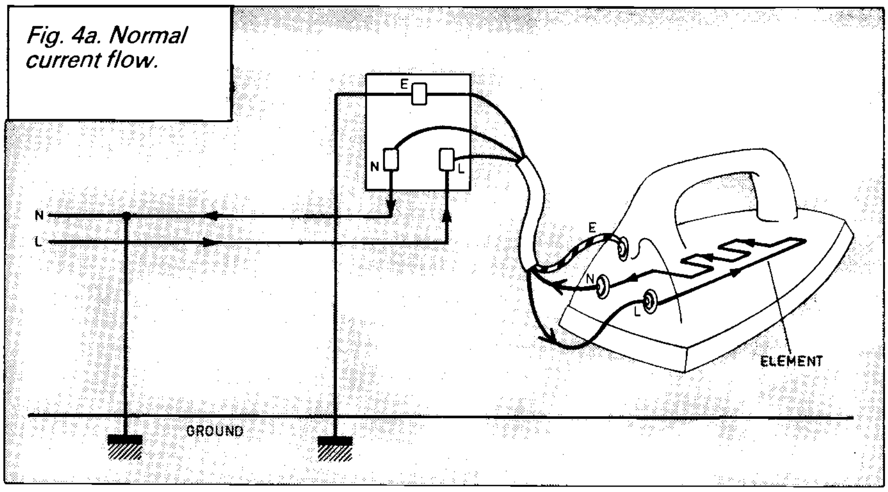
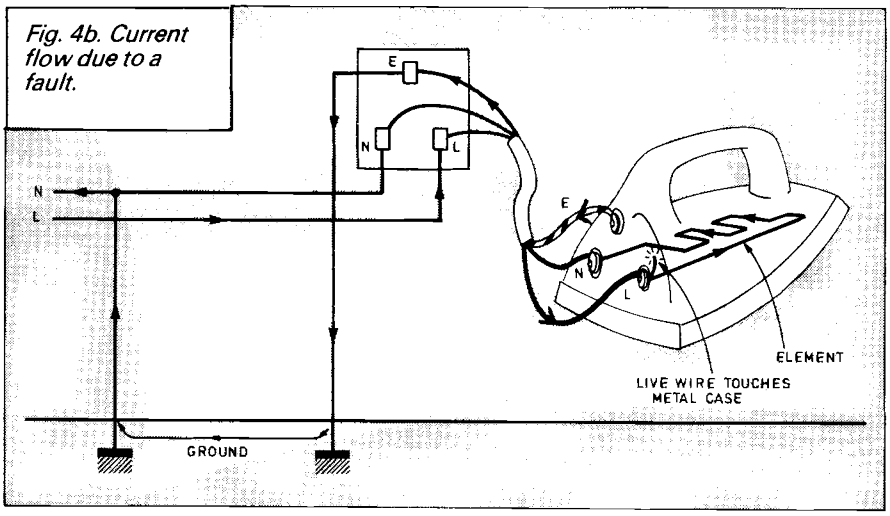
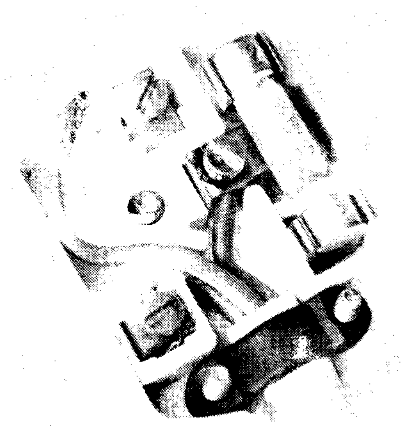
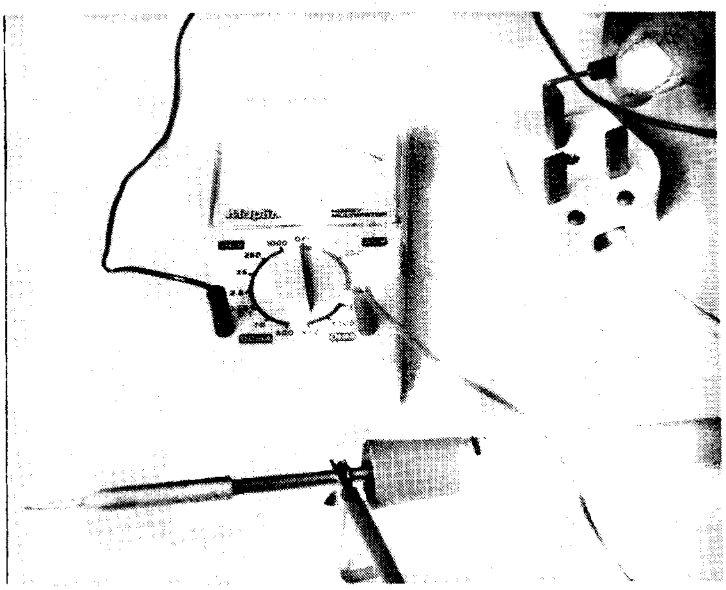


Fig. 4b. Current flow due to a fault.





Dangerous situation with earth wire disconnected.



Simple test to check appliance earth continuity.

resistance range. ***With the appliance unplugged from the mains;*** touch one probe on the earth pin of the plug and the other on a metal part of the appliance (see photograph of this test being carried out on a soldering iron). Practically zero resistance (a fraction of an ohm) should be indicated. This is a very basic test but is better than no testing at all. Note that this does *not* apply to *double-insulated* appliances (see below).

DOUBLE-INSULATION

Certain appliances do not need earthing. Totally plastic-cased equipment, for example, where there are no exposed metal parts and certain items which, although having exposed metal parts, are said to be *double-insulated.*

Here, because of additional insulation, it is impossible for a detached live wire to touch the metalwork whatever the fault. It is then possible to dispense with the earth wire. This is common practice with certain garden and DIY-type tools.

The correct wiring of a 3-pin 13A UK plug is shown in Fig. 5. Table. 1 shows the old wiring colour code mapped against the new one – there is still plenty of equipment in use with old coloured wiring although, by now, it should have been replaced with the modern equivalent. If equipment needing only a live and neutral feed is used then, of course, the connection to the earth pin is ignored.

Table. 1:

	New system	*Old system*
Live	Brown	Red
Neutral	Blue	Black
Earth	Green/Yellow	Green

When wiring a plug, the following points should be especially noted:

- The wires *must* be connected to the correct terminals.
- Only a *small* amount of insulation should be removed from the wires.
- When removing insulation, no strands of copper wire should be lost.
- Wire should be securely gripped *on the outer sheath.* It must not be possible to dislodge it with an accidental pull.
- The correct value of fuse must be fitted.

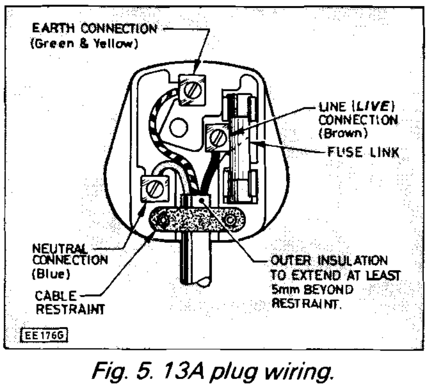


Fig. 5. 13A plug wiring.

Choosing the correct fuse value will be one of next month's topics.

In an appliance, any on-off switch is placed in the *live wire.* When switched off, the live feed is therefore disconnected. This is why it is essential when a mains plug is fitted, that the live and neutral wires are connected to the correct terminals.

If the neutral wire is inadvertently connected to the *live* terminal instead, the switch would appear in the *neutral* wire. The appliance would still work but, when switched off, the live wire would still be connected – a dangerous situation. Double-pole switches are inherently safer because they disconnect both live *and* neutral wires but they are more expensive.

SAFETY CHECK

Earth-loop shocks are more serious in a bathroom due to the likely combination of bare feet and condensation lowering the resistance, also the taps and pipes which may be touched will be earthed. This is why there are special regulations concerning the use of electrical equipment here. Use the following information to do a safety check yourself.

There must be no standard power socket in a bathroom. If one exists, *it has been installed by an amateur and must be removed and the circuit isolated.* A special shaver socket is allowed – perhaps combined with a small enclosed lamp. The light switch must be cord-operated and situated out of reach – probably on the ceiling. *There must be no wall-mounted switches.*

Any radiant heater must be situated high enough to prevent accidental touching and, again, the switch must be operated through a cord. Any such heater must be fixed securely to the wall and wired-in permanently – that is, not through a plug and socket.

An electric shower should be provided with a *double-pole* switch and, in common with other switches, must be ceiling-mounted and cord-operated. No appliance may be situated above the bath nor near enough to be touched by a person in the bath.

Obviously, leading a temporary supply into the bathroom by, for example, passing an extension lead under the door **is extremely dangerous.** The worst scenario is that of a person receiving a shock while submerged in bath water. The earth-loop resistance here is extremely low and the current through the body will be lethal.

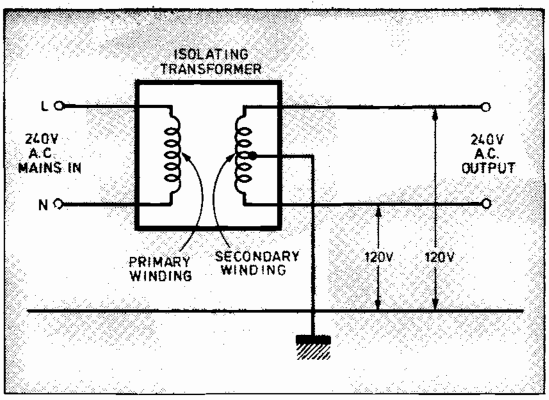


Fig. 6. Power isolated transformer wiring.

It is not unknown for mains electrical equipment to be placed on a shelf above the bath. It is difficult to see how a person doing this could be so stupid.

IN ISOLATION

We can eliminate the possibility of receiving an earth-loop shock by removing the connection between the neutral wire and ground. If a person then touched the live wire – even while making good contact with earth – there would be no circuit and therefore no shock (see Fig. 3).

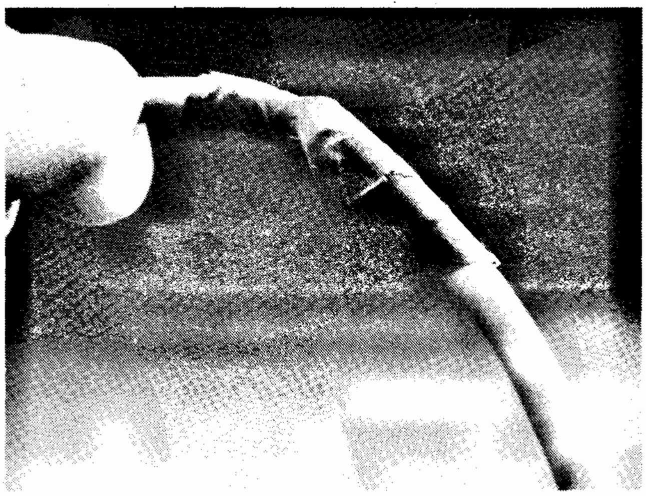
This can be achieved by using an *isolating transformer.* An example of a small isolating transformer is the one used in a shaver socket. This has the same number of turns on both primary and secondary windings so the voltages at both input and output are the same – that is, the output voltage will be 240V.

A shaver plugged into the outlet operates just as it would if connected *direct* to the mains. However, there is no longer a link between either output wire and earth (the terms *live* and *neutral* do not now apply).

Since a shaver socket provides an output at mains voltage, it is still possible to receive a lethal shock if both output terminals are touched at the same time but this is unlikely. However, check the condition of the razor plug and connecting wire regularly just in case it could happen.

More substantial isolating transformers are used to provide large-scale power. Often the secondary winding is centre-tapped to ground (see Fig. 6). Since this winding has two equal sections, only one-half mains voltage exists between either output wire and Earth i.e. 120V. Although it is now possible to receive an earth-loop shock by touching *either* output wire, the chance of a lethal shock is greatly reduced.

Last month we mentioned that portable tools on a building site are often powered from a 110V supply. This is done by using an isolation transformer having fewer than half the number of turns on the secondary winding compared with the primary. The secondary is wound in two equal sections centre-tapped to earth. This means that the maximum voltage between either output wire and ground is 55 volts and it is thought that, in the event of an earth-loop shock, the current would be too low to present much of a hazard.



***Never** repair a damaged lead in this way.*

HAVING AN EXTENSION

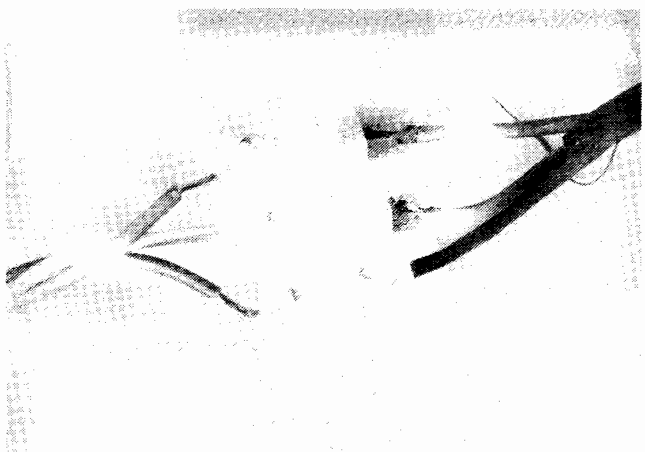
In an ideal world there would be no extension leads but they are sometimes necessary. A short discussion about their safety is therefore worthwhile.

If an extension lead is needed for a double-insulated appliance, this may be of the two-core (live and neutral) only variety and so save costs. The danger is in using it for an appliance which needs an earth connection. On the whole, it is safer to use only *three-core* extension leads.

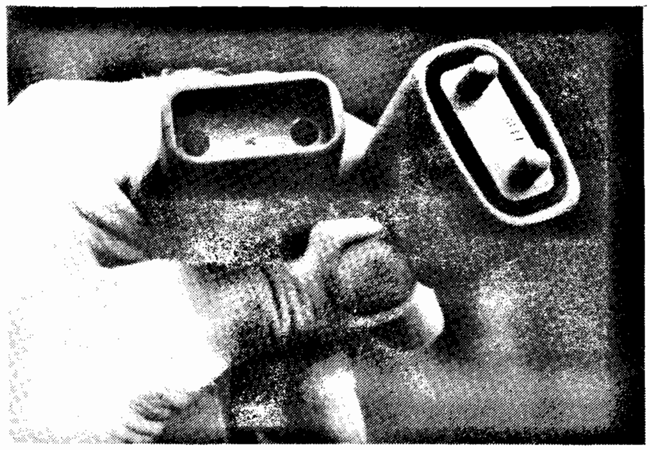
For the same reason, it is extremely foolish to mix pieces of two-core and three-core wire to make a long extension lead. If someone removed a plug cover to check that an earth wire existed, on seeing one, they would assume that it was continuous through to the other end. If the live wire in an appliance were to touch the case, the metal work would become live and deliver a shock to the next person handling it.

Ideally, extension leads *should not* be lengthened but, again, this is sometimes necessary. If it must be done, use proper flex connectors with cable grips and *never taped joints.* Do not repair sections of insulation removed by abrasion or accidental cutting by using p.v.c. tape or a screw terminal block. The whole length of wire must be replaced or, at least, the offending section removed and a proper connector used.

Sometimes the two parts of a flex connector are used the wrong way round and this is **extremely dangerous.** Each connector has a *plug* and a *socket* section (see photograph). It is essential for the *socket* to be used in the piece



***Dangerous** connections with too much insulation stripped off. Connecting blocks should only be used inside a suitable fixed housing.*



*The plug and socket of a two-core extension **must** be fitted in the correct part of the lead.*

of wire which is connected to the mains and the *plug* part to the wire leading to the appliance. If this precaution is not observed, then with the connector parted and with the lead plugged in to the mains, exposed live pins **will exist.**

Extension leads should be inspected regularly along their entire length since they are subject to more pulling and abrasion than other forms of wiring. Strain relief clamps in the mains plug and in any connectors *must* be regularly inspected for tightness. It often happens that wires are accidentally pulled free to expose live conductors. In a damp garden environment this is very dangerous.

The Earth wire in an extension lead should be checked for continuity every so often. *To do this, the lead MUST be disconnected from the mains.* A multitester set to its lowest resistance range should then be used to measure the resistance of the earth wire from one end to the other. Depending on the type of extension lead, an earth pin removed from a discarded plug may be used to make the connection at the socket end. Practically zero-resistance (a fraction of an ohm) should be indicated.

Note that in this discussion, we are not concerned with the *current rating* of the wire. This is equally important and will be looked at in detail next month.

RESIDUAL CURRENT DEVICE (RCD)

The Residual Current Device (RCD) is instrumental in preventing electric shock but – presumably because of its cost and some apathy on the part of householders – is not used as much as it should be. An RCD is often called a *Powerbreaker* or *trip switch*.

Contrary to popular belief, an RCD is not an overload cut-out so the correct fuse must still be fitted in the circuit. An RCD should always be used with extension leads and particularly with appliances being used in damp conditions or in the garden where there is a chance of the wire being cut accidentally.

An RCD is connected between supply and appliance so that the current in both live and neutral wires flows through it. Inside is a circuit which compares these currents. Normally they are the same (that is, current in equals current out) and there is no further effect. If someone touches a bare live wire, current will flow through the body to ground. The effect of this is to reduce the current returning through the neutral wire since some is now diverted to earth. This inbalance is detected and relay contacts break the circuit instantly.

Regulations state that the trip current of an RCD shall not exceed 30mA and it should operate in 40ms maximum. Although 30mA is regarded as a lethal current, the disconnection time is too short to cause harm. Before the circuit can be re-used, the fault must be corrected and the RCD reset by pressing a button.

RCD's come in various forms. The smallest type replaces a standard mains plug but there are also high-current ones which can protect a whole building. RCD's occasionally trip for no apparent reason so it is best not to use one where failure of the supply could be disastrous – with a freezer, for example. The test button provided on an RCD should be used regularly to test its action.

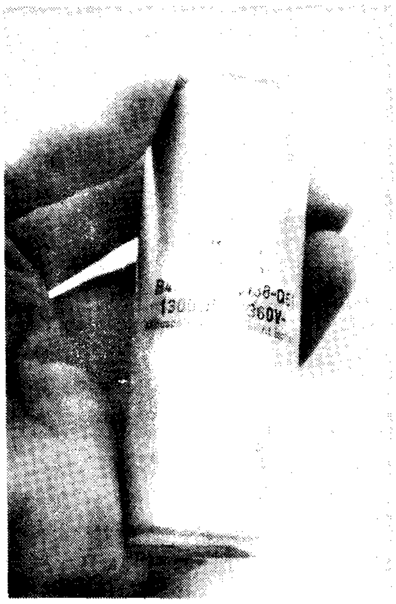
Touring caravan mains hook-up supplies must be protected with an RCD. Installing these, or adding to an existing system, must be carried out only by those with a proper knowledge of the regulations. A section of next month's work will be devoted to such caravan electrics.

FAINTING IN COILS

Suppose you are checking a relay by connecting its coil to a battery. This is a standard test and the armature will move and click confirming that it is working. If you hold the coil terminals between your fingers while you do this, as the battery is removed it is possible to receive a short, sharp shock.

This often confuses people since only a low-voltage (perhaps 9V) battery has been used as a supply. The shock is unlikely to be of any consequence – it occurs only for a very short time and is confined to the fingers but an explanation is in order.

When the battery is connected, a magnetic field is set up in the iron core on which the coil is wound. This causes the armature to be attracted and the contacts operate. When the battery is disconnected, the magnetic field collapses very quickly. This sets up a high reverse voltage (that is, in reverse compared with the battery supply) and this may be sufficient to cause a shock. To avoid it, never hold *both* coil connections when you test a relay.



A high voltage capacitor can store a dangerous charge.

Any coils of wire, especially when wound on an iron core to enhance the magnetic effect, can cause similar shocks. For this reason, it is unwise to experiment with transformers by connecting a battery while holding any terminals between the fingers. Some very nasty shocks can be delivered this way and there may be a stepping-up effect too.

CAPACITORS

Electronics enthusiasts should beware of another source of electric shock which may occur even when equipment has been switched off. This is the energy stored in a *capacitor*.

When a capacitor is connected to a d.c. supply, it will charge up until the voltage across its terminals matches that of the supply. It follows that a charged capacitor can deliver a shock similar to that which would have occurred had the victim touched the supply terminals *direct*. Real danger exists when a capacitor charges up to more than 25V or so.

In commercial equipment, a high-value resistor is usually connected between the terminals of a capacitor so that when the appliance is switched off, it gradually discharges. However, this cannot be relied on. It is best to check the voltage across the terminals of any suspect capacitor cautiously using a multitester set to an appropriate (or higher) voltage range. If it is charged to a dangerously high voltage it is best left to self-discharge – check again later.

Some people discharge capacitors by bridging the terminals with an insulated-handled screwdriver (this is not recommended as it is dangerous and it can damage the capacitor). With large-value capacitors – and especially where high voltages are involved – the effect can be very violent. This is because the amount of energy involved is quite high.

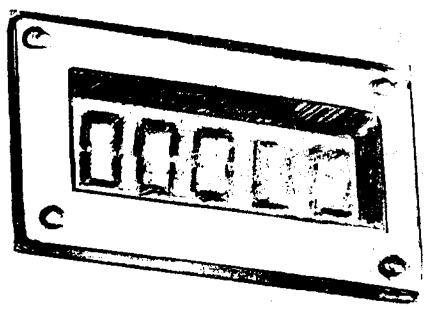
The resistance of the circuit is very low, so the current will be enormous – thousands of amps for a short while. This can cause a flash and melt off pieces of screwdriver. It has been known for pieces of molten metal to cause eye injury.

Problems usually occur with old valve-type equipment where the mains voltage is frequently stepped up to around 350V. Experimenting with such equipment can be very dangerous unless it is *unplugged* from the mains and any smoothing capacitors allowed to discharge first.

That's all for this month. Next time we shall begin by looking at electrical installations in touring caravans and continue with a discussion of the other dangers of electricity – Overheating and Fire.

Constructional Project

TIMER AND NiCAD CAPACITY CHECKER



ANDY FLIND

Check the condition of your NiCads – Don't let them fade away!

LIKE all batteries, NiCad cells do not last for ever. Occasionally they develop internal short circuits due to metal whisker growth, but more often their capacity simply fades away due to the well-known "memory" effect, or plain old age.

Camcorder batteries in particular often fail prematurely due to the use of relatively high charge and discharge rates. With the ever-increasing popularity of NiCads, a means of checking remaining storage capacity is highly desirable.

This project first saw daylight some three years ago, in answer to a need to test some single "AA" cells from a "Walkman" before a holiday. The principle was simple; the cells were fully charged, then discharged at their ten-hour rate whilst a timer recorded the period taken to reach the "discharged" state.

The circuit simply ran the cell right down, with a crystal oscillator and divider for timing. The display consisted of l.e.d.'s driven by the divider and was therefore a "binary" readout. It was crude and required a mains power supply, but it worked.

Holidays over, the possibility of checking transceiver NiCad packs for the author's employer was assessed, as these were causing problems. "Load disconnection" was required when these reached the "discharged" voltage, as with a battery some cells will always have less capacity than others and further discharge may cause permanent damage by "reverse-charging" these.

By now, the use of mains power for an instrument requiring an uninterrupted supply was causing concern. A battery-operated "micropower" circuit design would be preferable. However, whilst the l.e.d.'s could be turned off between readings, the added need for load disconnection required a relay, which would draw current incompatible with micropower design.

Gradually the project lost appeal, and was not revived until recently when it's suitability for testing camcorder batteries was realised. Meanwhile, new components had become available. A quick check of one catalogue revealed latching relays, which can be energised or de-energised with a single brief pulse instead of a continuous current.

Another catalogue offered a cheap five digit l.c.d. counter, ideal for the display. As this also provided a 512Hz output, a simple divider could turn it into a "seconds" elapsed time indicator able to record over 24 hours, with electronic stop-start.

It seemed wasteful to build such a sophisticated instrument just for checking the odd suspect battery, so it was decided to adapt it for more general timing tasks. Stop-start terminals are provided on the front panel, with a regulated supply which can be used for low-power interface circuitry.

No doubt readers will find many applications for the timer, the most obvious being to check the daily operating time of mains appliances. Notes for doing this will be given later.

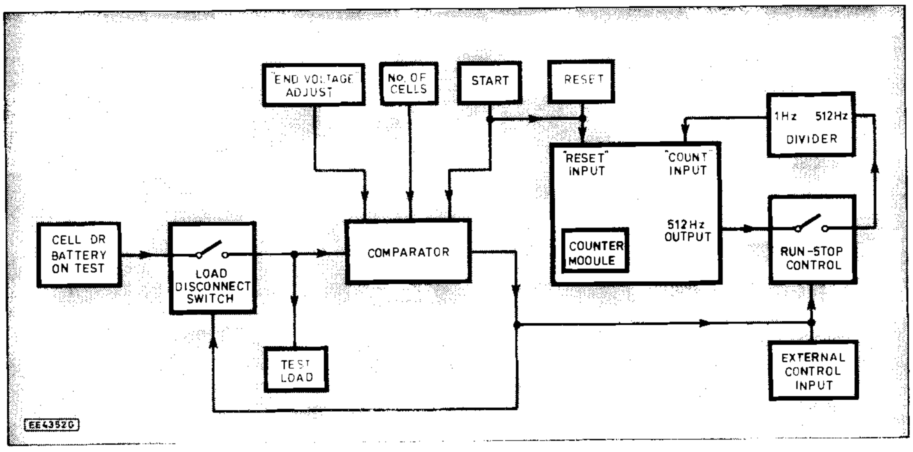


Fig. 1. Block diagram of the Timer and NiCad Capacity Checker.

HOW IT WORKS

A block diagram of the unit is shown in Fig.1. It can be seen that the counter's 512Hz output passes through a run/stop control circuit and a divider, then back to the "count" input to register seconds. The control circuit operates either from an external input or from the battery testing circuit, as does the display "Reset".

The comparator monitors the voltage of the cell or battery under test, disconnecting it and stopping the timer when the final value is reached. A switch allows adjustment for up to twelve cells.

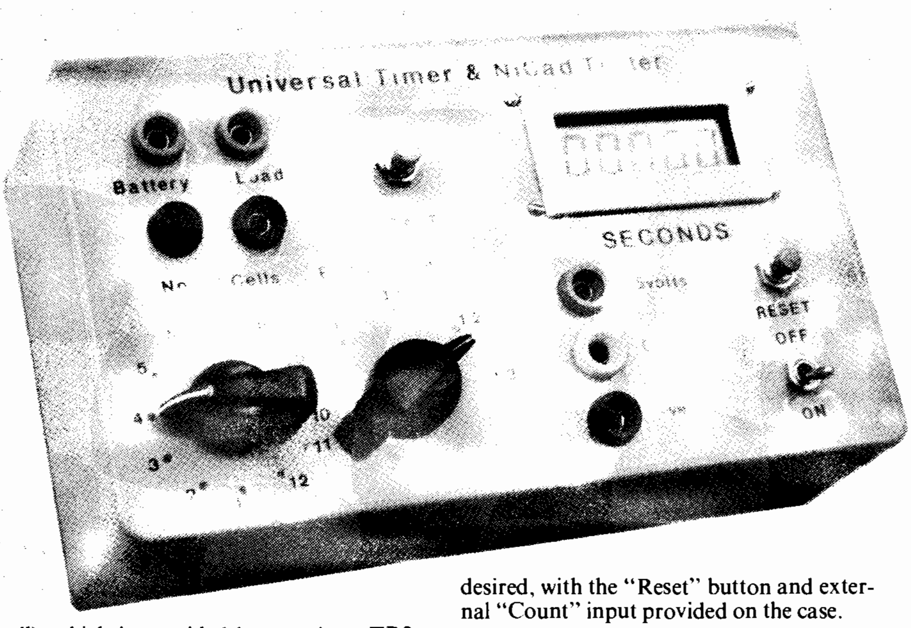
CIRCUIT DESCRIPTION

The circuit has been split into two sections, Timer and Battery Tester. Constructors wanting only the timer can build this on it's own, leaving out the parts needed for battery testing.

Starting with the timer circuit diagram, Fig.2, this operates as follows. The supply, nominally 9V from a PP3, is switched by S1 and regulated to 5V by IC1, with decoupling capacitors C1, C2, C3 and C4. IC1 is an LP2950CZ, which offers significant advantages over standard "78" type regulators, especially for battery operation.

The micropower regulator uses less current, and will operate with a much lower input-output voltage differential. It's output is more accurate, useful where, as here, it is used as a reference. Also, this project will operate from just above 5V and consumes about a quarter of a milliamp, it can be run with "flat" batteries from other appliances!

The counter module X1 requires a 1·5V supply (it is intended to work with a single



cell), which is provided by transistor TR2 and resistors R1, R2 and R3. It's output drives an input of IC2, to ensure this will work with the available 1·5V swing IC2 and IC3 are supplied with 3V from TR1.

Although the counter's 512Hz output is a squarewave, it swings not from zero to +1·5V as might be expected, but between zero and −1·5V! The counter apparently includes a negative rail generator as well as a clock.

This output is coupled by capacitor C7 into IC2d, one section of a CMOS 4016B quad switch. For the signal to pass through IC2d, IC2c must be "on", and for this either point "B" or the "Count" input must be positive, so providing the "run-stop" function.

The 3V peak-to-peak squarewave from IC2d drives the "clock" input of divider IC3, the divide-by-512 output of this goes to switch IC2b, which controls the "count" input of the counter X1, causing it to advance at the rate of 1Hz. IC2a operates the counter "reset" input, which resets the display to zero.

In this circuit IC2a is normally off, but a positive pulse from point "A" or a press of Reset switch S2 will operate it. This section of the circuit can be used on it's own if desired, with the "Reset" button and external "Count" input provided on the case.

BATTERY TESTER

The battery tester circuit, Fig.3, uses op.amp IC4 as a comparator. This is a 7611, a "micropower" device, with pin 8 connected to the positive supply it draws only a few microamps. It has a CMOS output stage which can swing virtually from rail to rail.

Resistors R22, R23 and R24 with potentiometer VR1 set the comparator switching point to the final or "end" voltage of a discharging NiCad cell. This is generally taken to be about 1·1V, but VR1 allows some adjustment. Positive feedback from R27 ensures rapid comparator switching, whilst pressing Start switch S4 forces it to reset.

Although this stage covers the voltage for a single cell, batteries of up to twelve cells are catered for by rotary switch S3 with resistors R11 to R21. Relay RLA is a latching type, with separate coils for "on" and "off".

When the output of IC4 goes high, IC5a output goes low. IC5c output thus remains low, but IC5b output goes high, causing a positive pulse of about 100mS at IC5d input. IC5d output pulses negative, operating the "on" coil of the relay through transistor TR4 to connect the battery on test to the comparator and load. At the same time, a pulse to point "A" from capacitor C10 and resistor R32 resets the timer, whilst a positive voltage from diode D1 and resistor R33 to point "B" sets it running.

When the battery voltage reaches the lower limit, the comparator output goes low and IC5a output goes high. This causes a negative pulse at IC5c output, which through transistor TR3 operates the "off" coil of the relay, disconnecting the battery. The positive supply is removed from point "B" and counting stops.

As this unit can test a wide variety of batteries with various capacities and voltages, it was decided not to include the "load" in the circuit. Instead, terminals are provided on the front panel to which users may connect the load of their choice. Since NiCads have a very flat discharge voltage characteristics, this will normally be just a resistor of suitable *value* and *wattage* rating.

CONSTRUCTION

The NiCad checker is built on a single-sided printed circuit board (p.c.b.) which is housed in a plastic case measuring 190mm x 110mm x 60mm. The p.c.b. topside component layout and underside full size copper master pattern is shown in **Fig. 4**. This board is available from the *EPE PCB Service*, code 857.

Construction is relatively uncomplicated, although the i.c.'s and the counter module are CMOS devices so the usual precautions against static damage should be observed. Sockets are advised for the relay and all i.c.'s except IC1, as this simplifies testing.

Circuit board assembly should start with the fitting of all components save IC2 to IC5 (only sockets mounted) and (the relay). The diode polarities and transistor types should be checked before insertion, as it's easy to make a mistake with these. It will be seen that transistor TR1 faces the opposite way to all the others.

