EVERYDAY PRACTICAL ELECTRONICS
JANUARY 1997
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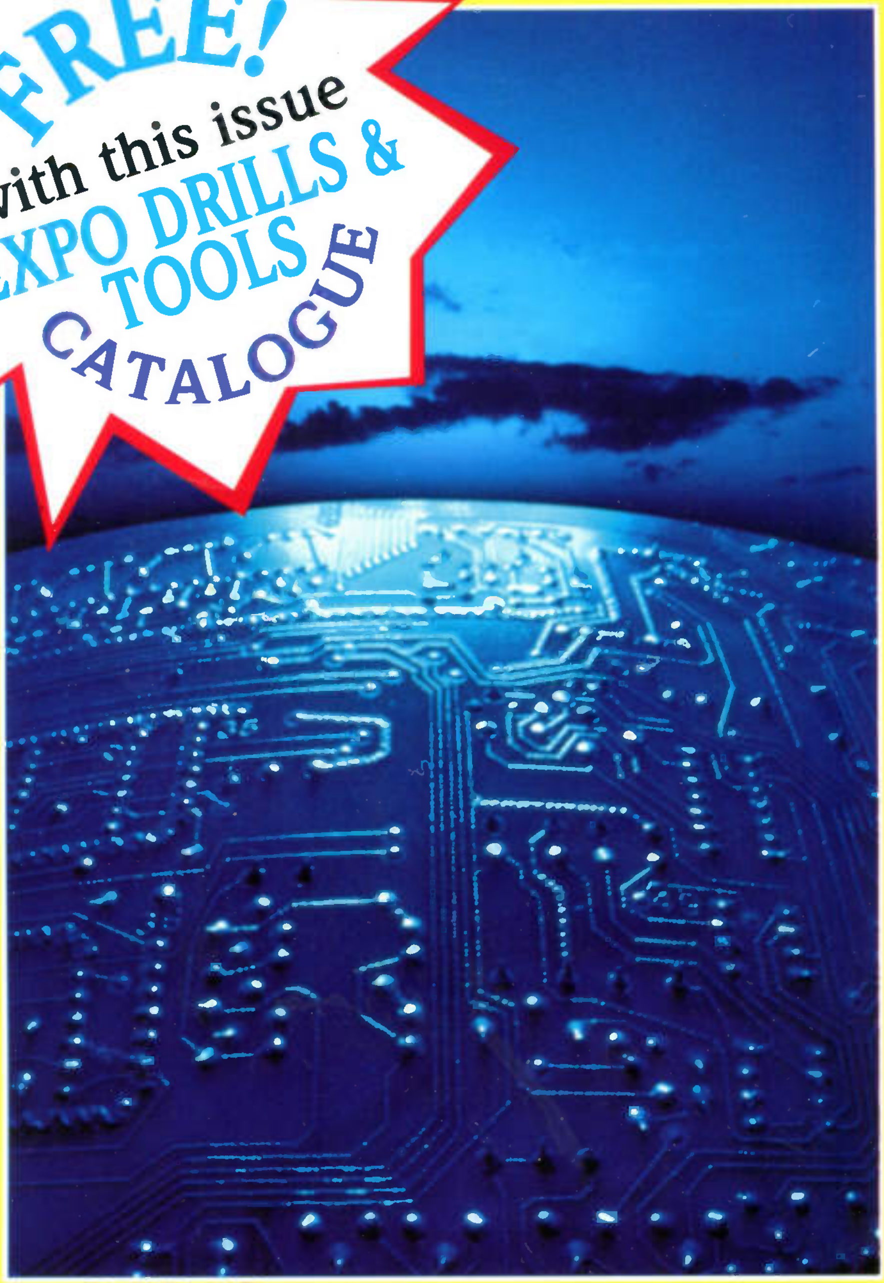


EARTH RESISTIVITY METER
Discover subterranean features

MAINS FAILURE WARNING
Sounds an alarm if mains is disconnected or fails

DIGITAL STORAGE PC OSCILLOSCOPE
Kit review

INGENUITY UNLIMITED
NEW TECHNOLOGY UPDATE
INNOVATIONS NET WORK
CIRCUIT SURGERY

THEREMIN MIDI/CV INTERFACE
The world's first design

THE NO. 1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

MOONSHINE BIBLE 270 page book covering the production of alchohol from potatoes, rice, grains etc Drawings of simple home made stills right through to commercial systems. £12 ref MS3

NEW HIGH POWER MINI BUG With a range of 800 metres or more and up to 100 hours use from a PP3 this will be popular! Bug measures less than 1" square! £28 Ref LOT102.

SINCLAIR C5 MOTORS We have a new ones available without gearboxes at £50 ref LOT25

BUILD YOU OWN WINDFARM FROM SCRAP New publication gives step by step guide to building wind generators. Armed with this publication and a good local scrap yard could make you self sufficient in electricity! £12 ref LOT81

PC KEYBOARDS PS2 connector, top quality suitable for all 286/386/486 etc £10 ref PCKB. 10 for £65.

TRACKING TRANSMITTER range 1.5-5 miles, 5,000 hours on AA batteries, also transmits info on car direction and motion!Works with any FM radio. 1.5" square. £65 ref LOT101

ELECTRIC DOOR LOCKS Complete lock with both Yale lock and 12v operated deadlock (keys included) £10 ref LOT99

GALLIUM ARSENIDE FISHEYE PHOTO DIODES Complete with suggested circuits for long range communications\switching £12 complete.

SURVEILLANCE TELESCOPE Superb Russian zoom telescope adjustable from 15x to 60x! complete with metal tripod (imposible to use without this on the higher settings) 66mm lense, leather carrying case £149 ref BAR69

WIRELESS VIDEO BUG KIT Transmits video and audio signals from a minature CCTV camera (included) to any standard television! All the components including a PP3 battery will fit into a cigarette packet with the lens requiring a hole about 3mm diameter. Supplied with telescopic aerial but a piece of wire about 4" long will still give a range of up to 100 metres. A single PP3 will probably give less than 1 hours use. £99 REF EP79. (probably not licensable!)

CCTV CAMERA MODULES 46X70X29mm, 30 grams, 12v 100mA, auto electronic shutter, 3.6mm F2 lens, CCIR, 512x492 pixels, video output is 1v p-p (75 ohm). Works directly into a scart or video input on a tv or video. IR sensitive. £79.95 ref EF137.

IR LAMP KIT Suitable for the above camera, enables the camera to be used in total darkness! £5.99 ref EF138

INFRA RED POWERBEAM Handheld battery powered lamp, 4 inch reflector, krypton bulb, gives out powerful infrared light! 4 D cells required. £39 ref PB1.

MONO VGA MONITORS, Perfect condition, Compaq, 14", 3 months warranty £29 ref MVGA

SOLAR COOKER GUIDE Comprehensive plans

9 WATT CHIEFTAN TANK LASERS

Double beam units designed to fit in the gun barrel of a tank, each unit has two semi conductor lasers and motor drive units for alignement. 7 mile range, full circuit diagrams, new price £50,000? us? £349. Each unit has two gallium Arsenide injection lasers, 1 x 9 watt, 1 x 3 watt, 900nm wavelength, 28vdc, 600hz pulse frequency. The units also contain an electronic receiver to detect reflected signals from targets. five or more units £299 ea. £349 for one. Ref LOT4.

TWO WAY MIRROR KIT Includes special adhesive film to make two way mirror(s) up to 60"x20". (glass not included) Includes full instructions. £12 ref TW1.

NEW LOW PRICED COMPUTER/WORKSHOP/HI-FI RCB UNITS Complete protection from faulty equipment for everybody! Inline unit fits in standard IEC lead (extends it by 750mm), fitted in less than 10 seconds, reset/test button, 10A rating. £6.99 each ref LOT5. Or a pack of 10 at £49.90 ref LOT6. If you want a box of 100 you can have one for £250!

RADIO CONTROLLED CARS FROM £6 EACH!!!! All returns from famous manufacturer, 3 types available, single channel (left,right,forwards,backwards) £6 ref LOT1. Two channel with more features £12 ref LOT2.

THOUSANDS AVAILABLE RING/FAX FOR DETAILS!

MAGNETIC CARD READERS (Swipes) £9.95 Cased with flyleads, designed to read standard credit cards! they have 3 wires coming out of the head so they may write as well? complete with control elctronics PCB. just £9.95 ref BAR31

WANT TO MAKE SOME MONEY? STUCK FOR AN IDEA? We have collated 140 business manuals that give you information on setting up different businesses, you peruse these at your leisure using the text editor on your PC. Also included is the certificate enabling you to reproduce (and sell) the manuals as much as you like! £14 ref EP74

PANORAMIC CAMERA OFFER Takes double width photographs using standard 35mm film. Use in horizontal or vertical mode. Complete with strap £7.99 ref BAR1

COIN OPERATED TIMER KIT Complete with coinslot mechanism, adjustable time delay, relay output, put a coinslot on anything you like! TV,s, videos, fridges, drinks cupboards, HIFI, takes 50p's and £1 coins. DC operated, price just £7.99 ref BAR27.

ZENITH 900 X MAGNIFICATION MICROSCOPE Zoom, metal construction, built in light, shrimp farm, group viewing screen, lots of accessories £29 ref ANAYLT.

AA NICAD PACK Pack of 4 tagged AA nicads £2.99 ref BAR34

PLASMA SCREENS 222x310mm, no data hence £4.99 ref BAR67

NIGHTSIGHTS Model TZS4 with infra red illuminator, views up to 75 metres in full darkness in infrared mode, 150m range, 45mm lens, 13 deg angle of view, focussing range 1.5m to infinity. 2 AA batteries required. 950g weight. £199 ref BAR61. 1 years warranty

LIQUID CRYSTAL DISPLAYS Bargain prices,

16 character 2 line, 99x24mm £2.99 ref SM1623A

20 character 2 line, 83x19mm £3.99 ref SM2020A

16 character 4 line, 62x25mm £5.99 ref SMC1640A

TAL-1 110MM NEWTONIAN REFLECTOR TELESCOPE Russian. Superb astronomical 'scope, everything you need for some serious star gazing! up to 169x magnification. Send or fax for further information ref TAL-1, £249

SOLAR ENERGY/GENERATOR PLANS For your home, loads of info on designing systems etc £7 ref PV1

SOLAR COOKERS Comprehensive guide to building solar powered cookers, includes plans, recipes, cooking times etc £7 ref SBC1

WOLVERHAMPTON BRANCH NOW OPEN AT WORCESTER ST W'HAMPTON TEL 01902 22039

CENTRAL POINT PC TOOLS Award winning software, 1,300 virus checker, memory optimiser, disc optimiser, file compression, low level formatting, backup scheduler, disk defragmenter, undelete, 4 calculators, Dbase, disc editor, over 40 viewers, remote computing, password protection, encryption, comprehensive manual supplied etc £8 ref lot 97 3.5" disks.

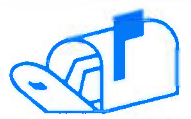
GOT AN EXPENSIVE BIKE? You need one of our bottle alarms, they look like a standard water bottle, but open the top, insert a key to activate a motion sensor alarm built inside. Fits all standard bottle carriers, supplied with two keys. **SALE PRICE £7.99 REF SA32.**

COLOUR CCTV VIDEO CAMERAS, BRAND NEW, CASED, £119.

PERFECT FOR
SURVEILLANCE
INTERNET
VIDEO CONFERENCING
SECURITY
DOMESTIC VIDEO

Works with most modern video's, TV's, Composite monitors, video grabber cards etc

Pal, 1v P-P, composite, 75ohm, 1/3" CCD, 4mm F2.8, 500x582, 12vdc, mounting bracket, auto shutter, 100x50x180mm, 3 months warranty, 10 or more £99 ea.



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http://www.pavilion.co.uk/bull-electrical

GOT AN EXPENSIVE ANYTHING? You need one of our cased vibration alarms, keyswitch operated, fully cased just fit it to anything from videos to caravans, provides a years protection from 1 PP3 battery, UK made. **SALE PRICE £4.99 REF SA33.**

DAMAGED ANSWER PHONES These are probably beyond repair so just £4.99 each. BT response 200 machines. REF SA30.

IBM PS2 MODEL 160Z CASE AND POWER SUPPLY Complete with fan etc and 200 watt power supply. **£9.95 ref EP67**

DELL PC POWER SUPPLIES 145 watt, +5,-5,+12,-12, 150x150x85mm complete with switch, flyleads and IEC socket. **SALE PRICE £9.99 ref EP55**

1.44 DISC DRIVES Standard PC 3.5" drives but returns so they will need attention **SALE PRICE £4.99 ref EP68**

1.2 DISC DRIVES Standard 5.25" drives but returns so they will need attention **SALE PRICE NOW ONLY £3.50 ref EP69**

PP3 NICADS Unused but some storage marks. £4.99 ref EP52

DELL PC POWER SUPPLIES (Customer returns) Standard PC psu's complete with fly leads, case and fan. +12v,-12v,+5v,-5v **SALE PRICE £1.99 EACH** worth it for the bits alone! ref DL1. **TRADE PACK OF 20 £29.95 Ref DL2.**

GAS HOBS AND OVENS Brand new gas appliances, perfect for small flats etc. Basic 3 burner hob **SALE PRICE £24.99** ref EP72. Basic small built in oven **SALE PRICE £79 ref EP73**

ENERGY BANK KIT 100 6"x6" 6v 100mA panels, 100 diodes, connection details etc. £69.95 ref EF112.

PASTEL ACCOUNTS SOFTWARE, does everything for all sizes of businesses, includes wordprocessor, reportwriter, windowing, networkable up to 10 stations, multiple cash books etc. 200 page comprehensive manual. 90 days free technical support (01342-326009 try before you buy!) **Current retail price is £129, SALE PRICE** £9.95 ref SA12. SAVE £120!!!

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

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

PC PAL VGA TO TV CONVERTER Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware.. Ideal for laptops or a cheap upgrade.Supplied in kit form for home assembly. **SALE PRICE £25 REF SA34**

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

YUASHA SEALED LEAD ACID BATTERIES Two sizes currently available this month. 12v 15AH at £18 ref LOT8 and 6v 10AH (suitable for emergency lights above) at just £6 ref LOT7.

ELECTRIC CAR WINDOW DE-ICERS Complete with cable, plug etc **SALE PRICE JUST £4.99 REF SA28**

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt. **£8.99 REF SA25.**

MICRODRIVE STRIPPERS Small cased tape drives ideal for stripping, lots of useful goodies including a smart case, and lots of components. **SALE PRICE JUST £4.99 FOR FIVE REF SA26**

SOLAR POWER LAB SPECIAL You get TWO 6"x6" 6v 130mA solar cells, 4 LED's, wire, buzzer, switch plus 1 relay or motor.Superb value kit **SALE PRICE JUST £4.99 REF SA27**

RGB/CGA/EGA/TTL COLOUR MONITORS 12" in good condition. Back anodised metal case. **SALE PRICE £49 REF SA16B**

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

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

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

PHONE CABLE AND COMPUTER COMMUNICATIONS PACK Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PC's over a long distance utilizing the serial ports. Complete kit £8.99. Ref comp1.

VIEWDATA SYSTEMS made by Phillips, complete with internal 1200/75 modem, keyboard, psu etc RGB and composite outputs, menu driven, autodialler etc. **SALE PRICE £12.99 REF SA18**

AIR RIFLES .22 As used by the Chinese army for training puposes, so there is a lot about! £39.95 Ref EF78. 500 pellets £4.50 ref EF80.