If a 9V supply is connected to the completed board, the regulated five volts should appear across capacitor C4, with about 3V across capacitor C5 and 1·5V across C6. (These last two may be 0·1V to 0·2V higher). The current consumption should be very low, always less than

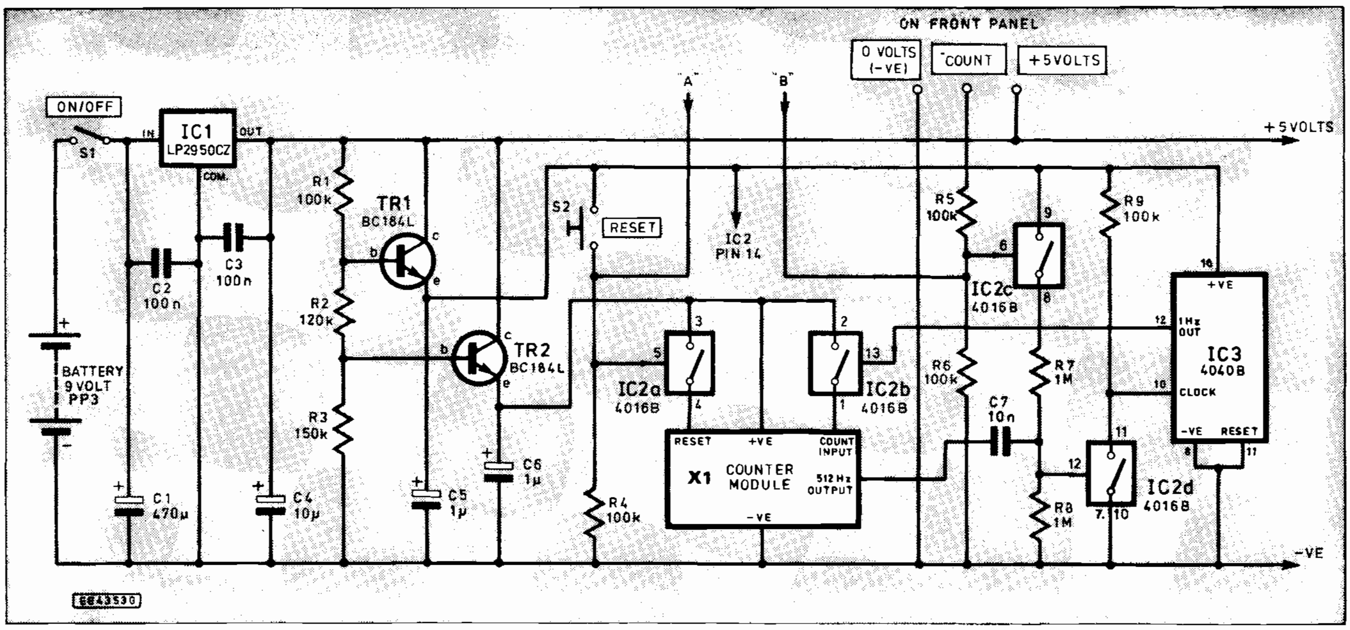
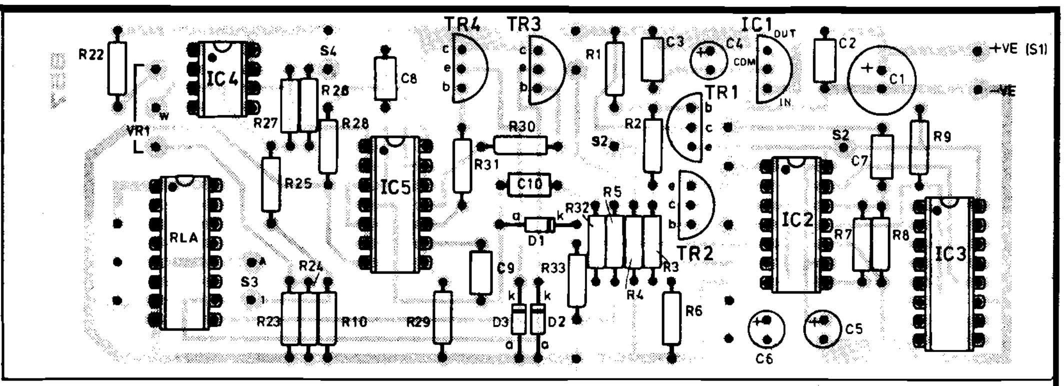
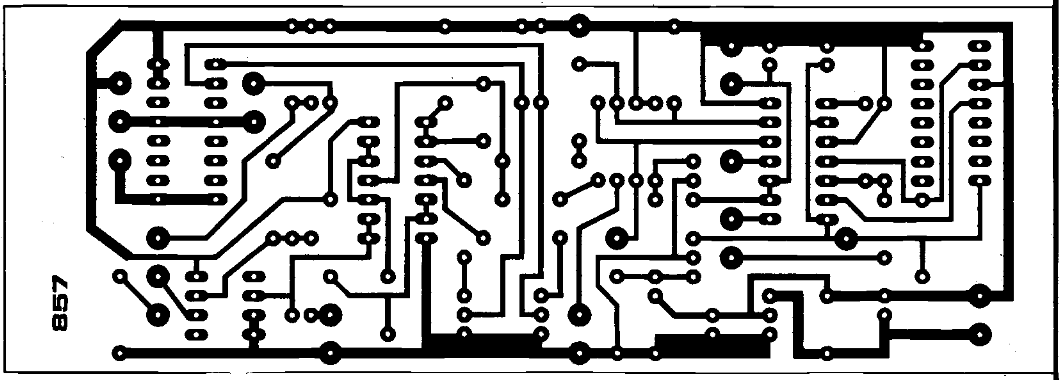


Fig. 2. Circuit diagram for the Timer section using a ready-made Counter Module.

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





COMPONENTS

Resistors

R1, R4, R5, R6, R9	100k (5 off)
R2	120k
R3	150k
R7, R8, R28, R29	1M (4 off)
R10 to R21	1k (12 off)
R22, R32, R33	68k (3 off)
R23	27k
R24	270k
R25, R26	33k (2 off)
R27	330k
R30, R31	4k7

All 0·25W 5% carbon film

Potentiometer

VR1	10k rotary carbon, linear

Capacitors

C1	470µ radial elect. 16V
C2, C3, C8, C9, C10	100n polyester layer (5 off)
C4	10µ radial elect. 50V
C5, C6	1µ radial elect.100V (2 off)
C7	10n polyester layer

Semiconductors

D1, D2, D3	1N4148 signal diode (3 off)
TR1, TR2	BC184L *npn* transistor (2 off)
TR3, TR4	BC214L *pnp* transistor (2 off)
IC1	LP2950CZ 5V micropower regulator
IC2	4016B CMOS quad switch
IC3	4040B CMOS 12-stage binary divider
IC4	ICL7611 micropower op.amp
IC5	4011B CMOS quad NAND gate
X1	Counter Module, with 512Hz clock output

Miscellaneous

S1	S.P.S.T toggle switch
S2, S4	Min. press-to-make release-to-break switch (2 off)
S3	1-pole 12-way rotary switch
RLA	5V 167 ohm, twin-coil p.c.b. mounting d.i.l. latching relay, with 1A d.p.c.o. contacts
B1	9V PP3 battery with connector leads

Plastic ABS case, size 190mm x 110mm x 60mm; 8-pin d.i.l. socket; 14-pin d.i.l. socket; (2 off); 16-pin d.i.l. socket (2 off); 4mm sockets, red (4 off); 4mm sockets, black (3 off); small pointer type knobs (2 off); multistrand connecting wire; mounting bezel for counter module; solder etc.

Printed circuit board available from *EPE PCB Service*, code 857.

Approx cost guidance only £36

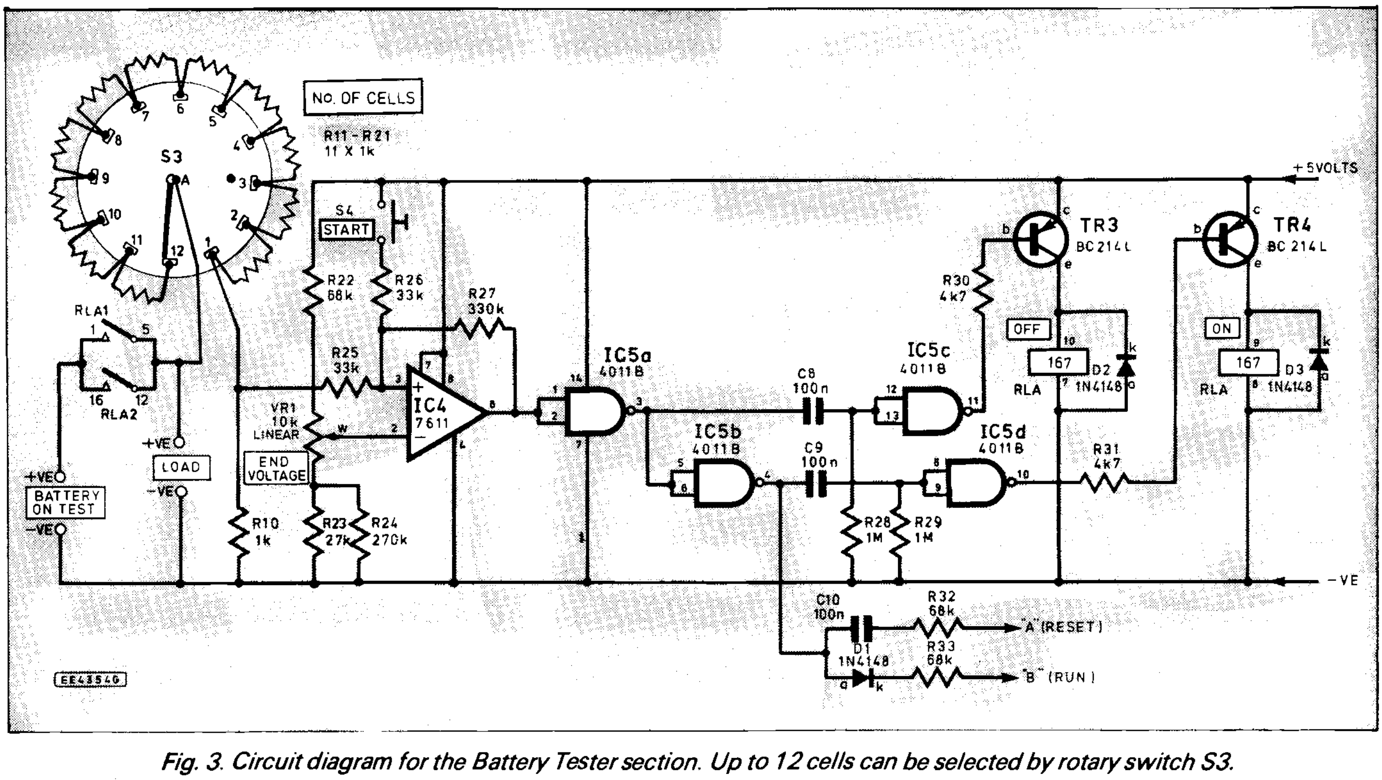
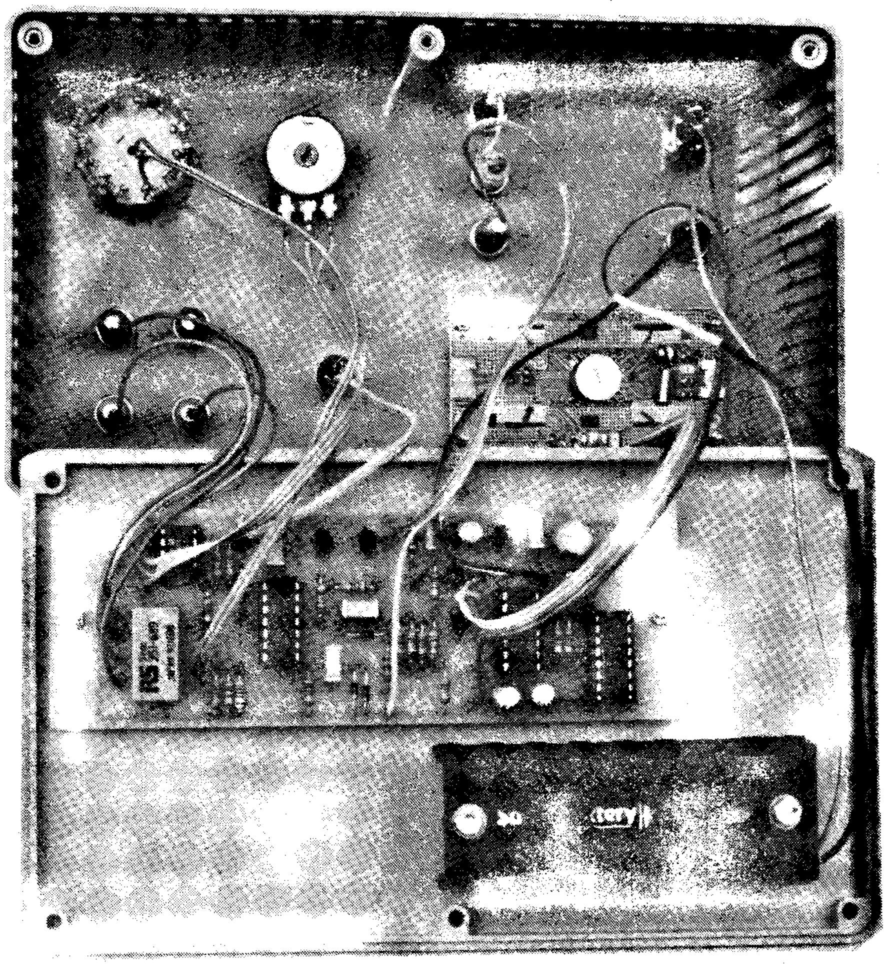


Fig. 3. Circuit diagram for the Battery Tester section. Up to 12 cells can be selected by rotary switch S3.

a milliamp except for a surge as the capacitors charge at switch-on, or when the relay operates.



Layout of components inside the case and on the lid.

FINAL ASSEMBLY

Further testing requires connection to the controls, which may be fitted to the case first for convenience. The layout is not critical in any way, that used with the prototype can be seen from the photos.

Resistors R11 to R21, all one kilohm, are soldered directly to switch S3 as shown in Fig.5; it is easier to do this before before fitting S3 into the case. It's advisable to test the completed switch and resistor assembly before installation.

The counter is supplied with a holder for a single AA cell, attached by four self-tappers. A suitable bezel was purchased with it for the prototype. The four screws and battery holder were removed, giving access to the external connections on the rear of the counter. The battery holder should be retained as it is useful for testing AA cells.

The diagram supplied with the counter module shows it from the front, so Fig. 5 shows connections to the rear for this project, together with all other connections to the p.c.b. A length of ribbon cable was carefully soldered to the counter before assembly into the bezel, and then the whole secured to the case with four 8BA screws.

FINAL TESTING

Once the board is connected to the controls, counter testing can proceed. When powered up, the counter display should appear, although it will not yet count. It will be found that when power is removed it will take some time for the display to disappear, due to power stored in the electrolytic capacitors.

If the battery tester has been built, IC2, IC5 and the relay should be fitted next, taking care to fit the relay the correct way round. With these in place, whenever "Start" (S4) is pressed there should be an audible click from the relay, although it will open again when the switch is released.

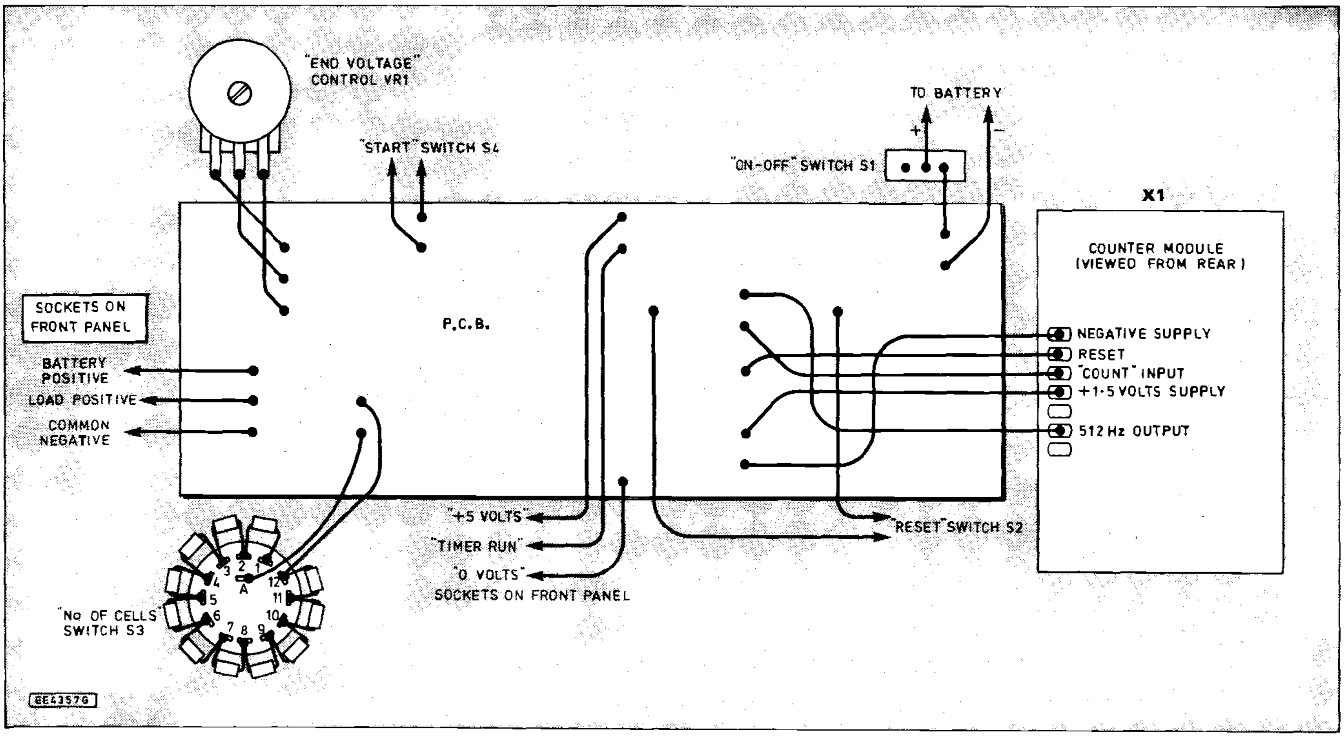
A simple check of the input circuit may now be carried out. The End Voltage control VR1 should be set to minimum (anticlockwise), Rotary switch S3 to position 4 (four cells) and the "+5 volts" socket on the front panel connected to the "Battery on Test" positive socket.

If S4 Start is now pressed, the relay should close and stay closed. If VR1 is now rotated slowly clockwise, at around 3/4 travel (equivalent to 1·25V) the relay should open. If this seems OK IC2 and IC3 can be fitted.

Connecting +5 volts to the "count" input should cause the counter to run. The previous test using the battery input with "+5V"can be repeated, when Start is pressed the counter should reset and start counting, and it should stop if the input voltage is removed, or VR1 rotated as before.

With testing complete, the p.c.b. is secured in the case with a couple of small screws, and the battery positioned beside it. The prototype used a small piece of cable-trunking as a battery holder.

Fig. 5. Interwiring from p.c.b. to all off-board components.



CALIBRATION

Finally, to finish the project the End Voltage control VR1 can be calibrated. The easiest way to do this is with a variable voltage power supply and a resistor arranged as shown in Fig.6a. If such a supply is not available the job can be done with a one kilohm linear potentiometer and a couple of resistors, using the +5V supply as shown in Fig.6b.

Either way, the procedure is as follows: With the Number of Cells switch S3 set to "1", VR1 at it's lowest setting (fully anti-clockwise), and the input voltage set to maximum, the Start button should be pressed and released. This will cause the relay to close.

The input should now be adjusted for an indication of 1·1V on the meter, and VR1 advanced slowly until the relay is heard to open. This should occur around the mid-point of VR1 and the point should be marked.

This process is repeated to find the other main points for VR1: 0·9V, 1·0V, 1·2V and 1·3V. The reason for this apparently complicated procedure is that, with a voltage source having series resistance, the voltage at the input will change when the comparator operates, and will even vary a little when the Start switch is pressed. It must therefore be set with the relay closed and S4 released.

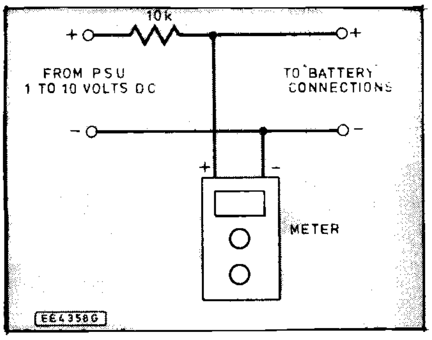
IN USE

This completes construction of the unit. For checking NiCad capacity, first give the cell or battery a full charge. Then connect it to the "Battery" terminals, with a suitable load resistance across the "load" terminals.

Set the "Number of Cells" to the appropriate value, and the End Voltage to the voltage-per-cell at which they are considered to be fully discharged, 1·1V being a suitable value. Then just press Start, and leave the unit to time the battery's discharge period. That's it, the process could hardly be simpler.

Cell capacities are usually quoted for a 10-hour rate, or their capacity when discharged over a period of ten hours. For an AA cell rated at 500mA-hour, a load is needed that will draw 50mA. Given that the nominal voltage of a cell during discharge is about 1·2V, a resistor of 1·2/0·05 ohms, or 24 ohms, would be the load to use. In practice a 27ohm component is fine.

Likewise, six 2amp-hour "C" cells would need a load of 7·2/0·2ohms, or 36ohms. A 33ohm load would do here, although 39 in parallel with 470 would be more accurate. With this example however, wattage must be considered. The dissipation will be 7·2 × 0·2W, or about a watt and a half, sufficient to produce some heat and also above the rating of small resistors. Larger ones can be used, or series and parallel combinations to spread the dissipation.



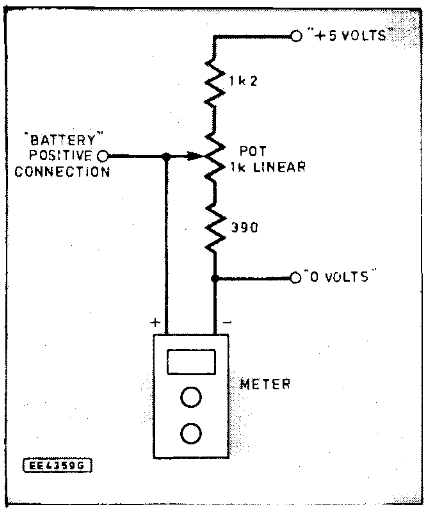


Fig. 6. Calibrating VR1. (a) Using a 1 to 10V variable power supply (above) and (b) using internal 5V supply (right).

However, if a camcorder battery is to be tested at it's working current, the dissipation may well be five to ten watts or more, so resistor ratings and heat dissipation will assume greater importance.

TIMER

Finally, the unit can be used as a timer. The obvious application is checking how much of the day an appliance, such as a fridge or a thermostatically controlled heater, actually runs.

This means interfacing the unit to the mains. There are various methods of doing this. Best of all is an isolated contact, if this is available. It probably won't be, in which case other means will have to be found. The simplest is a small transformer, supplying an external voltage to "count" as shown in Fig. 7a.

Application of an input voltage a little above the internal supply rail of the instrument will not cause any harm, as resistor R5 and the internal protection diodes of IC2 will handle it. The 100µF capacitor ensures a steady d.c. potential, whilst the 4k7 resistor discharges it within a second or two when the mains turns "off".

Another method, using a capacitive mains dropper and an opto-isolator, is shown in Fig. 7b. This is simpler and cheaper but potentially more hazardous, and *should only be used by experienced constructors*. In particular the 470nF capacitor ***MUST*** be rated for *continuous* application of mains supply voltage.

The simplest interface is photoelectric. Provided "dark" is dim enough, a phototransistor can be placed directly across the "+5V" and "count" connections, and will cause the timer to operate only when exposed to light. The one tried with the prototype had a flat to identify it's "collector", this went to the +5V side. This is all you need to find out how long the kids leave the lights on!

A CDS photocell also worked, but proved more sensitive. The simple circuit of Fig. 7c improves the performance for both CDS cell and phototransistor, and allows a reasonable degree of sensitivity adjustment.

Finally, note that as both negative and +5 volts are brought out to the front panel, it is possible to connect these together with potentially disastrous results for regulator IC1. If you think you're likely to do this, it might be wise to insert a 100 ohm or greater resistor between the board and this terminal to limit the maximum current that can be supplied from it. □

Fig. 7. Assorted interface circuits for the Timer.

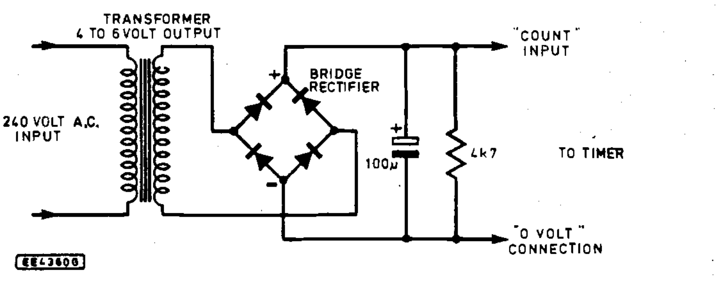


Fig. 7a. Mains interface using a transformer.

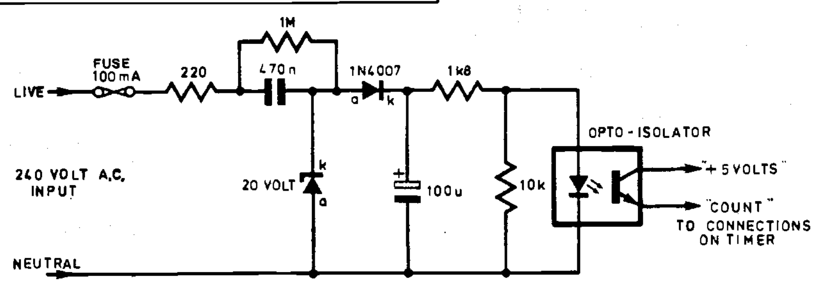


Fig. 7b. Transformerless mains interface. Note the 470n capacitor MUST be capable of operating at "continuous" mains voltage.

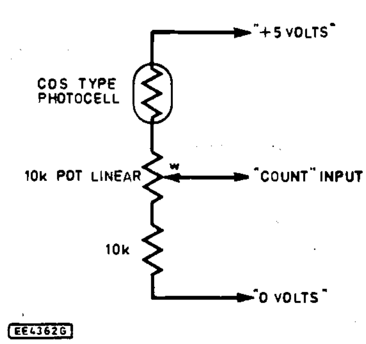


Fig. 7c. Photo-electric input.

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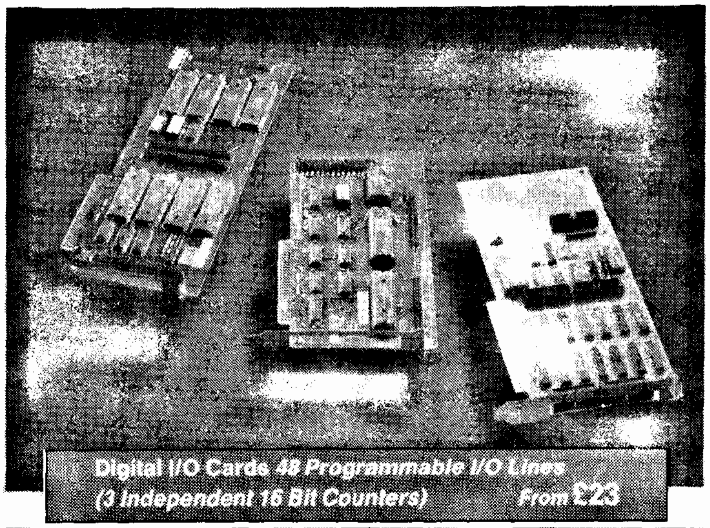

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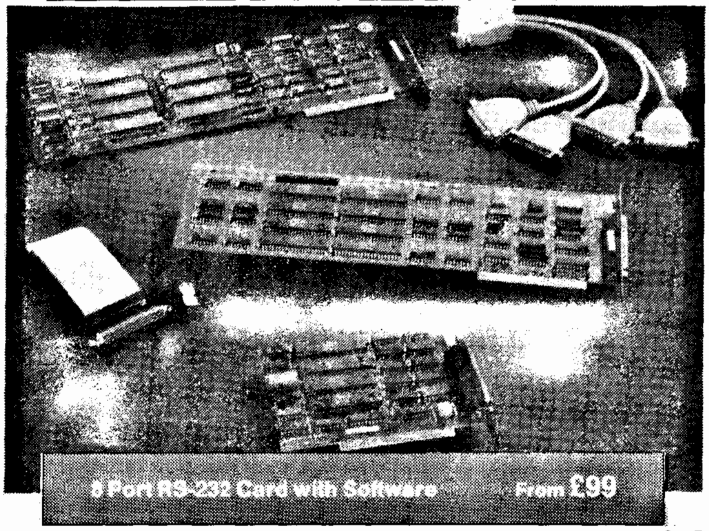

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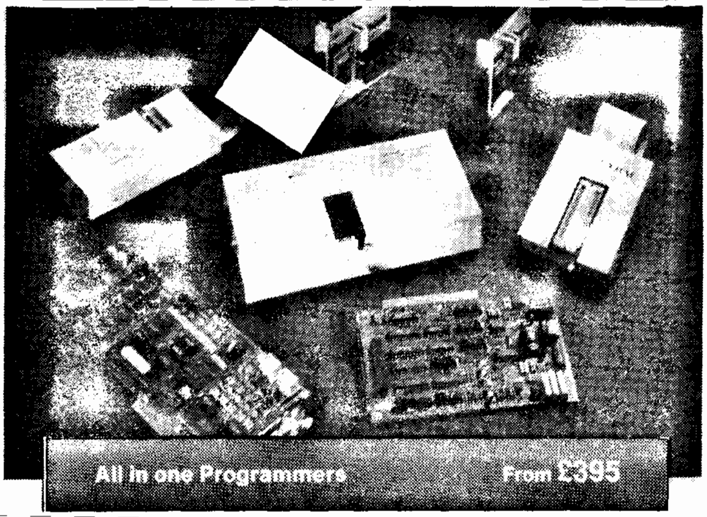

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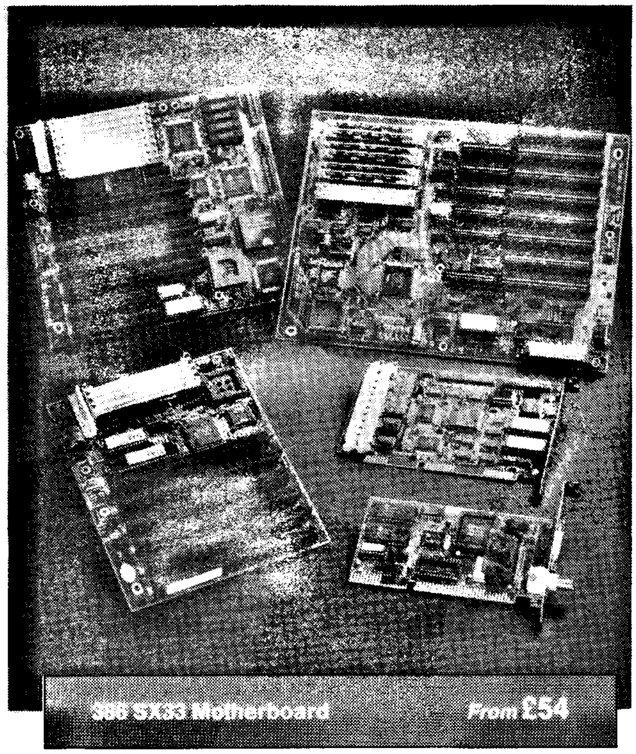

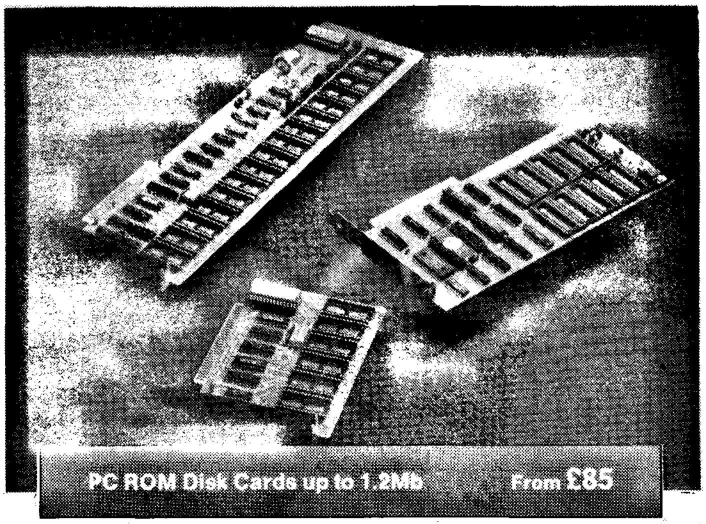

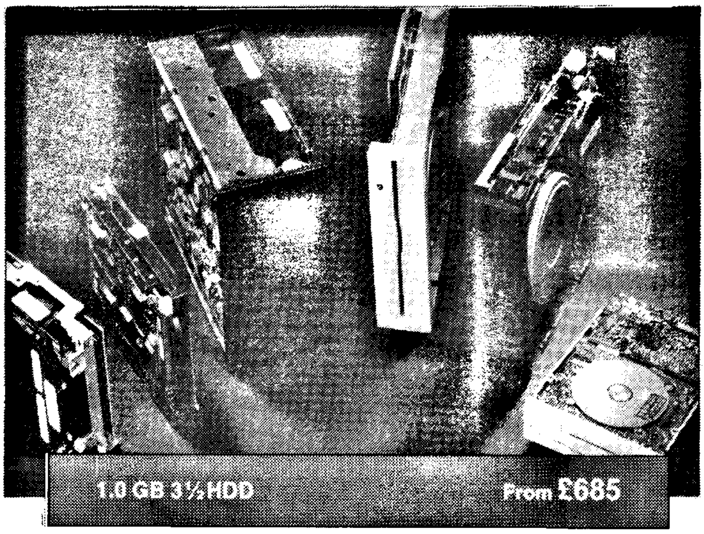

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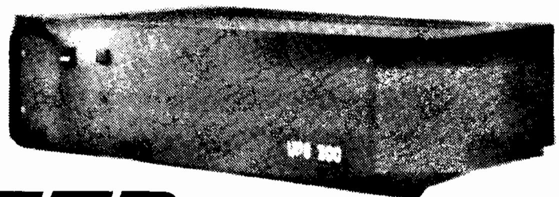


AND UNINTERRUPTABLE POWER SUPPLY

MARK DANIELS **Part Two**

A 250W to 600W design with pulse width modulation for voltage control and an uninterruptable supply add-on. It can also be built for 50Hz or 60Hz operation.

CONSTRUCTION of the Inverter p.c.b. was completed last month. Before continuing check that all components are fitted correctly to the p.c.b. and, if you have not already done so, solder the components to the top foil where appropriate. When the Inverter has been tested the p.c.b. should be given a coat of protective lacquer to prevent corrosion of the copper tracks.

CASE PREPARATION

This section describes all the case preparation details for the complete U.P.S. since all the metalworking will have to be completed before any components are fitted to the case. If only the Inverter section is being built then some of the holes will be redundant and may be omitted. Also, two extra holes are required for the battery leads and should be included.

A 3U high 19 inch rack mounting case is specified for the Inverter with U.P.S. since it will give sufficient room for internal mounting of the stand-by batteries and charger circuit. A smaller case may be used as an alternative for the stand alone Inverter, and many suitable metal ones are readily and cheaply available.

All necessary back panel cutouts for the complete U.P.S. are shown on the dimensioned drawing of Fig. 11. Before putting drill to metal ensure that all parts can be obtained and the mounting apertures required are identical to those on the diagram. If not, alternative cutouts will have to be made to suit. For the U.P.S., a 90mm slimline 240 volt fan, an I.E.C. mains inlet connector and a d.p.d.t. mains rocker switch rated at 5 amps (which are not included in the components list for the inverter) are also to be mounted on this panel, so it may be advisable to obtain them before starting the metal working.

The ten 4mm holes may easily be drilled and will cause few problems. The rest of the holes require a little more care and a somewhat different approach.

To drill six 13mm holes close together in thin sheet steel is asking for problems: the metal will almost certainly buckle, unless securely clamped with the drill mounted in a drill press. It may be wiser to drill small pilot holes and use a "Q-Max" chassis cutter or similar. A 14mm cutter, the smallest size generally available, should prove suitable. Alternatively drill the holes under size and finish with a file.

The 90mm hole for the fan may also be cut using a suitable punch, but being close to the edges of the metal it will generally cause considerable distortion. A better method, in this case, would be to use an electric jigsaw (preferably variable speed).

Mask the panel with tape before starting to protect the vinyl finish, mark out the cut to be made and drill a 10mm hole near the cut line. Clamp the metal securely and, with a fine steel cutting blade fitted to the saw, make the cut very slowly. Do NOT use cutting oil as it may damage the vinyl finish. **CAUTION:** Always wear eye protection when using a power saw to cut steel.

Punches are available for the remaining cutouts, but tend to be extremely expensive, particularly for the cruciform sockets. Circular 13 amp sockets of 50mm diameter are also suitable and the punches are cheaper so may prove a viable substitute.