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 £25 **REF: MAG15** 12v psu is £5 extra **REF: MAG5P2**

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

***FM TRANSMITTER KIT** housed in a standard working 13A adapter!! the bug runs directly off the mains so lasts forever! why pay £700? or price is £15 REF: EF62 (kit) Transmits to any FM radio.

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

GAT AIR PISTOL PACK Complete with pistol, darts and pellets £12.95 Ref EF82B extra pellets (500) £4.50 ref EF80.

6"X12" AMORPHOUS SOLAR PANEL 12v 155x310mm 130mA. **SALE PRICE £4.99 REF SA24.**

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

MIXED GOODIES BOX OF MIXED COMPONENTS WEIGHING 2 KILOS YOURS FOR JUST £5.99

4X28 TELESCOPIC SIGHTS Suitable for all air rifles, ground lenses, good light gathering properties. £19.95 ref R/7.

GYROSCOPES Remember these? well we have found a company that still manufactures these popular scientific toys, perfect gift or for educational use etc. £6 ref EP70

HYPOTHERMIA SPACE BLANKET 215x150cm aluminised foil blanket, reflects more than 90% of body heat. Also suitable for the construction of two way mirrors! £3.99 each ref O/L041.

LENSTATIC RANGER COMPASS Oil filled capsule, strong metal case, large luminous points. Sight line with magnifying viewer. 50mm dia, 86gm. £10.99 ref O/K604.

RECHARGE ORDINARY BATTERIES UP TO 10 TIMES! With the Battery Wizard! Uses the latest pulse wave charge system to charge all popular brands of ordinary batteries AAA, AA, C, D, four at a time! Led system shows when batteries are charged, automatically rejects unsuitable cells, complete with mains adaptor. BS approved. Price is £21.95 ref EP31.

TALKING WATCH Yes, it actually tells you the time at the press of a button. Also features a voice alarm that wakes you up and tells you what the time is! Lithium cell included. £7.99 ref EP26.

PHOTOGRAPHIC RADAR TRAPS CAN COST YOU YOUR LICENCE! The new multiband 2000 radar detector can prevent even the most responsible of drivers from losing their licence! Adjustable audible alarm with 8 flashing leds gives instant warning of radar zones. Detects X, K, and Ka bands, 3 mile range, 'over the hill' 'around bends' and 'rear trap facilities. micro size just 4.25"x2.5"x.75", Can pay for itself in just one day! £79.95 ref EP3.

3" DISCS As used on older Amstrad machines, Spectrum plus3's etc £3 each ref BAR400.

STEREO MICROSCOPES BACK IN STOCK Russian, 200x complete with lenses, lights, filters etc etc very comprehensive microscope that would normally be around the £700 mark, our price is just £299 (full money back guarantee) full details in catalogue..

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

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VOL. 26 No. 1 JANUARY 1997

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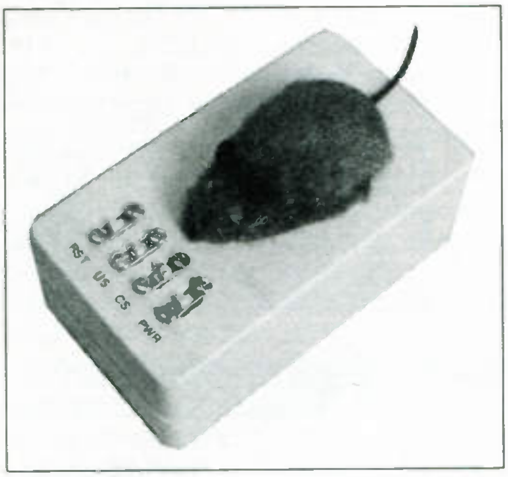
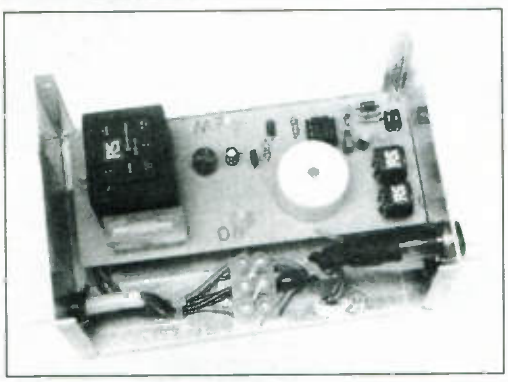
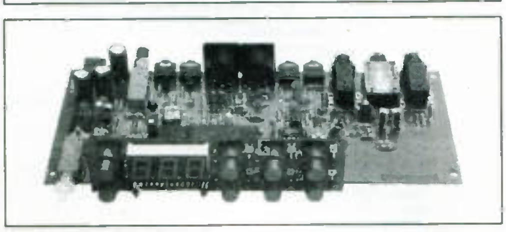
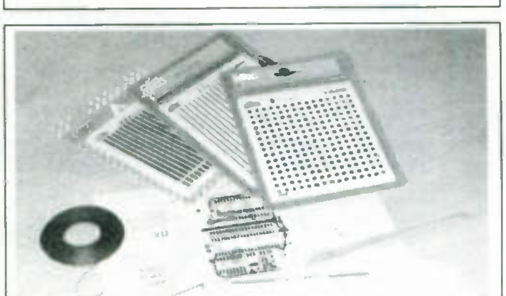
The No. 1 Magazine for Electronics, Technology and Computer Projects









Projects and Circuits

Series and Features

Regulars and Services

SEASONAL GREETINGS TO ALL OUR READERS

Our February '97 Issue will be published on Friday, 3 January 1997. See page 55 for details.

Transform your PC

into a digital oscilloscope, spectrum analyser, frequency meter, voltmeter, data logger . . for as little as £49.00

Pico's Virtual Instrumentation enable you to use your computer as a variety of useful test and measurement instruments or as an advanced data logger.

Hardware and software are supplied together as a package - no more worries about incompatibility and no programming required.

Pico Technology specialises only in the development of PC based data acquisition instrumentation. We have the product range and experience to help solve your test and measurement problem.

Call for your guide on 'Virtual Instrumentation'. We are here to help you.

The **ADC-10** supplied with PicoScope gives your computer a single channel of analog input.

ADC-10 £49
with PicoLog £59

Data Logging

Pico's range of PC based data logging products enable you to easily measure, display and record temperature, pressure and voltage signals.

TC-08 Thermocouple to PC Converter

- Supplied with PicoLog data logging software for advanced temperature processing, min/max detection and alarm.
- 8 Thermocouple inputs
- No power supply required.

TC-08 £199 ***TC-08*** £224 with cal. Cert.

complete with serial cable & adaptor. Thermocouple probes available.

Virtual Instrumentation

Pico's PC based oscilloscopes simply plug into the parallel port turning your PC into a fully featured oscilloscope, spectrum analyser and meter. Windows and DOS software supplied.

NEW ADC-200

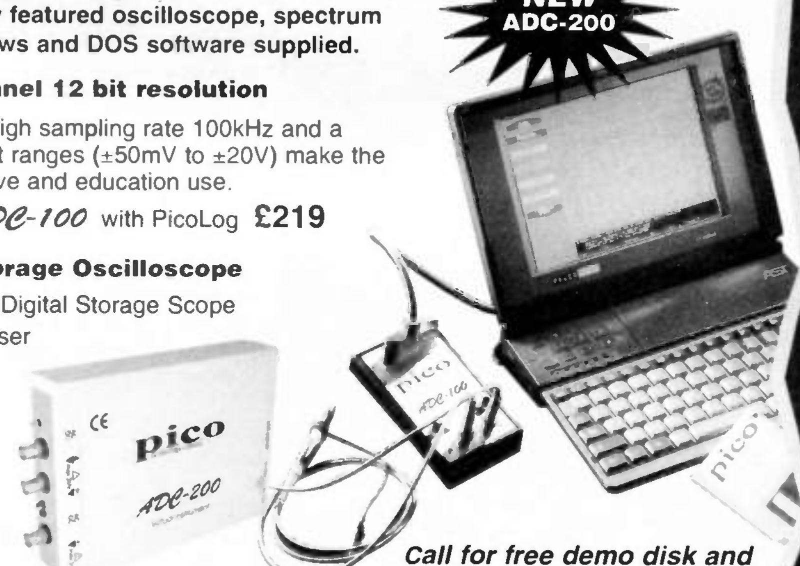
ADC-100 Dual Channel 12 bit resolution

The ADC-100 offers both a high sampling rate 100kHz and a high resolution. Flexible input ranges (±50mV to ±20V) make the unit ideal for audio, automotive and education use.

ADC-100 £199 *ADC-100* with PicoLog £219

ADC-200 Digital Storage Oscilloscope

- 50 MSPS Dual Channel Digital Storage Scope
- 25 MHz Spectrum Analyser
- Windows or DOS environment
- ±50mV to ±20V
- Multimeter
- 20 MSPS also available



ADC 200-20 £359.00
ADC 200-50 £499.00

Both units are supplied with cables, power supply and manuals.

Call for free demo disk and product range catalogue

Post & Packing UK £3.50, Export customers add £9 for carriage & insurance.

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E-mail: post@picotech.co.uk Web site: http://www. picotech.co.uk/

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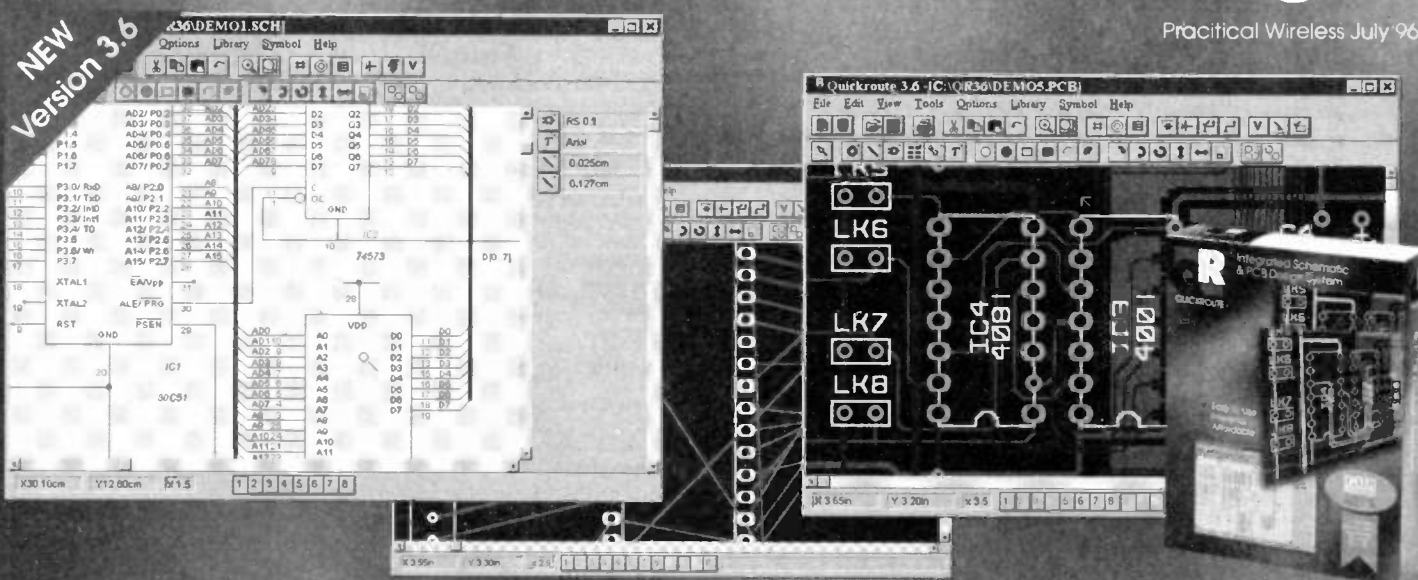
QUICKROUTE

"extremely good value for money for such a comprehensive package"

Practical Wireless July '96



Schematic capture, Autorouting & Design Checking for just £149*

NEW QR 3.6 Designer £149*

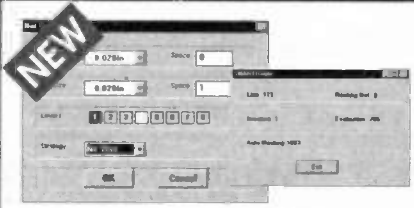
Take a look at Quickroute 3.6 Designer and you might be surprised! For just £149* you get easy to use schematic design (automatic junction placement, parts-bin, etc), "one click" schematic capture, autorouting on 1 or 2 layers, design rule & connectivity checking and a starter pack of over 260 symbols.

NEW QR 3.6 PRO+ £399*

For those needing more power & more features there is Quickroute 3.6 PRO+. For just £399 you get multi-sheet schematic capture, 1 to 8 layer autorouting, net-list import/export, links to simulators, CAD/CAM file export, Gerber import/viewing, DXF WMF & SPICE file export, copper fill, advanced connectivity checking with automatic updating of a PCB from a schematic, the basic set of over 260 symbols and library pack 1 which includes a further 184 symbols. More symbols are available in additional library packs available separately

Prices are Quickroute 3.6 Designer £149, Quickroute 3.6 PRO+ £399, SMARTRoute 1.0 £149.00, Library Packs £39 each. *Post & Packing per item is £6 (UK), £8 (Europe) and £12 (World). V.A.T must be added to the total.

NEW PLUG IN AUTOROUTER



SMART ROUTE

SMARTRoute is a new 32-bit autorouter from Quickroute Systems rated in ' category A' by Electronics World (Nov 96). SMARTRoute plugs straight into Quickroute 3.6, automatically updating Quickroute' s menus with new features and tools.

SMARTRoute 1.0 uses an iterative goal seeking algorithm which works hard to find the best route even on single sided PCB' s. SMARTRoute allows you to assign different algorithms, design rules, track & via sizes, layers used, etc to groups of nets for total flexibility. SMARTRoute 1.0 costs just £149*.

CAD CAM RECOMMENDED

QUICKROUTE SYSTEMS

Tel 0161 476 0202 Fax 0161 476 0505

Quickroute Systems Ltd. Regent House Heaton Lane Stockport SK4 1BS U.K.

WWW: www.quickroute.co.uk EMail: info@quicksys.demon.co.uk

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FIRST FIRST

It's not very often that we can claim a world first – sometimes we are not sure on this so we say nothing, but we have published a number of projects that we have not seen in other electronics magazines from around the world; it is, however, impossible to check every publication. What makes us so sure that the *Theremin Midi/CV Interface* is a world first is that this is a specialised area of music technology; all the Theremins available are well known, as are the various high technology music interfaces, etc. This is mainly because top level music making is a truly international business.

This is not a project for the beginner and not a cheap one either, with the high cost of p.t.h. printed circuit boards and the special preprogrammed chip, but we are proud to be able to publish the design which would otherwise not have been available to the hobbyist. It is after all a world first!

SECOND FIRST

Of course, we like to be first if we can and this month I'm happy to report another first for *EPE*. The magazine is the first independent hobbyist magazine to be stocked in Maplin stores throughout the UK. See our *Innovations* page for more details. Our thanks to Maplin and to our distributors Seymour for making this possible.

THIRD FIRST

We also believe we were the first UK electronics hobbyist magazine to have a Web page and to make much of our project software available *free* on the Internet (on this last point we believe we are the only magazine in the world presently doing this). Our Web site now carries a back number ordering page and plenty of regularly updated information about the magazine. I'm pleased to say that it is generating interest, orders and congratulatory comments from around the world.

We are, of course, working on a number of new and exciting projects which may also represent firsts. So, stick with us, it should be another interesting year; which brings me to our regular thanks and Seasonal Greetings to all our readers – we hope you have an enjoyable and peaceful 1997.

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 cost we cannot reply to queries by Fax.**

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

COMPONENT SUPPLIES
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.

We regret that **we cannot provide data, or answer queries, on projects that are more than five years old.**

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The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture. Legal remedies are available in respect of some of these circumstances, and readers who have complaints should first address them to the advertiser.

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We 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 buying any transmitting or telephone equipment as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; overseas readers should check local laws.

Constructional Project

EARTH RESISTIVITY METER

ROBERT BECK

Part 1

Your assistance to the local Archeological Society could be invaluable with this simple subterranean site detector at your command.

RESISTIVITY surveying is a method of detecting subterranean features and has been an investigative technique of archaeologists for many years. Archaeological features can often be detected when buried about one metre under the present ground level. Natural features such as gravel or peat beds buried under silt can be detected at much greater depths.

The same survey will detect both natural and archaeological features. In general, the former tend to have ill-defined "soft" edges whilst the latter consist of geometric "man-made" shapes; if it "looks like" the outline of a building, it probably is!

HISTORICAL BACKGROUND

The technique of resistivity surveying was first used by Civil Engineers for investigating the proposed sites of dams, etc. Archaeologists first realised its potential in 1946. These early instruments were powered by hand cranked a.c. generators and used a resistance bridge configuration to perform measurements, similar to the early "Megger" insulation test sets, although the latter used d.c.

The readings were taken by simultaneously winding the generator handle and reading a meter calibrated in Ohms. As a series of readings across a site was required, the procedure was slow and tedious. With the arrival of the transistor, resistivity sets designed specifically for archaeology gradually became quicker to operate.

Early transistor sets progressed through an a.c. bridge configuration, which had to be balanced with a calibrated potentiometer for each reading, to the present commercial instruments which are designed to log the readings directly into a data logger, displaying results in the form of a map on a portable computer in the field.

It is interesting to note in passing that resistivity measurements have recently been used for crack measurement in metals and also in medical applications.

WHAT IS RESISTIVITY?

Resistivity is defined as the resistance of a metre cube of material across opposite faces. It is therefore a standardised way of comparing resistances of various materials:

$$\rho = RL/A$$

Where:

ρ = resistivity
R = resistance of material along its length
L = length
A = area of cross section

The principle upon which resistivity surveying works is as follows:

The resistivities of stone, concrete and similar materials are relatively high, whilst the resistivities of nearly all soils are relatively low. Often ditch and pit fillings, which can no longer be seen on the surface, have an even lower resistivity than the surrounding soil.

The combined resistivity of soil and any included material is termed the *apparent resistivity*. If we measure the resistivity across an area of ground that has a stone block buried somewhere in it, the apparent resistivity will increase at that particular point. Similarly, if we cross the site of a silted-up ditch, the reading will decrease, as illustrated in Fig. 1.

We therefore have a method of detecting building foundations, walls, silted-up ditches and pits, etc. However, various

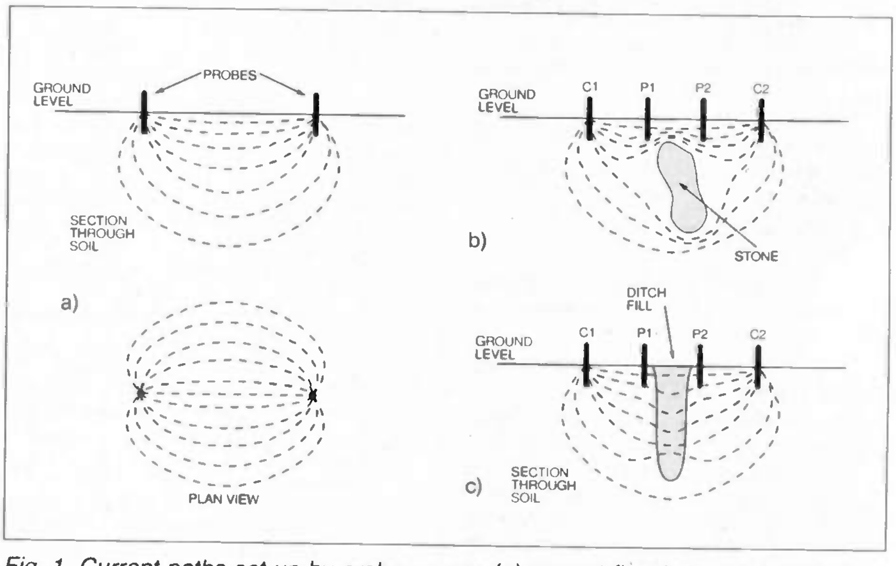
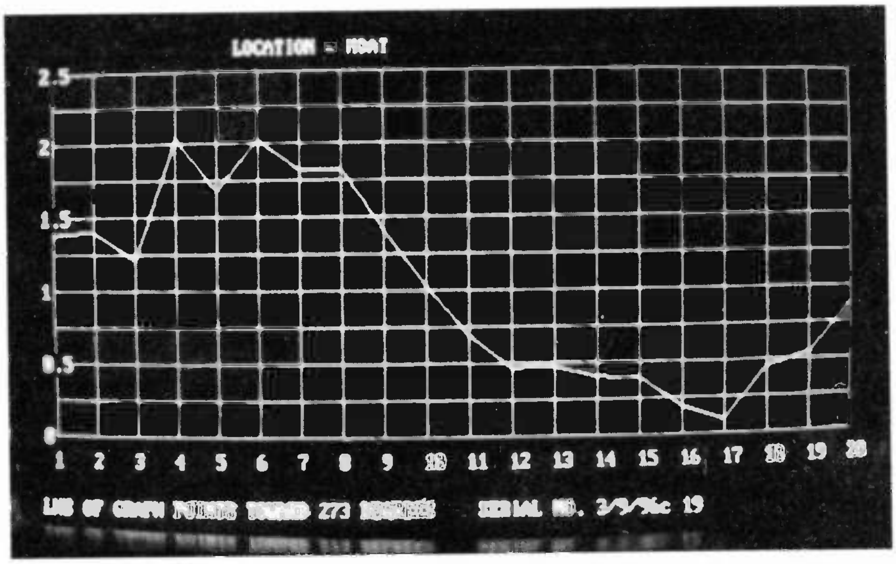


Fig. 1. Current paths set up by probe arrays: (a) current flow between two probes; (b) Wenner (see "Probe Configurations") array with stone below it; (c) Wenner array with ditch below it.



One way of analysing the sample results is to view them as a linear graph on a computer screen.

factors complicate the issue: the resistivity of soil depends upon its actual composition, the moisture present and the amount of compaction.

It therefore follows that taking just one or two readings over a site is meaningless and will convey no useful information to the operator. A series of readings must be methodically taken according to a pre-arranged plan.

The resistivity meter requires a system of probes pushed into the soil to a depth of about 250mm to make its measurements. Resistivity surveying can therefore be considered a non-destructive technique that will not harm an archaeological site – *providing that you do not dig the site to check your results!*

It is stressed that digging at sites of potential archeological interest should only be carried out under the supervision of suitably qualified archeologists. Advice on the ethics of amateur resistivity surveying, and about joining Archeological Societies, is given in Part 2, next month.

SOME PROBLEMS

Why can we not make earth resistivity measurements using the Ohmmeter that we already possess in our toolbox? It might be thought that a simple multimeter switched to a suitable Ohms range would be the most cost effective solution to resistivity measurement.

However, these meters use d.c. to perform resistance measurements. This presents some difficulties. The multimeter will respond to the following:

1. 50Hz mains derived currents circulating in the ground

2. "Battery effect", caused by chemical interaction between probes, and acids or alkalis naturally occurring in soils

3. Electrolytic effect of the measuring current passing through the soil.

The first two points are self explanatory but the third may need some clarification.

The electrolytic effect will cause a gradual increase in the contact resistance between the probes and the soil, making the reading on the multimeter gradually rise. This increase in contact resistance is caused by a film of gas coating the probes, due to water in the soil breaking down into its constituent parts of oxygen and hydrogen under the influence of the measuring current. Try this experiment:

Connect a multimeter, set to the Kilohms range, to two probes pushed into the ground about 200mm deep and 500mm apart. The probes can be pieces of welding rod, metal pipe, etc. Then switch the multimeter on and record the resistance readings against time.

You can see in Table 1 that the readings tend to increase with time and never quite settle down. This demonstrates the electrolytic effect of the measuring current.

Table 1

Time	Kilohms	Kilohms (leads reversed)
0 sec.	6·36	9·66
10 sec.	6·66	10·00
20 sec.	6·76	10·15
30 sec.	6·81	10·28
40 sec.	6·87	10·34
50 sec.	6·91	10·40
1·0 min.	6·95	10·44
1·5 min.	7·06	10·53
2·0 min.	7·17	10·57
2·5 min.	7·23	10·59
3·0 min.	7·23	10·63
3·5 min.	7·30	10·66
4·0 min.	7·30	10·69
4·5 min.	7·28	10·70
5·0 min.	7·36	10·72

It can be seen from the results columns that reversing the leads gives a totally different set of increasing readings. This is the result of the "battery effect" combined with the electrolytic effect.

Change the multimeter to the Millivolts D.C. setting and you will see a reading of, for example, 150mV, which demonstrates the "battery effect". Set the multimeter range to the Millivolts A.C. setting and a reading of, probably, 3mV to 4mV will be observed, thus indicating mains derived circulating currents.

Having now noted these complications we can consider ways of overcoming them.

SYSTEM REQUIREMENTS

An a.c. square wave oscillator needs to be used for supplying current to the soil. The frequency must not be too low or the electrolytic effect will become noticeable. Equally, the frequency must not be too high or ground inductive effects will become apparent. The frequency must not be a multiple of 50Hz otherwise we cannot use a synchronous rectifier at a later stage to remove unwanted 50Hz signals. The author's preference is to use 137Hz.

The oscillator is used to feed a constant current generator which enables a fixed current to be delivered to the soil, thus avoiding at least one variable. This current is fed into the soil via a pair of probes, known as the C_1 and C_2 probes.

The resultant voltage is picked out of the soil by a second pair of probes, known as the P_1 and P_2 probes and is a "floating" voltage in that neither probe is at the instrument's 0V rail voltage.

This necessitates the use of a differential amplifier because neither input terminal of the input amplifier can be connected to earth. The input impedance of the differential amplifier should be as high as practical so as to swamp any contact resistance associated with the P_1 and P_2 probes.

The output of the amplifier then goes to a synchronous rectifier so that only those signals which are in phase with the oscillator are rectified. The rectified signal can now be fed to a digital multimeter which makes a convenient readout device. The block diagram in Fig. 2 illustrates the principle.

Any cube of soil that we wish to measure does not exist in isolation, it is part of the whole earth. Therefore the adjacent soil also helps to conduct the current. If a pair of probes is inserted into the soil, the current between them tends to fan out in all directions, gradually weakening as it spreads further from the centre line between the probes (see Fig. 1a).

The effect is analogous to that which can be seen when iron filings are used to trace the lines of force of a bar magnet. In the case of the soil cube, the electrons, being similarly charged, repel each other, to cause the fanning out of the current.

It is possible to connect an a.c. measuring device directly across the probes which

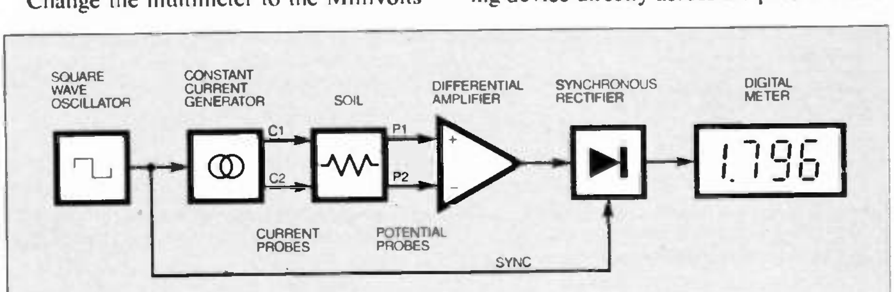


Fig. 2. Block diagram for a basic earth resistivity meter.

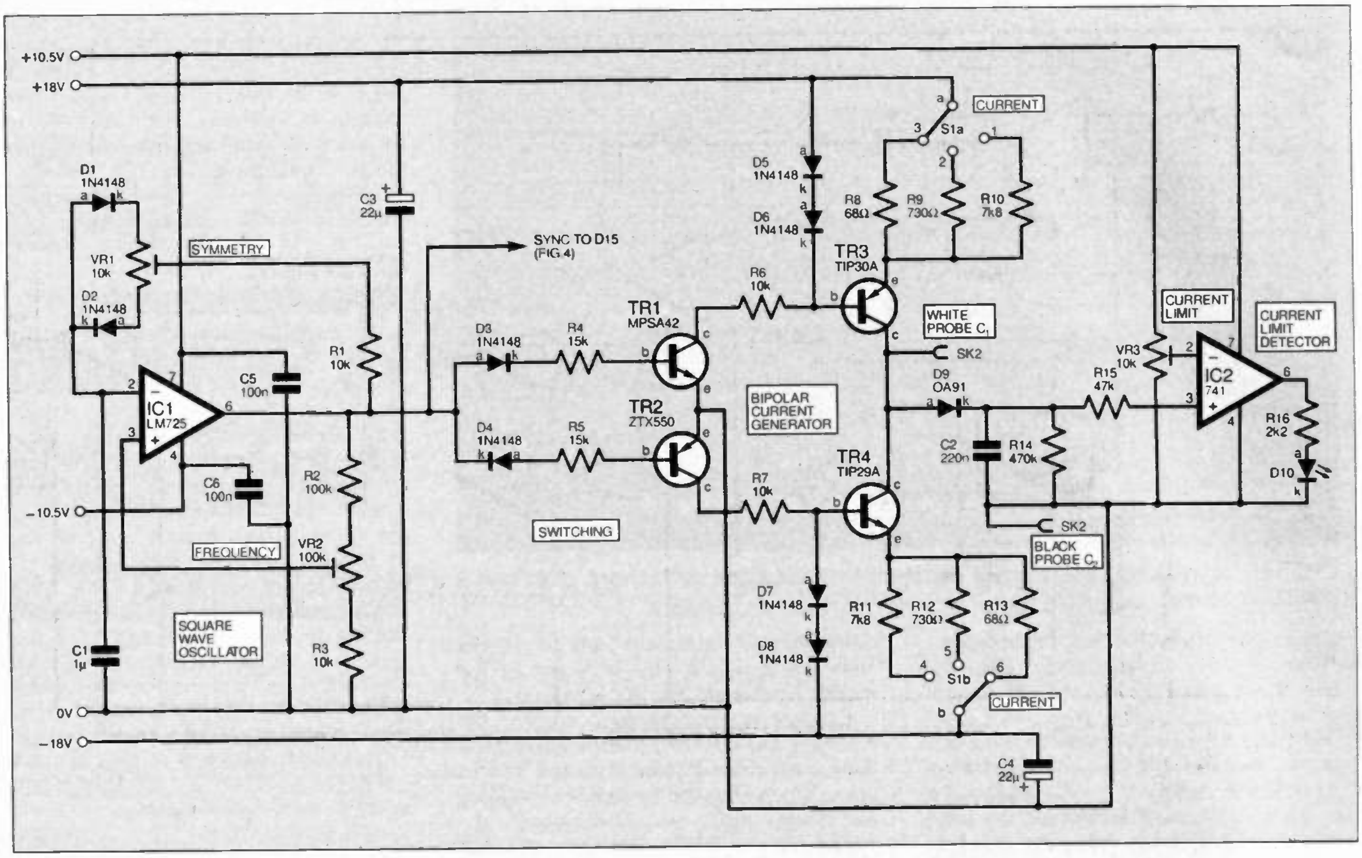


Fig. 3. Circuit diagram for the Current Generator.

are injecting the a.c. into the soil. We would have enough data to calculate the resistance between the probes using Ohm's Law, i.e. R = V / I.