An alternative method of making the necessary cut-outs is to mark out the holes and chain drill inside the lines before knocking out the waste. File to the finished size, using the components as a guide. There are only two components to be fitted to the front panel, but considerable care must be taken to avoid marking the brushed finish when drilling and filing, other than this the same techniques as applied to the back panel may be employed. A suitable front panel layout is given in Fig. 12.

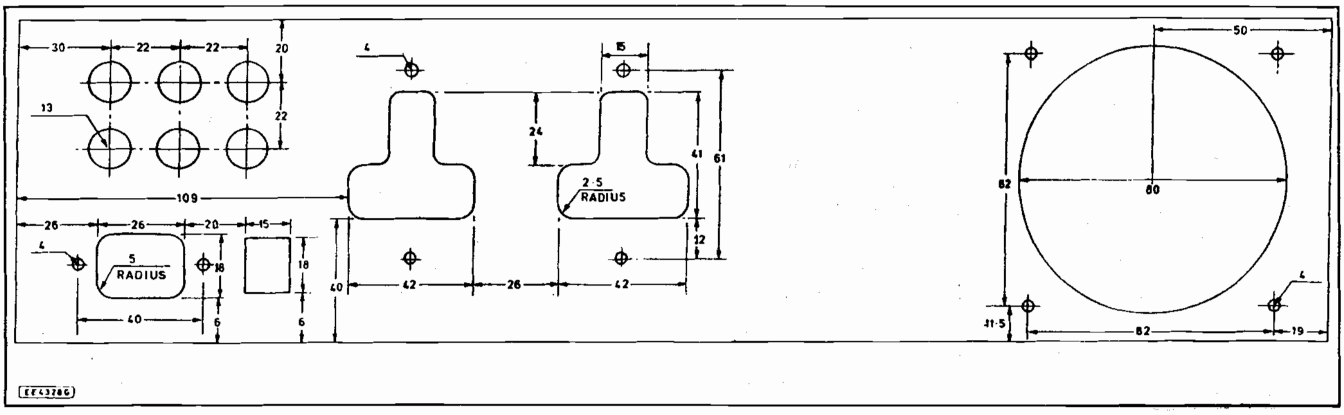


Fig. 11. Back panel cut-out for the U.P.S./Inverter.

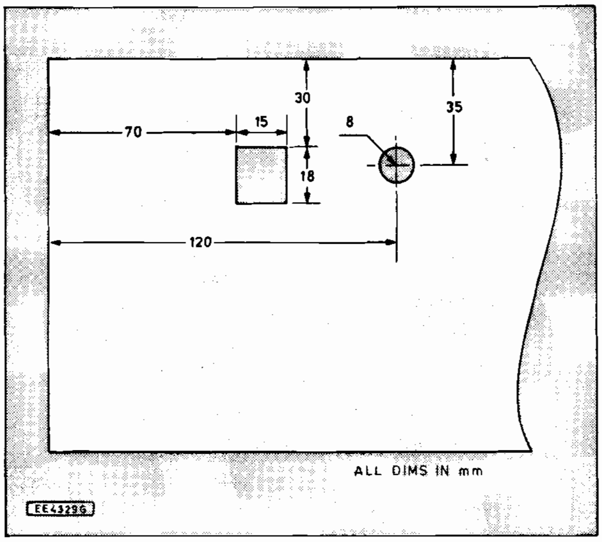
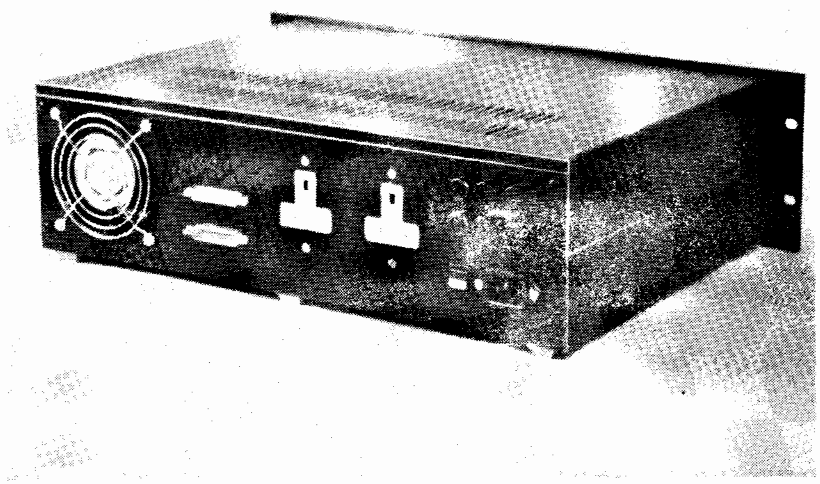


Fig. 12. Front panel cutout details.



Layout of the back panel for the U.P.S.

Clean any burrs off with a fine file before lettering the panels then apply two coats of semi-matt lacquer to protect the letters.

Assemble the components to both panels before finally putting the case together in accordance with the manufacturers instructions.

HEATSINK ASSEMBLY

Fit a silicone rubber insulating gasket to each BUV20 power transistor (TR7, TR8) before fitting uninsulated crimp type butt connectors (blue insulated crimps may be used if the insulation is removed first) to their emitter pins (see Fig. 13 for pin-out). Crimp the connectors before soldering to ensure a good joint and insulate with heat resistant sleeving where they pass through the heatsink.

Fit a silicone rubber gasket to each 2N3055 (TR5, TR6) and fasten a BUV20 and a 2N3055 to each heatsink with long "top hat" insulating bushes in the heatsink for the mounting bolts to pass through. No heatsink compound is necessary if silicone rubber gaskets are used. Use M3 x 16mm screws inserted from the top side of the transistors with a plain and a spring washer under each nut.

A short length of 20 s.w.g. tinned copper wire fitted with M3 eyelets at each end should be used to make the connection between the collectors of each pair of transistors. Fit the eyelet between two plain washers and fit a spring washer under the nut. The spring washers must NOT be omitted as the nuts will eventually work loose leading to a non-existent electrical connection and ultimate failure of the expensive output transistors.

CHOKE CONSTRUCTION

The output filter choke L3 is wound on a large ferrite core with thick enamelled copper wire. A single 110 turn winding is wound in four close spaced layers on the bobbin and is terminated at any convenient pair of tags on the bobbin.

The winding direction and precise number of turns is unimportant, four complete winding layers of 1·2mm (or thicker) enamelled wire will be adequate. The inductance of the completed choke should be approximately 5·6mH and its d.c. resistance less than 0Ω1.

P.T.F.E. pipe thread tape may be used for covering the winding, applied tightly this will reduce vibration and aid noise reduction although the prototype was left uncovered and produced little noise.

Before assembling the core to the wound bobbin clean the mating faces to ensure a zero gap when finally clamped. This will reduce the possibility of cracking the fragile ferrite core material and reduce buzzing when in operation.

MAIN ASSEMBLY

The case layout for the Inverter components is shown in Fig. 14 and should be adhered to if the U.P.S. add-on is to fit in the remaining space.

The printed circuit board is mounted vertically by means of an aluminium angle bracket, 165mm by 115mm with a 30mm lip along one long side. Four 10mm long insulated pillars are used between the bracket and the p.c.b. with a sheet of insulating material, such as acetate (available from photocopier suppliers or stationers), secured between the p.c.b. and the pillars to prevent possible short circuits between the board and the metal.

The pre-assembled heatsinks can be fitted, with the connections facing outwards as shown, using the pre-punched holes in the bottom of the case and self-tapping screws in the keyhole slots provided in each extrusion.

An optional 80mm fan may be fitted on top of the heatsinks using self-tapping screws in the same keyhole slots as above. If heatsinks other than those recommended are used an adaptor plate similar to that shown in Fig. 15 will have to be fabricated.

The large electrolytic supply decoupling capacitor C1, if fitted, is fastened to the case with a capacitor mounting clip as shown. C1 is only essential if long input cables are fitted but may be retained with some benefit in other cases. Values between 10,000µF and 47,000µF are recommended, with the larger sizes giving maximum benefit, albeit at a price.

Fit the toroidal transformer T1 between the two supplied neoprene gaskets, with the dished steel washer on the top, and clamp it down with the bolt. One of the pre-punched holes in the bottom of the case may be used for the mounting bolt after opening it up to 6mm.

IMPORTANT: Do NOT overtighten the nut as this can damage the insulation on the windings, causing an internal short circuit and ultimate failure of the transformer. Also ensure that the top end of the mounting bolt cannot come into contact with anything electrically connected to the chassis (including the case lid) as this would constitute a shorted turn and cause the transformer to overheat. Do not attempt to make an earth connection via this mounting bolt either as this will have the same effect.

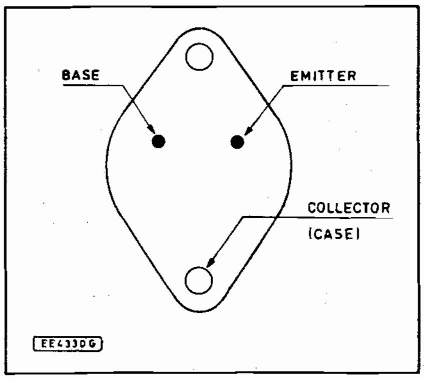
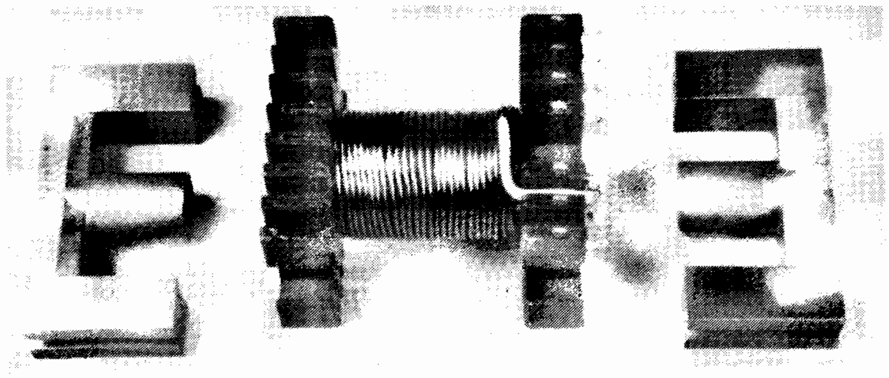


Fig. 13. Power transistor connections.



Exploded view of inductor L3

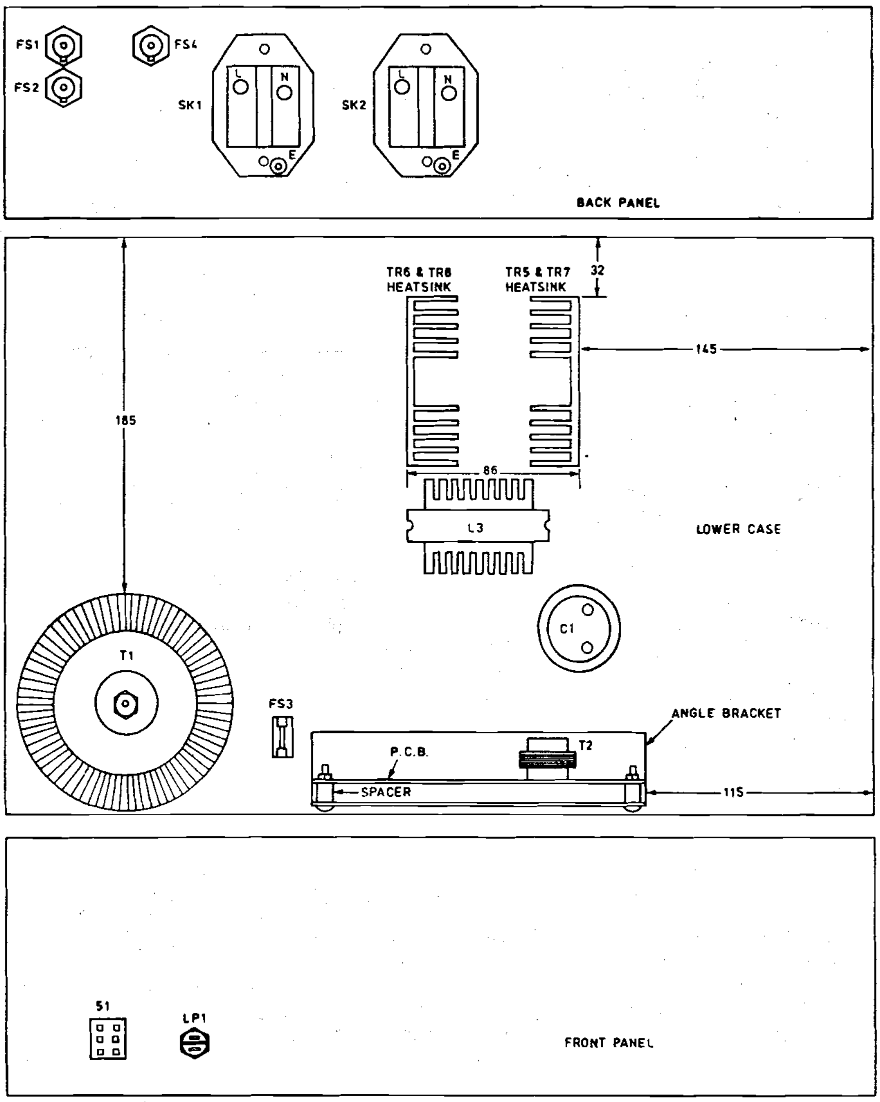


Fig. 14. Case layout for the main components.

LOW POWER WIRING

The main wiring diagram of Fig.16 shows all the low current connections to be made between the p.c.b. and off-board components using 7/0.2mm stranded wire. Sensible use of colour coding is recommended as this will ease the task considerably and make fault finding at a later stage much more straightforward.

If p.c.b. plug and socket connectors are used the terminals will need to be crimped or soldered onto the ends of each lead before fitting them into their respective positions in the shell. Ensure that all wires are of adequate length to reach their destinations when correctly routed, they can always be shortened at a later stage.

All six leads from PL2 go directly to the power transistors TR5 to TR8. Extreme care must be exercised when making the connections to these devices since an error here will almost certainly result in one or both of the BUV20's self-destructing at switch on. Sleeve the connections to the transistor pins, preferably with heat shrink sleeving, as a precaution against possible short circuits.

Three of the leads from PL1 go to the main switch S1. Care should be taken to ensure that the correct lead is connected to the common terminal of the switch. Only one pole of this d.p.d.t. switch is presently used, the other being reserved for the U.P.S. circuit to be described next month.

Two of the remaining connections on PL1 are for the 12 volt d.c. supply, which is fused at 250mA in the positive line by FS3. The other connects directly to the negative supply rail and provides the common return for the logic and p.w.m. circuits. The final connection to this plug provides a 7·5 volt supply to the U.P.S. add-on board to be described next month and should be ignored at present.

HIGH POWER WIRING

The remaining wiring is high voltage and/or high current and must be carried out in accordance with the I.E.E. wiring regulations for the completed inverter to be electrically safe.

All cables on the high voltage side must be rated for continuous operation at mains voltage and must be suitable for the anticipated maximum current (approximately 1·7 amps).

The high current cables in certain sections of the low voltage side may be called upon to carry currents of up to 40 amperes. A minimum cross-section of 6mm² is necessary for all internal wiring operating at this current. The battery leads may need to be considerably thicker and should be chosen according to their length and the recommendations in Table 2.

Flexible cable above 6mm² cross-section may prove difficult to obtain from your regular electronic component supplier, although Maplin list some up to 10mm² for use with their high power car audio equipment.

Welding cable, which is ideal, is much more readily available, along with suitable solder lugs, from large motor factors or welding equipment suppliers. This is normally extremely flexible and easy to work with, soldering being accomplished with a gas torch! Large crocodile clips of the type fitted to car booster cables should also be stocked by the same sources and will be ideal for the final battery connection.

All the heavy current wiring is shown in Fig. 17, with appropriate cable sizes indicated. Heavier gauge wire may be substituted, but the indicated sizes should be regarded as an *absolute minimum*. Keep all low voltage, high current connections as short as possible to minimise cable volt drops.

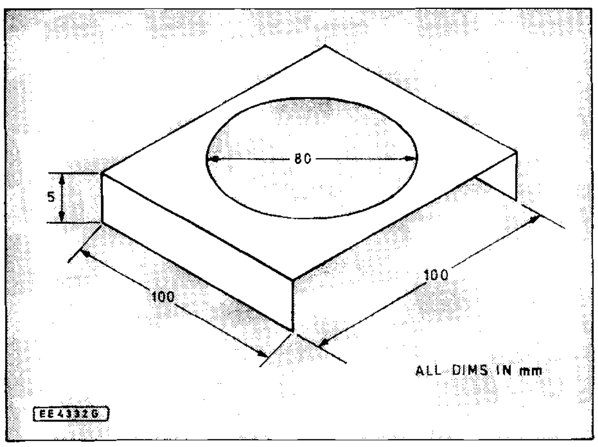
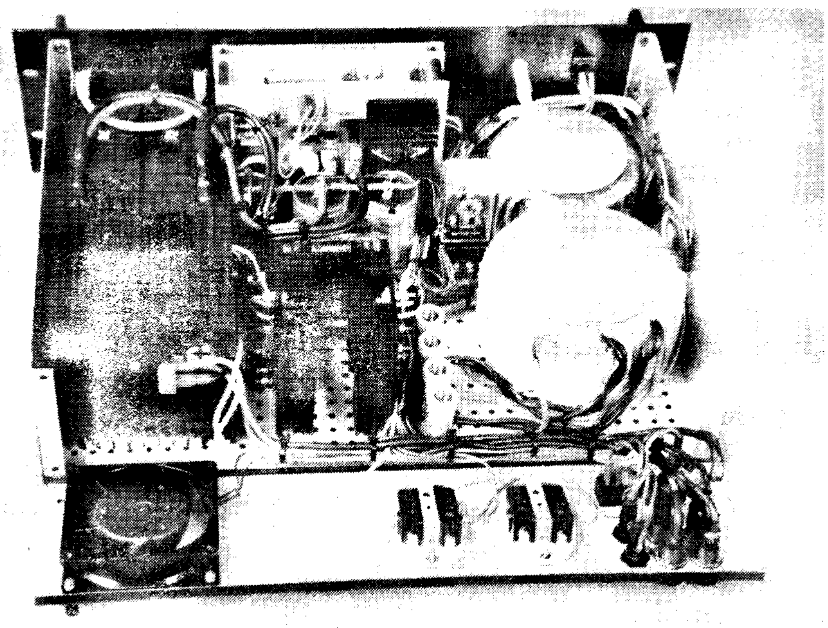


Fig. 15. Adaptor plate for optional fan mounted on the heatsinks – not shown in photographs.



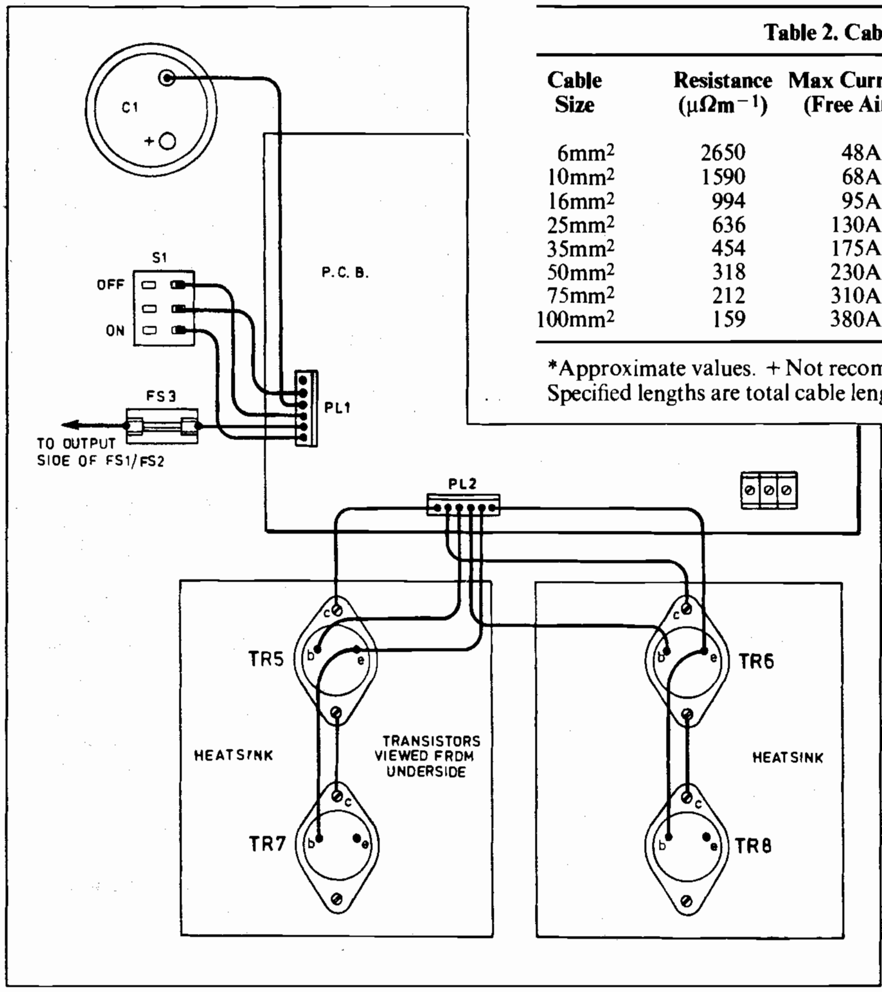


Fig. 16. (above) Main wiring diagram.

Table 2. Cable Size Recommendations.

Cable Size	Resistance ($\mu\Omega m^{-1}$)	Max Current (Free Air)	Max length for 0·2V Drop @ 25A	Max length for 0·2V Drop @ 60A
6mm²	2650	48A	3.0m	+
10mm²	1590	68A	5.0m	+
16mm²	994	95A	8.0m	3.0m
25mm²	636	130A	12.5m	5.0m
35mm²	454	175A*	17.5m	7.0m
50mm²	318	230A*	25.0m	10.5m
75mm²	212	310A*	+	16.0m
100mm²	159	380A*	+	21.0m

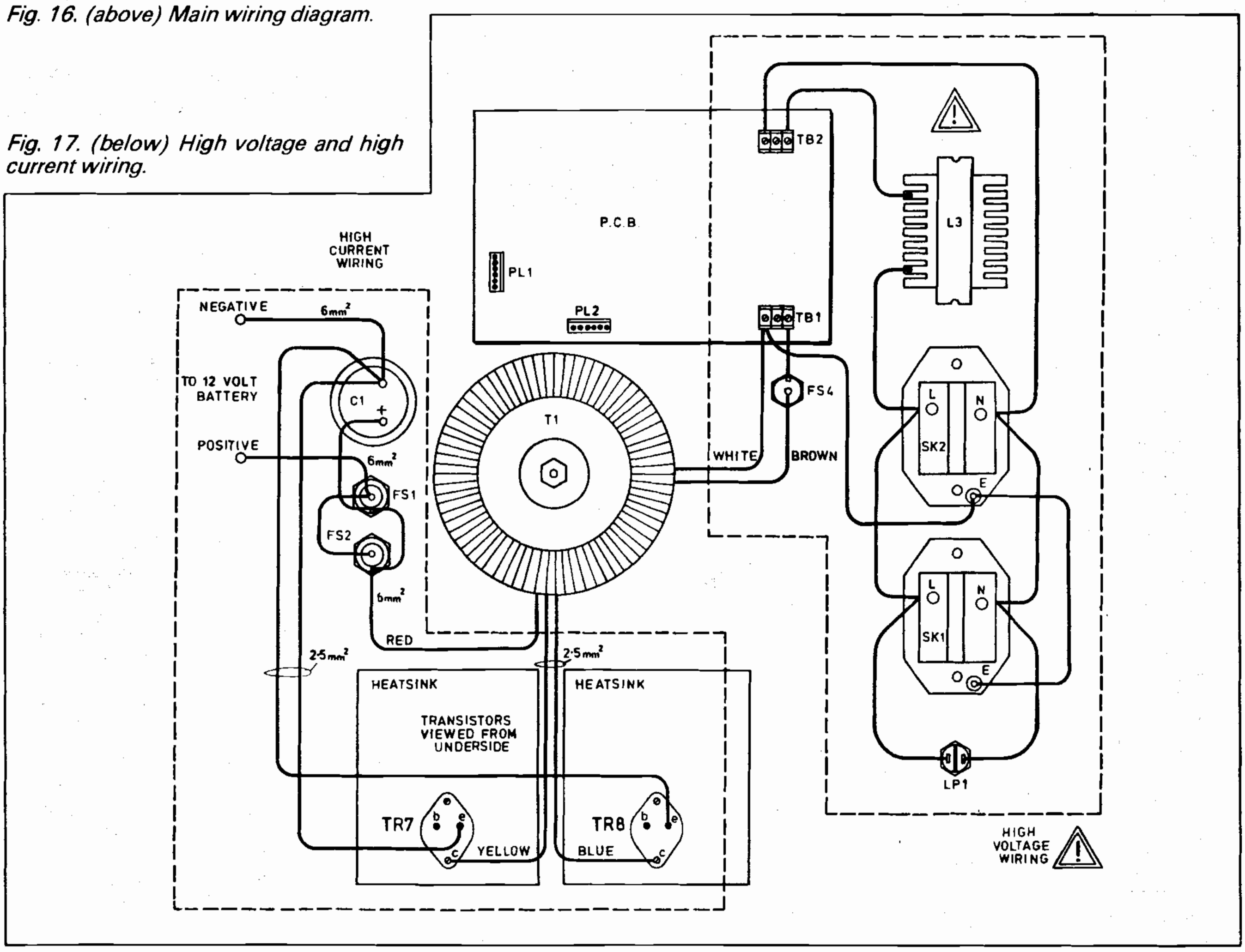
*Approximate values. + Not recommended.
Specified lengths are total cable lengths, i.e. feed and return.

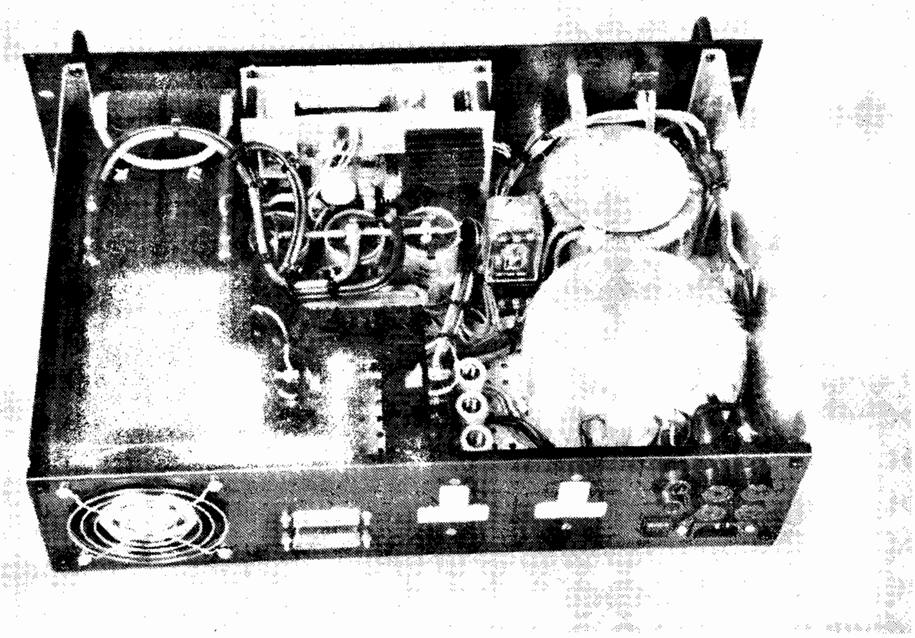
TRANSISTOR CONNECTIONS

The emitter terminations for TR7 and TR8 are made by crimping and soldering an M5 tag onto the end of a length of 2·5mm wire. The tag may then be slipped onto the bullet connector already attached to the emitter pin of the transistor and soldered in place. A lot of heat is required for this and a soldering iron rated at a minimum of 50 watts will be required. Keep the iron on the joint until the solder flows around the entire connection, which may take 20 or 30 seconds and although the transistor may get very hot during this operation it will survive, provided it is well heatsinked.

Solder tags (M3) fitted to the blue and yellow leads of **T1** will facilitate connection to TR7 and TR8 collectors via the transistor mounting bolts.

Fig. 17. (below) High voltage and high current wiring.





Use a plain washer either side of the tag and a spring washer under the nut.

If loading is expected to be intermittent or light a 30 amp terminal block, may be used for the connection to the battery leads, otherwise a 50 or 100 amp rating is required. The larger sizes of welding cable (above 10mm^2) will need the 100 amp type to accommodate the conductor size. Most small electrical factors will sell these in one and two-way strips cut from a standard 12-way block.

Large compression type cable glands should be fitted through the back panel to provide strain relief for the battery leads. The terminal lugs for large welding cables are normally fitted with a special crimping or swaging tool which compresses the soft copper lug around the cable providing a very secure joint. Some of the smaller suppliers will terminate the cables for a small charge.

An alternative method is soft soldering which may be readily carried out at home with a standard full size gas torch. Strip the insulation back approximately 10mm to 15mm from the cable end and fit the terminal, compressing it sufficiently with a pair of pliers to grip the cable lightly. Support the cable with the terminal uppermost and apply heat to the terminal, taking care not to burn the cable insulation. With the joint up to temperature remove the flame and feed flux cored solder into the joint until it is saturated, re-heating as necessary. Two metres, or more, of 22 s.w.g. solder may be needed for each joint.

Once cooled the joint should be taped with p.v.c. insulating tape and bolted to the appropriate crocodile clip, slipping the insulated handle grip onto the cable first.

SETTING UP AND INITIAL TESTING

Before rushing out and removing the car battery to test the newly completed inverter spend a few minutes re-checking all wiring and p.c.b. assembly (also make sure removal of the car battery will not affect a coded stereo or the car electronics, which in some case may need expensive resetting if the battery is disconnected).

The time spent at this stage could save hours of valuable time and money later – remind yourself how much the pair of BUV20 transistors cost, as these are the most likely components to suffer terminal failure if an error has been made! ***Read this section thoroughly before proceeding.***

Initially fit FS1 in its holder and leave FS2 out. Ensure that the other two fuses are fitted and of the correct rating. Check that the preset VR1 is adjusted to the mid-point of its travel and that S1 is in the "Off" position.

Connect the battery leads to a 12 volt car battery, which is known to be fully charged and in good condition, observing polarity as **no reverse polarity protection is provided.** See the Modifications section at the end of this article if this is desired.

Connect a meter set to read 500 volts a.c. to the output of the inverter and, if available, a 30 amp f.s.d. ammeter in series with the battery positive connection. Switch the inverter on and watch the ammeter needle, which should flick momentarily across a large part of the scale before quickly settling down close to the zero. Any reading much greater than two amps indicates a potential fault and the Inverter must be switched off immediately and all wiring double checked. In practice the off-load input current will probably be 500mA or less.

Check the voltage indicated by the voltmeter, anything in the region 200 to 350 volts is indicative of normal operation. Adjust the preset VR1 to obtain approximately 240 volts. With the step regulation employed exact voltages are often unattainable and will vary by a few volts in normal circuit operation, but this is unimportant in this type of application.

Switch off and check the temperature of all the power transistors, including TR3 and TR4 and the small voltage monitoring transformer T2. Also check resistors R24 to R29 and R33, some of which may be quite hot, but not unacceptably so.

If all is well so far, run the Inverter off-load for a minimum period of 30 minutes whilst checking all of the above components for any sign of overheating. **Always switch off before touching anything since mains voltages are present on the p.c.b. and some of the wiring.**

LOAD TESTING

Connect a small load of around 25 watts (e.g. a soldering iron) to the Inverter and check the voltage, which may change slightly. Monitor the temperature for a further five minutes before connecting a larger load of around 100 watts (a table lamp is ideal).

The power transistors should start to warm up a little now and it would be wise to keep an eye on all high current connections, particularly soldered ones, for any sign of potential failure. Fifteen to twenty minutes should reveal any problems likely to occur at this stage.

Full load for this Inverter is 300 watts continuous and will require FS2 to be fitted for a prospective input current of around 30 amps.

Two table lamps fitted with 150 watt bulbs (the shades will need removing!) will provide a suitable full load test and will require the battery to be in good condition and to have been fully charged for the initial stages of testing.

CAUTION: *The battery may gas heavily during this test, producing hydrogen and oxygen which will form an* ***EXPLOSIVE*** *mixture. Do* ***NOT*** *smoke near the battery or produce sparks or naked flames of any kind.* Extinguish any gas soldering irons, even the catalytic types which do not produce an actual flame. **Simply disconnecting one of the crocodile clips from the battery before switching the Inverter off will cause a spark of sufficient magnitude to initiate an explosion!** See also the section on Safety (last month).

A 30 minute continuous full load test should be accepted as the minimum before the Inverter is put into service. The main points to watch are the soldered connections to the BUV20 output devices, FS1, FS2 and the centre-tap of T1. The transistors will get quite hot during this test, but should remain below 85°C at all times. If not, consider upgrading the heatsinks or fitting the optional fan.

The Inverter should be able to maintain at least 220 volts into the load for the full 30 minutes of the test. If it does not, suspect the battery first, then try adjusting VR1 slightly to ensure that the maximum pulse width is being obtained. An oscilloscope may be helpful here (see the section on Fault Finding). Note: it may be necessary to adjust VR1 to obtain the best regulation across the entire load range.

At this stage it may be prudent to disconnect the Inverter and run the car engine for a while to replenish the charge in the battery. The final test is to use the Inverter with an electric drill under load which will require an input current to the Inverter of around 45 to 50 amps. The prototype was tested using a heavy duty portable drill with a 620 watt motor to bore a 16mm diameter hole through mild steel!

The performance was not quite up to mains standard but the task was still completed quite rapidly.

FAULT FINDING

The complete circuit is quite complex and fault finding may be quite a daunting prospect. If the circuit is considered in sections as shown in the block diagram of Fig. 6 each may be individually analysed in a simple and straight forward manner by referring to the appropriate sections of the text and main schematic of Fig. 7. A multimeter and an oscilloscope are the most useful pieces of test equipment for fault finding on this circuit, without them there is very little you can check.

Before delving into the depths of the electronics check for simple things such as ruptured or missing fuse links, poor battery connections, etc.

If the Inverter refuses to work at initial power up re-check all connections between the p.c.b. and off-board components, then check the p.c.b. for bad joints and incorrectly placed or orientated components. At this stage do not assume that any of the components are faulty, as this is most unlikely unless they failed when the circuit was switched on, in which case there is still an error to locate.

Home produced p.c.b.s are another likely source of errors, particularly when as complex as the double-sided board in this Inverter. Check the p.c.b. against the foil patterns of Fig. 10 and the circuit diagram of Fig. 7 (last month).

If FS3 ruptures repeatedly at switch-on it is likely that D1 is connected with the incorrect polarity and should be replaced with a correctly fitted new one. Measure the voltage across the Zener diode D2 which should be 7.5 volts ± 5 per cent and compare this with the voltage across the power supply pins of each i.c. in turn. Zero volts at any i.c. indicates a broken or missing track.

Once it is ascertained that power is present at all i.c.s the inputs and outputs may be checked using an oscilloscope. The output of one should match the input to the next (refer to Fig. 7 to obtain connection details).

LOGIC CIRCUITS

For the logic circuits it is worth noting the following. An AND gate requires a logic 1 (about 7.5 volts) on both inputs to give a logic 1 at its output, anything else will give a logic 0 (zero volts). The Schmitt Inverters in IC10 change a logic 1 at the input to a logic 0 at the output and vice-versa. The NOR gate in IC6 will only give a logic 1 at its output when all inputs are logic 0, otherwise it gives logic 0.

If the Inverter runs but will not regulate the fault is most likely to be around the op. amps IC8 and IC9 or the NOR gate IC6. Check that transformer T2 is giving an output of around 12 volts a.c. Capacitor C15 should have approximately 12 volts d.c. across it which is regulated to 5·1 volts ±5 per cent by D6. A voltage of approximately 0·6 volts across a Zener would normally indicate that the diode is incorrectly polarised. Check also that the voltages across the resistors in the potential divider are in proportion to their value.

The power output stage is relatively simple and should not pose any problems. Simple checking of the connections and security of the joints will usually suffice. It is possible, though unlikely, that a transistor may have failed at initial power up, in which case the following section may provide some fault-finding clues.

COMMON FAILURE MODES

Practical experience with Inverter design over a period of several years has generated a list of stock faults and common failure modes. A number of these are presented here, but the list is by no means exhaustive and should not be treated as such.

Failure mode 2 is the most common, occurring in probably 90 per cent of cases, fortunately it is also the easiest to diagnose.

1. CMOS devices, when they fail, often "crowbar" the power supply rails. To detect which device has failed, once a short-circuited supply has been spotted, simply involves measuring the voltage across the supply pins of each chip in turn with a digital multimeter. The failed device will be the one with the lowest supply voltage measured and may be removed, the supply re-checked and a new device inserted.

2. Switching transistor base-emitter junction breakdown is characterized by the other transistor overheating as it drives pulsed d.c. into a low resistance primary winding. If this is not spotted immediately the remaining functional transistor will also breakdown.

When the first transistor fails the tone of the Inverter will change dramatically, from a smooth buzzing to a raspy tone. Switch off immediately to preserve the surviving device.

With the case lid removed it is normally fairly easy to detect which device has failed, since its base voltage will rise taking the voltage across its base-emitter shunt resistor several times higher than normal. The resistor is called upon to dissipate several times its rated power and overheats turning it black or brown. A darkened R28 indicates TR7 failure, likewise with R29 and TR8. Replace both transistor and resistor in each case.

3. Collector-base junction failure is much rarer and is accompanied by a similar change in Inverter tone, but no base-emitter resistor darkening.

To determine which device has failed in this case the transformer must be disconnected from the power transistors and the circuit powered up transformerless. Connect a 1k resistor between each collector and the 12 volt rail and use an oscilloscope to look at the waveform across each resistor. The good transistor will produce a reasonable quality square wave on the 'scope, whereas the failed device will produce a straight line at 12 volts.

Fit a replacement BUV20 and re-check with the 'scope before re-connecting the transformer.

4. A timebase failure will often leave one transistor switched off whilst the other drives d.c. into the low resistance primary winding of the transformer.

The Inverter stops functioning immediately in this instance, accompanied by complete silence, i.e. no change in tone first. The failed transistor is located as in 2 or 3 above, but the timebase must be repaired before re-starting the Inverter.

EARTHING

There are a number of ways of wiring the output of the Inverter, including one which requires no earth connection. For maximum safety earthing is necessary in the majority of applications.

The simplest method is to connect one side of the high voltage secondary to mains earth and to the socket outlet earth terminal, as shown in the wiring diagram of Fig. 17. This method may also be used with a properly installed grounding rod where no mains supply is installed. Consult the I.E.E. Wiring Regulations for further information on the installation of grounding rods.

Moving motor vehicles require a different earthing method to that described above, since they are not fixed in relation to the ground. In this case the 0 volt (white) side of the secondary should be connected to the negative* battery connection and also to the earth terminal of the socket outlets. A grounding strap, of the type sold as a travel sickness remedy, should also be fitted to the vehicle in accordance with the manufacturers installation instructions to dissipate any static electricity build-up on the vehicle.

It may be necessary to use the Inverter without an earth connection in some circumstances, which will not be described here since they are well known to those who will need this facility. Since a non-earthed winding leaves the supply voltage floating it is possible for *either* side of the supply to be at a high potential above earth (although normally it will also be at a high impedance) it is therefore necessary for BOTH output leads to be fused identically.

The connection between the secondary 0 volt lead and the socket earth terminals should be omitted. If you do not specifically need an earth free supply, or are at all unsure about its application, then you **MUST** earth the output in one of the ways described above.

A residual current device (R.C.D.) which detects earth leakages and automatically disconnects the supply in the event of a fault would be a sensible addition to the Inverter, particularly in the earth free configuration. All commercial units are supplied with full installation instructions which must be adhered to, further information on installation and use may be found in the I.E.E. Wiring Regulations.

**This applies to negative ground vehicles only. For positive ground systems this connection must be made to the positive battery terminal.*

MODIFICATIONS

The output frequency may readily be changed to 60Hz for use with American equipment by substituting a 4·9152MHz crystal for X1 as suggested in the text. To obtain 117 volts connect a 240 to 110 volt step-down transformer to the output of the

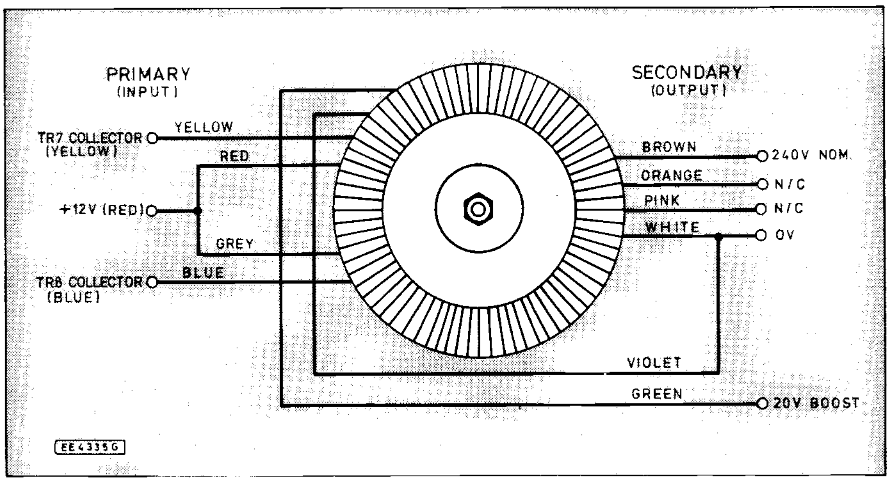


Fig. 18. Connection details of the transformer used for the 600W version.

Table 3. Power Transistor Specifications.

Type	I_C (max)	PO (max)	V_{CE} (max)	H_{FE} (min)	at I_C	Case*
2N3055	15A	115W	60V	20	4A	TO3
2N3771	30A	150W	40V	15	15A	TO3
BUV20	50A	250W	125V	20	25A	TO204
BUP49	90A	300W	80V	15	80A	TO204
BUP48	100A	300W	60V	10	100A	TO204

*TO204 is identical to TO3, with the exception that it has 1.6mm diameter pins for heavier current handling.

Inverter and adjust VR1 to give approximately 117 volts across the 110 volt winding.

For a greater power output a larger transformer will be required, a 9E284 will be suitable for up to 600 Watts. The connection details for this multiple winding transformer are provided in Fig. 18.

The BUV20 output transistors will also need upgrading to BUP49 or BUP48 (see Table 3 for specifications) devices in order to take full advantage of the greater output capabilities. Resistors R24 and R25 will need reducing to 10 or 12 ohms, with a 2 Watt rating. Heatsinks, cables and fuses, etc. will also require appropriate increases in their respective ratings.

The chokes, L1 and L2, in the secondary circuit may be retained as they have a maximum rating of 3 amps. It is advisable to reinforce the p.c.b. tracks carrying this current with 20 s.w.g. tinned copper wire to prevent them from melting at full load.

By duplicating R24 to R29, C7 to C12, TR5 to TR8, L1, L2, VDR1, VDR2, FS4 and T1 the control electronics may be employed to drive more than one Inverter. T2 connects to only one of the power transformers, which then becomes the master and has better regulation than the rest. Separate input fuses should also be used for each additional transformer. Up to three slave Inverters may be run in conjunction with one master. If the slave units are to be switched to allow individual control double pole switching of the power Darlington base drives MUST be employed.

All the above components will have to be mounted off the main p.c.b. and TR3 and TR4 will need additional heatsinking. The p.c.b. tracks connecting the power transistors will need uprating with tinned copper wire to provide the extra current handling capabilities required to drive the multiple Darlington power stages. This also applies to the 600 watt single transformer Inverter.

POLARITY PROTECTION

To provide protection against accidental reversed battery connections a 15A stud rectifier should be connected across the centre-tap (red) of T1 and the battery negative lead. The cathode must be positive.

In the event of the battery connections being reversed a large current will flow through the rectifier and cause the fuses FS1, FS2 to fail and the rectifier to fail to a short circuit. All three components should then be replaced before correctly reconnecting the battery.

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I.E.E. Wiring Regulations, 16th Edition

ACKNOWLEDGEMENTS

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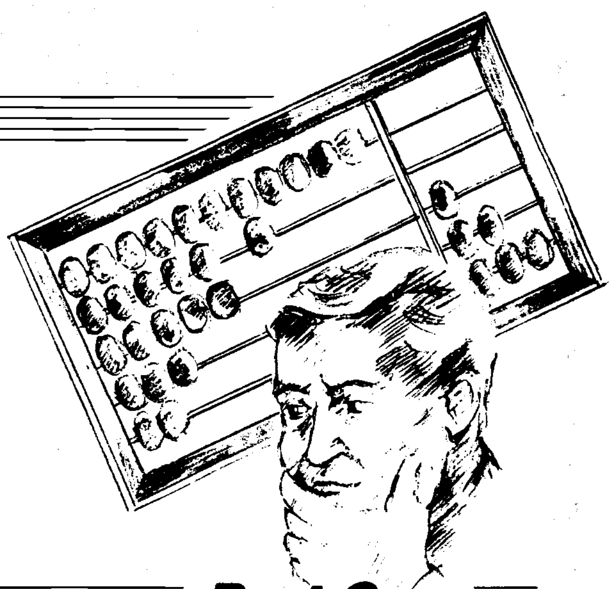
Next Month: Uninterruptable Power Supply add-on.

Special Series

CALCULATION CORNER



Getting to know the basics

S. KNIGHT — **Part One**

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. As far as possible, everything will be kept on a quite elementary level so that even those readers who are not taking examinations in this subject will, we hope, find something of interest to them and, hopefully too, overcome their fears by giving them an opportunity to see how illusionary many of these fears actually are.

THE only piece of equipment you will need for this series, beside some sheets of paper and a pencil, is a calculator. For the earlier parts of the course this need be nothing more than a basic model having the four functions of add, subtract, divide and multiply along with a square root and a reciprocal key. Later on we will need keys for the trigonometric and logarithmic functions but don't be deterred by the appearance of these words. By the time they turn up, you should be meeting them (if you haven't already) with sufficient confidence to see these imposters for what they really are.

In general terms then, there will be brief notes on the relevant theory, worked examples to illustrate methods, with explanations where these are needed, and each part will conclude with some self-assessment problems showing, where possible, the practical applications of the calculations. The solutions to these will be provided in the following part.

We begin in this introductory part of the series by sorting out the basic units we will be working in. Others will turn up as we go along but we need right from the word go those units (and their sub-units) associated with the simple electrical circuits, shown in Fig. 1.1 to get us on our way.

THE ELECTRIC CIRCUIT

All sources of current electricity provide a concentration of negatively charged particles, the **electrons**, at one terminal of the source, the negative pole, and an equivalent deficiency of electrons at the positive pole. When the poles are connected together by way of a conducting path, the electrons, with their negative charges, move from the negative to the positive pole, so constituting an electric current. This is how we accept things today.

However, before the electron was discovered and the true nature of electricity was properly understood, it was quite naturally taken for granted that current flowed around a circuit from the positive pole (what we might call the *high potential* point) to the negative pole (the *low potential* point), and all the rules and conventions about how the electric circuit worked and how electricity was generated were established on this premise.

To avoid turning everything on its head as it were once the true nature of things became known and to leave the conventions undisturbed, it became necessary to distinguish between the true current flow and, up to that time, the assumed current flow. The problem was resolved by calling the true current flow (from the negative to the positive pole) the **electron flow**, and the supposed current flow (from the positive to the negative pole) the **conventional flow**. In all our work on passive circuit systems, the conventional flow will be used. When we get on to active systems – those with transistors, for example, we will find that the true electron flow is often a lot more useful.

CURRENT AND QUANTITY

An electric current is the movement of free electrons along a conducting path. The unit of current is the **ampere** (I) and is the *rate* of flow of about $6{\cdot}3 \times 10^{18}$ electrons per second (the power of ten method of expressing a number is discussed in detail later in this article). This enormous number, which is greater than six million million million times the charge on an individual electron (which is much too small to be of practical use) is the basic **quantity** of charge known as the **coulomb** and symbolised Q. Hence one ampere is a rate of flow of one coulomb per second, or

$$Q \text{ (coulombs)} = I \text{ (amperes)} \times \text{time (seconds)}$$

A current of one ampere may not be large to the power engineer but it is to the electronics man. It is therefore divided into a thousand parts called **milliamperes** (mA) and each of these in turn is divided into a further thousand parts called **micro-amperes** (μA). So:

$$1\text{mA} = \frac{1}{1{,}000}\text{A} = 0{\cdot}001\text{A} = 10^{-3}\text{A}$$

$$1\mu\text{A} = \frac{1}{1{,}000{,}000}\text{A} = 0{\cdot}000001\text{A} = 10^{-6}\text{A}$$

We will come back to these different ways of expressing the same quantity in a little while.

ELECTROMOTIVE FORCE

A battery or any other source of electricity has the ability to move a quantity of electrons along a conductor; this ability is known as the **electromotive force** (e.m.f.) and represents an electrical *pressure*. The unit of this force is the **volt**, symbolized E. There is also a pressure developed between any two separated points in a circuit, say, between the ends of a resistor, established by the flow of current through the resistor. This is known as a **potential difference** (p.d.) and is also measured in volts, symbolized V. It is important to distinguish between the precise meanings of e.m.f. and p.d. and Fig. 1.1 should make this clear for you.

Like current, the volt is divided into a thousand sub-units called **millivolts** (mV) and each millivolt is further divided into a thousand parts called **microvolts** (μV).

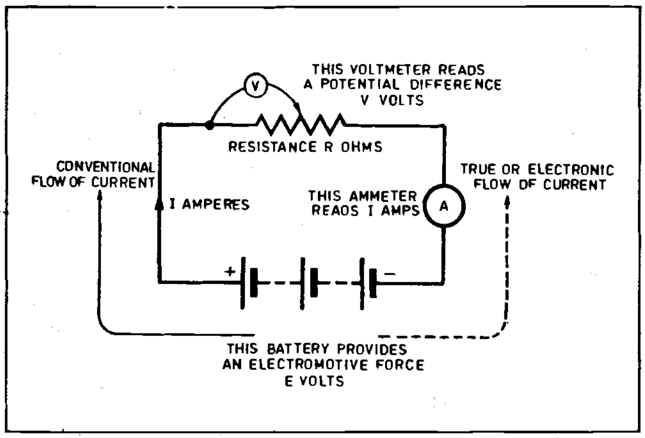


Fig. 1.1. The essential details of the simple electric circuit.

So:

$$1\text{mV} = \frac{1}{1{,}000}\text{V} = 0{\cdot}001\text{V} = 10^{-3}\text{V}$$

$$1\mu\text{V} = \frac{1}{1{,}000{,}000}\text{V} = 0{\cdot}000001\text{V} = 10^{-6}\text{V}$$

RESISTANCE

We can define resistance as that property of a substance which opposes the passage of electrons through it. Those substances which offer only a small opposition to the flow are known as conductors; those which offer an extremely large opposition are known as insulators. Resistance is denoted by the symbol R and the unit of resistance is the **ohm**, symbol Ω (omega). A resistance of 1Ω is small in relation to the resistances normally used in electronics and larger units, the **kilohm** ($1\text{k}\Omega = 1{,}000\Omega$ or $10^3\Omega$), and the **megohm** ($1\text{M}\Omega = 10^6\Omega$) are used.

An alternative way of looking at resistance, and very useful in certain calculations, is to consider a conductor not in terms of its *opposition* to electron flow but in terms of its *ability* to conduct. Hence a circuit of *high* resistance could equally be described as having a *low* conductance, and conversely. **Conductance**, therefore, is the inverse of resistance and is expressed as the reciprocal of resistance:

$$\text{Conductance (G)} = \frac{1}{\text{Resistance (R)}}$$

and is measured in **Siemens** (S).

OHM'S LAW

In an electrical circuit, the current I is directly proportional to the applied e.m.f. or to the p.d. across the conductor. It is also inversely proportional to the resistance of the conductor. Hence I varies as V or as $1/R$. We will use the symbol V for voltage throughout this section, irrespective of whether it is an applied e.m.f. or a potential difference.

By choosing the appropriate units therefore we get the relationship $I = V/R$. We can say that an ampere is therefore the current flowing in a resistance of one ohm when the voltage across the resistance is one volt. Clearly, if any two of the quantities are known, the third can always be calculated. This simple relationship (which nonetheless is very difficult to *prove*) between I, V and R is known as **Ohm's Law**.

TRANSPOSING A FORMULA

In Ohm's law as given above, the current I is known as the *subject* of the formula since its value is given in terms of V and R. For example, if V = 5 volts and $R = 2\Omega$, then $I = 5/2$ or 2·5A. As arranged, therefore, the formula will enable us to find I for any values of V and R. However, in other circumstances the current and the resistance may be known and we need to find the voltage.

The formula we now want must have voltage V as the subject and this has to lie on the left-hand side with the other variables I and R appropriately arranged on the other side. This rearrangement is known as **transposition** and the result of the transposition must be such that the intrinsic truth of the original statement, that is, $I = V/R$, is not altered.

Any formula (and we will meet with quite a few as we go along) gives us the relationship between one variable quantity and others; it may be compared to a pair of scales in which an originally balanced condition can only be restored if anything added to or removed from one of the pans is added to or removed from the other pan. With a formula, the original equality (indicated by the equals sign =) is no longer valid if anything changed on one side of the equation is not identically changed on the other. We will illustrate this procedure on the formula $I = V/R$.

To make V the subject, we *multiply* both sides by R so that we get

$$IR = \frac{VR}{R}$$

and then $IR = V$ or $V = \mathbf{IR}$

since the R's cancel out on the right-hand side.

To make R the subject, we *divide* each side of this last formula by I so that

$$\frac{V}{I} = \frac{IR}{I}$$

and then

$$\frac{V}{I} = \mathbf{R} \text{ or } \mathbf{R} = \frac{\mathbf{V}}{\mathbf{I}}$$

since the I's now cancel out on the right-hand side.

We now have all three possible arrangements of I, V and R. Summarising, we have

$$\text{Current } I = \frac{V}{R} = \frac{\text{voltage}}{\text{resistance}}$$

$$\text{Voltage } V = IR = \text{current} \times \text{resistance}$$

$$\text{Resistance } R = \frac{V}{I} = \frac{\text{voltage}}{\text{current}}$$

Ohm's law can be applied to a complete circuit or to any part of a circuit and should be memorised in all three forms.

SOME WORKED EXAMPLES

Here are a few worked examples on what we have talked about so far. At this very basic level it is easy to make up such examples for yourself and you should do this until you are completely familiar with all the units we have so far mentioned

1. A current of 0·5A flows for a period of 1 minute; what quantity of electricity has moved around the circuit? How many electrons does this quantity represent?

$$\text{Quantity } Q = I \times t \text{ coulombs (C)}$$

Keep the proper units in mind here: I = 0·5A, T = 60 secs; then

$$Q = 0{\cdot}5 \times 60 = \mathbf{30C}$$

Now 1 coulomb is equivalent to the charges of $6{\cdot}3 \times 10^{18}$ electrons. Hence 30 coulombs is equal to

$$6{\cdot}3 \times 10^{18} \times 30 = 189 \times 10^{18} \text{ or } \mathbf{1{\cdot}89 \times 10^{20}} \text{ electrons}$$

Most calculators have a key to facilitate the entering of large numbers like 10^{18}. This key is usually marked EXP, so the above calculation would be done by entering 6·3 *times* 30 *times* EXP 18 and the answer will appear as 1·89 20, the index being spaced out from the other part of the number. Try to develop the use of this key as it will be very useful in many electronic calculations.

2. What voltage is required to produce a current of 0·35A in a resistance of $7{\cdot}5\Omega$?

Here we have I = 0·35A, $R = 7{\cdot}5\Omega$ and we need to find V
Using V = IR we get $V = 0{\cdot}35 \times 7{\cdot}5 = \mathbf{2{\cdot}625V}$

3. A circuit carries a current of 150mA when the applied voltage is 13·8V. What is the circuit resistance?

Here we have I = 150mA, V = 13·8V and we need to find R.

So we can use the relationship $R = V/I$. But we must *not* write the equation as $R = 13{\cdot}8/150$; the current has to be expressed in amperes, not milliamperes. 150mA = 0·15A, hence

$$R = \frac{13{\cdot}8}{0{\cdot}15} = \mathbf{92\Omega}$$

4. A circuit of resistance 28Ω is connected to a battery of e.m.f. 5V. What current flows in the circuit?

The actual calculation should present us with no problem but the form of the answer might. Here we have $R = 28\Omega$, E = 5V, and we have to find I.

$$\text{Using } I = \frac{E}{R} \text{ we get } I = \frac{5}{28} = 0{\cdot}178571428\ldots\text{A}$$

on our magic machine, but *never* write down a string of figures such as this as an answer to a question, particularly if it is an examination question. *An answer cannot be more accurate than the accuracy of the information supplied.* It would be quite sufficient in this case to leave the answer as 0·18A (or as 180mA) or, of course, as a fraction 5/28A. We will return to this question of accuracy in a later section.

POWERS OF TEN

You will have noticed from what we have already mentioned about sub-units and multiples of the basic units, mA, μA, kΩ and so on, that powers of 10 appear in all cases. This simplifies calculations since it is a lot easier to use, say, $4{\cdot}7 \times 10^6\Omega$ than to write out 4,700,000Ω; both forms represent 4·7MΩ (often written 4M7.

Try to use the powers of 10 in this way whenever you can, remembering that a *negative* power of 10 represents a *fraction*: 10^{-1} for example represents 1/10 or 0·1, and 10^{-3} represents 1/1,000 or 0·001. For example, a current of 0·017A is expressed as 17mA since $0{\cdot}017 = 17 \times 10^{-3}$, and a voltage of 6,275V is expressed as 6·275kV since $6{,}275 = 6{\cdot}275 \times 10^3$.

In many cases, of course, there is no objection to your using decimal fractions, such as 1mA = 0·001A or 30mV = 0·03V. Use whichever method you feel most comfortable with, but *avoiding* long decimals like expressing 1μA as 0·000001A or 10pF as 0·00000000001 farads!

The most commonly encountered prefixes in electronic calculations are given in the following table.

MULTIPLEXER	PREFIX	ABBREVIATION
10^6	mega	M
10^3	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

You will probably recall that when we *multiply* powers of 10 we simply *add* the indices and when we *divide* we *subtract* the indices. So, for example

$10^5 \times 10^3 = 10^{5+3} = 10^8$; and $10^5 \div 10^3 = 10^{5-3} = 10^2$.

Take particular care when negative indices turn up, such as

$10^{-7} \times 10^3$ which becomes

$10^{-7+3} = 10^{-4}$ or $10^4 \div 10^{-3} = 10^{4-(-3)} = 10^{4+3} = 10^7$.

The next examples will make the method clear.

5. A current of 275μA flows in a resistance of 3·3MΩ. What voltage is developed across the resistance?

Here $I = 275\mu A = 275 \times 10^{-6}A$, $R = 3{\cdot}3M\Omega = 3{\cdot}3 \times 10^6\Omega$. This then expresses both I and R in the basic units of amperes and ohms.

Then since V = IR we get $V = 275 \times 10^{-6} \times 3{\cdot}3 \times 10^6$ volts. The powers of 10 cancel out and we have $V = 275 \times 3{\cdot}3 =$ **907·5V**

6. What value of resistance is required to limit a current to 1·5mA when a voltage of 270V is applied?

We already have the voltage in its basic units but it is still convenient to express it in powers of 10. So we have $I = 1{\cdot}5 \times 10^{-3}A$, $V = 2{\cdot}7 \times 10^2V$. Then

$$R = \frac{V}{I} = \frac{2{\cdot}7 \times 10^2}{1{\cdot}5 \times 10^{-3}} = \frac{2{\cdot}7}{1{\cdot}5} \times 10^5\Omega$$

$$= \mathbf{1{\cdot}8 \times 10^5\Omega}$$

Be sure you understand how we arrived at this: we divided 10^2 by 10^{-3} so the indices were subtracted as 2 minus (−3) which is 2 + 3 = 5. The answer can of course be expressed as 180kΩ or as 0·18MΩ.

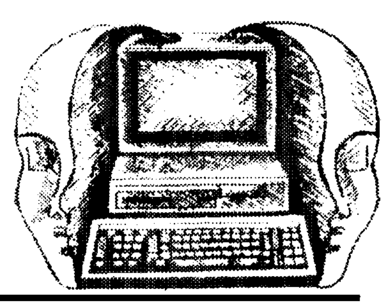
SELF ASSESSMENT

This is as far as we will go this month and a number of self-assessment problems follow. Some of these are not just repetitions of the worked examples in the above text. They can all be solved by the general methods and information given but for some of them you will have to think things through for yourself. The solutions will be given next month.

1. What basic unit is also known as the ampere-second?
2. If 1 coulomb is equal to $6{\cdot}3 \times 10^{18}$ electron charges, what is the charge of a single electron?
3. Q = It coulombs. Express t in terms of Q and I, hence find how long a current of 700mA must flow for 126 coulombs of charge to be moved around a circuit.
4. What is the conductance of a 47Ω resistor
5. A coil has a conductance of 0·125S. What is its resistance?
6. A current of 25mA flows through a 470Ω resistor. What voltage would be measured across the resistor? Is this voltage an e.m.f. or a p.d.?
7. Express, preferably in powers of 10, the following quantities: (a) 15mA in A, (b) 256μV in V, (c) 8·2MΩ in Ω. (d) 3185mS in S, (e) 650μC in C.
8. Write down the three forms of Ohm's law in terms of conductance (G) instead of resistance (R).

Next month: Ohm's Law and its applications.

INTERFACE



Robert Penfold

A START was made on the subject of EPROMs and EPROM programming in an *Interface* article a few months ago. Progress has been limited due to the arrival of various printed circuit design programs for review, but this month we resume our look at EPROM programming with a review of the MQP Electronics Model 200P EPROM programmer. This is designed for use with PCs, and it does not require a particularly advanced host PC. However, one having a hard disk drive is a definite advantage, since the supplied software seems to make quite frequent disk accesses.

Hardware

The programmer itself is housed in a tough metal case which is largely devoid of controls. In fact the only control is the on/off switch on the rear panel. The unit has an internal mains power supply incidentally. A 32-pin ZIF (zero insertion force) socket is mounted at the front edge of the top panel, and this has the usual lever to trap and release the EPROMs. Markings on the top panel make the correct positions for 24 and 28 pin devices perfectly clear.

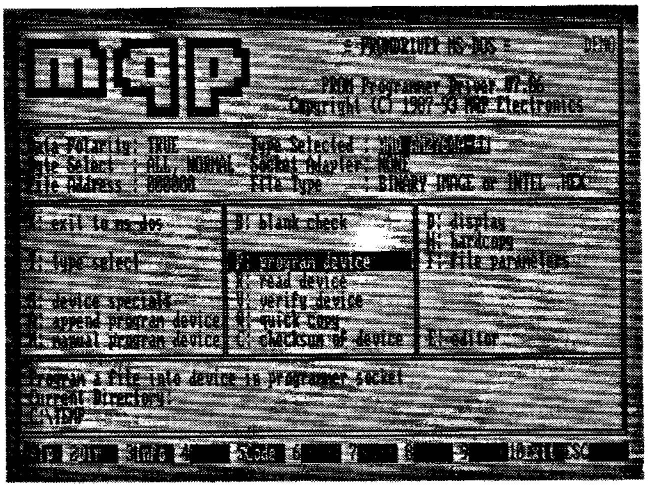
To the left of the ZIF socket there are indicator lights which show whether the power is switched on, and whether the ZIF socket is active. This second indicator is important, since damage can occur to an EPROM if it is connected or disconnected while the ZIF socket is active.

Connection to the host PC is via the parallel port, and a suitable cable is supplied with the unit. Using the parallel port could be a bit inconvenient as many PCs will already have a printer connected here. A serial version of the programmer is also available, and this would probably be a more convenient option for most users. However, the parallel port version presumably gives shorter programming times.

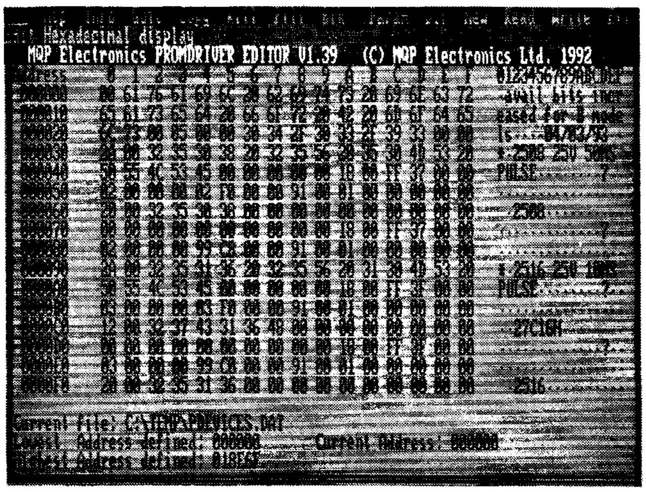
A very wide range of devices can be programmed, including all normal 24, 28, and 32 pin EPROMS. It is also possible to program EEPROMs and emulators. Various other components can be programmed via adaptors which are available as optional extras. These include 40 pin EPROMs, the 8748 and 8751 families, and the Z8 single chip micro-controller. The MQP 200P should be able to handle any normal programming requirements.

Software

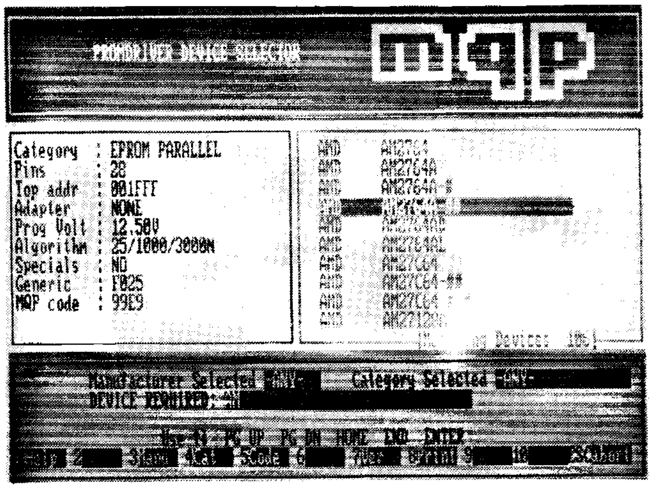
The reason that the programmer is virtually control-free is that, like most units of this type, it is largely software controlled. It is supplied complete with programs that provide the usual range of facilities, and can handle a wide range of devices. The software is on a single 3·5 inch double den-



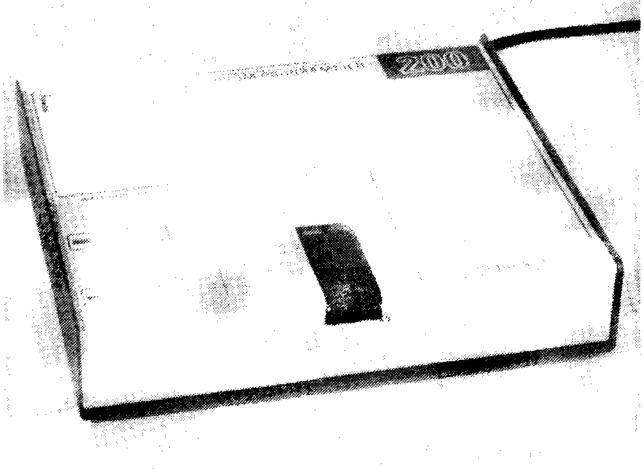
The main control screen.



The editor screen.



The device selection screen.



The MQP 200P EPROM programmer.

sity disk, and it is easily installed. It is possible to run a demonstration version of the software so that you can familiarise yourself with its operation before any real programming is attempted.

When the main program is first run it is necessary to complete a simple installation process to make sure that the software is set to communicate with the programmer properly. If all is well, you are then taken into the main control screen. There is no mouse control with pop-down menus. Instead, the top section of the screen shows the options currently selected, while the lower section is a large menu area. The desired option is selected by pressing the appropriate key, or using the cursor to highlight the option and then pressing ENTER.

This method of control is a bit old fashioned, but it works well in an application such as this. Moving around the program is certainly very quick and easy, even when using it for the first time. Provided you have some previous knowledge of EPROMs there should be no difficulty in finding your way around this program and using it effectively.

Database

The first task is to set the program to suit the particular type of EPROM you will be using. This does not work on the basis of selecting a particular pinout configuration and programming voltage. The software has a substantial database of EPROMs and their characteristics.

If you wish to program (say) a TI 2564, then you simply specify TI as the manufacturer and 2564 as the device you wish to program. Provided the program has an entry for the device in question, general details (number of pins, programming voltage, etc.) will be shown on the screen, and the EPROM programmer will be set to suit this particular device.

A wide range of devices are catered for, and I found matches for all my 25*** and 27*** series EPROMs. If an exact match cannot be found, then it would presumably be possible to find an entry for a device having identical characteristics.

The database is quite sophisticated. For example, you could just give "27" as the first two digits of a type number, and the program will then provide a list of devices which have type numbers starting with these two digits. It is then possible to scroll slowly through the list, looking at the characteristics of each device as you do so.

Programming

Once the correct EPROM type has been selected it is possible to check that a device is blank, or to read in the contents of an EPROM and examine it. The contents are displayed in the both hexadecimal and ASCII form, using the conventional screen arrangement. A useful hex/ASCII editor is provided, and this can be called up from within the main program. This makes it easy to make changes to an existing program, or to enter a new one from scratch. The contents of an EPROM can be saved to a file, and it is possible to read in a file of 8-bit binary values.