This method does work but it has one major problem in that we are measuring voltage at either end of a hemisphere of current. If we introduce two separate electrodes and use them only for "picking off" a voltage, we have an electrode system that is more depth sensitive.

The reason for this is that, in the case of two probes only, we are measuring the effect of the current mainly running along the surface of the soil. Whereas, in the case of two pairs of probes, we are not measuring the effect of the current that is off the probes' horizontal axis to such a great extent, thereby forcing the probe configuration to be more depth sensitive compared to surface sensitive.

The potential difference being measured is on the flat surface of a hemisphere, not across the opposite faces of a cube. Therefore it follows that we are not calculating actual resistivity, which depends on the particular probe configuration in use. However, there is no need to calculate true resistivity figures, because only relative readings are required.

CIRCUIT DESCRIPTION

Having looked at a bit of theory, let's get right down to earth and describe the circuit for a simple Earth Resistivity Meter. The circuit diagram for the first part of it, the Current Generator, is shown in Fig. 3.

Op.amp IC1, together with its associated components, forms an oscillator giving a square wave output which is balanced about the 0V line, and at a frequency of 137Hz. The output appears at pin 6, with its amplitude being a little below the 10·5V supply rails.

The symmetry of the waveform is accurately set by preset potentiometer VR1 in conjunction with diodes D1 and D2, The precise frequency is set by preset VR2. Capacitor C1 forms part of the time constant for the oscillator.

A non-polarised polyester capacitor *must* be used for C1. It should *not* be an electrolytic capacitor as this would have a certain amount of leakage current, which may vary with temperature, and cause the oscillator to drift from the desired frequency.

The output at IC1 pin 6 is passed to the switching circuit, formed around transistors TR1 and TR2, which "enables" either the positive or negative half of the bipolar current generator, as appropriate. Positive constant current is generated by TR3 in conjunction with diodes D5 and D6, and selectable emitter load resistors R8 to R10. Negative constant current is similarly generated by the circuit around TR4, D7, D8 and switched resistors R11 to R13.

Selection of the emitter loads is carried out by the dual 3-way switch S1a/b. The output current range is selectable at 0·1mA, 1mA or 10mA, in order of switch positions 1 to 3.

The selected current is available directly as an output at the collectors of TR3 and TR4, via socket SK1. The amount of current being delivered is detected by the circuit around IC2, which is, in fact, actually a voltage level detector. The voltage level is, of course, relative to the current being drawn via SK1.

Diode D9, resistor R14 and capacitor C2 form a rectifier and smoothing circuit. Op.amp IC2 is configured as a comparator, with preset VR3 providing the reference voltage.

When the voltage across the current output goes to too high a value, indicating that the current generator is feeding into too high a load, l.e.d. D10 will light. This indicates that an erroneous reading is occurring, because there is insufficient voltage available to drive the demanded current.

In this case, the Current switch, S1a/S1b, should be set to a lower value which would accept a higher load resistance.

The voltage drop in the soil caused by the current driven through it is detected by the P_1 and P_2 probes, which feed their signals to a Differential Input Amplifier comprising IC3a, IC3b, IC4a and IC4b, as seen in Fig. 4.

Over-voltage protection for the dual amplifier IC3 is provided by Zener diodes D11 to D14. Being 9·1V diodes, any voltage between the probe and earth that is above 9·1V will cause one of the diodes to conduct, thus protecting the amplifier.

Amplifier gain is set by selecting one of three resistors, R23 to R25, by the Gain switch S2. The gain may be calculated from the following formula:

$$\text{Gain} = 1 + (2R_{FEEDBACK}/R_{SWITCH})$$

thus:

$$\text{Gain} = 1 + (2 \times 10000/R_{SWITCH})$$

The resistors chosen give switched gains of × 10, × 100 and × 1000.

The amplified signal is passed to IC4b, which acts as a Synchronous Rectifier. A reference signal is obtained from *pin* 6 of IC1 (Fig. 3) and fed to diode D15. When the cathode (k) of D15 is positive, no voltage will be applied to the gate (g) of field effect transistor (f.e.t.) TR6. This will cause

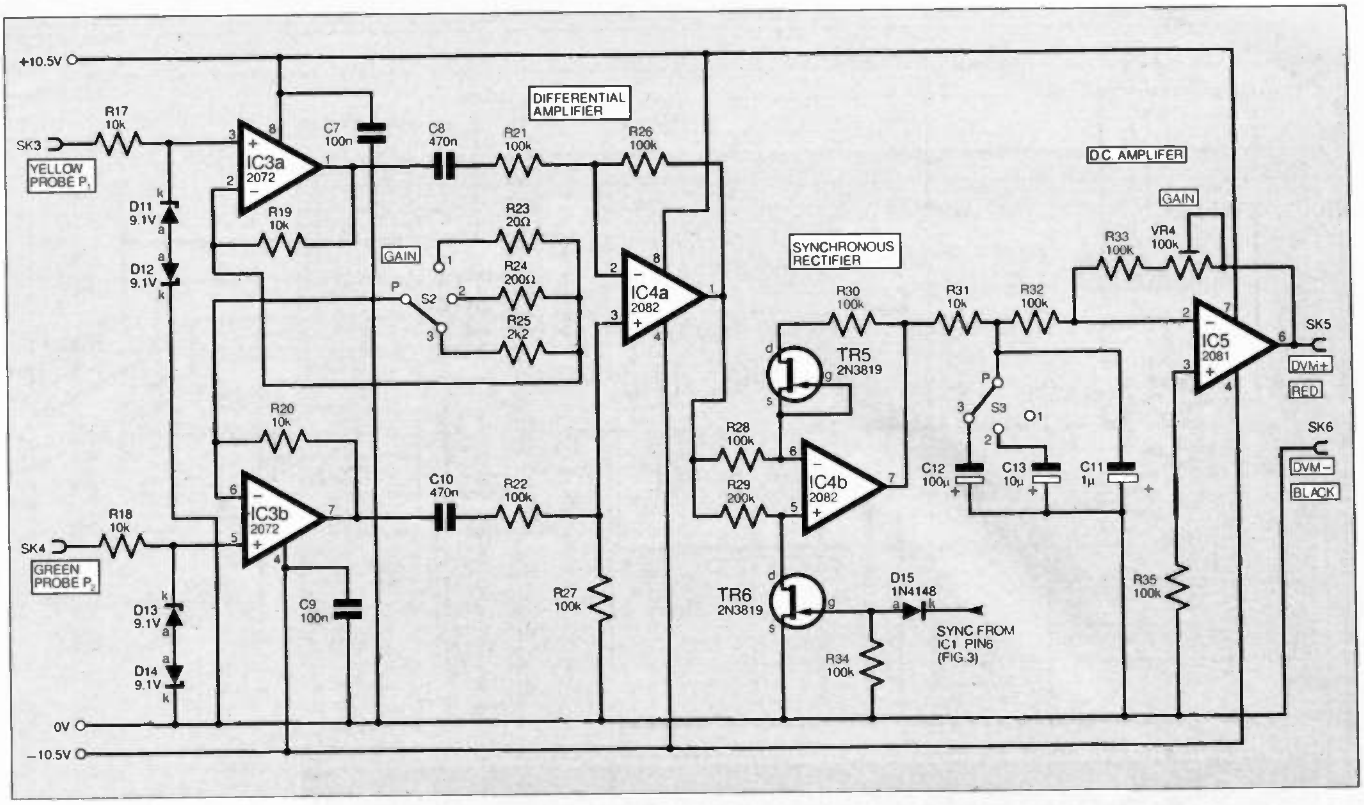


Fig. 4. Circuit diagram for the Differential Input Amplifier, Synchronous Rectifier and D.C. Amplifier.

the f.e.t. source-drain (s-d) path to conduct, thus grounding input pin 5 of IC4b.

The circuit then acts as an inverting amplifier with a gain of − 1. Its input pin 5 is damped by resistor R29 which, because of its high resistance compared to the output impedance of the last stage, will cause no noticeable loading.

When the cathode of D15 is negative, the gate voltage of TR6 will be about − 11V and the f.e.t. source-drain path will be high impedance, and so act as an open circuit. The circuit will then act as a non-inverting amplifier with a gain of + 1.

Basically, the gain is determined by the relative values of resistors R28, R29 and R30. The inclusion of the f.e.t. TR5 in the feedback path helps to stabilise any tendency towards gain-change caused by temperature drift.

When the input signal to the Synchronous Rectifier (via D15) is positive, the output will be the same amplitude as the input, but will be reversed in polarity. When the input signal is negative, the output signal will also be negative, but still having the same amplitude as the input.

The rectified signal at IC4b pin 7 will always be negative, with any signals that are out of phase with the oscillator being superimposed as an a.c. waveform on the d.c. output signal.

The output from IC4b pin 7 is passed through a low-pass filter consisting of resistors R31, R32, and capacitors C11 to C13. This will remove most of the unwanted a.c. signals that are present. C12 and C13 can be switched in or out of the circuit by S3, so allowing the filter response times and effectiveness to be changed.

However, increasing the effectiveness of the filter by increasing the value of either of these capacitors will slow the response time of the circuit. The values chosen represent a suitable compromise for minimising the interference found in most rural locations.

The output from the D.C. Amplifier IC5 is then fed via sockets SK5 and SK6 to a digital voltmeter (DVM). A toolbox type digital multimeter, set to a relevant voltage range, is suitable, with connecting leads of about 500mm in length. If desired, a digital panel meter may be incorporated in the case containing the resistivity meter. It did not seem to be a cost effective exercise to build a digital indicator for this circuit.

Whatever type of indicator is used, it should have ranges from 0V to 10V d.c., down to 0V to 100mV f.s.d. (full scale deflection).

POWER SUPPLY

As shown in Fig. 5, power is supplied by two batteries, B1 and B2, which may be any type of battery that can supply 18V at only a few milliamps. Rechargeable NiCad cells stripped from old radio equipment have been found to be ideal! An alternative suggestion is two PP9 batteries in series for B1, and a similar arrangement for B2.

The twin power supplies are regulated down to + 10·5V and − 10·5V by IC6 and IC7, in conjunction with Zener diodes D16 and D17.

CONSTRUCTION

These circuits are built on two printed circuit boards, whose details are shown in Fig. 6 and Fig. 7. The boards are available from the *EPE PCB Service*, code 131 (Current Gen.), 132 (Amp/Rect.).

It is recommended that d.i.l. (dual-in-line) sockets should be used for all the integrated circuits (i.c.s). Mount the resistors, diodes and capacitors first, followed by the transistors and i.c.s. Correctly observe the polarity of all but the resistors.

Prepare a suitably sized diecast case by drilling holes for the sockets, p.c.b. fixing holes and switches. Mount these components and instal the p.c.b.s using 6BA

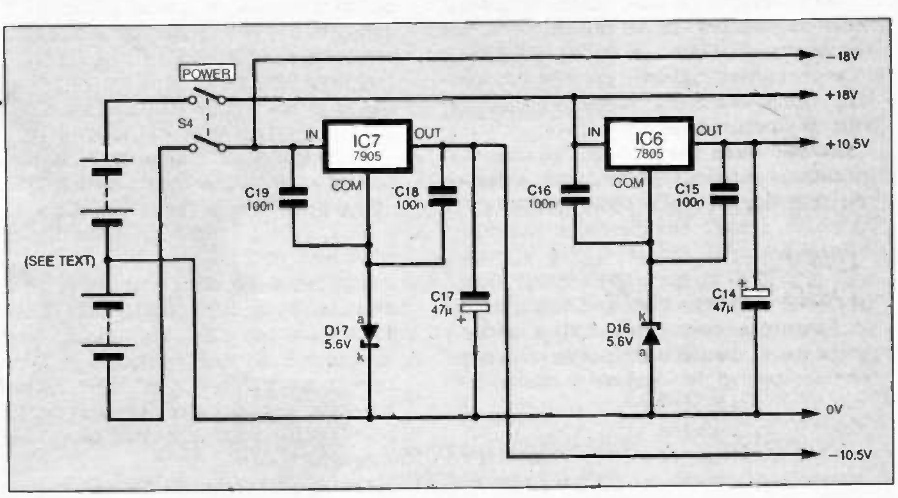


Fig. 5. Power supply circuit diagram.

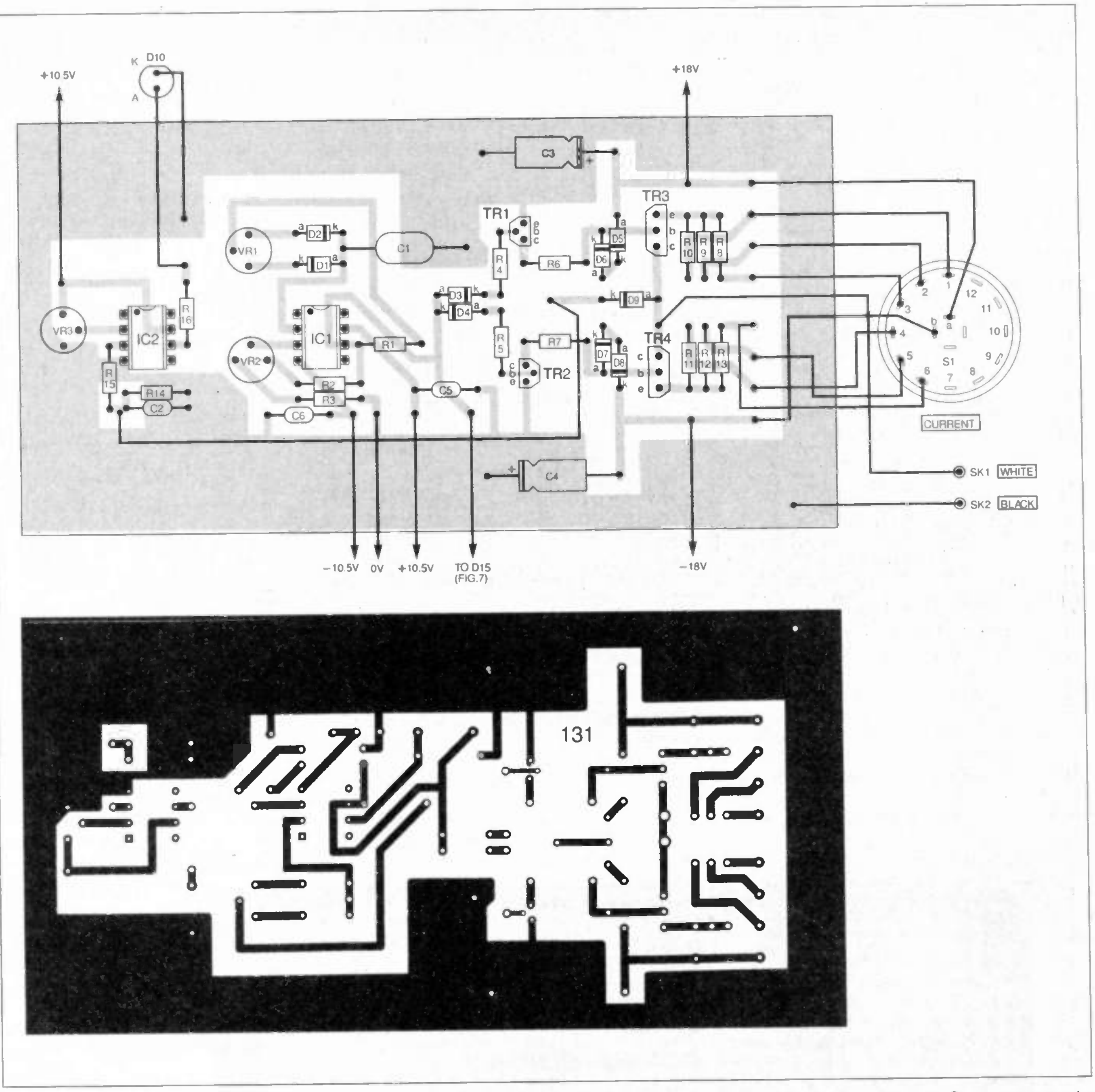
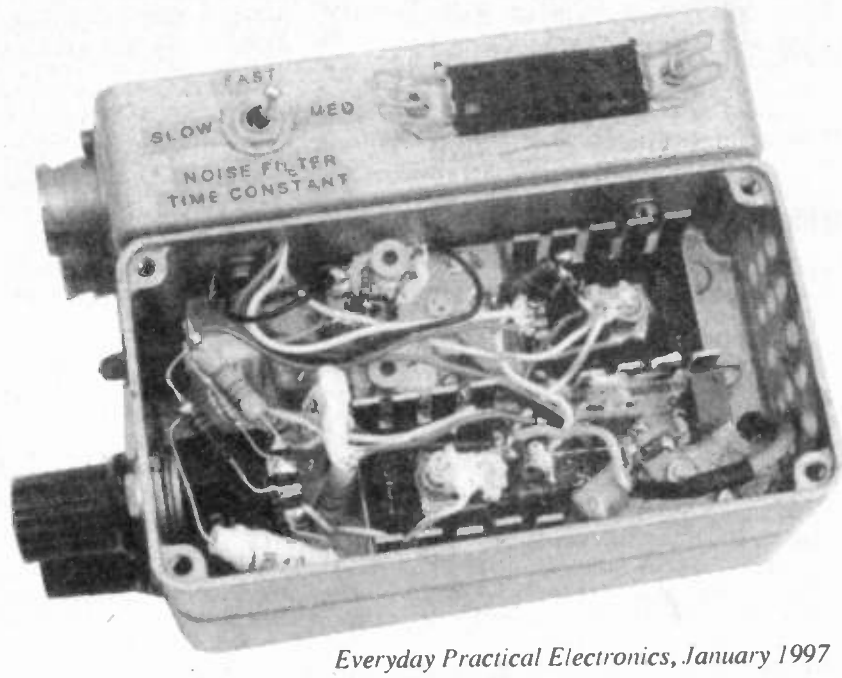