It is also possible to enter a program on an address by address basis. This is probably not a very practical means of programming 100K into a EPROM, but it is a quick and easy method for applications where only a few dozen bytes need to be programmed. There is a useful "quick copy" facility. This enables an EPROM to be read, and then copied onto a blank EPROM. Several copies can be made one after the other if desired.

The editing facilities are comprehensive, and make it very straightforward to get the right data into memory and ready for programming into an EPROM. The programming process itself is very rapid. I did not make any accurate timings, but fully programming some 2764 EPROMs only seemed to take about 20 seconds or so.

EPROM manufacturers recommend fast program techniques for many devices. The slow way is to apply the programming voltage for the same length of time for each address. The duration used is a relatively long one that is guaranteed to "blow" the EPROM properly.

The quick way is to use a very short pulse, and then check to see if the current byte of data has been programmed correctly. This process is continued until the current byte has been "blown" into the EPROM successfully. Using this method the time taken to fully program an EPROM will vary somewhat from one component to another, but it always seems to be just a fraction of the time needed using the slow method. Where appropriate, the MQP 200P will use the fast programming method.

Conclusion

The MQP Model 200P EPROM programmer is a very solidly made piece of equipment. Unusually for a computer peripheral, there was no difficulty in getting everything connected together properly, and it worked first time! The software does not have a particularly modern user interface, but it is still very easy to use. A small ring-bound manual is supplied with the unit, but I did not find it necessary to refer to this very often. The facilities offered by the software are fairly comprehensive, and cover all normal requirements.

I did not test the unit using a vast range of EPROMs, but it worked flawlessly using some 25*** and 27*** series components. The MQP Model 200P is equipped to handle virtually any normal EPROM, and via optional adaptors it can handle the more awkward programmable components such as serial EPROMs. It is undoubtedly a very desirable piece of equipment which seems to be free from any serious defects.

At a price of £295-00 for the basic unit it is not particularly cheap in absolute terms. Bear in mind that when experimenting with EPROMs an eraser is every bit as important as a programmer. An eraser is likely to cost about £50-00 or so. Even assuming you already have a suitable host PC, getting into EPROM programming using the MQP model 200P is a fairly costly business.

In fairness though, it has to be pointed out that compared to other EPROM programmers this unit offers very good value for money. Cheaper programmers are available, but they are very basic compared to the MQP Model 200P. Some can only handle one particular type of EPROM. If you are looking for a comprehensive PC EPROM programmer, then this one should certainly be given serious consideration. It is available from **MQP Electronics Ltd**, Dept EPE, Unit 2, Park Road Centre, Malmesbury, Wiltshire SN16 0BX. Tel 0666 825146.

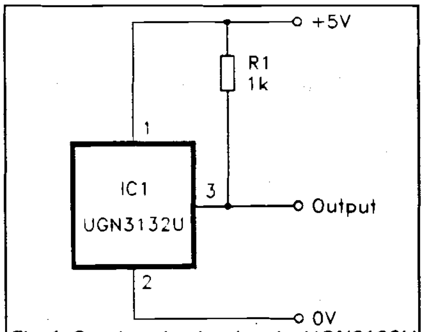


Fig. 1. Sensing circuit using the UGN3132U.

Hall Effect

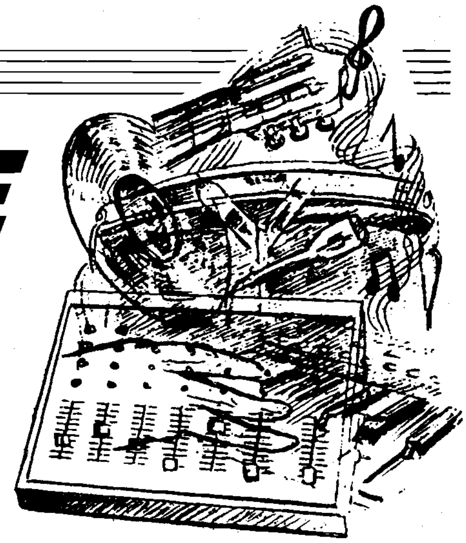
Some time ago I mentioned the demise of the TI TL170C and TL172C Hall effect switches. These are semiconductor switches that are activated by magnetic fields. They are popular for use as sensors in model railways and robotics, offering a modern alternative to reed switches. One or two readers wrote in to point out that other Hall effect devices were still available. Unfortunately, a little investigation showed that although some likely looking alternatives were still listed in catalogues, they had in fact been discontinued. Other devices were still available, but they proved to be too expensive or were simply not suitable.

The latest Maplin catalogue includes some new Hall effect devices. I tried out the UGN3132U in the circuit shown in Fig.1, and it works very well. The output stage is an open collector type, and the only discrete component needed is pull-up resistor R1. Although this is just a three terminal device, it apparently has quite a complex internal circuit. The sensitivity is certainly good, and trying various small bar magnets gave a range of at least 10 millimetres. This is more than adequate for applications such as train position sensing. In fact the less sensitive (and cheaper) UGN3133U should be adequate for most applications.

An important point to note about these two sensors is that they are operated by an alternating field. In other words, if the north pole of a magnet is used to switch the device on, only a south pole will switch it off again. This can be used to good effect in some applications where it permits direction sensing using multiple magnets.

If simple position sensing is all that is required, use two bar magnets mounted about 20 millimetres or more apart. They should be set so that one applies a south pole to the sensor and the other applies a north pole. This will always give a transition at the output of the sensor when the train (or whatever) passes. In a model railway context I found that simply mounting a small bar magnet lengthwise along a piece of rolling stock gave the same effect. This applies one pole to the track sensor and then the other, and the fact that the magnet is not end-on to the sensor does not seem to affect the maximum operating range.

Construcional Project



MULTI-PURPOSE AUDIO SYSTEM

Part 4 – 10W plus 10W STEREO POWER AMPLIFIER and SYSTEM POWER SUPPLY

MAX HORSEY P.C.B. Design JAMES GREEEN

If you want to set up a home recording system, mix sound videos, run a disco or a small band then these modules are for you! All modules will operate alone, but are compatible with each other.

SO FAR in this short series of audio modules we have dealt with a 12-channel mixer, individual microphone and RIAA pre-amps, and a tone control module with or without a stereo 1W amplifier. We continue the series this month with a 10W plus 10W Stereo Power Amplifier, including the system power supply.

The 10+10 watt amplifier and power supply unit forms the last link in the audio chain. The amplifier is based on the TDA 2030 i.c. The specification for this i.c. seems to vary depending upon the supplier, but it is capable of up to 20 watts when driven at full voltage (30V) with a loudspeaker impedance of 4 ohms. The power supply described in this article provides about 26V, and since many loudspeakers have an impedance of 8 ohms a power rating of 10W per channel is a more realistic, if conservative claim.

The TDA2030 is a small inexpensive device, yet is capable of very good results. The output current is limited to a safe operating level and the i.c. features built in short circuit protection and thermal shutdown. In other words, if it becomes too hot it switches off automatically until it has cooled down.

POWER SUPPLY REQUIREMENTS

The TDA2030 may be operated on a dual rail supply, but in this project the single rail option is used since the design of the power supply is simplified (and therefore less expensive). The circuit may also be driven at reduced power from a single 12V supply.

The current required depends upon the supply voltage and the sound level. For example the quiescent current (i.e. the current when there is no audio signal) is between 30mA and 40mA. On a 12V supply the average current used is less than 500mA when played at "full" volume. (The meaning of "full" is described in the next paragraph). When used at a higher voltage the power supply must be capable of supplying an average current of 1A.

The gain of the circuit is set by external resistors. The gain does *not* depend upon the operating voltage. In other words the sound level is roughly the same regardless of whether the i.c. is supplied with 12V or the 26V in this project.

However, as the volume level is advanced, clipping will occur more quickly on a 12V supply than if the circuit had been driven from 26V. Clipping causes sound distortion. It is easy to make the circuit produce a louder sound – simply changing the value of one resistor will achieve this; but the term "full" volume means the maximum level of sound *before* distortion occurs.

PRINCIPLE OF OPERATION

The TDA2030 power amp i.c. behaves like an ordinary operational amplifier and in this circuit is connected in a non-inverting mode. However the pin layout and pin numbers are different to a "normal" op. amp, such as the 741.

Unlike a 741 the output current is quite large and hence the current flowing through the supply rails is equally large. This can cause interference to adjacent conductors and great care is needed in the design of the layout. **Testing the circuit on prototype board, or building on stripboard is *not* recommended.**

CIRCUIT DESCRIPTION

A glance at the 10W plus 10W Stereo Power Amplifier circuit diagram shown in Fig. 1 should reveal the similarity between this circuit and a standard single rail non-inverting amplifier as represented by the Microphone Amplifier in a previous article. The two stereo halves are identical, and as usual, only one (the left hand channel) will be described.

The power supply connections to the TDA2030 are via pin 5 (positive) and pin 3 (negative, or 0V in this case). The non-inverting input is at pin 1, the inverting input at pin 2 and the output from pin 4.

When used on a single rail supply, the average voltage at the inputs and output must be held at half the supply voltage. This is achieved by the potential divider comprising resistors R1 and R2. This voltage is coupled to pin 1 via R3.

The audio signal input is applied via capacitor C1. No volume control is provided since the Tone Control Module (last month) controls the volume. However, Fig. 2 shows how a volume control could be added if required.

FEEDBACK

The output from pin 4 is connected to the inverting input (pin 2) via resistor R5. Resistor R4 has no effect on the d.c. feedback level since any d.c. is blocked by capacitor C3. Since any change of d.c. level at the output is fed back to the *inverting* input pin 2, the change self cancels, producing a gain of unity i.e. the d.c. output from pin 4 equals the d.c. input at pin 1. Hence the d.c. levels at pins 2 and 4 settle at the same voltage as pin 1 – half the supply voltage.

However, the a.c. audio signal can pass via capacitor C3. Therefore a.c. changes at pin 4 are not self cancelling and there is a gain of approximately the ratio of resistor R5 to R4.

Either one or both these resistors can be changed in value if a different gain is required. Note the point made earlier however, that the maximum sound output is determined by the power available from the supply and the power handling capacity of the i.c. Simply increasing the gain in order to produce a louder sound will result in distortion.

OUTPUT

The output from the i.c. is fed to the loudspeaker via capacitor C5. C5 is necessary since the d.c. output from pin 4 is at half the supply voltage. Connecting a loudspeaker directly to this supply would be very unwise.

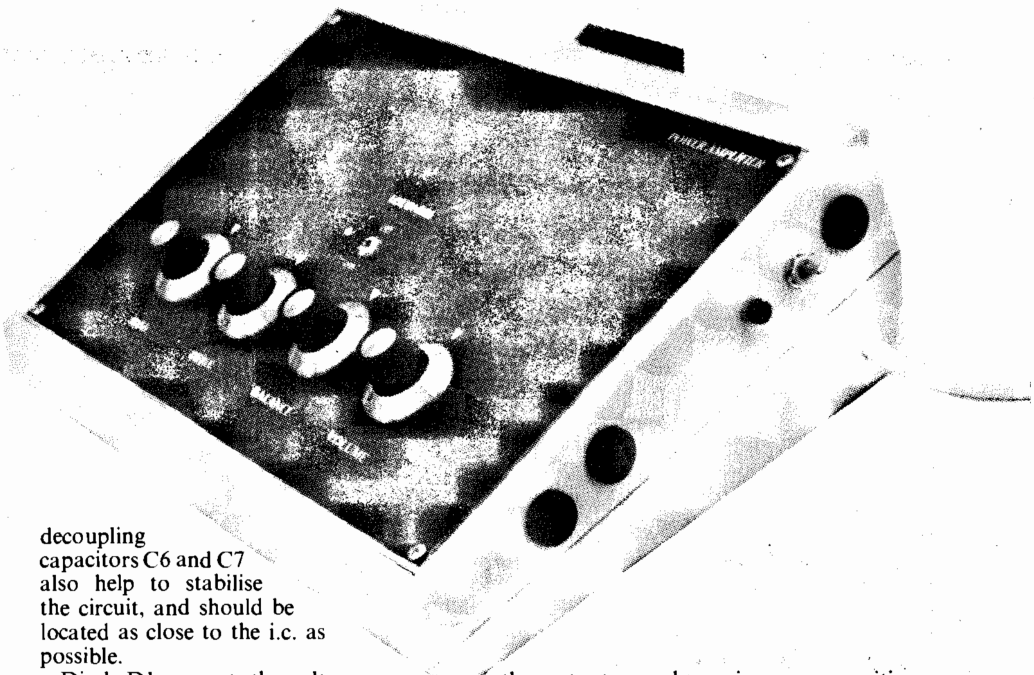
The capacitor blocks the d.c. but allows the a.c. audio signal to pass. The loudspeaker should have an impedance of 4 ohm for maximum power; however an 8 ohm speaker is very satisfactory.

STABILITY

The high currents flowing through the supply rails and the output tend to cause instability problems. This may be in the form of high frequencies – beyond the audio spectrum – which result in distortion, high power consumption and over-heating of the i.c.

Stability may be restored by careful design of the p.c.b. layout, and by adding components such as resistor R6 in series with capacitor C4. This is known as a Zobel network and eliminates very high frequencies caused by the loudspeaker. The decoupling capacitors C6 and C7 also help to stabilise the circuit, and should be located as close to the i.c. as possible.

Diode D1 prevents the voltage at the 0V rail ever becoming more positive than the output and similarly, D2 prevents the output ever becoming more positive than the positive rail. This protects the i.c. against all known causes of disaster!



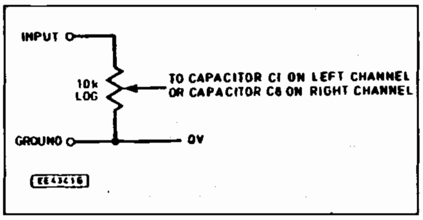


Fig. 2. Adding a Volume control to the Power Amplifier. A second potentiometer is required for the other channel, or use a dual (stereo) control.

STEREO PAIR

The two circuits of the stereo pair are identical. They may share the same power supply if preferred, but in this project the current requirements were more easily satisfied by using the supplies from two separate secondary windings on the mains transformer.

However, the 0V connections are joined at *one* point. Some care must be observed if the 0V or ground lines are connected at other points since an "earth loop" could be introduced, resulting in mains hum.

COMPONENTS

POWER AMPLIFIER

Resistors

R1, R2, R3	100k (3 off)	
R4	4k7	
R5	150k	See SHOP TALK Page
R6	1Ω	
R7, R8, R9	100k (3 of)	
R10	4k7	
R11	150k	
R12	1 Ω	

All 0·25W carbon film

Capacitors

C1, C8	1μ polyester layer (2 off)
C2, C9	22μ axial elect. 35V (2 off)
C3, C10	4μ7 radial elect. 63V (2 off)
C4, C11	0μ22 disc ceramic (2 off)
C5, C12	2200μ axial elect. 35V (2 off)
C6, C13	0μ1 disc ceramic (2 off)
C7, C14	100μ radial elect. 35V (2 off)

Semiconductors

D1, D2 D3, D4	1N4001 1A 50V rect. dode (4 off)
IC1, IC2	TDA2030 20W power amp. (2 off)

Miscellaneous

SK1, SK2	Phono chassis socket (2 off)
SK3	4-way spring-loaded, lever action, speaker connector

Console case (with metal sloping front panel), size 262mm x 160mm x 78mm; printed circuit board available from *EPE PCB Service,* code 852a (power amp); high power, twisted vane, heatsink (9·9°C/W), size 38mm x 28mm x 22m (2 off); loudspeakers to choice; screened audio cable; multistrand connecting wire; p.c.b. supports; solder triminal pins; solder etc.

Approx cost guidance only **£27** *excl. speakers*

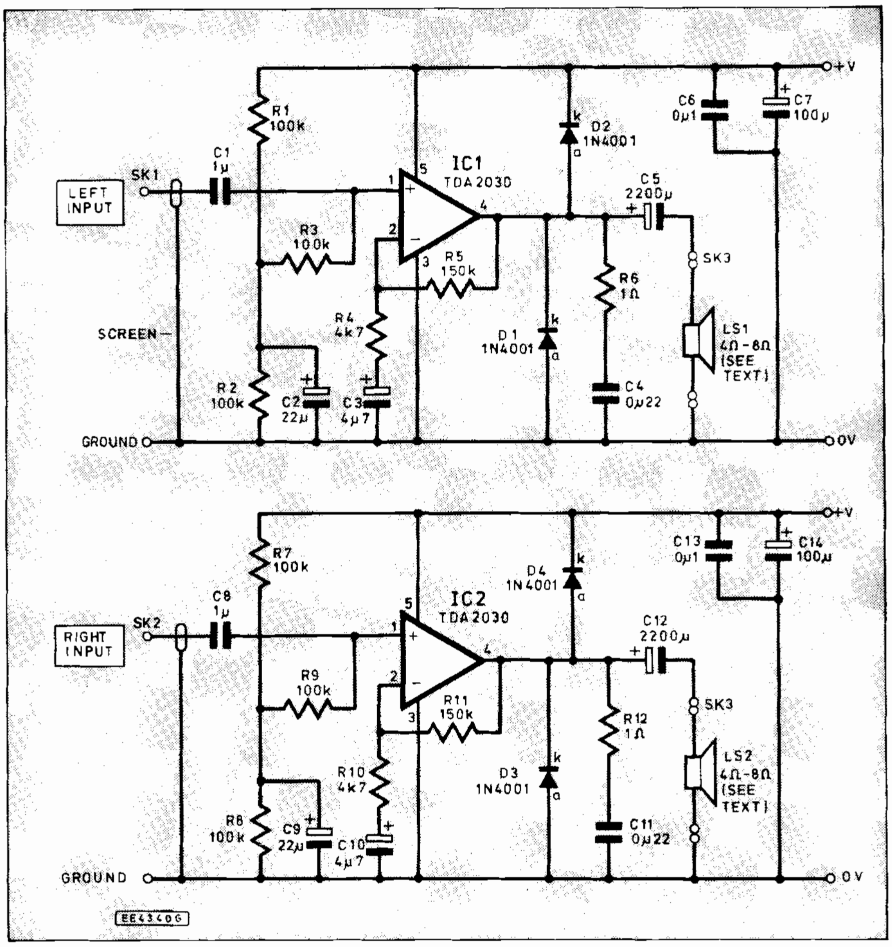
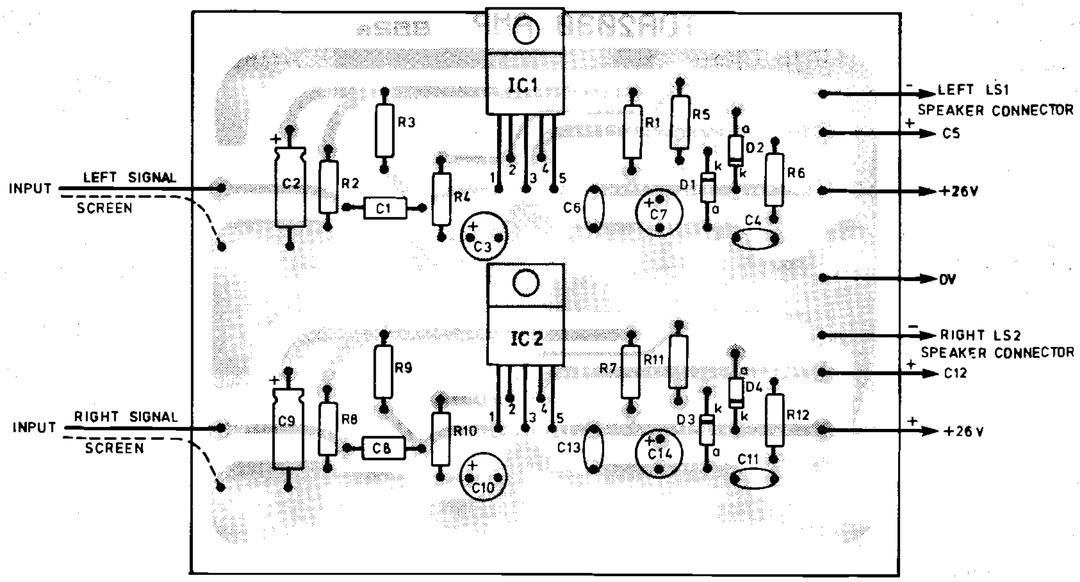


Fig. 1. Circuit diagram for the 10 plus 10 Stereo Power Amplifier



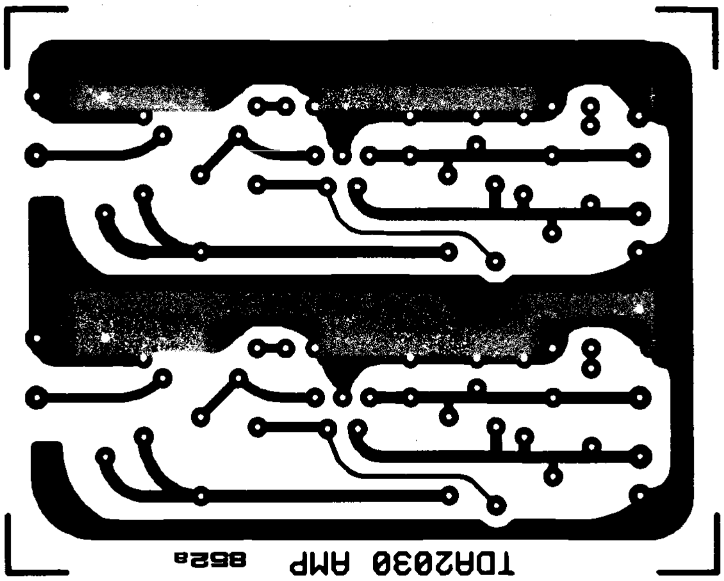


Fig. 3. Printed circuit board component layout and full size copper foil master pattern for the Power Amplifier.

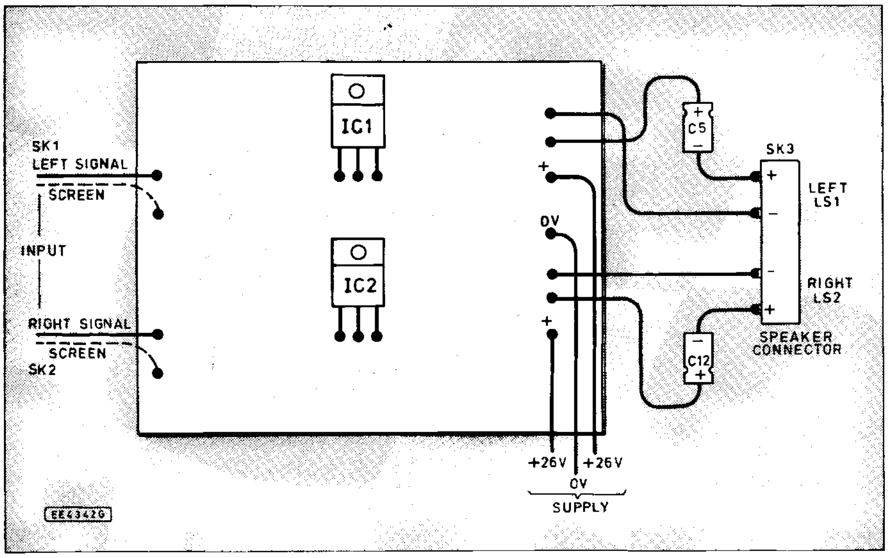


Fig. 4. Interwiring to the amplifier printed circuit board if it is to be used as an individual module.

CONSTRUCTION

The layout of this circuit is quite critical and use of the printed circuit board (p.c.b.) layout provided is recommended. Stripboard is unlikely to offer good results (see "Stability" above), and prototype board (breadboard) may fair even worse.

The p.c.b. topside component layout and the full size underside copper foil master pattern for the Power Amp. is shown in Fig. 3. This board is available from the *EPE PCB Service,* code 852a.

Begin construction by checking the TDA2030 i.c.s. Some are designed to stand upright, and others lie flat. If you have the lie flat types it may be wise to bolt on the heatsinks before inserting the i.c.s into the p.c.b. Check that the i.c.s will fit into the holes in the board, but do not solder them in at this stage.

The smallest components, such as resistors and diodes should be inserted and soldered in place first. Check that the diodes are the correct way round. Next insert and solder the smallest capacitors, noting that C1 (and C8) are non-electrolytic even though they are quite high in value.

The larger electrolytic types should now be inserted, checking that they are fitted the correct way round. The negative (−) side is generally marked on the capacitor body, and the positive side is indicated by a longer lead. Note capacitors C5 and C12 are mounted off the board at a later stage.

All the inter-board leads should be connected using p.c.b. terminal pins. These make life much easier, especially when installing the boards into the case. Ensure that the leads are colour coded and not too thin. Stranded wires (such as "extra flex") are ideal. If the amplifier board is to be used seperately, the interwiring to the p.c.b. is shown in Fig. 4.

Remember that *long* thin leads may result in instability. The audio input leads should be screened cable, with the outer copper "braid" connected to the power amp copper "ground" (0V) as shown; the other end of the screen is left unconnected.

Now solder in the i.c., first bolting on the heatsink if it is to lie flat against the p.c.b.

If you intend using the suggested case and layout, then the i.c. will eventually need to be gently prized into a 45 degree angle. Do this at the last moment, i.e. when installing the board into its case, since the i.c. will not tolerate a change of mind!

TESTING

Warning: If abnormal results are obtained during testing, switch off and check the polarity of the diodes and electrolytic capacitors. It is very easy to make a mistake, with disastrous consequences!

Each stereo half of the amplifier should be tested separately at this stage, using a 12V supply if one is available. A 100mA supply will test whether a fault exists, without damaging the circuit. However, a supply capable of delivering up to 1A will be required to test the *sound* quality.

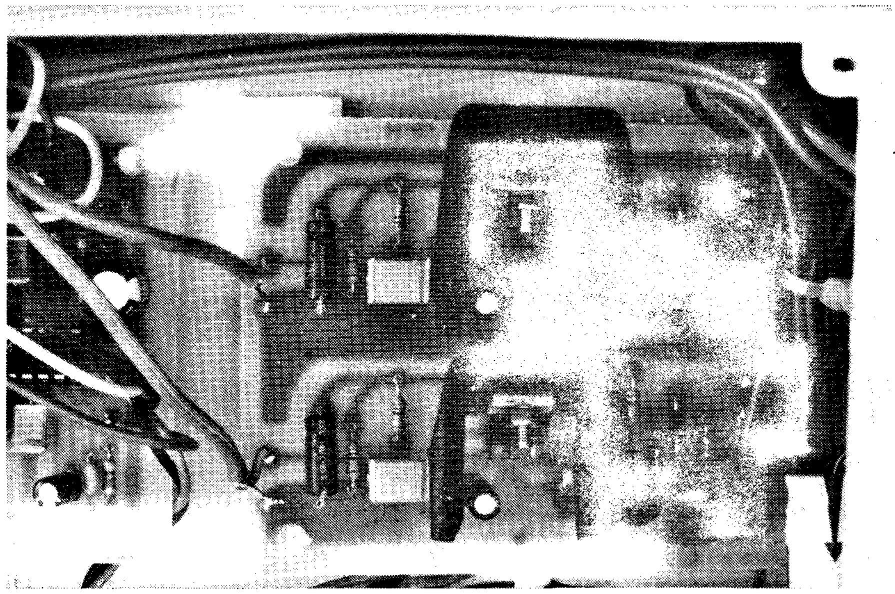
Connect capacitor C5 temporarily to the output, with the positive (+) side of C5 connected to the board solder pin which leads from the output of the IC1. One side of a speaker should be connected to the negative side of C5 and the other side of the speaker to the 0V line. (The same procedure should be adopted when checking the right channel i.e. IC2/C12).

Do not connect an audio input at this stage. Switch on. There should be no noise or hum from the speaker, the i.c. should not get hot, and the current used should be less than 50mA per stereo half.

If these conditions are not met, switch off without delay and check for faults. Bridges, and components the wrong way round are obvious problems; less obvious is overheating (and high current consumption) of the i.c., caused by instability. (The causes of instability were discussed earlier).

APPLYING AN AUDIO SIGNAL

A volume control is essential at this stage when applying an audio test signal. The amplifier should be connected to the output from the Audio Mixer or Tone/Volume Control Module (previous articles) or some other device where the volume can be controlled. Otherwise a volume control should have been included as shown in Fig. 2.



The completed power amplifier board showing the heatsinks bolted to the i.c.s.

Set the Volume control to a low level, apply an audio signal, and carefully advance the volume. Hopefully the signal will be played through the speaker.

As the volume level is advanced distortion will arise, the degree depending upon the voltage and current available from the supply. A 12V 1A supply should allow an appreciable level of sound, but the 26V supply suggested will result in an appreciable jump in quantity and quality.

FAULT FINDING

Try to use a regulated 12V supply if possible when fault finding, since it is easy to short circuit connections when taking voltage measurements. Begin by taking some d.c. voltage measurements using a voltmeter, without an audio signal. Connect the negative lead of the voltmeter to 0V in the circuit, and use the positive voltmeter lead as a probe.

Check the power supply pins on the i.c. pin 5 should be at the supply voltage, and pin 3 should be at 0V. Note that the pin numbers count from left to right when the i.c. is viewed from the front. The d.c. voltage at pins 1, 2 and 4 should be half the supply voltage.

Any errors in these readings indicates a short circuit, open circuit (e.g. a dry joint) a wrong resistor value, or an electrolytic capacitor or diode the wrong way round. If the voltage at pin 1 is wrong, check the voltage at the junction between resistors R1 and R2. An error here indicates that R1 or R2 or possibly R3 are not the correct values, or are not connected properly.

Further tests require an oscilloscope to monitor the a.c. audio signal through the circuit. When an audio signal is applied to the input there should be a small signal (e.g. about 1V or less, peak voltage) at pin 1 and a larger signal at pin 4. Note that there will be a constant d.c. voltage present. The oscillocope input should be switched to "AC" to remove the d.c. from the display. If the signal at pin 4 is not magnified check the values of resistors R4 and R5.

SYSTEM POWER SUPPLY

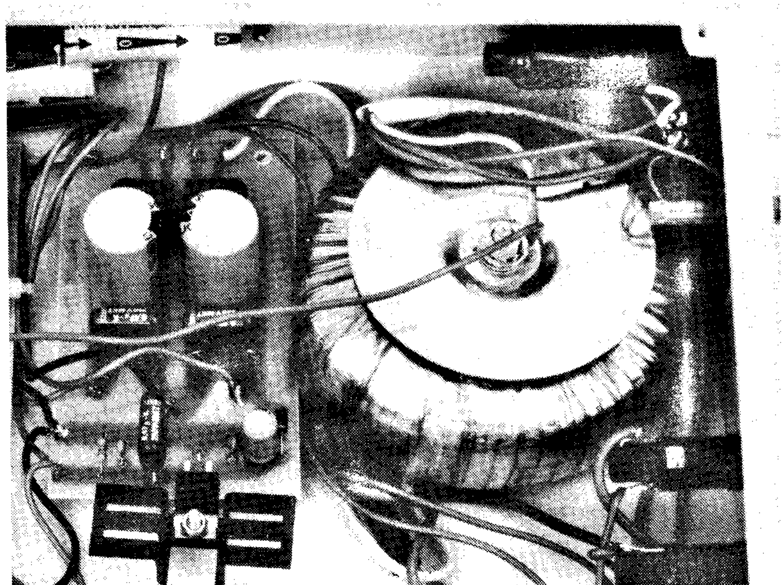
THE System Power Supply produces *two* unregulated outputs of 26V, plus a 12V *regulated* output. The two 26V supplies are designed for the power amplifier (one supply for each channel) and the 12V supply drives the tone control module and if required, the 6-Channel (12 mono) Stereo Mixer.

A regulated supply is not required for the single rail power amplifier since a slight change in voltage only affects the maximum sound level achieved, not the level at that particular moment. The amplifier could have been designed for a plus/minus 15V dual supply, but an even larger transformer would have been needed particularly to allow for the wasted power in the regulators.

The power supply for an amplifier always accounts for a significant part of the weight, size and cost, and this one is no exception. The average current required by each amplifier is less than 1A. However, it is essential to allow for the larger current required for the audio peaks, hence the choice of an 80VA toroidal transformer.

A 50VA transformer would also be satisfactory, and a standard (non toroidal) type could be used at about half the cost. However, a standard transformer might produce more magnetic interference, and will not fit inside the case specified.

The current required by the Tone Control Module is not particularly significant, and even with the Mixer connected to the same supply, the 12V regulator may be powered by one of the 26V supplies with no ill effect.



The finished power supply, with "gull-winged" heatsink, sits next to the toroidal mains transformer.

CIRCUIT DESCRIPTION

The complete Circuit diagram for the System Power Supply is shown in Fig. 5. The a.c. mains is delivered via switch S1 and a mains neon, with intregral resistor, indicates the presence of the supply. An anti-surge fuse is suggested for FS1 since the type of transformer used causes a high initial surge of current to flow at switch on.

The transformer is a toroidal type rated at 80VA with 2 × 18V secondaries (Maplin code YK17T). Toroidal transformers are more expensive than standard transformers, but produce a lower magnetic field and a well regulated supply. The type chosen also fitted easily into the case which was chosen to match the Audio Mixer.

However, if a different case is used, and the supply is not required to power the mixer, a 50VA chassis mounting transformer with a 2 × 20V output will probably work just as well, and costs half as much, although *care* must be taken with the layout since magnetic interference from the transformer could cause "mains hum".

Since the two 26V supplies are identical, only one will be described. The 18V a.c. output is changed to d.c. by the bridge rectifier REC1, and smoothed by capacitor C1. The voltage across the capacitor rises to nearly 26V d.c. which represents the approximate peak level of the 18V a.c. supply.

However the current available drops from the 2·22A output from the transformer to 1·6A. This is more than sufficient to drive the power amplifier and 12V regulator which in turn powers the tone control module and mixer. Capacitor C3 removes any spikes present on the supply.

Diode D1 allows current to flow and charge capacitor C5, which provides a smooth supply for the regulator IC1. This converts the supply to a very stable 12V, with current limited to 1A. This is much more than required, since the Tone Control Module and Mixer together require less than 100mA. Capacitors C6, C7 and C8 remove any spikes present on the supply rails.

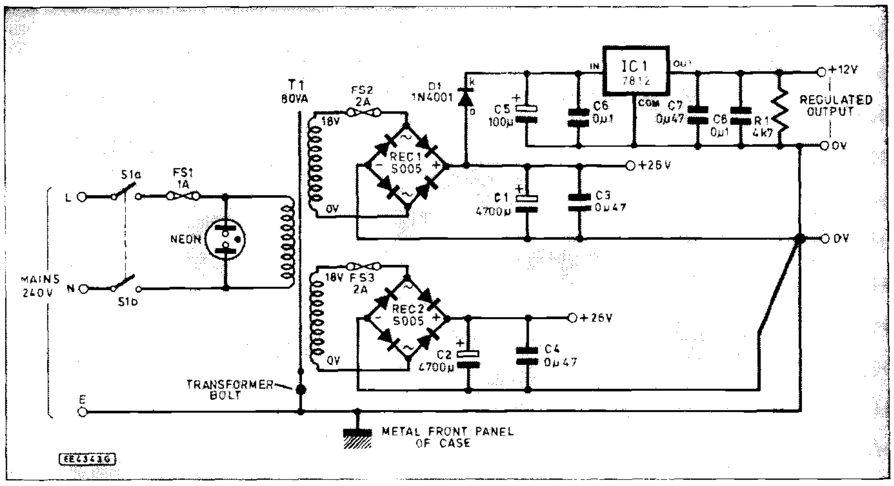


Fig. 5. Full circuit diagram for the System Power Supply. Note the common 0V point.

CIRCUIT LAYOUT

Some care is required to ensure that the amplifiers in the p.c.b. design etc. receive a stable, spike free supply. Substantial copper tracks have been used in the p.c.b. design and the 0V supplies have been

COMPONENTS — SYSTEM POWER AMPLIFIER – CONSTRUCTION

POWER SUPPLY

Resistors
R1 4k7 0·25W carbon film

Capacitors
C1, C2 4700µ radial elect. 35V (2 off)
C3, C4, C7 0µ47 polyester metallised (PEPT) film, 100V (3 off)
C5 100µ radial elect. 35V
C6, C8 0µ1 disc ceramic

Semiconductors
D1 1N4001 1A 50V rect. diode
REC1, REC2 S005 2A bridge rectifier (2 off)
IC1 7812 +12V 1A voltage regulator

Miscellaneous
T1 80VA toroidal mains transformer, with 2 x 18V secondaries
FS1 20mm panel fuseholder, with 1A anti-surge fuse
FS2, FS3 20mm panel fuseholder, with 2A quick-blow fuse (2 off)
S1 D.P.D.T. mains on/off toggle switch

Printed circuit board available from the *EPE PCB Service*, code 852b (power supply); neon mains indicator; TO220 top mounting heatsink; p.v.c. fuseholder insulating boot; p.c.b. supports; earthing solder tag; multistrand connecting wire; power output plug and socket (see text); solder etc.

Approx cost guidance only **£28**

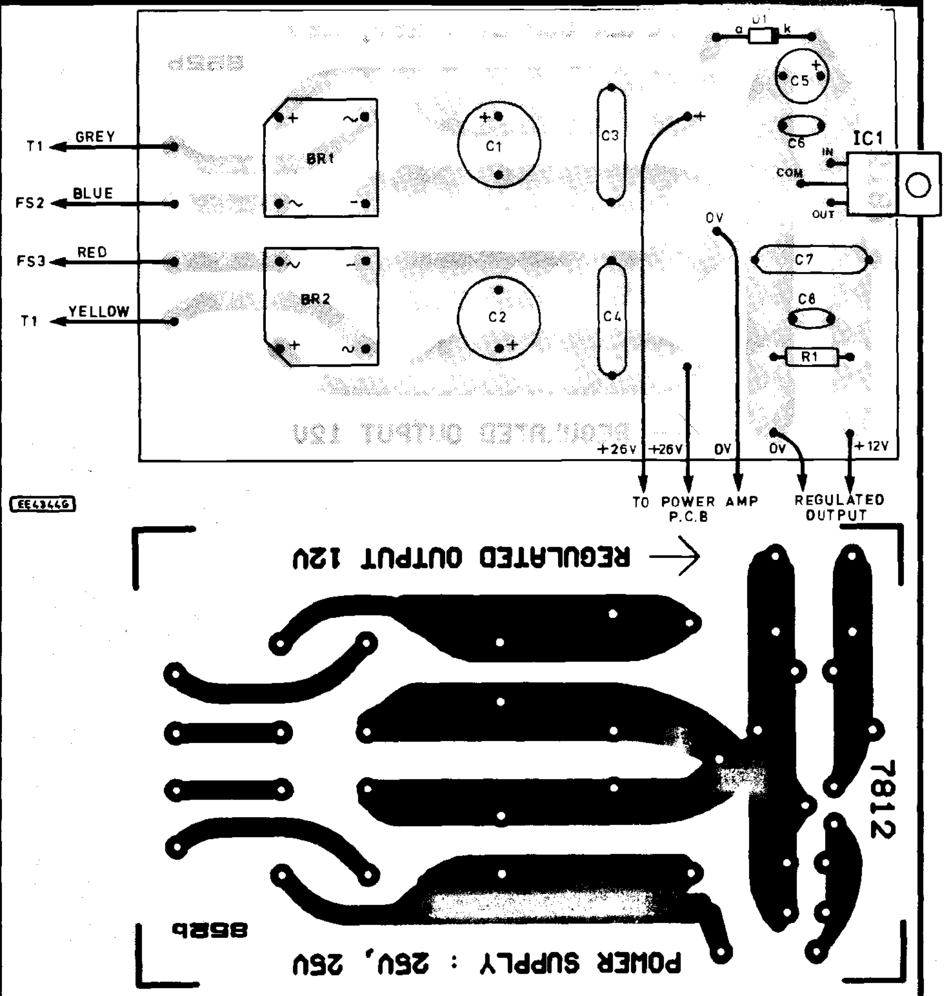


Fig. 6. System Power Supply printed circuit board component layout and full size underside copper foil master pattern.

joined at a single point to help avoid "earth loops".

The 0V point is also connected to the mains "Earth". However this could be removed if the screen or ground connection elsewhere in the audio system is connected to the mains "earth" at any other point.

CONSTRUCTION - POWER SUPPLY

The Power Supply printed circuit board topside component layout and full size underside copper foil master pattern is shown in Fig. 6. This board is available from the *EPE PCB Service*, code 852b.

Begin construction by soldering in the smallest components, such as small capacitors, diode D1 (the correct way round) and the resistor. Be careful to fit the bridge rectifiers REC1 and REC2 the correct way round *(in mirror image fashion)* as shown in Fig. 6 and Fig. 7..

The leads of the 12V regulator i.c. (type 7812) should be bent slightly since the p.c.b. pads are not in line. Placing the pads out of line allows large solder joints to be made without the risk of bridging. Next solder in the terminal pins ready for the wire connections to be made later.

Finally, insert the large electrolytic capacitors, taking great care to fit them the correct way round. The negative side is marked on the body of the capacitor, and the positive side is indicated by a longer lead. Remember that these capacitors are likely to rupture if used with the wrong polarity (i.e. the wrong way round). A small heatsink should be fitted to the regulator i.c.

TESTING

It is always wise to test a power supply with a voltmeter before connecting it to another circuit! If an a.c. supply of between 6V and 20V is available it could be connected to the input of the p.c.b., with a d.c. voltmeter monitoring the output. Otherwise testing will have to wait until the transformer is *safely* installed into the case, and connected to the mains supply.

Avoid the temptation to connect the mains transformer before dealing with the case; this is both difficult and highly dangerous.

CASE DETAILS

The case must be large enough to house the two power amplifier circuits (which will normally be housed on a single p.c.b.), the power supply p.c.b., and tone control module, together with the mains transformer fuses etc. Space is also required for the heatsinks and the volume/bass/treble/balance controls which are fitted to the sloping metal front panel. A case was chosen to match the Audio Mixer but some care is required both to ensure that all the items fit, and that there is no interference between the a.c. supply and the sensitive audio circuits.

The suggested internal layout showing the positioning of the p.c.b.s is shown in Fig. 8. The amplifier heatsinks will fit, providing the i.c.s are carefully bent into a 45 degree angle. Note that the heatsinks will be at 0V – *Do not let them touch any other metal surface.*

FRONT PANEL

The layout of the front panel is determined to some extent by the components underneath. You can use the template from last month (Fig. 10), if you are including the Tone Control, the hole spacings are the same but the overal size is larger. Make two

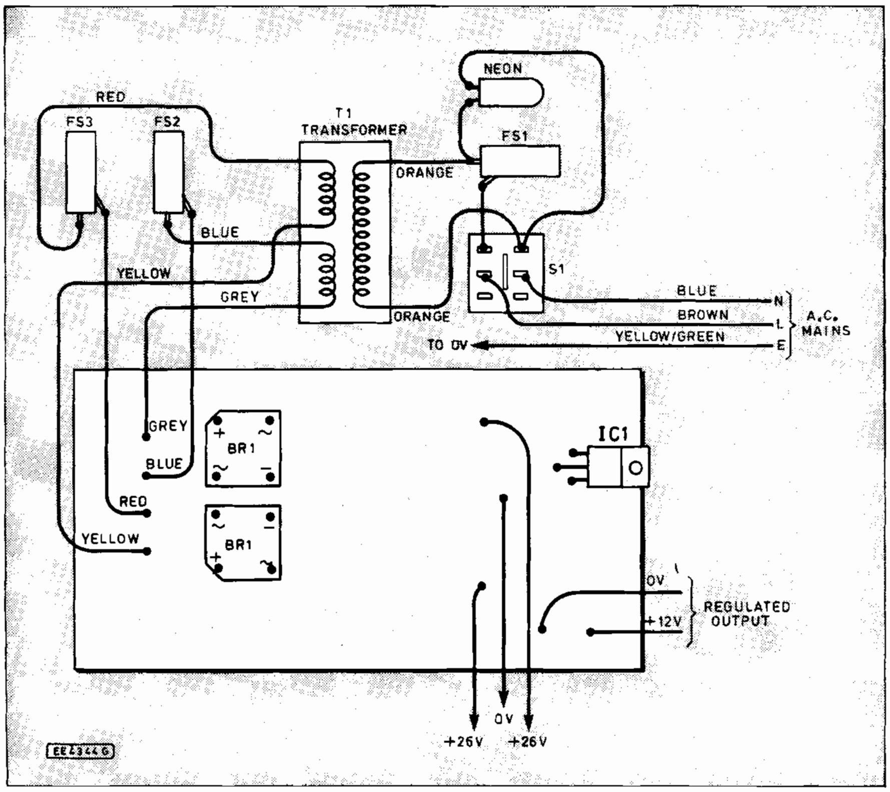


Fig. 7. Interwiring from the circuit board to the toridal mains transformer and other off-board components.

copies, so that one may be taped in position on the front panel for drilling and the other, covered with material, for the finished panel.

Changing the positions of the potentiometers (pots) or switches should be done with caution, checking that there is sufficient clearance below the metal panel. Fortunately the audio signal does not pass through the wires linking the pots. with the tone control circuit, so screened leads are not required.

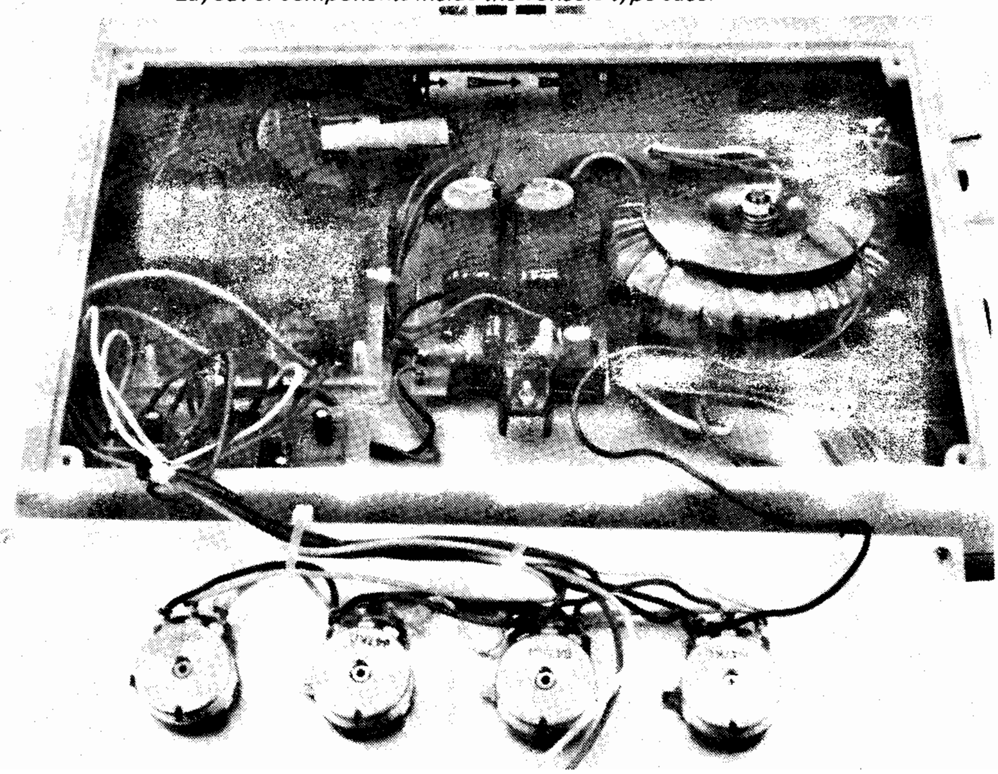
Begin case preparation by carefully marking out all the holes required in the case. Some extra ventilation holes in the base and at the back are desirable, since the heatsinks become quite hot when the amplifier is driven at high levels.

The loudspeaker output connectors provide a convenient method of connecting bare loudspeaker wires to the amplifier, and require six holes, two for mounting with M3 nuts and bolts, and one for each terminal. Two other holes are required at the back for the phono input connectors.

A power output socket was provided in the side of the prototype to enable the Audio Mixer to be powered. It may be wise to fit a different type of connector, since plugging in an external power unit to this output socket would damage the regulator i.c.

Five holes are required in the right hand side panel, three for the fuseholders, and one each for the mains cable, mains switch and neon. The mains devices are best positioned in the least accessible place, behind the transformer. However, check that there is sufficient clearance, bearing in mind that the transformer must be fitted at the right hand side of the case to allow space for the p.c.b.s.

Layout of components inside the console type case.



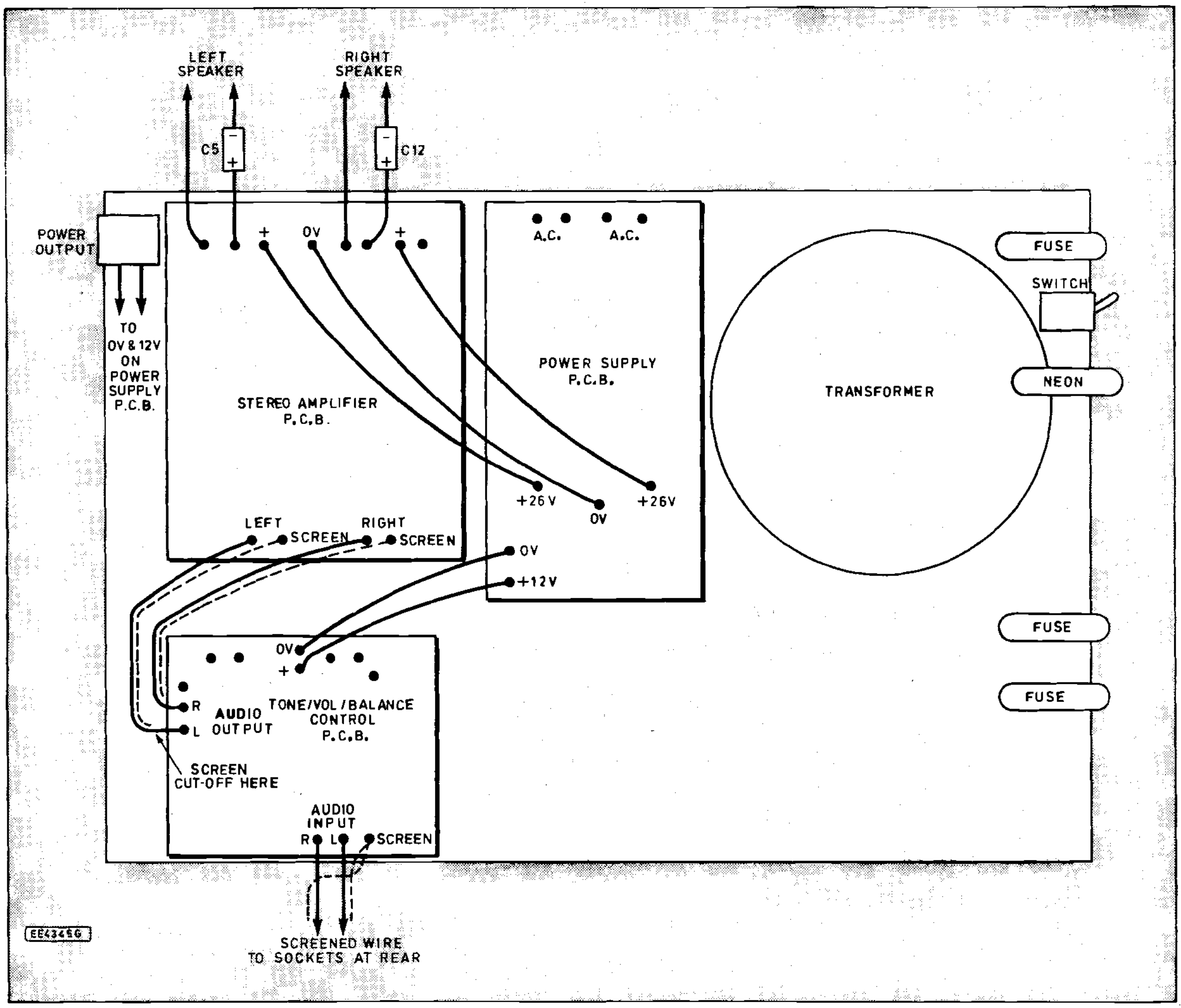


Fig. 8. Positioning and interwiring between the Stereo Power Amplifier, Tone Control and System Power Supply printed circuit boards. All mains connecting terminal points at the fuse, transformer, switch and neon must be covered with insulating sleeving.

The transformer is mounted on the base of the case using the single bolt provided. A word of caution here! Two large flexible washers are provided to sandwich the toroidal transformer, together with a dished washer which is placed on top. When the bolt is placed through the case, and tightened, the case will distort and possibly break. An old piece of p.c.b. or stripboard, about 9cm. square placed between the flexible washer and the case will help prevent damage. However, do not overtighten the bolt.

If the amplifier is housed in a metal case, ensure that the transformer mounting bolt does not touch the top of the case as well as the bottom. This is because the bolt will act like a shorted transformer winding, and generate a large quantity of heat.

TRANSFORMER CONNECTIONS

The only exposed mains connections are the tags of switch S1 and the mains fuse holder. If these are insulated with suitable sleeving there is little risk of shock even if the unit is tested with the front panel removed.

The instructions supplied with the transformer should be checked, but it is likely that the orange coloured leads are connected to the 240V primary coil. Connect the mains circuit as shown in Fig. 7, noting that the mains Earth (E) is joined to the metal front panel.

The two secondary windings are likely to be coloured Red/Yellow, and Blue/Grey. Connect these leads exactly as shown in the diagram, including the protective fuses in the circuit.

INTERWIRING

How the p.c.b.s are arranged in the case and interwired is shown in Fig. 8. They may be mounted using self-adhesive p.c.b. supports and/or the self-tapping screw mounting holes provided in the case.

Complete the wiring between p.c.b.s *after* mounting them in position (assuming terminal pins have been used) in order to route the leads neatly around the boards. D.C. power leads should be colour coded red and black and should not be too thin. Stranded wires will give the best results; keep them as short as possible, but route them neatly around the edges of the p.c.b.s.

All audio connections must be made with *screened* cables. The screen braiding of the lead which connects the Tone Control Module to the Amplifier should be neatly cut away at the Tone Control p.c.b. end of the cable, since the 0V connection is made via the power supply and a possible "earth loop" will be avoided.

The tone control pots. and switch are best connected at this stage since the wires can be cut to an exact length. However, it is likely that they will have already been connected in order to test the tone control module, in which case they can either be removed, or bound up neatly. Since they only carry d.c. supplies (not the audio signals) no precautions need be taken regarding screening.

FINAL TOUCHES

The photocopy of the front panel, which has been covered with self-adhesive book covering material, should be attached to the metal panel, behind the controls fixing bolts and washers, using thin glue or Pritt stick. It may be possible to reverse the image and produce a white on black copy.

Finally screw the front panel into place, trim the shafts of the pots. to a suitable length and fit the control knobs. Calibrated control knobs are suggested to provide a neat finish.

THE MOMENT OF TRUTH

If the mains transformer has been connected for the first time, it is worth checking that the supply to the power amps is about 26V while there is time to switch the unit off!

All being well, and assuming that each module has been individually tested during its construction, the chances are that the whole project will work with little trouble. When fitting the front panel in place, ensure that the flexible cables do not touch any of the heatsinks. If necessary, support the wires with cable ties. The final step is to connect the mixer unit, sit back, and marvel at your craftsmanship.

Next Month: We add the option of a Balanced Stereo Microphone Pre-Amplifier module. This type of pre-amp is essential for high quality work.

ELECTRONIC TESTING AND FAULT DIAGNOSIS

MIKE TOOLEY BA

Mike Tooley examines one of the latest distance learning offerings from the National College of Technology.

THE National College of Technology (NCT Ltd.) was founded approximately seven years ago. Since then it has provided training for several thousand students and currently has over 900 students taking courses. It is interesting to note that 85 per cent of NCT's students are industrial practitioners (mostly engineers and technicians) whilst the remaining 15 per cent are hobbyists and enthusiasts.

NCT is no stranger to the development of electronics distance learning courses. The college has now produced more than a dozen distance learning packages, including several popular courses dealing with analogue electronic circuits, digital circuits, and programmable logic controllers.

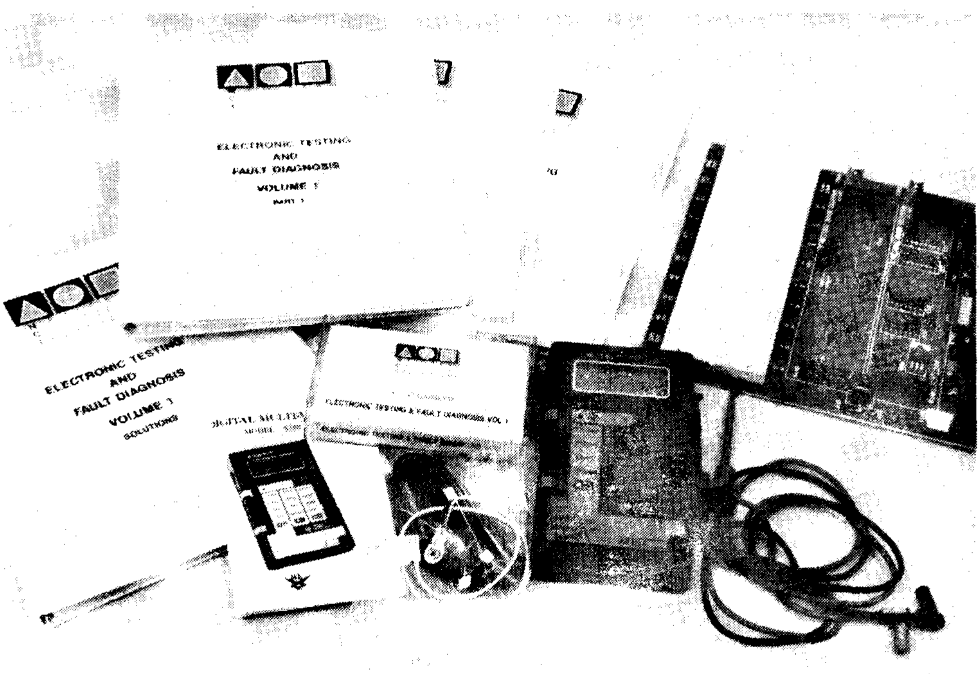
NCT's clients include colleges and firms as well as independent learners. Many colleges have used NCT packages as an integral part of "bridging" courses where students use distance learning material to "top up" their existing knowledge to a point which can allow them to join a conventional full-time or part-time BTEC programme.

Employers, on the other hand, tend to use NCT courses as a means of developing particular skills that are in short supply. Distance learning is a particularly cost-effective way of doing this without having to recruit specialist staff.

ELECTRONIC TESTING

NCT's latest course is delivered in two Volumes entitled *Electronic Testing and Fault Diagnosis*. Volume 1 has been designed to lead on to Volume 2 however, students with some previous experience may find that they can move straight to Volume 2. The contents for Volumes 1 and 2 are summarised in Tables 1 and 2, respectively.

Each of the two course Volumes involves more than 65 hours of study. NCT provides a suggested timetable which should suit the vast majority of students. This timetable gives suggested times for each of the course assignments but these are for guidance only (individual students may find that they need more or less time depending upon their own individual circumstances and, in particular, the level of previous experience that they may, or may not have.



As with other NCT courses, the learning process has been designed around a series of practical assignments which enable students to learn from hands on experience. The study time for these assignments varies from about 1 to 4 hours. Volume 1 contains 80 student centred assignments and over 120 self test questions.

More than 100 student centred assignments and 114 self test questions are provided in Volume 2. In addition, those who have registered for NCT tutoring support will have three test papers to complete. For this reason, NCT's students will not be able to complain that they don't have enough work to do!

DISTANCE LEARNING

Distance learning provides an alternative to conventional day release, evening and short courses held at technical and further education colleges and other training centres. Distance learning is inherently more flexible than conventional learning methods; you can study at a time and pace to suit you. This means that you can structure your learning experience to occupy the time that you actually have available - you don't need to attend your local college on a regular day or evening each week.

The better distance learning providers, NCT included, make available tutor support. This is an important aspect of a distance learning course since, however good the materials you are provided with, there will always be questions and problems that are best resolved by discussion with a tutor. Furthermore, the fact that there *is* a named person available at the end of a telephone can be a great reassurance.

You probably won't need to talk to your tutor on a regular basis but the simple fact that he or she is there and ready to share your problems can be instrumental in giving you extra confidence to tackle concepts that you might otherwise be completely unfamiliar with.

Distance learning also requires that you have all of the support materials and hardware available that would be provided as a matter of routine in a conventional learning centre. In the case of an electronics course, this means not only providing the electronic components that you may need to carry out practical circuit construction but also the provision of a means of connecting the components together (i.e., "breadboarding") and testing the circuits when they are completed.

Contents of Volume 1 (left).

Table 1
Contents of Volume 1

PART 1	
Introduction to your course	
Assignment 1.	Know your circuit board
Assignment 2.	Testing your printed circuit board
Assignment 3.	Introducing Integrated Circuits
Assignment 4.	Resistors
Assignment 5.	Voltage measurements
Assignment 6.	Use of the Ohmmeter
Assignment 7.	Testing series circuits 'A'
Appendix 1.	Resistor E – ranges
PART 2	
Assignment 8.	Cells and Switches
Assignment 9.	Current measurements
Assignment 10.	Ohm's law
Assignment 11.	Testing series circuits 'B'
Assignment 12.	Testing parallel circuits
PART 3	
Assignment 13.	Testing series/parallel circuits
Assignment 14.	Digital numbers and logic
Assignment 15.	Testing the INVERTER gate
Assignment 16.	Counting in binary
Assignment 17.	Testing the AND gate
Assignment 18.	Testing & Diagnosis Workshop 'A'
Assignment 19.	Testing & Diagnosis Workshop 'B'
Course Topic Reference	

Table 2
Contents of Volume 2

PART 1	
Introduction to your course	
Assignment 1.	Essential revision and workout
Assignment 2.	Soldering techniques 'A'
Assignment 3.	Capacitor testing
Assignment 4.	Testing RC circuits
Assignment 5.	Using the analogue multimeter
Assignment 6.	Shunts and multipliers
Appendix 1.	Capacitor codes
Appendix 2.	Recharging your gas soldering iron
Appendix 3.	Integrated circuit pin-out references
PART 2	
Assignment 7.	Soldering techniques 'B'
Assignment 8.	The fundamentals of semiconductor devices
Assignment 9.	Diode tests, characteristics and fault diagnosis
Assignment 10.	Circuit construction and testing 'A'
Assignment 11.	The transistor – serviceability testing
Assignment 12.	Transistor circuits and characteristics
PART 3	
Assignment 13.	Transistor biasing and testing
Assignment 14.	Understanding and testing the NAND gate
Assignment 15.	Logical specifications and operation
Assignment 16.	The 555 timer
Assignment 17.	Circuit construction and testing 'B'
Assignment 18.	Workshop 'A', Circuit construction
Assignment 19.	Workshop 'B', Assembly and test

All this means that a great deal of care and thought has to be put into planning the contents of the practical assignments and the contents of the kits that accompany a distance learning package.

SUCCESS FACTORS

At the outset it is important to realise that successful completion of a distance learning course depends almost entirely on two factors; the level of personal commitment on the part of the individual student and the quality of the material and learning support provided. NCT are well aware of this and have, as a result, made a great deal of effort to ensure that the learning materials are of a very high standard.

Successful electronic fault diagnosis, on the other hand, depends upon the depth of understanding of the behaviour of electronic components, circuits and systems. Diagnostic technicians rely very heavily upon their knowledge of how a device *should* work when it is functionally sound. Only when this knowledge is adequate can a technician fully appreciate that a circuit *has* developed a fault condition. Furthermore, a thorough understanding of circuit behaviour is essential if a technician is to be able to diagnose the cause of a problem *and* how it should be corrected. The NCT course aims to impart just this sort of information.

CERTIFICATION

One of the major attractions of the NCT courses is that they can lead to the award of a nationally recognised certificate. This provides students with some tangible evidence of their achievement which can be used to enhance employment prospects and also as a means of progression to other awards at equivalent or higher levels. These Certificates are awarded by a well respected body, the Business and Technology Education Council (BTEC).

Recognising that perhaps not every student will want to obtain a certificate (actually, the vast majority do!), NCT have made the BTEC assessment component optional with a modest additional fee to cover registration and certification.

PHASE TESTS

Students who wish to qualify for a certificate must achieve a certain level of attainment on each of the three phase tests supplied with each Volume of the course. The phase tests are designed to check the student's understanding of each part of the course but they can also be taken at the end of the course if a student decides to register for certification at a later stage.

Where students may be unsure of the required level of performance, NCT's tutors will provide advice and guidance. Most students will not find this aspect of the course particularly arduous and the vast majority of NCT's students do register for tutor support and do obtain the BTEC Certificate of Achievement when they complete the course.

HARDWARE

NCT believe in supporting their distance learning packages with sufficient hardware to carry out a large number of practical assignments. In the case of *Electronic Testing and Fault Diagnosis*, this naturally extends to soldering and measurement techniques using digital and analogue multi-range meters and a logic probe. The digital multimeter (a 3½-digit l.c.d. instrument) is supplied with Volume 1 whilst the analogue test-meter (which offers 2kΩ/V loading on both a.c. and d.c. ranges) comes with Volume 2.

A neat portable gas-powered soldering tool provides students with a means of practising basic soldering technique. It is also the means by which two of the circuits used in the later assignments for Volume 2 are assembled onto stripboard. Nor has NCT forgotten the need for a soldering iron stand – a large paper clip is supplied together with instructions for bending it to form a simple but nevertheless effective holder!

NCT's experimental motherboard is neat and well thought out. It contains a prototyping breadboard area with space for up to six standard 14 or 16-pin d.i.l. packaged integrated circuits, an on-board +5V regulator, and a number of l.e.d.s, drivers and switches. The motherboard also has space for two smaller daughterboards which can be used to further extend the range of functions.

Contents of Volume 2 (right)

The motherboard is screen printed with component legends and well made. Its layout is logical and this makes it easy to understand and use. If you have never made use of a breadboard before, NCT's hardware and detailed instructions should make this a very simple and totally painless experience! Finally, it is worth noting that NCT's motherboard is used on other courses and students will be able to make further use of it at some later date.

AUDIO CASSETTE TAPE

The audio cassette tape supplied by NCT is used, together with the course books at regular intervals throughout the course. As with other NCT courses, a cheery female voice welcomes you to the National College of Technology and reminds you that tutor support is available to all registered students. She explains that if you are attending a conventional college, the role of tutor will be performed by your college lecturer.

The introductory part of the audio tape explains the basic concepts of the course and briefly describes the constituent parts of the NCT package. All of this information is available in writing but NCT's friendly voice reinforces this and helps to remind you what the course is all about.

Undoubtedly the two most important parts of this introductory audio material is the advice given on setting aside study time on a regular basis. The discipline of a regular learning routine should not be underestimated. Such a routine can take the form of a number of short study periods at regular times dispersed throughout the week or perhaps just two or three longer periods each week.

THE TEXT

In each of the Volumes, NCT supplies three course books together with a book containing fully worked solutions to the assignments. This is where the NCT course really excels. The text is very thorough and it leaves very little to chance as the reader is guided gently but firmly through each of the Assignments and Workshops. At all times, the approach is both friendly and logical.

NCT believe that all study should be enjoyable and the course books have been written in a style which not only emphasises the essential points but also gives the learner a great sense of achievement. At times, the writing style is perhaps too chatty. Comments like; "*Phew that was a marathon but you are truly introduced to the soldering technique. You had better take a break.*" and "*Now for some sneaky test questions, moan!*" are a little unnecessary. You either like this style or you hate it...

ASSIGNMENTS AND WORKSHOPS

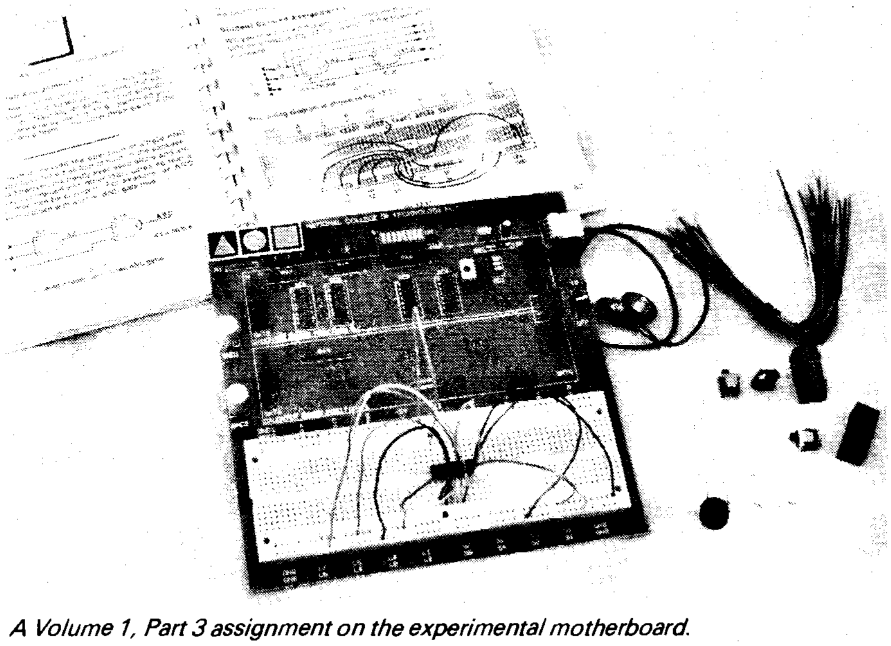
Each of the course assignments is fully described within the books that accompany each part. Each assignment is presented with a list of learning outcomes. As an example, the third Assignment from Volume 1 is entitled "Introducing Integrated Circuits" and it should be completed within about 2 to 3 hours. When the assignment has been completed, students should be able to:

- Understand why the word "integrated" is used.
- Understand the terms "chip" and "d.i.l." pack.
- Explain how d.i.l. packs are assembled.
- Identify d.i.l. packs and their pin numbers.
- Test i.c.'s as the course proceeds.