Fig. 6. Details of the component layout and full size underside copper foil track master pattern for the Current Generator p.c.b.

nuts and bolts, or sturdy p.c.b. mounting pillars.

The prototype of this circuit was actually constructed on stripboards which were mounted in three small diecast cases, each measuring 60mm × 110mm × 30mm, each one being bolted to the other with 6BA nuts and bolts.

However, with the p.c.b. design shown, only one box needs to be used; a suggested minimum size is about 140mm × 70mm × 60mm. Double-check the size of your assembly before buying a case, since individual component sizes may vary depending on the source. You might consider buying a diecast case with a rubber gasket round the lid to help minimise the risk of water ingress when out in the field!



The author's prototype, built on stripboard and mounted in three combined boxes.

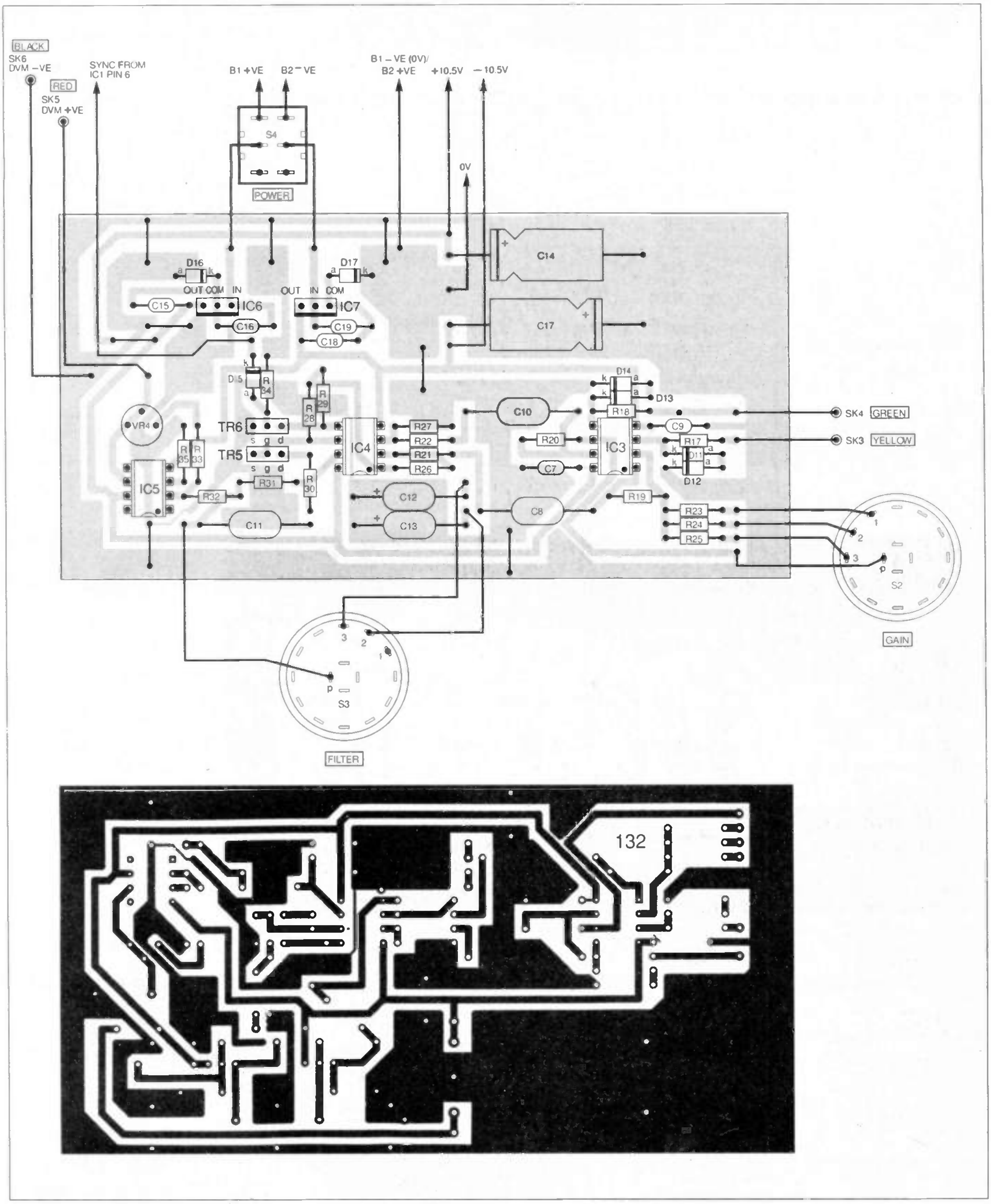


Fig. 7. Details of the component layout and full size underside copper foil track master for the Amplifiers and Rectifier p.c.b.

ADJUSTMENTS

If you have an oscilloscope and frequency meter, proceed as follows:

1. Switch on. Measure the positive supply line at C15 $+V_e$ and check that it is +10·5V. Measure the negative supply line at C17 $-V_e$ and check that it is −10·5V.

2. Connect a frequency meter to IC1 pin 6 and set VR2 to give an output of 137Hz. If no frequency meter is available, use a medium impedance earpiece connected between IC1 pin 6 and the 0V line and estimate a suitable tone, i.e. a little above 100Hz (rectified mains hum frequency).

3. Connect an oscilloscope to IC1 pin 6 and set VR1 so that both halves of the square wave are the same. Ascertain that the amplitude is about 11V, and that it is symmetrical about the 0V line. If no oscilloscope is available, set VR1 mid-way.

4. Temporarily connect a test resistor across the C_1 and C_2 terminals. Select the test resistor value and current generator output according to Table 2. Connect the

Table 2

Current Setting	Test Resistor
0·1mA	10kΩ
1mA	1kΩ
10mA	100Ω

COMPONENTS

Resistors

R1, R3, R6, R7, R17 to R20, R31	10k (9 off)
R2, R21, R22, R26 to R28, R30, R32 to R35	100k (11 off)
R4, R5	15k (2 off)
R8, R13	68Ω (2 off)
R9, R12	730Ω (2 off)
R10, R11	7k8 (2 off)
R14	470k
R15	47k
R16, R25	2k2 (2 off)
R23	20Ω
R24	200Ω
R29	200k

All 0·6W 1% metal film

See SHOP TALK Page

Potentiometers

VR1, VR3	10k horiz. preset (2 off)
VR2, VR4	100k horiz. preset (2 off)

Capacitors

C1	1µ metallised polyester, 100V
C2	220n disc ceramic, 25V
C3, C4	22µ axial elect. 63V (2 off)
C5 to C6, C7, C9, C15, C16, C18, C19	100n disc ceramic (8 off)
C8, C10	470n polyester (2 off)
C11	1µ tantalum bead, 35V
C12	100µ axial elect. 35V
C13	10µ axial elect. 35V
C14, C17	47µ axial elect. 35V (2 off)

Semiconductors

D1 to D8, D15	1N4148 silicon signal diode (9 off)
D9	OA91 germanium signal diode
D10	red l.e.d.
D11 to D14	BZY88C9V1 9.1V 500mW Zener diode (4 off)
D16, D17	BZY88C5V6 5.6V 500mW Zener diode (2 off)
TR1	MPSA42 *npn* transistor
TR2	ZTX550 *pnp* transistor
TR3	TIP30A *pnp* high power transistor
TR4	TIP29A *npn* high power transistor
TR5, TR6	2N3819 *n*-channel f.e.t. (2 off)
IC1	LM725 op.amp
IC2	741 op.amp
IC3	2072 dual op.amp
IC4	2082 dual op.amp
IC5	2081 op.amp
IC6	7805 +5V 1A voltage regulator
IC7	7905 −5V 1A voltage regulator

Miscellaneous

B1, B2	18V battery – see text (2 off)
S1 to S3	4-pole 3-way rotary switch (3 off)
S4	d.p.d.t. toggle switch
SK1	4mm socket, white
SK2, SK6	4mm socket, black (2 off)
SK3	4mm socket, yellow
SK4	4mm socket, green
SK5	4mm socket, red

Printed circuit boards, available from the *EPE PCB Service*, codes 131 (Current Gen.) and 132 (Amp/Rect.); 8-pin d.i.l. socket (5 off); 4mm plugs, qty to suit; knob (3 off); case (see text); probe materials (see text); nuts, bolts and washers; connecting wire, solder, etc.

Approx Cost Guidance Only — **excl. case and probes** — **£48**

Table 3

Gain	Load	Output
× 10	10Ω	0·1V
× 10	100Ω	1V
× 10	1000Ω	10V
× 100	1Ω	0·1V
× 100	10Ω	1V
× 100	100Ω	10V
× 1000	0·1Ω	0·1V
× 1000	1Ω	1V
× 1000	10Ω	10V

oscilloscope across the resistor (scope probe tip to C_1). The oscilloscope should show a 137Hz trace at approximately ±1V, symmetrical about the 0V line, at all three settings of current selector switch S1.

If any discrepancy is noted, the appropriate resistor (R8 to R13) on switch S1 should be checked. These resistors may be made up with a series and/or parallel connection of more than one resistor if a high degree of accuracy is desired.

5. Set the test resistor to 10Ω. Set the amplifier gain switch (S2) to × 100. Adjust preset VR4 for a d.c. output of exactly 1V across SK5 and SK6.

6. Connect P_1 to C_1, and P_2 to C_2. Connect a resistance box or a series of fixed resistors between P_1 and P_2. Set the amplifier gain (S2) and the resistance box to the figures in Table 3 and check that the output is correct.

7. Set the test resistor to 10kΩ and switch S1 for a current output of 1mA. Adjust preset VR3 until the l.e.d. D10 just lights.

This completes the tests and adjustments. Let's now probe deeper:

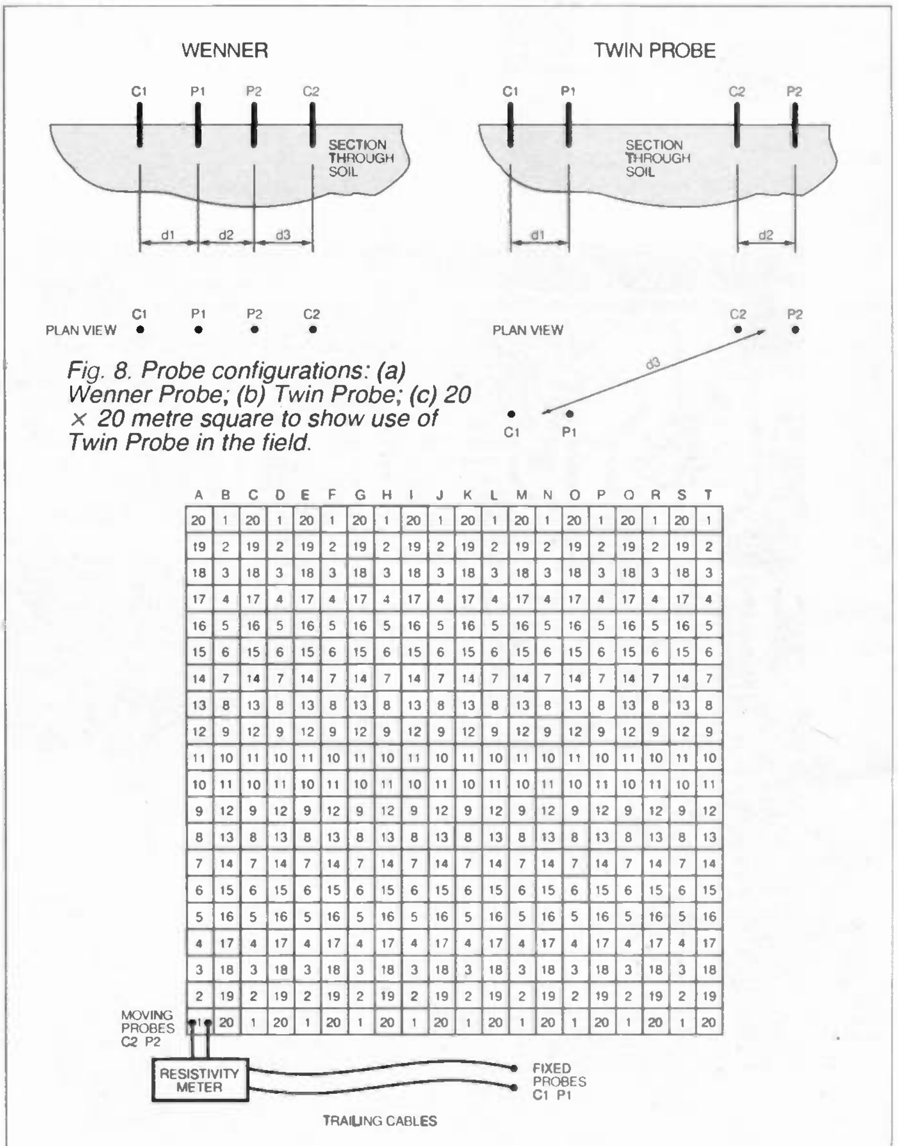


Fig. 8. Probe configurations: (a) Wenner Probe; (b) Twin Probe; (c) 20 × 20 metre square to show use of Twin Probe in the field.

PROBE CONFIGURATIONS

Now let's look at some probing factors before considering the probes themselves.

There are several probe configurations that may be used, but the two that are now widely employed are the Wenner and the Twin Probe:

Wenner configuration

In the Wenner configuration, as illustrated in Fig. 8a, all probes are equally spaced in a straight line. A spacing of about one metre being suitable for general use. The two outer probes being C_1 and C_2 with the two inner probes being P_1 and P_2.

The Wenner is suitable for linear traverses to check a site for anomalies (readings caused by buried features) before a more detailed survey is carried out.

To convert instrument readings for this configuration to resistivity, use the following formula:

$$\rho A = 2\pi dV/I$$

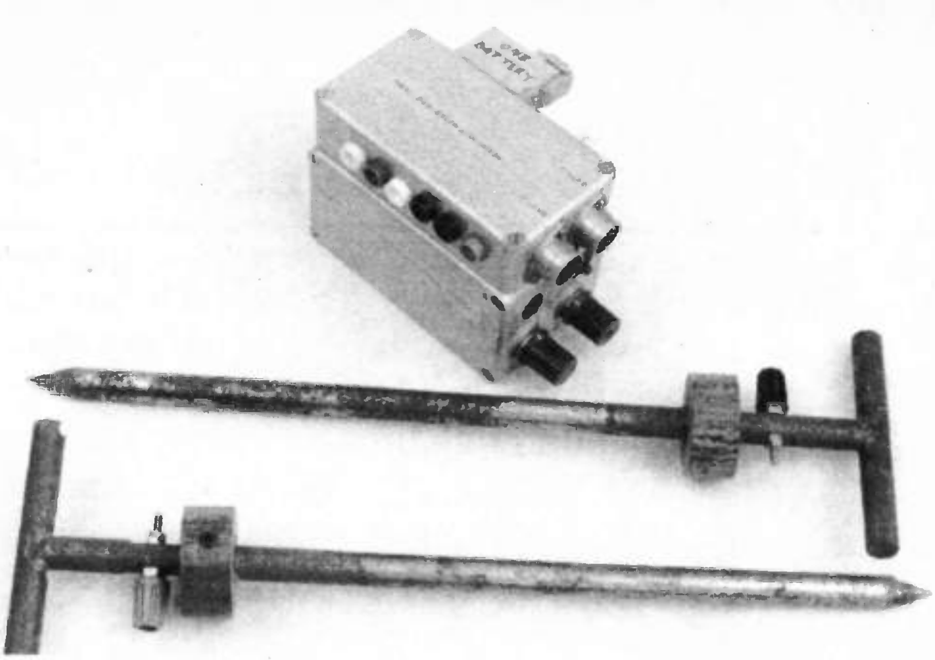
where:

ρA = apparent resistivity
d = probe spacing
V = indicated voltage divided by the amplifier gain.
I = current

Twin Probe configuration

In the Twin Probe configuration, as illustrated in Fig. 8b, probes C_1 and P_1 are inserted just off the area to be surveyed and are known as the fixed pair. Probes C_2 and P_2 are moved across the area to be surveyed as a pair at the same distance apart.

This moving pair is placed in the squares of a grid previously laid out with strings or measuring tapes, as represented in Fig. 8c.


Two of the short probes alongside the author's prototype model.

The spacing of the C_1 and P_1 probes should equal that of the C_2 and P_2 probes and be about 500mm. The spacing between the fixed pair and the moving pair can be anywhere between 15 metres and 50 metres.

Probes C_2 and P_2 may be fixed to a frame (as shown next month, for example), complete with the electronic unit to make a very easy to use setup.

To convert instrument readings for this configuration to resistivity, and referring to Fig. 8b, use the following formula:

$$\rho A = (2\pi V / I) \times (1 / ((2 / d1) - (2 / d3)))$$

Construction of the probes themselves is very simple; none of the materials or their dimensions are critical and may be dictated by what is to hand.

In Fig. 9a is shown a substantial probe that is made out of stainless steel tubing with a brazed on T-handle and tip which assists in soil penetration. This probe is designed to be used with the operator in a standing position.

A set of four probes made up as in Fig. 9a make ideal Wenner probes because, as this configuration needs to be continually moved, tall probes avoid bending the back.

A smaller version of Fig. 9a is shown in Fig. 9b; this has a 4mm screw terminal added, an alternative method of wire connection. Probes may be constructed of materials other than stainless steel, which is expensive and a little difficult to procure.

An extremely simple probe is shown in Fig. 9c and which may be constructed from 6mm diameter metal rod, i.e. brazing or uncoated welding rod, mild steel, silver steel, etc. A depth guide consisting of a band of paint or insulating tape is added and connections are made to the top of the rod with a crocodile clip.

The depth stop illustrated in Fig. 9d is adjustable by means of an Allen key. The material need not be insulating, and could be of metal if desired.

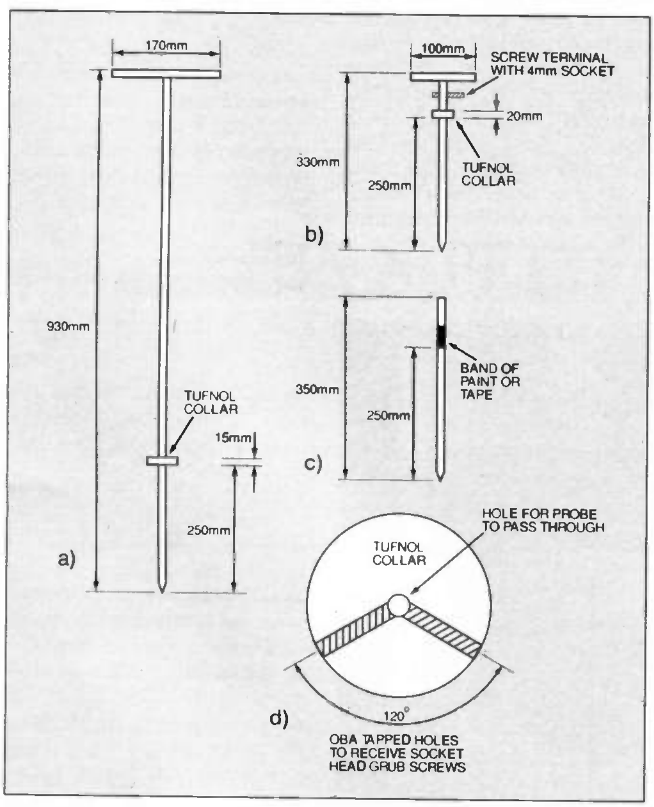


Fig. 9. Construction details of the probes: (a) long probe; (b) short probe; (c) simple probe; (d) detail of depth stop.

PART TWO

In the concluding article next month, the techniques and ethics of earth resistivity surveying will be discussed.

QBASIC PROGRAM

A copy of the author's program – for displaying graphics of the earth resistivity results – written in QBasic (for a PC-Compatible computer), is available from the Editorial Office for the sum of £2·50 UK, £3·10 overseas surface mail or £4·10 airmail. This is to cover admin costs and postage, the disk itself is *free*. You are welcome to copy this program and give it to your friends. See *PCB Service* for ordering details.

The program can also be downloaded *free* from our FTP site: **ftp://ftp.epemag.wimborne.co.uk**, in the sub-directory: **pub/PICS/Earth.Meter**.

SWATCH, MERCEDES AND THE SMART CAR

Has the pollution-free urban-mobility problem been cracked at last?

– by Hazel Cavendish

IT is hard to think of anything more beneficial to life in our polluted cities today than the development of a viable micro-car based on innovative electronics and having zero emissions.

With an increasing number of major cities all over the world planning to ban conventional petrol-engined cars from their centres, it has been obvious that a lucrative opportunity existed for a manufacturer of a really small unit of transport for the city worker.

SWATCHMOBILE

The good news is that the innovative Swiss Swatch company has joined forces with Mercedes-Benz to build just such a car in France, using the genius of Swatch's Nicolas Hayek and the expertise of Mercedes-Benz in a combination of microelectronics and precision mechanics which offer safety and high performance in its urban mobility concept. Mercedes will engineer the car and Swatch will sell it.

The MK Micro Compact Car known as the SMART car (nicknamed the Swatchmobile by the Motor trade) is promised to the world in 18 months in its initial petrol version, followed by a turbo-diesel in 1999, and finally an all-electric zero-emissions model in the year 2000, with a project cost of DM 2 billion.

"Individual mobility" is the name of the game, the car being a two-seater, two feet shorter than a Mini, which will take two adults or one adult and two children and, although small outside, is remarkably spacious in its interior.

"Our task is to turn our vision of a systematically futuristic vehicle into a marketable product that will stand up to competition," says Hans Jurg Schar, Executive Vice-President of Sales.

SINCLAIR APPROVAL

Britain's micro-car guru, Sir Clive Sinclair, has always backed the electric car, saying that Britain is out-of-date in regarding it as a lethargic vehicle which is short of range. For some time he has been urging that we need to consider "second cars" for local use to combat urban pollution.

"Keep the Volvo for longer trips, and rent it out for occasions, but use the electric town car for shopping and taking the children to school", he says, pointing out that the town car needs a range of only 40 miles and a top speed of 40mph, with the added advantage of good reliability and probably 100,000 miles before service is needed.

The remarkable feature of the SMART project is its multi-national character. The head office of MC AG is at Swatch HQ in Biel, Switzerland, where marketing, sales, finance and controlling divisions are located. Development of the car takes place in Renningen, Germany, but production is in the hands of MCC France at Hambach in Lorraine, chosen because it is sited logistically in central Europe and is served by a network of international traffic connections.

Here a large-scale international industrial park, "Europole", is currently under construction, where planning permission was granted at very short notice – hardly surprising in view of the number of jobs the project is bringing to the area.

VEIL OF SECRECY

Unfortunately for journalists, a veil of secrecy is drawn over the details of the electronics used in the car. Many telephone calls and faxes to both Swatch and Mercedes have produced polite evasions and a snowstorm of publicity material which reveals little technical data. With both America and Japan working feverishly towards the same goal, this is perhaps understandable. SMART is undoubtedly a hot number.

We are told there is an electronically controlled drive power management system, and an expendable "Mobibox" module which provides the vehicle with "communications infrastructure for enhanced mobility" and which is an important part of the safety system.

The highlight of the design is said to be the automated manual six-speed transmission which saves fuel and makes driving particularly enjoyable. "Precise electronic control replaces raw muscle power, so that a light tap on the gear-shift suffices to change to the next gear", says the Company leaflet. An electronic immobilizer is also included, as no doubt the SMART will be irresistible to car thieves in the city.

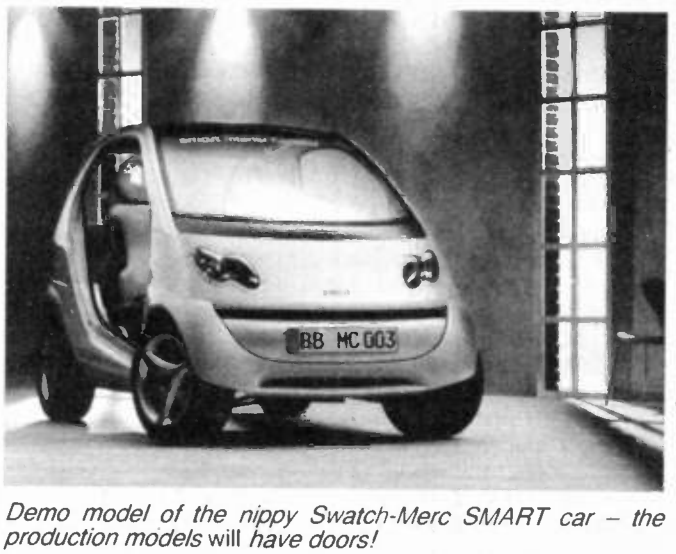
In March 1998 the 900cc three-cylinder eco-turbo petrol machine with intercooler and dual ignition will be introduced to the market. Four litres of petrol will take you 100kms, while the Diesel model will only require three litres to cover that distance. Acceleration is remarkably nippy, being 0 to 60kph in six to seven seconds with the top speed at a surprising 100kph.

NiCad POWERED?

What of the battery – the stumbling block with all electric cars?. Mum's the word, unfortunately, but perhaps a hint that something entirely new may have been developed is given by the statistic that car batteries account for 500 jobs in the local industrial infrastructure, by far the highest number, apart from those connected with the production of tyres.

Sir Clive Sinclair hazarded a guess that the car will probably develop the nickel-cadmium battery as being the most suitable choice.

A right-hand drive version of the car will be produced, though it may be five years before it is available in Britain.



Demo model of the nippy Swatch-Merc SMART car – the production models will have doors!

MAPLIN STOCKS EPE

THERE'S great news for Maplin customers and *EPE* readers! *EPE*, your favourite electronics magazine, is now on sale in all of Maplin's 35 stores nationwide.

Moreover, we are the *first* independent electronics magazine to become available from Maplin. And this is a coup for both Maplin and *EPE*! Just think, next time you nip into your local Maplin store for the odd resistor or hifi system, or browse through their new "ginormous" MPS catalogue, you can pick up *EPE* as well. So, on both counts, you're bound to get good reading.

Both we and Maplin are delighted with this beneficial initiative. It will certainly help to expand the electronics market in which you, we and they have such an intense interest.

Indeed, on a very serious level, the health of the hobbyist electronics market is actually under threat by the actions of some of the major retail newsagents. Some are hinting that they will only continue to stock specialist magazines if the publisher provides them with an "incentive". *We place on record our strong objections to this marketing ploy.*

By such restrictive actions, specialist publications catering for a diverse range of activities, not just electronics, could be forced off the shelves of many newsagents. It is not in the public interest, *your* interest, or that of the publishers, or of the retailers who advertise in the associated publications, that this should happen.

But the warning signs are there, and we must take appropriate action, adopting not just Plan B, but C to Z as well; so should other electronics retailers, adopting Maplin's enlightened outlook by stocking *EPE*, the independent Number One Magazine for Electronics Technology and Computer Projects. (We also applaud the foresight of Cirkit, Greenweld and Omni who already do so!) Other retailers, you are invited to ask us for details on how you too can sell *EPE* from your stores.

Readers, what can you do? For a start, complain to the manager of any store which appears reluctant to stock *EPE* and other specialist magazines. Secondly, encourage your local electronics retailer to keep *EPE* on his counter. Thirdly, and to *really* safeguard your continued receipt of *EPE*, take out a yearly or two-yearly subscription! This will also save you money - obviously a good deal is on offer! See page 70 for details.

A further plan which both we at *EPE* and Maplin are developing strongly is our presence on the Internet. We have a wealth of material available from our Web site at **http://www.epemag.wimborne.co.uk**, and there is free access to the software required for some of our constructional projects.

Maplin, via their site, provide on-line data for many of the special chips and components they stock. On their site they also have, for example, the demo software for the *PCS32 Digital Storage Oscilloscope Interface* which Robert Penfold reviews so favourably in this issue. Have a good browse of Maplin's informative site, at **http://www.maplin.co.uk**.

For more information about Maplin and their stores (they even have overseas branches), call them on 01702 554000.

EASY LOGGING

DATA logging is a subject referred to in this month's *Earth Resistivity Meter* article. That design uses the author's own logging software, but for many other situations you could well find that Lascar's new EasyLog EL-2 unit will provide suitable facilities.

EL-2 is a hand-held multi-function module which, in conjunction with a suitable sensor, will measure, display, record and control temperature, voltage, current, humidity, pH, frequency and rate count. The module is configured using Windows-based control software, EL-WIN, and the stored data can be saved and graphically presented or exported to popular spreadsheets.