Later in Volume 1, students are involved in a "Testing and Diagnosis Workshop". This constitutes the eighteenth assignment and it has been designed to take about four hours to complete. The learning outcomes for this assignment are that students should be able to:

- Test and understand the behaviour of series circuits.
- Test and understand the behaviour of parallel circuits.
- Test and understand the behaviour of combinational circuits.
- Deduce causes of faults in all of the above.
- Conduct remedial action to overcome the faults within circuits.

The first assignment in Volume 2 provides essential revision (including resistor colour codes, using a digital multimeter to measure voltage, current and resistance, calculations involving voltage, current and resistance, binary to decimal number conversion, and truth tables.



A Volume 1, Part 3 assignment on the experimental motherboard.

The structure of the Volume 2 course is to have an on-going project within the text. As the student increases his/her skills level so the project is expanded until all the various parts of the project are connected together to form a composite working system.

The last assignment in Volume 2 (entitled "Workshop B: Assembly and Test") is designed to take about 4 hours to complete and it allows students to:

- Examine the correct behaviour of a 555 timer in an astable mode.
- Test the operation of a transistor circuit.
- Drive the transistor circuit from the 555 circuit.
- Test the combined circuit operation.
- Verify the correct operation of a diode circuit.
- Drive the diode circuit from the transistor circuit.
- Test the completed circuit assembly.

The workshop sessions are extended assignments which aim to establish the fault conditions which students may well encounter in practice. Unlike the assignments which lead up to them (most of which deal with a specific topic) the workshop sessions provide a specific range of techniques for circuit testing and encourage students to develop a structured and systematic approach to fault finding. NCT's workshops succeed admirably in putting the under-pinning knowledge developed as the course progresses into practice.

Where students have opted for tutor support, NCT reserve the right to call in students' completed workbooks so that they can be examined by an external (BTEC appointed) assessor. This is only likely to happen within 90 days of the completion of the course and all submitted material is returned to students. As is normal practice with BTEC approved programmes, certification is only likely to be withheld if the prescribed minimum standard has not been reached or if the course books have not been satisfactorily completed.

IN CONCLUSION

NCT's new offering can be very highly recommended. Students who successfully complete the course will have acquired a range of useful skills and should be capable of dealing with routine fault-finding on a wide variety of basic electronic circuits. Course volumes three and four are already in the pipeline and these will enable students to study more complex systems using the basic skills from the earlier courses. So, if you are a looking for a means of developing your own fault-finding competence and one that will lead to a recognised BTEC certificate, you need look no further!

The National College of Technology can be contacted at PO Box 11, High Street, Wendover, Bucks., HP22 6XA. Tel: (0296) 624270. Volume 1 of the Electronic Testing and Fault Diagnosis course costs £199, Volume 2 costs £210 (plus VAT and carriage). Students with previous experience who opt to start at Volume 2 must also to invest in a "start-up" kit priced at £69 (VAT and carriage extra). NCT tutor support for each Volume costs a further £29.50 (plus VAT). Alternatively, the combined fee for tutorial support and BTEC registration is £51 (plus VAT).

FOX REPORT

by Barry Fox

Wharfedale Revisited

The first time I visited the Wharfedale factory, some twenty years ago, it was at Idle, near Bradford. Founder Gilbert Briggs had by then sold out to Rank and the company had grown a large research and development division.

Wharfedale hosted open days for the press every year and we saw what the researchers were developing, and heard their theories on sound. We also visited the loudspeaker factory and saw the production lines.

I was always very impressed with the research and development. The division employed some of the best engineering brains in the country who worked with a large anechoic chamber, and developed some of the first laser holography and computer equipment for analysing cone performance.

But year after year I reckoned that the factory production lines were only busy because Japanese factories could not compete on price when shipping speakers, which are largely empty boxes of heavy wood, across the world. Although the work staff was loyal, Wharfedale's production lines were very old and inefficient, and the unions were resisting change.

Over the years Wharfedale tried to improve its lines, but there was no real incentive because the Japanese still could not compete on price and were often buying Wharfedale speakers for sale with Japanese rack systems. In 1979 Wharfedale made a million speakers. But things slid downhill and in 1982 Rank sold out to a private owner, Peter Newman. By 1985 the company had moved out of the large Idle factory and into smaller premises in Crossgates, Leeds.

Things then slid even further downhill In all there were ten different managing directors in twelve years. The once famous name Wharfedale ended up as a "W" logo on a lot of very "samey" black box loudspeakers. For a while it looked as if Wharfedale would disappear altogether, going the same way to oblivion as other famous British hi fi names like Leak, Garrard and Armstrong. But in October 1992 Mission merged with Wharfedale under Verity Group PLC.

Mission Control

Mission's founder Farad Azima admits that Verity found that what it had bought was "grim – much worse than we were led to believe". Wharfedale was very heavily in debt. In August 1993 Verity completely re-structured Wharfedale, with Hong Kong OEM supplier Tomei buying 7·7 pre cent.

"This gives Wharfedale the chance to move into affordable electronics, by using Tomei's Far Eastern manufacturing base" says Azima. "Press reports of a tie-up with Sansui are not true. Tomei owns distributor Cascade in the UK and Cascade distributes Sansui in the UK. That is the only connection."

Technical Director Stan Curtis tells what Verity found when they looked at Wharfedale's factory and warehouse in Leeds.

"Stock supposedly worth several million pounds, was covered with a half inch layer of dust, with ten year old company labels. We just got rid of it. You have never seen so many skips lined up.

"The company was adopting the scatter gun approach. It had lost its way. The last new driver was made in 1984. The company had gone off into making esoteric products, like the ceramic dome tweater which must have been the most expensive audio product ever designed in the UK. It cost £37 to make, and was on the parts list at £3.

"The Option One dipole loudspeakers cost £10,000 a pair. The company only sold seven and one pair was given away. There were a thousand different drive units and several hundred different loudspeaker models. Wharfedale would make anything for anyone who asked for it, even for short runs where tooling up would cost more than the profit.

"But Wharfedale had a very loyal workforce, and is very good at manufacturing drivers. Wharfedale very nearly died. Anyone with business sense and no commitment to the audio industry would have just walked away.

Moving Ahead

"We are now moving Wharfedale away from the hi fi niche. We want to capitalize on the name. Everyone knows someone who has at some time bought a Wharfedale speaker so they know the name. We have got a new logo. The old one looked old-fashioned and a 'W' means nothing. Wharfedale were making loudspeakers that sounded good, but they now look very dated."

The new Modus Vivendi range (Latin for "way of life") is based on modular design; black rounded cubes with a mid/l.f. driver inside and a tweeter on top that can be turned by hand. The whole range uses just five drivers, two tweeters and three mid/l.f. units. The plastic moulded cubes can be clipped together with wooden planks to make a wide range of different sized cabinets. Curtis calls it his Leggo kit.

The first prototypes are just coming off the moulds. Production quantities left the factories just before Christmas, for sales in January. There will be a big push for the US market in Las Vegas in January with sales and distribution handled by Verity, North America. There will be a remote control Dolby Pro Logic amplifier in January, too.

"Wharfedale will not be Mission's B brand" says Azima "like Aiwa to Sony. Both companies will have their own production facilities. Leeds is not in the same league as Mission, which has probably the most modern factory in Europe. But in a few weeks the bulldozers move into Wharfedale at Leeds to start re-building the lines. It's the re-birth of a company that is going to be great again."

Curtain Up

On a radio phone-in recently I had a call, which I do not doubt was genuine, about a listener's electronic problem. All round his house he has remote control equipment. Everything, from the flame effect fire to the window curtains, is under infra-red remote control. And by rotten luck, the code for opening and closing the curtains matches some of the recording control codes for his VCR.

He never knew this until his neighbours tactfully asked him why his curtains kept opening and closing on evenings when he was out. What was happening was quite simple. He also had a VideoPlus remote which beams out a signal to switch on the VCR, select a channel and start recording, and then switches it off again at the end of a taped programme. When the VideoPlus triggers the VCR, the curtains obediently open, close, open and close again.

The solution? Easy. The same as for anyone who finds that one piece of audio or video equipment is triggered by the remote control for another. Just put a high tech piece of cardboard over the remote control sensor "eye" of the equipment you have less interest in controlling.

In this case, this would presumably be the remote control for the curtains, not the VCR.

SHOP-TALK

with David Barrington

Autolight

The ready-made cupboard light used in the prototype *Autolight* project was purchased from **Maplin**, code KR34M. This lamp is operated by a pull-cord switch and is powered by two D-size batteries, not included. The lamp will, of course, have to be adapted as outlined in the article. Obviously, other lamps can be used here provided they can also be adapted.

The specified multizone infra-red pyroelectric (PIR) sensor used in the model was obtained from **Mailtech** (☎ ***058 474475***) and is their sub-miniature FIRM-287 type, listed at £5.95 plus 75p p&p. These miniature infra-red sensors are beginning to appear in other advertisers listings.

If any readers have difficulty in locating a source for the microphone op. amp type ICL7611 it is currently being listed by **Cricklewood Electronics** (☎ ***081 452 0161***) and **Greenweld** (☎ ***0703 236363***). The light-dependent resistor may not be listed by its type number ORP12, but most of our component advertisers know this device and carry a suitable substitute.

We feel sure that the 6V 80 ohm miniature relay is, in fact, the Maplin micro-miniature version, code FM89W. Other relays can be used provided they have similar electrical characteristics. They may not fit on the board and watch out for differing pin-out arrangements.

Pound Heater Thermostat

One or two items called for in the *Pound Heater Thermostat* have been selected to fit on the "custom" printed circuit board and if any alternative components are offered they should be checked to see that they will fit on the board before purchasing. The printed circuit board has been specially designed to fit the specified weatherproof box and also carries mains voltages, so *never handle the unit with the lid removed unless it is unplugged from the mains.* It is recommended that the unit is powered from the mains via a mains "Powerbreaker" for personal safety.

The weatherproof and frostproof plastic box is an RS component and is rated down to −20°C. The box is available from **Electromail** (code 507-933), RS's mail order outlet. The cable sealing glands are coded 544-011. Waterproof plastic cases are also offered by many of our advertisers, together with waterproof sealing glands, and again a check should be made to see that the p.c.b. will fit inside before purchase.

The "flatpack" 8A 12V relay only appears listed in the Electromail catalogue, code 344-467. Other relays could be used but they must have sufficient electrical ratings and fit on the p.c.b. or be able to fit safely inside the case.

The p.c.b. mounting 3VA mains transformer used in the model is available from several sources, such as Verospeed (part no. 289-51565G) and Electromail. The latter's code has been changed from 207-829 to be superseded by 210-774.

The printed circuit board is available from the *EPE PCB Service*, code 856. The 8-pin accurate temperature sensing i.c. type LM311N should be stocked by most major component suppliers. If any readers have difficulty in finding a 25-turn cermet potentiometer, the one in the prototype came from an RS supplier and is coded 186-542.

250W/600W Battery to Mains Inverter

It should be pointed out that anyone undertaking the task of building the *Battery to Mains Inverter* should be skilled in electronics construction work. Also, it is ***vitally important*** that they should read the "Safety Panel", published last month.

The toroidal inverter transformer has been specially made up for this project by **Jaytee** (☎ ***0227 375254***) and readers should quote code 7E283 for the 300VA version and code 9E284 for details of the 600VA 600W version. The 3VA mains transformer is an RS component stocked by Electromail, code 207-780.

We have been unable to locate any source for the 4·096MHz (50Hz) or the 4·9152MHz (60Hz) crystals other than **Farnell** (☎ ***0532 636311***). If they are unwilling to supply, then someone like **Greenweld** (☎ ***0703 236363***) might be persuaded to order for you.

The 5·6mH choke was made up on a EC70 ferrite coil kit from **Electrovaule** (☎ ***0784 442253***), order codes B66343-GX127 (core 2 off), B66278-B1011T1 (bobbin) and B66278-B2002 (mount). The 47μH 2A axial choke is listed by Maplin (UM12N). The BUV20 transistor varies in price quite considerably from just over £4 up to about £8. The ones used in the model were purchased from **JPG Electronics** (☎ ***0246 211202***) and cost £4.50 plus p&p each.

The double-sided printed circuit board can be obtained from the *EPE PCB Service*, code 855. The 7W wirewound resistor and mains rated X-class capacitor should be generally available.

Finally, some errors crept into part one and remained undetected during the checking process. The corrections are listed under the "Please Take Note" section.

Timer/NiCad Capacity Checker

Looking through the components list for the *Timer/NiCad Capacity Checker* project several items appear to be "special" and only available from a single source.

At the heart of the circuit is the special Counter Module X1, with a 512Hz output. This ready-built module comes on its own small p.c.b., including a 5-digit liquid crystal display, and was purchased from **Maplin** (☎ ***0702 554161***) code FS13P.

The twin-coil 5V latching relay is another device that could be classed in the special category and only appears to be available from Electromail or through any *bona-fide* RS component stockist. This d.i.l. package relay can be ordered by quoting stock number 351-689.

The 5V micropower regulator LP2950CZ is also available through the above mentioned sources, code 648-567. The ICL 7611 micropower op. amp is currently being listed by **Cricklewood** (☎ ***081 452 0161***) and **Greenweld** (☎ ***0703 236363***).

The printed circuit board has been designed to take the d.i.l. type relay and is obtainable from the *EPE PCB Service*, code 857 (see page 83).

10W plus 10W Stereo Power Amplifier

Before we move on to buying components for this month's audio module in the *Multi-Purpose Audio System* series, we gave some incorrect information on the centre-off switches required for the Mixer module in part one. These switches should be p.c.b. mounting types for use on 0·1in matrix spacing. The ones used in the prototype came from **Rapid Electronics** (☎ ***0206 751166***), code 75-0195 (s.p.d.t. centre-off) and 75-0205 (d.p.d.t. centre-off).

Now for this month's *10W + 10W Stereo Power Amplifier*. We do not expect too many problems to arise when purchasing components. Certainly, the TDA 2030 20W power amplifier i.c. is stocked by most of our component advertisers.

If you build the power supply, the 80VA toroidal transformer came from **Maplin**, code YK17T. The amplifier heatsink, code FG55K, came from the same source.

We suggest you shop around for the console type case as prices vary quite considerably. The two printed circuit boards are available from the *EPE PCB Service*, codes 852a (amp) and 852b (power supply).

Circuit Surgery

A couple of points have been passed on by Alan regarding this month's *Circuit Surgery* column.

The bipolar version of the ICL8211CPA and ICL8212CPA programmable voltage detector are stocked by Electromail, codes 283-249 and 636-615. If you want the CMOS versions, these are stocked by Farnell, see *Surgery* column.

The Darlington transistor and relay can be chosen to suit required application.

PLEASE TAKE NOTE

Three-way Christmas Tree Lights Flasher (*December '93*)

Page 888, Fig. 1. The type number for the "bridge" diodes D1 to D4 should read 1N4004. The components list is correct.

Waterproof Delay Switch (*December '93*)

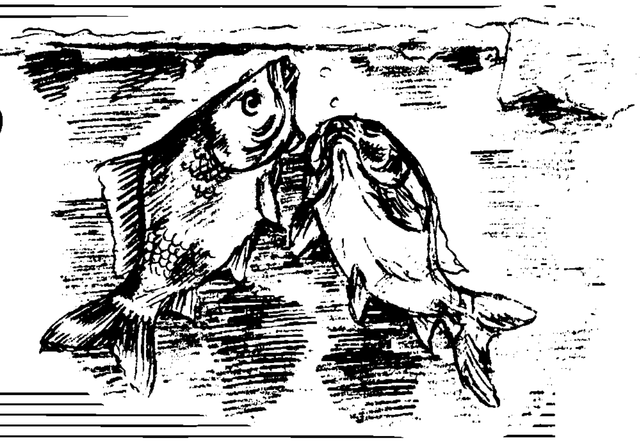
Page 937, Fig. 3. The terminal block TB2, pin 2 should read L (live) IN (input).

250W/600W Battery to Mains Inverter (*December '93*)

Page 912/913, Fig. 7. The connections between IC10 and IC4/IC5 have had their order reversed. The connections should be as follows: IC10a pin 10 to IC4a pin 13; IC10b pin 12 to IC4b pin 8; IC10c pin 6 to IC4c pin 6; IC10d pin 8 to IC4d pin 2; IC10e pin 2 to IC5a pin 8; IC10f pin 4 to IC5b pin 12.

Page 916, Fig. 10. Transistors TR3 and TR4 are shown incorrectly orientated. Their pins, however, are correctly annotated and the photograph on the same page shows the correct orientation. This error crept in when the original BD437 devices used in early prototyping were replaced with the current TIP31 type and the diagram was not updated.

POND HEATER THERMOSTAT



A. R. WINSTANLEY

An essential winter accessory for pond fish enthusiasts. Ensures that fish will not suffer if the pond ices over.

THOSE readers who keep coldwater pond fish will know of the dangers which exist during wintertime, when low temperatures can give rise to ice formation on the fishpond. During summer, the oxygenating plants in the water provide a plentiful supply (hopefully) of oxygen which enables the fish to breathe.

In severe winters, no such oxygen is produced and so the pond's inhabitants rely on air entering the water from the surface. If the pond then freezes over, firstly the air supply to the fish is reduced if not cut off altogether, and secondly, toxic gases from decomposing material in the water can build up in the pond and poison fish.

Several tricks are employed by fishkeepers during icy weather to help the fish to breathe and gases to escape. A floating electric heating element is popularly used, the idea being that the warmth generated by the heater provides some local heating and keeps a small surrounding area – say 12 to 18 inches diameter – of water free from ice. The object is not to heat up the water to any extent but merely provide an air-hole in the ice.

FIT AND FORGET

Forgetting to switch the unit on during icy weather could result in thick ice formation with possible distress being caused to fish, and the build up of toxins and the lack of air can eventually be fatal to the pond's inhabitants. Conversely, leaving the heater continually switched on is wasteful and can only shorten the life of the heater.

Fish enthusiasts who own any expensive breeds such as Koi Carp will not wish to take any risks and even if you simply keep cheap and cheerful goldfish, you will certainly want to take precautions to protect them during harsh weather conditions. The Pond Heater Thermostat was designed as a "fit and forget" outdoor controller which monitors the ambient air temperatures and switches on the floating pond heater if the air temperature drops to near zero degrees Celsius.

The prototype unit has been of great success when used at the author's fish pond, and it reliably powers a nearby floating electric heater when the air temperature is just above freezing or colder. By using the Pond Heater Thermostat, it is no longer necessary to remember to watch weather forecasts and turn on the heater if frost or ice is looming.

In fact, the prototype has been operating very efficiently under very harsh weather conditions when temperatures have been measured as low as –8 degrees Celsius.

FISH AND CHIPS

Aquarists will know that the most common method of maintaining temperatures in a tropical fishtank is to use a bi-metallic strip thermostat immersed in the water. These are notoriously temperamental to set up at the desired switching point and their crude method of operation can be unreliable. Additionally they are generally uncalibrated.

The problem of detecting near-zero temperatures as required in our outdoor pond application is solved by employing a solid-state temperature sensing integrated circuit. In fact several types of device are available in this category, and one of the cheapest types, the well-established LM3911N is used in this design. A simplified block diagram of this device appears in Fig. 1.

Table 1: Kelvin Temperature Scale

The Celsius Scale of temperature measurement has an identical temperature interval to that of the Kelvin Scale. In order to convert from Kelvin to Celsius, it is necessary to "re-align" the two scales by a factor of 273 thus:

Freezing Point = 0 Degrees Celsius = 273 Degrees Kelvin

Steam (Boiling) point = 100 Degrees Celsius = 373 Degrees Kelvin

Therefore, Degrees K = Degrees C + 273

and, Degrees C = Degrees K – 273

Examples
+20 degrees Celcius = 293 degrees Kelvin
+5 degrees C = 278 degrees K
–2 degrees C = 271 degrees K

HOW IT WORKS

The LM3911N is a highly accurate temperature measuring chip which is usable between –25° to +85° Celsius. The device comes in an 8-pin d.i.l. package which contains a temperature sensor, supply voltage reference and a comparator.

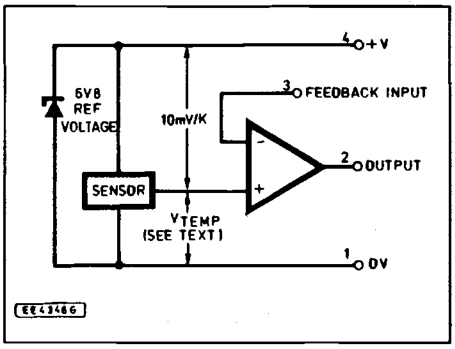


Fig. 1. Simplified structure of the LM3911 temperature sensor chip.

Its circuit utilises a pair of transistors operating at differing currents as the temperature sensor, and since the base-emitter voltages of the transistors vary by a tiny amount with temperature, the difference in the base-emitter voltages can be utilised to generate a temperature-dependent potential difference. The result is that the sensor is very stable and highly accurate.

From the block diagram, it can be seen that the temperature sensor output is equal to 10mV/ degree Kelvin – directly equivalent to 10mV/ degree Celsius. (A brief explanation of the Kelvin scale of temperature measurement is given Table 1.) It can be seen that the temperature sensor is directly connected to the non-inverting (+) input of an operational amplifier.

REFERENCE VOLTAGE

Also on board the chip is a stable voltage reference working in a manner similar to a

Zener diode. This reference voltage is used by the temperature sensor, and requires an external voltage-dropping resistor to be connected to pin 4 of the i.c., with the Zener forward current preferably kept to a minimum (1mA or less is recommended), in order that the self-heating effects of the i.c. are minimised – this helps to improve accuracy.

The reference voltage is typically 6·85V, and given that the potential at the sensor output varies by 10mV/degree Celsius as shown in the diagram, it means that the voltage at the non-inverting input (call it

The temperature control is set by the user so that the voltage at the inverting input of the comparator (pin 3) equals the voltage from the temperature sensor which will exist at the non-inverting input when the i.c. is at the desired switching temperature.

For example earlier we saw how, at a temperature of 25°C, the voltage (Vtemp) at the non-inverting input was 3·87V. By setting the preset control VR1 to this voltage also, the comparator will then be at the thermostat switching point of +25°C.

As the ambient temperature rises above this set point, the voltage at the non-

The only point to note is that it is necessary to set the external control quite accurately because an error of only 0·1V at pin 3 is equivalent to a temperature spread of 10°C.

CIRCUIT DESCRIPTION

The full circuit diagram for the Pond Heater Thermostat is given in Fig. 2 and, as can be seen, is very simple.

The LM3911N, IC1, behaves as an on-off thermostatic controller. The circuit

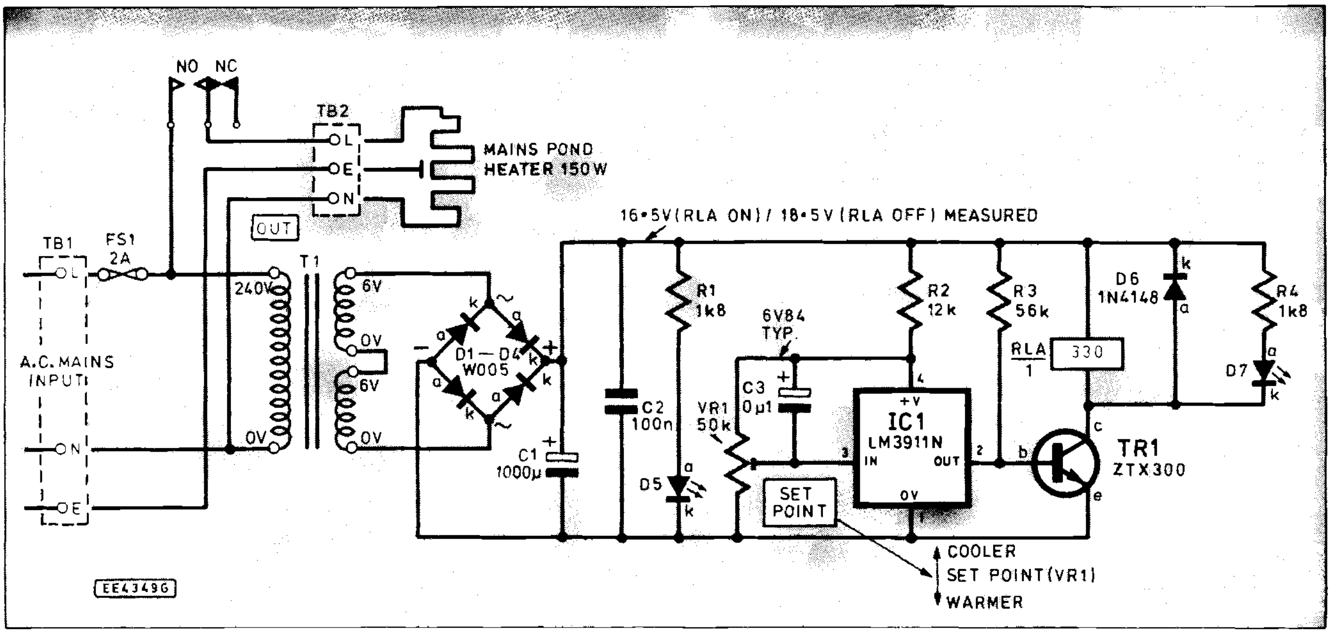


Fig. 2. Complete circuit diagram for the Pond Heater Thermostat.

Vtemp) of the op.amp with respect to 0V is equivalent to:

Vtemp = (6·85–10mV/degree Kelvin) Volts.

For example, at an ambient temperature of +25°C., this equates to a temperature of 298 degrees Kelvin. The sensor output voltage at 10mV/ degree K is thus 2·98V as measured between the sensor output and the +6·85V reference rail. This is indeed confirmed in the manufacturer's data.

Using the above formula, Vtemp therefore typically equals 3·87V (6·85 – 2·98V) at a temperature of +25 degrees Celsius.

At a temperature of, say, +85 degrees, Vtemp typically equals 3·27V.

It can be seen therefore that, with respect to the 0V rail, the voltage at the op.amp non-inverting (+) input decreases as the i.c. temperature increases.

FEEDBACK

No mention has yet been made of the "feedback" input (pin 3) to the op.amp, which is actually the inverting input (–). By normal comparator action, when the non-inverting input has a higher voltage than the inverting input, then the output of the op-amp (pin 2) is *high*, and vice versa.

Looking at how this device can be used as a thermostat, in our application we want a simple on-off controller which can operate at a switching point of just above freezing – say +1°C.

Given that the non-inverting input is directly connected to the temperature sensor (and is not accessible), in order to act as a simple thermostat, an external reference voltage is set at the feedback input terminal by using a potential divider strapped across the 6·85V reference, (VR1 in Fig. 2).

inverting input of the comparator will decrease at a rate of 10mV/ degree Celsius. Pin 2 will therefore be low because the non-inverting input voltage is less than the inverting voltage.

Conversely when the ambient temperature falls, the non-inverting input voltage will rise until it exceeds the set point, as determined by VR1. Then the comparator output pin 2 will go high. Thus a simple on-off temperature controller can very easily be formed, using a simple potential divider to act as the temperature control point.

is mains powered, and uses a 12V step-down transformer T1 coupled with a standard full-wave bridge rectifier circuit (D1 to D4 and smoothing capacitor C1) to produce a d.c. supply rail of approximately 16V to 18V. The l.e.d. D5 is a power-on indicator.

The 18V rail is too high of course for direct operation of IC1 and so R2 is a series dropping resistor which limits the current to just 1mA for the internal reference voltage. The voltage at pin 4 is therefore about 6·8V (and this can be measured with a voltmeter).

Preset control VR1 is a 50kilohm 25-turn cermet trimmer, the wiper of which is connected directly to pin 3 (comparator feedback input) and is used to adjust the thermostat switching point. Capacitor C3 removes any noise and improves stability.

The output of the i.c. drives a simple transistor switch TR1 which is used to control a mains-rated relay RLA. Diode D6 removes back e.m.f. when the relay de-energises, in order to protect the transistor and chip.

Preset VR1 is adjusted to the desired set point, which in this application should be no more than +1°C – equivalent to setting a voltage at pin 3 of about 4·11V or so (but this setting depends on the actual Zener reference voltage of readers' individual units – see later).

When the i.c. temperature exceeds +1°C, therefore, the voltage present at the comparator non-inverting input is *less than* 4·11V and so the comparator output is low, near 0V. The transistor switch is off.

When the ambient temperature drops, the non-inverting (+) input of the comparator is sent more positive, towards the internal 6·85V reference, until the set point voltage of 4·11V is exceeded, when pin 2 goes high, switching on the transistor.

This then completes the circuit to relay RLA which operates and closes the normally-open mains-rated contacts RLA1. These directly switch on the mains (L) supply to the floating heating element which is connected via terminal block TB2. The l.e.d. D7 also illuminates to indicate that the heater has switched on.

Resistor R3 is required in order to shunt an internal resistor which is present at the comparator output, and enables more base drive current to flow into the transistor TR1.

The thermostat will cycle quite happily like this, turning the heater on and off according to the ambient temperatures detected by the integrated circuit.

SOAK TIME

One further practical aspect to take into account is the fact that the "die" or chip within the i.c. is, of course, embedded in the plastic resin of the dual-in-line package. This can slow down the reaction of the i.c. slightly because it takes time for the ambient temperature to soak through to the silicon chip itself – especially when the device is mounted flush on a printed circuit board and the changes in temperature are slight.

In practice this can be adjusted out by trial and error, trimming VR1 accordingly to advance the point at which IC1 would trigger: This compensates for any temperature lag. It is also necessary to use a multi-turn preset for VR1 because the i.c. is very sensitive, and a 25-turn preset makes setting up much easier.

The prototype was quickly set up and was adjusted once only, and has been in successful operation for many months. It starts to power the heater on and off when the temperature is just above freezing, and the heater is hard on at sub-zero levels.

CONSTRUCTION

***Important Safety Notice:* Constructing this unit involves making MAINS connections. Any reader who is not certain of being able to build it safely is strongly advised to seek professional advice. If necessary, a qualified electrician should carry out the fixed installation work.**

The Pond Heater Thermostat is designed for outdoor use in harsh weather and the circuit itself is constructed on a single-sided glass-fibre printed circuit board size 130mm x 70mm. This is available from the *EPE PCB Service* code 856.

The printed circuit board (p.c.b.) topside component layout and full size underside copper foil master pattern is shown in Fig. 3. If you are tempted to produce your own p.c.b., make sure you keep to the published design i.e. large "ambient sink" plane and large tracks for mains voltages. All connections to IC1 (pins 1 to 4) are on one side of the d.i.l. package, but pins 5 to 8 are electrically isolated from the integrated circuit. In order that the i.c. can monitor the ambient temperature more

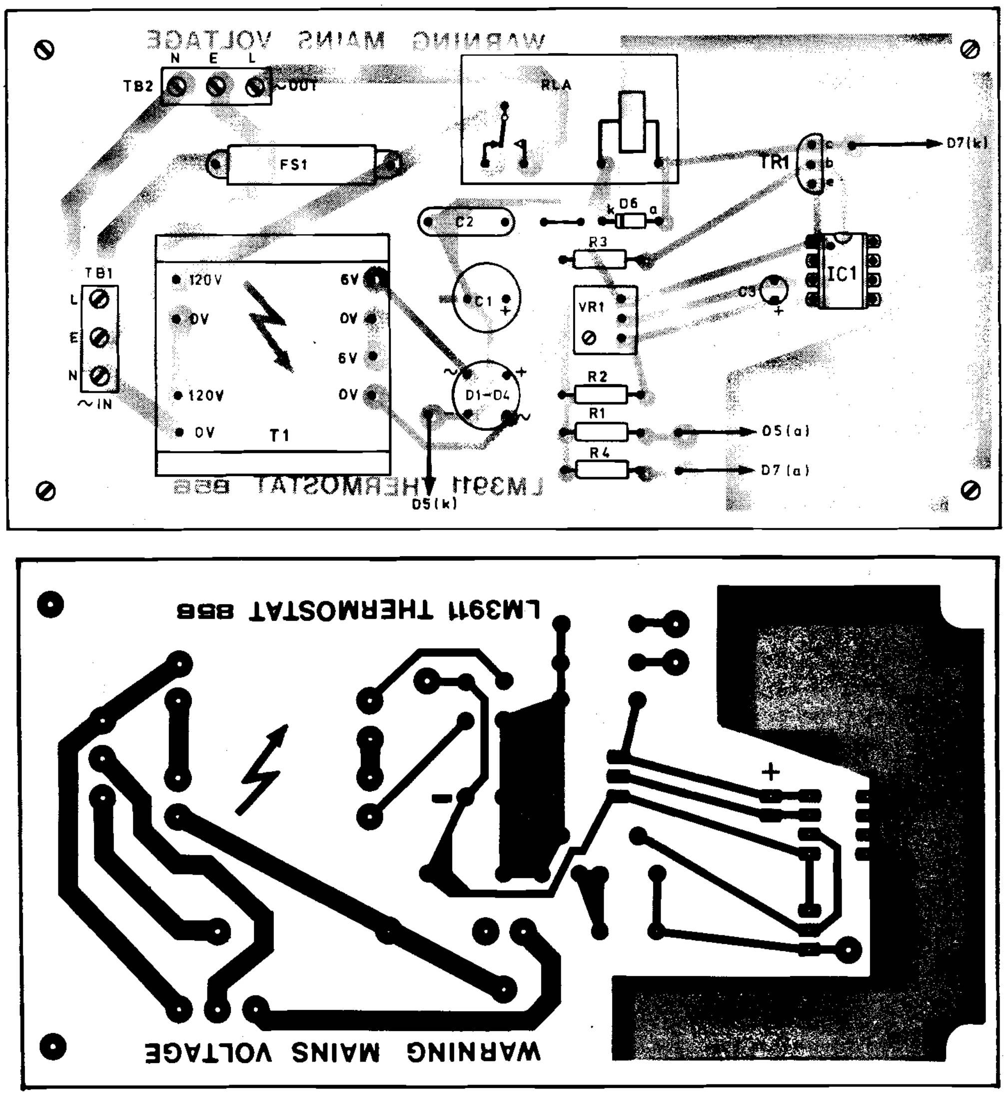


Fig. 3. Printed circuit board component layout and underside copper foil master pattern (full size). Note the large area of copper which act as a heatsink (cold) for the i.c.

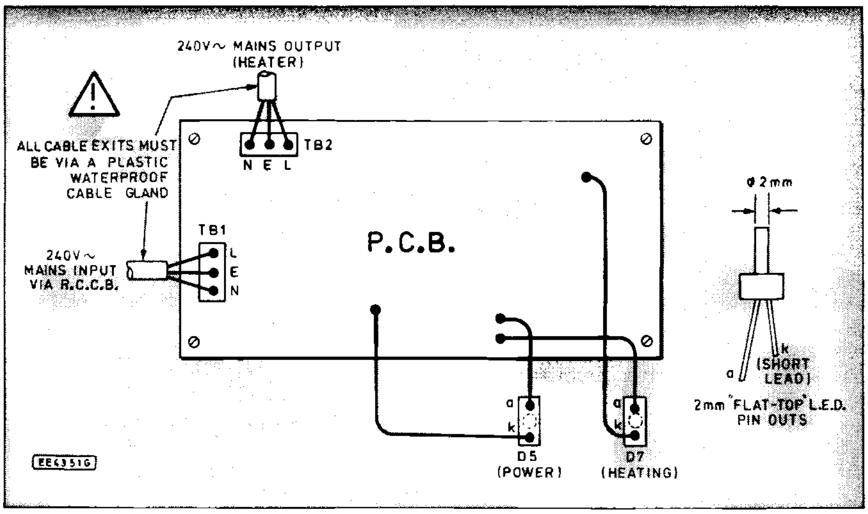


Fig. 4. Wiring from the circuit board to the power-on and heating l.e.d.s.

effectively, a large area of copper foil acts as a simple heatsink, monitoring the surrounding heat level, and this is soldered directly to pins 5 to 8 of the chip. This helps the surrounding heat (or cold) to soak through to the i.c. die.

In fact National Semiconductor suggest that a d.i.l. heatsink is bonded to the package to improve thermal transfer even more, but the author could not successfully locate a suitable type.

This printed circuit board has been specially designed to fit a weatherproof and frostproof plastic box, RS type 507-933, which measures 160mm x 80mm x 55mm. It is rated down to -20°C and so should be quite shatterproof at sub-zero temperatures. The box incorporates p.c.b. mounting bushes which are utilised to carry the p.c.b. shown, using M3 screws.

All parts including the mains-voltage section are p.c.b. mounted for maximum reliability. Other parts may not fit the p.c.b. so check before purchasing.

Construction starts by fitting the smaller, lighter components to the board in accordance with Fig. 3. Observe carefully the polarity of the bridge rectifier, electrolytic capacitors and transistor. Note that you should solder the i.c. directly to the board as shown without using a socket.

Follow on with the relay, mains terminal blocks and finally the mains transformer. An insulated cover fuseholder is recommended for FS1.

The lid of the plastic box needs to be drilled to take the two light-emitting diodes, and here 2mm diameter "flat-top" types were used on the prototype. Two 2mm diameter holes were drilled in the lid and the l.e.d.s are a tight, waterproof push fit giving a very neat effect.

They are connected to the board with flying leads, and it must be ensured that the lead-outs will not touch or interfere with the p.c.b. once the lid is screwed down. Other types of l.e.d. can be used but it may be necessary to seal them with silicone sealant to prevent water seeping in.

It is also necessary to drill the box to accept a mains cable input, 6A three-core cable is suitable and this ***MUST*** be fitted through the box using a plastic cable gland with sealing washer to make the cable entry waterproof. Similarly a cable exit is needed for the heating element, which will probably also use 6A three-core cable. Again

COMPONENTS

See SHOP TALK Page

Resistors
- R1 1k8
- R2 12k
- R3 56k
- R4 1k8

All 0·25W 5% carbon film

Potentiometer
- VR1 50k 25-turn cermet preset

Capacitors
- C1 1000µ radial elect. 25V
- C2 100n polyester
- C3 0µ1 tantalum bead, 35V

Semiconductors
- D1 to D4 W005 50V 1A bridge rect.
- D5, D7 2mm flat top l.e.d. (2 off – see text)
- D6 1N4148 signal diode
- TR1 ZTX300 *npn* transistor
- IC1 LM3911N temperature sensor i.c.

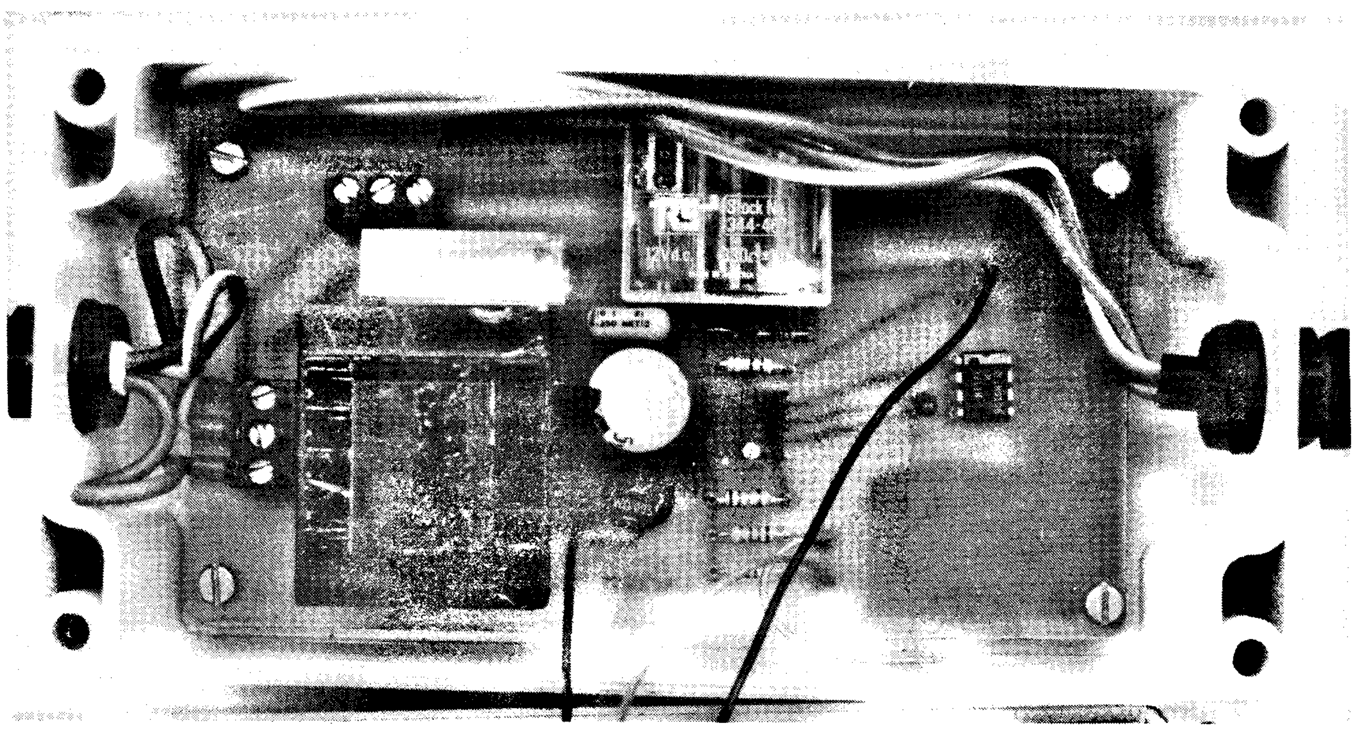
Miscellaneous
- RLA 12V 330ohm coil flatpack relay, with s.p.c.o. contact rated at 8A 250V a.c.
- T1 3VA p.c.b. mounting mains transformer, with 0V-6V, 0V-6V secondaries
- FS1 20mm p.c.b. insulated fuseholder, with 2A quick-blow fuse
- TB1, TB2 3-way p.c.b. mounting screw terminal block, mains rated (2 off)

Weatherproof ABS box, size 160mm x 80mm x 55mm; cable-sealing glands (2 off); 6A 3-core mains cable, length as required; connecting wire; M3 x 10mm pan-head screws for p.c.b. mounting (4 off); solder etc.

Printed circuit board available from the *EPE PCB Service*, code 856.

Approx cost guidance only **£30** *excl. Heater*

Interior of the completed thermostat showing layout of components inside the waterproof case.



a weatherproof cable gland *MUST* be employed.

The mains flying leads are connected to the appropriate screw terminal blocks – taking great care to ensure that stray *strands of wire do not short adjacent* terminals. It is ***essential*** that the earth continuity is maintained, so that the metal case of the heating element is properly connected to the mains Earth (E) input.

TESTING AND CALIBRATION

After construction is complete, the best way to test the unit is to power it up using a d.c. bench power supply rather than connecting it to the mains. Clip an 18V d.c. supply across the positive and negative leads of the bridge rectifier.

By rotating VR1 with a trimming tool it should be possible to make the relay (and l.e.d. D5) turn on and off. This confirms that the comparator and temperature sensor are working. Then trim VR1 so that the thermostat will switch at +1°C. It is possible to calibrate this point to a certain extent by taking a few test readings, preferably with a DMM (digital multimeter).

It is best to adjust your setting to take account of the tolerance of the Zener reference voltage because yours may not be precisely 6·85V, so you can get a good idea of the setting required at VR1 wiper for your unit by using this simple formula, which is based on the voltage divider effect present at the comparator non-inverting input:

$$V_{temp} = V_z - 2{\cdot}74V$$

where Vtemp is the voltage at pin 3 (the switching voltage for +1°C operation) – you will trim this with VR1, and

Vz is the reference voltage of your unit (measured at pin 4 (+) and pin 1 (0V) – this should be between 6·55V and 7·25V).

N.B. 2·74V represents the temperature sensor output voltage at a temperature of +1°C (i.e. 10mV per degree Kelvin).

Measure the reference voltage of your i.c. then calculate the setting you need for your own unit and trim this with VR1, monitoring the potential at pin 3 of IC1. For example, if you measure a reference voltage of 6·25V at pin 4, you will need to trim VR1 so that pin 3 measures roughly 3·51V. *A reference voltage of 6·85V for instance* would require VR1 to be trimmed to 4·11V.

Using this simple method you will be able to easily set up your unit on the bench so that it will start to switch just above freezing point.

Even using a high impedance DMM it was found that the meter loaded the circuit slightly, and in view of the high sensitivity of the LM3911, the simple calibration procedure will enable you to position VR1 at approximately the correct setting. However, you will still probably need to make one or two trial and error fine adjustments *in situ* to finalise the setting up.

If no test equipment is available, then you will have to adjust VR1 by trial and error. If you use the "trial and error" method, take great care to keep clear of mains components, and to keep water out of the box when the lid is removed.

You could for instance, test your unit by using a cool box filled with ice packs to simulate near-freezing conditions. A mercury thermometer will be of help also.

INSTALLATION

If you are satisfied that the device operates correctly, the Pond Heater Thermostat can be installed outdoors perhaps by securing the box to a wall or a nearby fixture. It will be seen that the wall-mounting holes in the weatherproof box are outside the sealed compartment, and it is therefore not necessary to seal the box mounting screws. However, ensure that the lid is secured evenly but *do not overtighten* the screws as the bushes may be damaged.

It is recommended to connect the mains power to your Pond Heater Thermostat through an Earth Leakage Circuit Breaker/Residual Current Device (ELCB/RCD) for maximum protection.

It is important to remember that floating heater elements must not be powered unless they are in water – do not operate them unless they are submerged or they could be seriously damaged. Floating them in a **nine** litre (two-gallon) bucket of water will be quite adequate if you power up the unit indoors.

The siting of the Thermostat is quite *important, and you need to bear in mind* any likely windchill or sunlight which might affect the operation slightly. It is best to locate the unit in a sheltered spot as near to the pond as possible. It will be simple to compensate for any local conditions by adjusting the Set Point preset VR1 as necessary.

In normal operation you will hear the relay switch on and off (with l.e.d. D7 turning on and off) as the thermostat responds to changing temperatures. A slight relay "chatter" may be evident at times but this is normal and there is no need to be concerned.

Larger pools may use several heaters and it should be possible to connect up to two extra heaters from the same circuit as the unit could comfortably handle up to 500 Watts. Each cable exit from the box *MUST* employ a sealing gland.

LOW VOLTAGE HEATERS

Presumably on the grounds of improved safety, it is now possible to use a low voltage heating element which is powered from the mains via a heavy duty (typically 50VA) step-down transformer, which itself is situated under cover. It should be perfectly feasible to use these low voltage systems also with the Pond Heater Thermostat, by connecting the mains (primary) of the transformer in place of the mains heating element, at TB2.

A low voltage heater has not been tested with the prototype shown, and the only potential problem may be noise or spikes generated by the step-down transformer when RLA1 switches it off. It might be a good idea to carefully wire a 240V varistor (mains transient suppressor) across the Live and Neutral connections at TB2, i.e. in parallel with the transformer unit. It is still important to protect yourself from the mains-voltage side of the circuit by using an ELCB/ RCD trip. □

Techniques

ACTUALLY DOING IT!

by Robert Penfold

TRADITIONALLY, electronics is a hobby that is pursued most earnestly in the colder months of the year. We are now well into a new season, and no doubt many potential newcomers to the hobby are wondering whether or not they should try their hand at project building.

A factor that deters many would-be project builders from actually making anything is "will it work" syndrome. Worries about spending good money on a project that will never work are understandable, but are probably less justified than in the past. These days the average project is rather more complex than its counterpart of twenty or thirty years ago, but for a number of reasons it represents a far lower risk.

GENUINE DUDS

Some constructors complain about the high cost of modern components, but as I have pointed out before, most components are now relatively cheap. Allowing for inflation, many semiconductors are only about one to ten per cent of their cost 20 to 25 years ago. Switches, cases, and most passive components are also only a fraction of their previous cost. Although the average project seems to get more complex year-by-year, the "real terms" cost probably gets lower.

Although one might expect the reduction in cost to be accompanied by a reduction in the quality of components, this is not the case. Manufacturing and testing methods have steadily improved over the years, and "dud" components are now very few and far between. If you were to buy several thousand components a year for the next 20 years, the chances are that you would not get a single "dud" (excluding any components that had sustained obvious physical damage at some stage). Some mechanical components (particularly switches) are no longer built to "belt and braces" standards, but they will still stand up to many years of use.

At one time there was a serious problem with so-called "genuine duds". These were sub-standard semiconductors that were bought by unscrupulous retailers and remarked to look like the "real thing". Fortunately, this practice seemed to die out many years ago. Presumably there is no point in faking components which cost a few pence each when bought in bulk. Any semiconductors you buy these days will be good quality devices which meet the full manufacturers specification.

KEEP IT SIMPLE

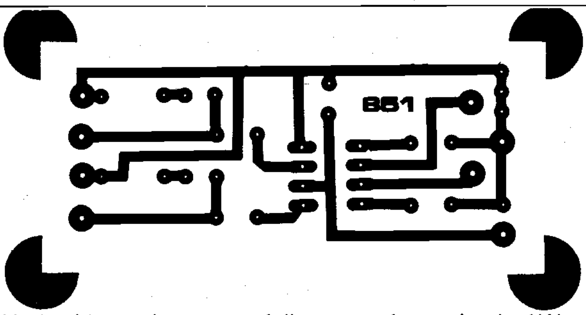
Although the general complexity of projects has increased over the years, there are still plenty of simple projects published. Although it is tempting to dive straight in and build an impressive up-market project, this is definitely not a good idea. Starting with a complex project does not guarantee failure, but it certainly reduces your chances of success.

The larger the number of components you have to deal with, the greater the risk of components being swapped over, fitted the wrong way round, or whatever. With a simple project you are risking relatively little money, and have a very good chance of producing a project that will work first time.

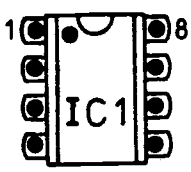
It is probably best to start with something mundane, such as a simple radio, or a car or household gadget. From time to time I still receive letters from readers who are having problems with a project, but where it is clear from their comments that they have misunderstood its precise use. In some cases it is obvious that the project is actually functioning, and that it is the constructor's expectations that are at fault!

P.C.B.

When selecting your first project I would suggest that you look for one that can be built on a ready-made printed circuit board (p.c.b.). This is not a ploy on my part to boost sales of ready-made printed circuit boards. Using a printed circuit board it is relatively difficult to make mistakes. It is possible to make an error such as fitting a component between the wrong pair of holes, but any mistakes that are made usually become obvious before the board is completed.



Underside p.c.b. copper foil pattern for a simple 1W Stereo Amplifier (Dec '93), ideal project for the newcomer.



Pin one of an i.c. is usually identified by spot indent and/or half circle on the top of the device.

The main alternative to a ready-made printed circuit board is stripboard. This is a form of proprietary printed circuit board which is drilled with a matrix of small holes, and has rows of copper strips on one side. It is an excellent product, but when using stripboard it is easy to make a careless error such as fitting a component leadout into the wrong hole. Spotting an error such as this can be quite difficult. Problems with short circuits between the copper tracks also tend to be more common than when using a custom printed circuit board.

It is probably best to avoid projects which have large amounts of "spaghetti" wiring from the board to controls, sockets, etc. This wiring is not actually too difficult to fit, but there is more scope for confusion and errors in this type of wiring than when fitting components to the circuit board.

You should definitely not start with mains powered projects. These are **potentially lethal** and should only be undertaken by those who know what they are doing. There are plenty of safe, battery powered projects to choose from.

PREVENTION

It is clearly a good idea to get things right first time, rather than to make mistakes and then do some fault finding. Check carefully that each component is fitted in the right place. Double check resistor colour codes, and look carefully at each resistor to determine the colour of each band.

The body colours of some modern resistors make it hard to see the colour codes clearly. Particularly under artificial light, red, brown, and orange bands can be difficult to distinguish from one another. A fairly powerful magnifier makes the task much easier, and should also be helpful when reading the tiny lettering used on many semiconductors.

Some components are polarised, and must be fitted to the board the right way round. Electrolytic capacitors are the most common type of polarised component. These are usually marked clearly with "+" and or "–" signs to indicate their polarity, and component overlay diagrams are marked in the same way. This makes it very easy to get their orientation correct. Note that getting an electrolytic capacitor the wrong way round can result in it bursting and being rendered completely useless.

SEMICONDUCTOR ORIENTATION

Virtually all semiconductors must be fitted the right way round if they are to function properly. Integrated circuits often draw very high supply currents if they are fitted the wrong way round, which usually results in their rapid destruction. It pays to be especially careful with integrated circuits, particularly the more expensive types.

Component overlays do not usually leave room for any doubt about the correct orientation for semiconductors, but before fitting a transistor make sure that two of the leadout wires have not become crossed over. This can easily happen, and is very difficult to spot once the device has been soldered in place.

There is a temptation to rush through construction and get the completed project switched on as soon as possible. When building anything, rushing the job is almost invariably an approach which leads to careless errors. Take your time, and keep checking everything that you do. Look carefully at what you are doing, and do not jump to conclusions. Thoroughly check the finished unit against the construction diagrams. I think it is fair to say that most of the errors in non-functioning projects are glaringly obvious.

PICKING FAULT

If the unthinkable should happen and the finished unit does not work, the problem is almost certainly due to a simple error somewhere. Check everything again, component by component, and wire by wire. Many constructors find it is best to put the project to one side for a day or two, and then take a fresh look at it. This will often result in the mistake being spotted almost at once.

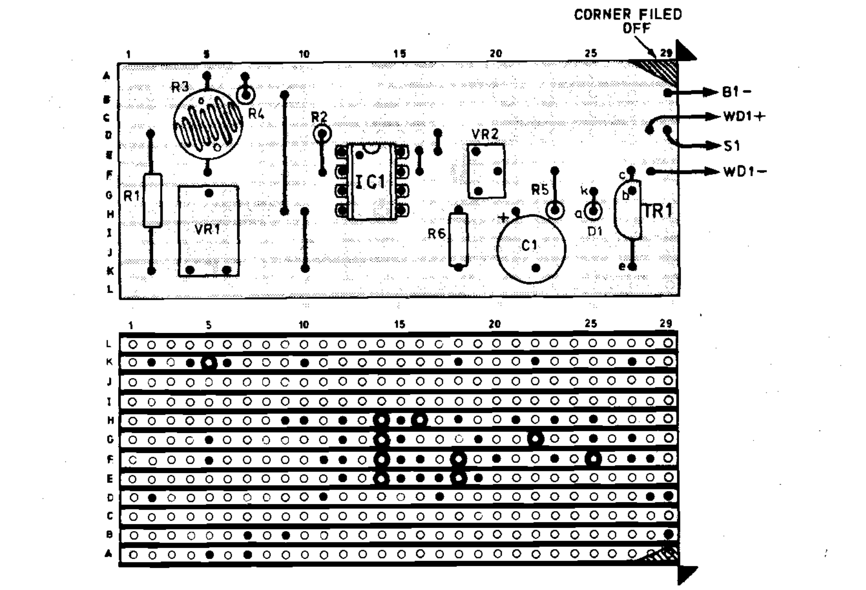
With modern components and solder, "dry" joints are less of a problem than they once were. They can still occur from time to time though, unless your soldering technique is sound. There is insufficient space available here for a proper discussion of soldering procedures, but there are some common mistakes which beginners should try to avoid.

Only use a soldering iron and solder which is intended for electronic construction work. This means an iron fitted with a miniature bit of around two millimetres in diameter, and having a rating of about 15 to 25 watts. The solder should be a 60/40 tin/lead type (not a 60/40 lead/tin solder) having built-in flux.

Both surfaces to be joined must be reasonably clean. Tin the bit with solder and apply it to the joint first, and then feed in plenty of solder. Do not feed a lot of solder onto the bit of the iron and then try to "pour" this onto the joint. That is the most efficient way of producing a "dry" joint! Keep the tip of the bit well "tinned" with fresh solder.

Accidental short circuits between tracks due to solder splashes and blobs of excess solder are a likely cause of problems. These are not usually too difficult to spot on a custom printed circuit board. Some form of magnifier is very useful when looking for excess solder, and something like an 8× loupe (also known as a "lupe") is ideal. Solder splashes are sometimes hidden underneath excess flux.

Special solvents for cleaning printed circuit boards are available, but any fairly stiff-haired brush (an old toothbrush) seems to be equally effective at removing flux. Pay particular attention to areas of the board where the joints are crowded together. This mainly means areas of the board occupied by d.i.l. integrated circuits or other in-line components.



The top and underside views of a piece of stripboard used to build a simple light sensitive alarm (Cupboard Guard – Aug' 93).

INTERWIRING

As already pointed out, the wiring to the controls etc. often gives problems. This can be due to a simple wiring error which is easily located and corrected. It can also be due to confusion caused by components of the same general type having quite different physical appearances. For example, in my spares box I have standard jack sockets in three totally different styles. A wiring diagram for one style of socket is of little help if you have a different type.

Experienced constructors can simply make a few tests on controls and sockets to determine the correct method of connection, but for absolute beginners there is no alternative to copying the pictures. This will obviously be much easier if you obtain components that closely match those used in the prototype. This is in turn much easier if you have a good range of component catalogues. Many newcomers to the hobby overlook the importance of component catalogues, and soon run into trouble as a result of this.

CATALOGUES

Component catalogues are particularly useful for beginners, as they contain helpful illustrations of components, plus a lot of data and other useful information. This helps to familiarise you with components, and should generally clarify things. Component catalogues are given away with *Everyday with Practical Electronics* from time to time, or can be bought at quite low prices. Some of the larger ones cost a few pounds each, but they are often supplied with discount vouchers which enable the cost of the catalogue to be recouped if you spend a moderate amount on components.

It is understandable if constructors would prefer to spend money on components instead of using it to buy catalogues. However, this is definitely a false economy. In terms of their usefulness, component catalogues more than justify their cost. Obtain as many catalogues as you can, and buy at least one really large component catalogue.

POSITIVE THOUGHT

If you run into problems with a project, the most important thing is to think positively. If you get everything connected together in the correct manner, the project will work. It is just a matter of going through the component layout and wiring until everything is correct.

The most important thing is to actually have a go at building a project, which is a lot more fun than sitting around thinking about it. Do not worry if there are some points about the components or construction of the project that you do not fully understand. Once you have the components everything will probably become apparent.

VIDEOS ON ELECTRONICS

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

VT201 to VT206 is a basic electronics course and is designed to be used as a complete series, if required.

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VCR MAINTENANCE

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Each video uses a mixture of animated current flow in circuits plus text, plus cartoon instruction etc., and a very full commentary to get the points across. The tapes are imported by us and originate from VCR Educational Products Co, an American supplier.

(All videos are to the UK PAL standard on VHS tapes)

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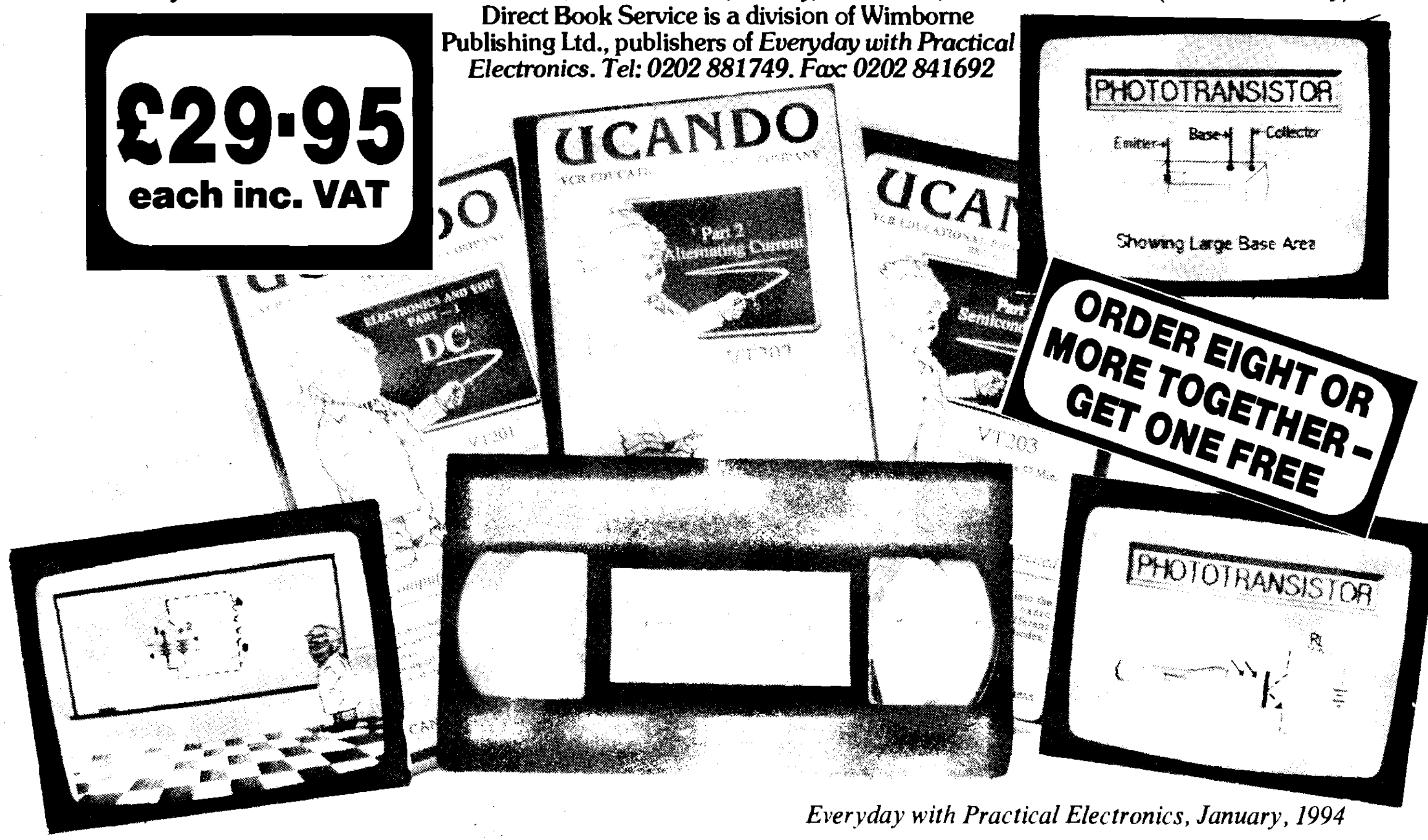

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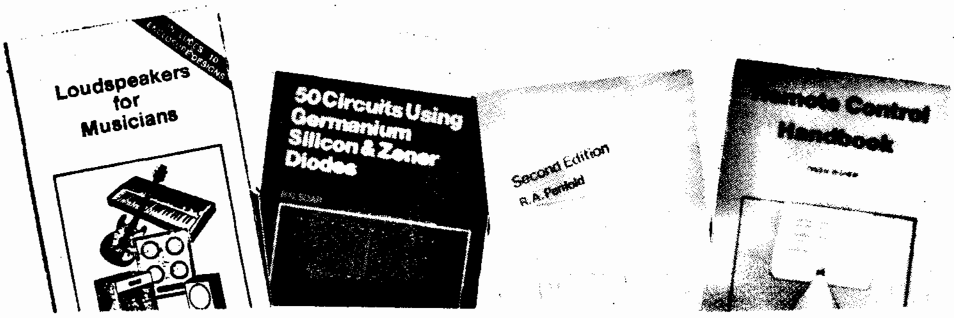

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REPORTING AMATEUR RADIO

Tony Smith G4FAI

SURVEY FAVOURS MORSE

At the time of writing (October), the Radio Society of Great Britain had not yet announced the result of its survey among UK radio amateurs on whether they are for or against the idea of a Morse-free HF licence. However, RSGB representatives at the IARU Region 1 Conference in Belgium, in September, reported that the survey has revealed an overwhelming majority in favour of maintaining a Morse code requirement.

This interesting news was disclosed during discussion on a motion from the Austrian national radio society, OVSV, that "This conference maintains its present position concerning the necessity of a Morse code test without technical aids as part of the licence requirements for radio operators under 30MHz."

The motion was carried by 38 votes in favour, with none against, and five abstentions. Surprisingly, the RSGB was among the abstentions and their representatives explained that they were not voting because the survey results had not yet been discussed by their national Council.

The first report on this paradoxical voting pattern appeared in the October issue of *Morsum Magnificat*, the Morse magazine. As the survey result was apparently known before the conference, RSGB members who supported the retention of the Morse test are now questioning why their conference representatives were not given a clear mandate to vote in accordance with the results of the survey.

CHASING ISLANDS

"Islands on the Air" is among the four top international HF award programmes in amateur radio. It was created nearly 30 years ago by Geoff Watts, a leading UK shortwave listener. The Radio Society of Great Britain took it over in 1958 and it is now managed by an RSGB IOTA Committee.

It is an award programme for radio amateurs and SWLs interested in making, or hearing, contacts with islands and island groups worldwide. Eighteen different awards are available, graded in difficulty, and there is a Plaque of Excellence for supreme achievement.

While being attractive to island "chasers", the programme also offers a challenge to island "activators", those who like to combine radio with travelling, sailing, camping, or mountaineering. Groups, or individuals of this ilk undertake IOTA expeditions to put "rare", sometimes uninhabited, islands on the air, and advance news of their activities is contained in the RSGB's weekly DX News Sheet (DXNS) and other DX bulletins.

Island news can also be heard on the IOTA net at 1300 GMT on 14·260MHz on Saturdays and on 21·260MHz on Sundays. In fact, these frequencies, together with 28·460 and 28·560MHz are used as the meeting place for island stations at any time.

IOTA DIRECTORY

The IOTA Directory contains all the rules, and claims to list at least 99·9 per cent of the world's ocean islands appearing on a scale map of 1,000,000: 1. Grouping limits the size of the list, but the 30 or so largest islands in the world all count separately as do all islands recognised as countries for the American DXCC award, and many other single islands which do not fall naturally into wider groupings.

Each qualifying island/group activated since 15th November 1945, for which evidence of contact has been provided, has been allocated an IOTA reference number, and these numbers are often quoted on QSL cards (for example, EU-001, Dodecanese Is). Some 750 islands/groups have reference numbers, and groups which have yet to be activated have been included in the directory without a number as a guide to enterprising activators.

An IOTA convention is held at least once a year where participants can meet each other, discuss their common interests and hear about the adventures and experiences of some of the island expeditions mounted on their behalf. Additionally, an IOTA contest was held in 1993 for the first time, providing an opportunity to work/hear many more islands/groups in one weekend than is normally possible.

IMPRESSIVE VOLUNTARY EFFORT

The starting off point for newcomers is to get a copy of the IOTA directory, and then work for the IOTA 100 Islands award. This requires proof of contact with, or hearing, at least 100 islands/groups with different reference numbers, including at least one contact with each of the seven continents. Many amateurs and SWLs will find that QSL cards they already have will take them some way towards gaining the first award, thus whetting their appetite to go on to the higher levels.

Much painstaking effort has been involved in producing the rules, the list of islands and the comprehensive criteria needed for island eligibility, also in administering the programme on a continuing basis. This work by members of the IOTA committee, and Country Assistants acting as local IOTA administrators in their own countries, impressively demonstrates the degree of voluntary effort that many radio amateurs are willing to "put back" into their hobby.

The programme is non profit-making, but has to be self-funding to meet administration costs, etc. Charges are therefore made for certificates and directories. Additionally, UK radio amateurs and SWLs taking part in the programme must be members of the RSGB, but this requirement does not apply to participants from other countries.

The IOTA directory, printed or on computer disk (disk provided), costs £6.00, US$10 or 15 IRCs (£7.00, US$12 or 18 IRCs outside Europe). It can be obtained from the RSGB IOTA Director, Roger Balister G3KMA, La Quinta, Mimbridge, Chobham, Woking, Surrey GU24 8AR. Send a self-addressed adhesive label and make cheques (sterling only) payable to R. Balister. The Directory is also available in foreign language versions in French, German, German Braille, Italian, Polish, Portuguese and Spanish, with one or two more translations pending.

If you become addicted to IOTA (which does happen!), you will then want to have the DX News Sheet which is a "must" for all serious DX operators, involved in IOTA or not. Write for details to the RSGB, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE.

YOUNG AMATEUR AWARD

The Young Amateur of the Year Award 1993 has gone to 15-year old Tim Munn G7OTO/2E1AMX, from Ventnor, Isle of Wight. Organised by the Radiocommunications Agency, in conjunction with the Radio Society of Great Britain, this award aims to increase interest in, and introduce more young people to, amateur radio. This, says the RA, reflects the recognition of both the Agency and the Government that amateur radio is an excellent training ground for the future supply of electronics and communications engineers.

Tim became interested in the hobby when he was 10, and now runs a radio club at Sandown High School. He is one of the youngest Novice Instructors in the UK and recently his first three pupils all passed the Novice Radio Amateur Examination (NRAE).

He has constructed many items of home-made equipment, including an 80m receiver and a 50MHz transmitter/receiver, and is converting a Storno radio telephone to 2m operation. He received £250, a certificate signed by the President of the Board of Trade, a visit to the RA's Radio Monitoring Centre at Baldock, and other prizes.

Close runner-up was Simon Kahn, aged 14, G0STU/2E1AAB, of Salford, Lancs, who passed his Radio Amateur's Examination at the age of 11, subsequently passed the NRAE, and on his 14th birthday obtained his full licence. He is heavily involved with the Bury Radio Society, edits the society's magazine *Feedback* and, like Tim, is also an Instructor for other youngsters in the Novice Licence scheme. He too received a number of prizes and an invitation to visit Baldock.

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