The in-built display consists of a 3½ digit l.c.d., and the non-volatile memory can record up to 8000 readings. Power is supplied from a 3·6V long-life Lithium batter.

For more information, contact Lascar Electronics Ltd., Module House, Whiteparish, Salisbury, Wilts, SP5 2S. Tel: 01794 884567.

LOW COST

IF YOU are in need of low cost electronics design software, why not consider the new EDWin NC package from Visionics? It is the non-commercial licence version of their successful EDWin EDA software, and which is available at a fraction of the cost. It includes all the features of its bigger brother.

Prices of EDWin NC start at just £49, including VAT, for the basic version, which comprises schematics, p.c.b. layout, 500-device library, basic autorouter, full post processing facilities, although it has a limit of 100 components per circuit. Several extended versions are available, at up to only £114.

The system is delivered on CD-ROM (which, of course, many computers now have as standard) and includes comprehensive manuals. The software runs under Windows 3.1x, 95 or NT.

For more information, contact Swift Designs Ltd., Business & Technology Centre, Bessemer Drive, Stevenage, Herts, SG1 2DX. Tel: 01438 310133.

PRESS-N-PEEL APPEAL

OVER the years, many innovative printed circuit board prototyping materials have hit the headlines, though not all of them have withstood the test of user acceptance. The Press-N-Peel (PNP) technique, however, seems as though it could well represent a welcome breakthrough for the prototyping market.

With PNP, no expensive materials or equipment are necessary, not even an ultra-violet exposure unit. All you need, basically, is access to a photocopier and a hot domestic smoothing iron. This product is so versatile that you can photocopy a p.c.b. layout from a magazine page and have a board ready for drilling in little more than the time it takes to etch it. If you use computerised p.c.b. drafting software, you can even output a print of your board direct onto PNP, via a suitable printer of course!

Once the image has been printed onto PNP, you are ready to transfer the circuit to "raw" copper-clad p.c.b. material - no more resist coated copper, no more light source, just plain copper clad fibre-glass or equivalent.

Using your household iron set to about 150°C (Hot), you simply lay the PNP image down onto the copper-clad board and smooth it down with the iron. You can tell by the darkness of the image when the transfer has stuck.

When the board has cooled, the film is peeled leaving the area of trackwork stuck to its surface. Etching is then done in the usual way, after which the PNP resist is wiped off using the PNP stripper solvent supplied.

It all seems like child's play - so we've asked our Tech-Ed to try it on his next prototype!

For further information, contact Press-N-Peel Etching Supplies Ltd, 18 Stapleton Road, Peterborough PE2 6TD. Tel: 01733 233043.

New Technology Update

Ian Poole highlights the battle against the ever increasing problems of environment pollution and waste facing today's i.c. manufacturers..

GREEN issues are playing an increasing role in today's technology. For example many cars are now being designed to be recyclable, as are many other products. In the realm of electronics, battery technology is one area where the subject has been covered in recent months in this column.

However, this is not the only area where "conservation" is of great importance. The manufacture of integrated circuits (i.c.s) uses vast amounts of energy. There are also many dangerous substances which are used in the process, and a number of unfriendly by-products are produced.

Vast Quantities

The integrated circuit industry manufactures a vast number of circuits each day. The average household is likely to buy at least two or three products each year which contain i.c.s. Multiply these figures by the numbers of households, and it is possible to see that even to supply a country like the UK, vast numbers of i.c.s are needed.

These i.c.s only cover those required for domestic use. Commercial users also consume enormous quantities of chips as well.

To be able to meet this demand, it is estimated that a typical i.c. manufacturing plant makes around two million i.c.s a month. There are many fabrication plants dotted around the world and the number is growing all the time as the recession recedes and demand rises. This increase is expected to last for some time, making the current problem of pollution from these plants worse than it is today.

Typically, it takes about ten gallons of water to make each i.c.. This means that a plant manufacturing two million i.c.s a month will use 20 million gallons of water. This is in addition to the large amounts of heat required in processes such as diffusion and epitaxy. Turning the raw silicon into complete i.c.s requires hundreds of steps to be completed.

Additional problems are caused by the use and creation of toxic substances. Although it is possible to dispose of certain amounts of toxic chemicals, the amounts now being produced are reaching levels where the increase cannot continue indefinitely. This is particularly true for plants manufacturing gallium arsenide chips!

Groundwork

Until recently comparatively small amounts of work had been undertaken to look into ways of creating more environmentally friendly processes. Even now the work is in its early stages and will take many years to incorporate into the large number of plants around the world.

The first stages involved assessing the amount of water which was used. During the manufacture of an i.c. there are many different stages including etching, doping, epitaxial growth and the like. After many of these stages it is necessary to wash or rinse the chips with very pure water to remove the impurities from the surface.

Computer simulations have now been devised to simulate some of the processes. In a typical rinse operation a cassette containing about 50 wafers is lowered into a water container. This undergoes several cycles of rapid filling and draining after which the water is allowed to flow through the container to remove the last impurities.

The computer simulations showed that slowing the rate at which the water is allowed to flow removes the impurities more effectively.

CAD Developments

The key to all of these improvements has been the development of programmes to enable these predictions to be made. Manufacturing i.c.s is a large but relatively niche market and as such CAD software for some of the more specialist applications has to be specifically written if required.

This is a costly business and unless companies and organisations see real benefits they are unlikely to undertake the work. Now that green issues are becoming more important, and the impact on the environment is more likely as a result of the vast numbers of chips being manufactured the impetus is there to develop the required simulation tools.

Before these first simulation tools were developed the extent of the savings were not obvious. Now that they can be shown, the tools are likely to be developed further and used much more extensively. Already, Hewlett Packard has implemented some changes as a result of them and they have confirmed that making the suggested process changes reduce cold water consumption by up to 80 per cent and reduce the times in some areas by considerable amounts.

The time reductions alone can represent an attractive proposition for manufacturers because they allow more efficient usage of the plant. This results in a larger throughput and greater return on investment. In view of the phenomenal costs of i.c. fabrication plants this is particularly important.

Major Savings

Having proved that there are major savings in terms of environmental pollution, and greater financial gains for manufacturers, work is progressing to investigate other areas of the operation of i.c. manufacture. Much of the focus will be placed upon extending the capabilities of existing tools and developing new ones which will be able to model other areas of production.

It is pointed out that in this way process changes can be simulated on computers relatively easily before large amounts of investment are placed into changing the existing plant, or overloaded production lines are stopped to update them.

A number of other areas for research have also been outlined. The first is to further develop the ideas behind the rinsing and cleaning operations, to make them more efficient and save more water.

One approach that will be used is to investigate methods of recycling more water. Another will involve looking at how to reduce the level of chemicals which need to be used, and washed from the wafers and from the system as a whole.

Another area for concern is in the use of chemicals called perfluorocarbons. These currently replace chlorofluorocarbons which were previously used and are now known to damage the ozone layer.

The chemicals used now are far less damaging to the ozone layer, but any reduction in the levels escaping into the atmosphere will help reduce the depletion of ozone.

One of the other areas to come under investigation is the lapping or polishing process. This is used to bring the wafers to a very high degree of smoothness. With half micron semiconductor technology in use today, very high degrees of smoothness are required, often to atomic levels.

To achieve this different levels of lapping or polishing are used and then this is followed by chemical etching. This leaves residues which can contain chemicals which are hazardous if not properly treated. To be able to reduce the environmental effects new processes are being proposed which will convert the residue to a solid form which can be handled and disposed of safely.

Future

With the ever increasing number of integrated circuits being produced, and their increase in size and complexity, the environmental impact of this industry will grow if it continues unchecked.

The improvements demonstrated so far show that reducing the environmental effects can progress hand in hand with improvements in efficiency. If this proves to be the case, then perhaps more industries may follow suit.

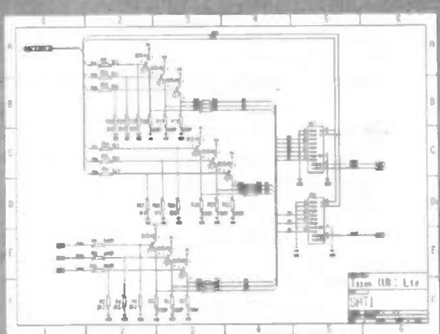
Is your PCB design package not quite as "professional" as you thought? Substantial trade-in discounts still available.

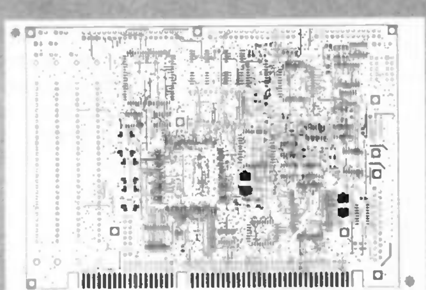
BoardCapture

Schematic Capture Design Tool

£395

- Direct netlist link to BoardMaker2
- Forward annotation with part values
- Full undo/redo facility (50 operations)
- Single-sheet, multi-paged and hierarchical designs
- Smooth scrolling
- Intelligent wires (automatic junctions)
- Dynamic connectivity information
- Automatic on-line annotation
- Integrated on-the-fly library editor
- Context sensitive editing
- Extensive component-based power control
- Back annotation from BoardMaker2





BoardMaker

BoardMaker1 - Entry level

£95

- PCB and schematic drafting
- Easy and intuitive to use
- Surface mount and metric support
- 90, 45 and curved track corners
- Ground plane fill
- Copper highlight and clearance checking

BoardMaker2 - Advanced level

£395

- All the features of BoardMaker1
- Full netlist support- BoardCapture, OrCad, Schema, Tango, CadStar
- Full Design Rule Checking both mechanical and electrical
- Top down modification from the schematic
- Component renumber with back annotation
- Report generator- Database ASCII, BOM
- Thermal power plane support with full DRC

BoardRouter

Gridless re-entrant autorouter

£200

- Simultaneous multi-layer routing
- SMD and analogue support
- Full interrupt, resume, pan and zoom while routing

Output drivers - Included as standard

- Printers - 9 & 24 pin Dot matrix, HPLaserjet and PostScript
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Constructional Project

PSYCHO RAT

NICK SHELDON

Using the power of logic, Psycho Rat demonstrates the psychology of "conditioning".

THERE are many principles in psychology which can be demonstrated with dedicated electronic hardware. One of these is a learning theory known as classical conditioning, and it is that which will be described in this article. To demonstrate this "conditioning", a practical model in the form of "Psycho Rat" has been produced.

To a pure scientist, psychology can sometimes seem nebulous, lacking a real core of experimentally proven, mathematically expressed theories. Some psychologists are proud of this state of affairs, describing their vague, quasi-mystical ramblings as "idiographic." The opposite, scientific approach is termed "nomothetic."

SCIENCE OF BEHAVIOUR

Early psychology was defined as "the science of consciousness", and relied heavily on speculative introspection. As a reaction against this, in 1913 J.B. Watson founded a movement known as behaviourism, which instead defined psychology as "the science of behaviour." The objective was to make psychology as rigorously scientific as other sciences, such as physics and chemistry.

Watson popularised the work of the Russian physiologist I.P.Pavlov, who had researched the digestive process. In the course of Pavlov's experiments, it was noticed that the dogs, which formed the experimental subjects, sometimes salivated *before* food was given to them.

Rather than dismissing this inconvenient finding, Pavlov researched it, and discovered what came to be known as "classical conditioning".

Two kinds of stimuli were defined by Pavlov: conditional and unconditional. An unconditional stimulus could be the sight of food, which the innate, automatic, unconditional response would be to salivate.

If a bell was sounded when the food was produced, this bell became capable of producing the same response. In Pavlov's terms, the bell would be a conditional, learnt stimulus. Watson believed that all learning could be described in terms of the learnt associations between stimuli and responses. This became known as "S-R psychology".

CLASSICAL LOGIC

Perhaps surprisingly, classical conditioning can be represented in terms of Boolean functions. There are two inputs: the unconditional (US) and conditional (CS) stimuli, and one output: the response (R).

Before conditioning takes place, the situation can be described with the Truth Table shown in Fig. 1. This shows that the response (R) simply equals the unconditional stimulus (US) input, the reason being that the (ultimately) conditional stimulus is neutral prior to conditioning. Consequently, this input has no effect at this stage, the output only being true if the unconditional input is true.

US	CS	R
0	0	0
0	1	0
1	0	1
1	1	1

R = US

Fig. 1. Initial Truth Table

US	CS	R
0	0	0
0	1	1
1	0	1
1	1	1

R = US + CS

Fig. 2. "OR" Truth Table

After conditioning, the Truth Table changes to that shown in Fig. 2., which indicates that the new function is the OR of the unconditional and conditional stimuli. This is because the output (R) is now required to be true if either the conditional stimulus input OR the unconditional stimulus input is true, or both are true (inclusive OR).

The situation which changes the state of the system is the occurence of the unconditional stimulus at the same time as the conditional one, i.e. the AND of the two stimuli. Psychologists rather grandly call this a temporal contiguity.

The basic circuit thus consists of five elements: 1. the logic to provide the first truth table; 2. the logic to provide the second truth table; 3. a means to detect the temporal contiguity; 4. a means to store the learnt state; 5. A data selector to choose between the outputs of 1 and 2. A block diagram is shown in Fig. 3.

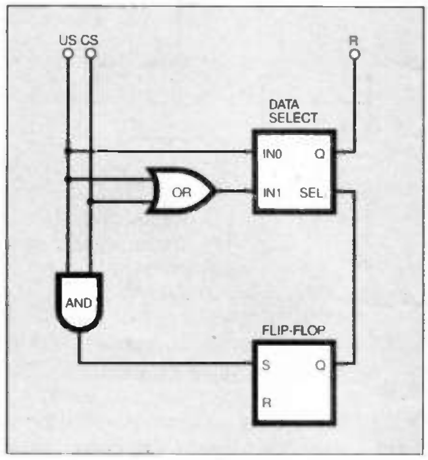
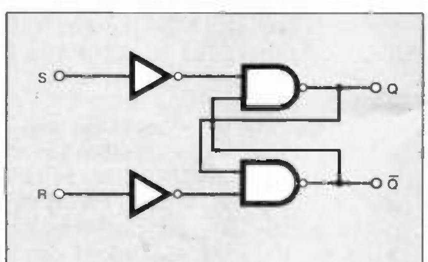


Fig. 3. Data select block diagram.

The more complex elements of the circuit, sections 4 and 5, can themselves be analysed with Truth Tables and constructed out of individual gates. The reason for this approach is three-fold: first, a typical hobbyist's spares box is more likely to contain gates than complex logic i.c.s; second, it is very instructive to see how these more complex functions are built up; and third, this approach does not increase the i.c. count.

Taking the S-R (Set-Reset, not stimulus-response!) of the flip-flop which forms part 4 of the circuit, the gate level implementation is shown in Fig. 4. This can be analysed by considering it as having two



S	R	Q
0	0	0
0	1	0
1	0	1
1	1	X

S	R	Q
0	0	1
0	1	0
1	0	1
1	1	X

Fig. 4. Gate level implementation.

truth tables - one for each state. The condition when S and R are both high is undefined, and is shown in both truth tables as an "X".

The first of the two Truth Tables in Fig. 4 is for the flip-flop initially in the reset state. Consequently, the reset (R) input has no effect, change only taking place when the set input is true, changing the flip-flop to the Set state.

The second Truth Table in Fig. 4 shows the situation when the flip-flop is set. Here, the set (S) input has no further effect, change only taking place when the Reset input is true.

Part 5 of the circuit, the data selector, can be analysed as shown in Fig. 5. The resulting gate level implementation also being shown in the same figure. The data selector can be considered as having three inputs: the two data inputs and the select input.

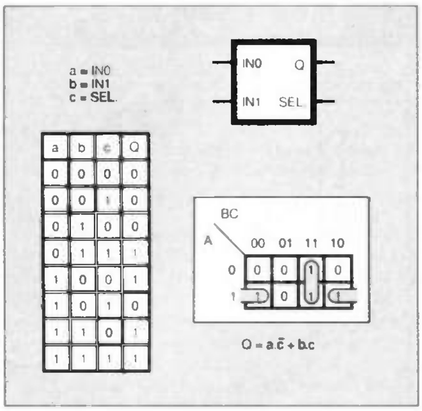


Fig. 5. Data analysis.

Taking the select input as selecting input 1 when it is high (1), the Truth Table is determined as follows: when input 0 (a) and input 1 (b) are both false (=0), the output Q is false irrespective of what value c, the select input, takes. When input 0 is false but input 1 is true (= 1), the output Q is true only when the select input is high (selecting input 1). When input 0 is true but input 1 is false, the reverse situation takes place, namely, the output Q is true only when the select input (c) is false (selecting data input 0). Finally, when both input 0 and input 1 are true, the output Q is high irrespective of the select input's status.

KARNAUGH MAP

This three input Boolean function can be represented with an 8-element Karnaugh map, also shown in Fig. 5. The map can be thought of as representing the surface of a toroid – a ring doughnut-like structure.

Consequently, the edges of the map are really in contact with each other, top with bottom and left with right. This is important, because the logical minimisation (simplification of gate implementation) which the Karnaugh map allows depends on groups of "ones" being spotted, and, as can be seen from Fig. 5, one of these two groups is at either edge of the map.

The vertical block of ones in the third column of the Karnaugh map has two variables in common: B and C. this means that this portion of the map can be represented with the logical formula B AND C. Note that the variable A is not required.

The second group also has two variables in common: A and NOT C. This means that this part of the map can be represented by the Boolean function A AND NOT C. These two functions are then combined by ORing them to produce the complete data selector logic.

FINAL LOGIC

The complete theoretical circuit of Fig. 6 can be constructed entirely out of NAND gates with no increase in complexity. De Morgan's law states that A OR B = NOT (NOT A and NOT B), i.e. two inputs ORed together is the same as two inputs both inverted, ANDed and then inverted once more. This is shown stage by stage in the Truth Table Fig. 6.

Consequently, the OR gate can be simulated with an AND gate having both inputs and the output inverted (see Fig. 7) – in other words, a NAND gate with both inputs inverted with other NANDS. The inverter in the data selector can be obviated by utilising the inverted output of the S-R flip-flop, and replacing the AND gates of the data selector with NAND gates permits the OR function to be provided by another NAND gate, again courtesy of De Morgan. The final logic for our Psycho Rat using NAND gates is shown in Fig. 8.

a	b	$\bar{a}$	$\bar{b}$	$\bar{a}\cdot\bar{b}$	$\overline{\bar{a}\cdot\bar{b}}$	a+b
0	0	1	1	1	0	0
0	1	1	0	0	1	1
1	0	0	1	0	1	1
1	1	0	0	0	1	1

Fig. 6. Demonstration Truth Table.

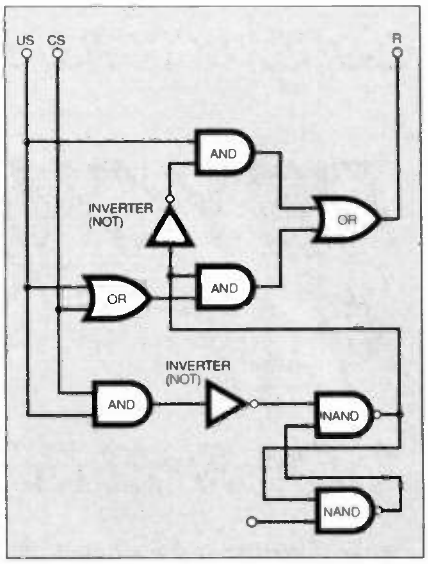


Fig. 7. Theoretical circuit using NAND gates.

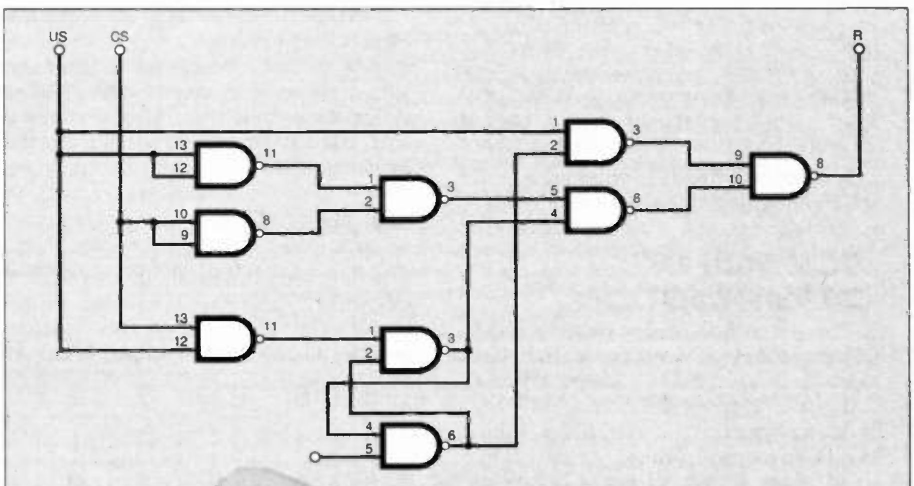
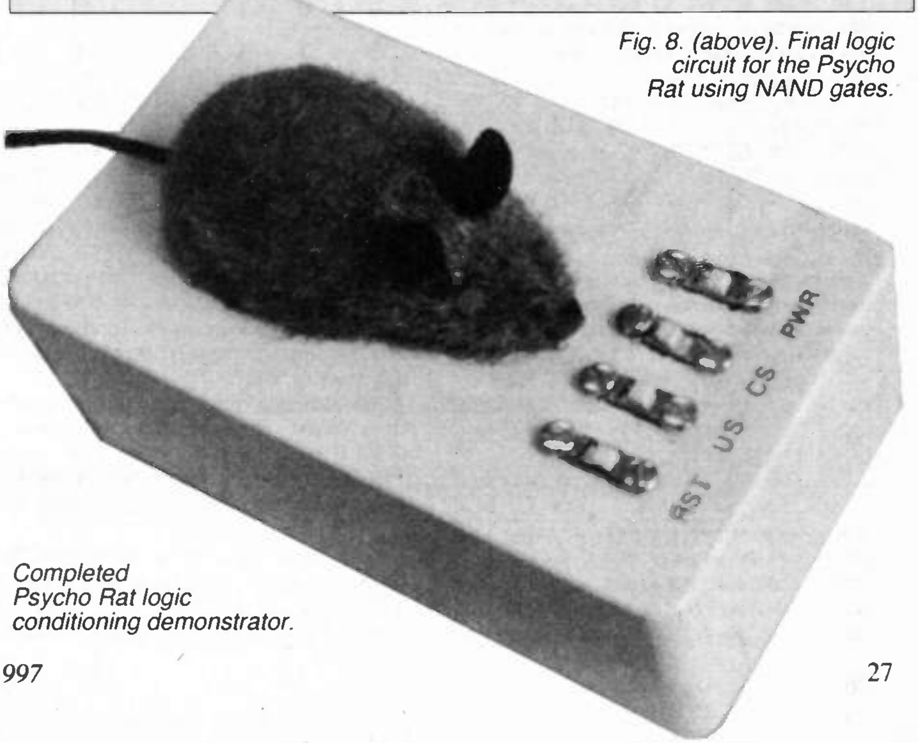


Fig. 8. (above). Final logic circuit for the Psycho Rat using NAND gates.



Completed Psycho Rat logic conditioning demonstrator.

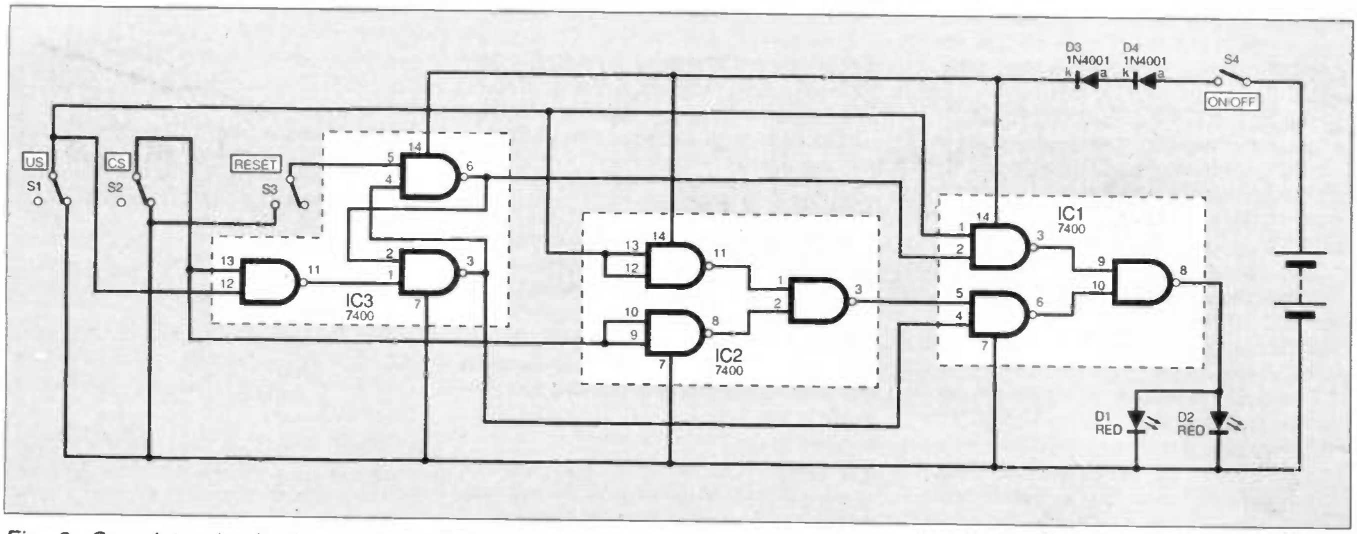


Fig. 9. Complete circuit diagram for the Psycho Rat using three quad 2-input NAND gate i.c.s

PSYCHO RAT

The complete circuit diagram for the Psycho Rat is shown in Fig. 9. Two diodes D3, D4), in the positive supply line, drop the battery voltage to about 4·8V for the TTL circuitry.

The "stimuli" for the Rat are provided by two switches, one for the Unconditional Stimulus (S1) and one for the Conditional Stimulus (S2). Miniature s.p.d.t. slide switches were used, allowing the inputs to float high when operated (being *standard* 7400 TTL this is permissable).

Response in the rat is shown by its eyes lighting up! This is achieved by using two 3mm l.e.d.s (D1, D2) wired in parallel. Note that current limiting resistors are not needed.

A third switch, S3, is provided to reset the flip-flop, which on switching on may be initially set, and a fourth switch (S4) controls the power supply.

CONSTRUCTION

The circuit was finally built on a P.C. Bimboard, having been transferred from a plug-in type Bimboard where it had been "prototyped". This can also be easily transferred to stripboard. The Bimboard component layout is shown in Fig 10.

The completed board and associated components were cased in a white plastic box, with the top half of a clockwork plastic mouse fixed to its top. The wiring for the "eyes" (l.e.d.s) is taken through a hole in the box's lid and through the underside of the rat.

Letraset rub-down transfers were used for labelling-up the switches. A small section of the P.C. Bimboard was removed with a hacksaw so that the circuit would fit into the largest white plastic box available, white having been chosen for ease in labelling.

IN ACTION

"Psycho" is operated as follows. First, it is switched on, and the Reset switch S3 momentarily operated, in case the flip-flop is set. The effect of the unconditional stimulus is then demonstrated – the US

COMPONENTS

Semiconductors See SHOP TALK Page

D1, D2	3mm light emitting diode, red (2 off)
D3, D4	1N4001 1A 50V rec. diode (2 off)
IC1 to IC3	7400 quad 2-input NAND gate (3 off)

Miscellaneous

S1 to S4	miniature s.p.d.t. slide switch (4 off)
B1	AA size 1·5V battery (4 off), with holder

Plastic ABS white case, size 143mm x 58mm x 81mm; P.C. Bimboard; 14-pin d.i.l. socket (3 off); battery clip; 2-way terminal block; rubber feet (4 off); rub-down lettering (Letraset); clear varnish to protect lettering; multistrand connecting wire; self-tapping screws (12 off): solder etc.

Approx Cost Guidance Only £12
excluding Rat, Batts and Letraset

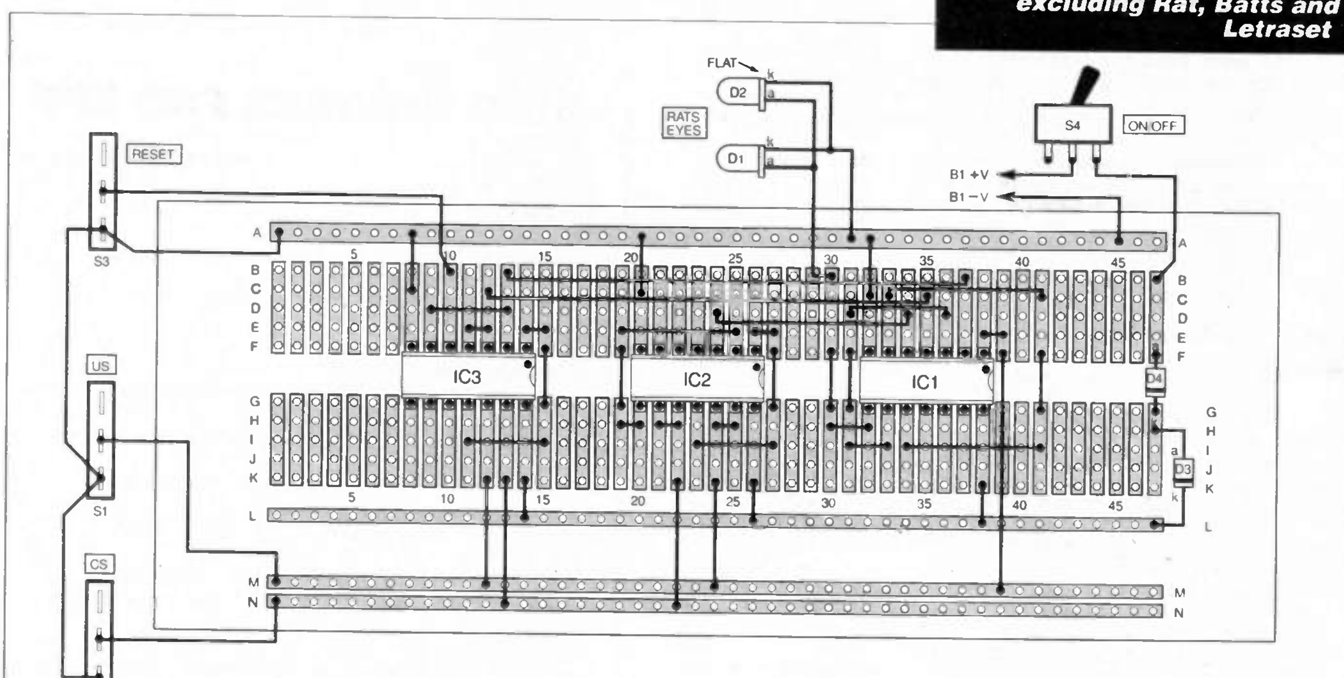
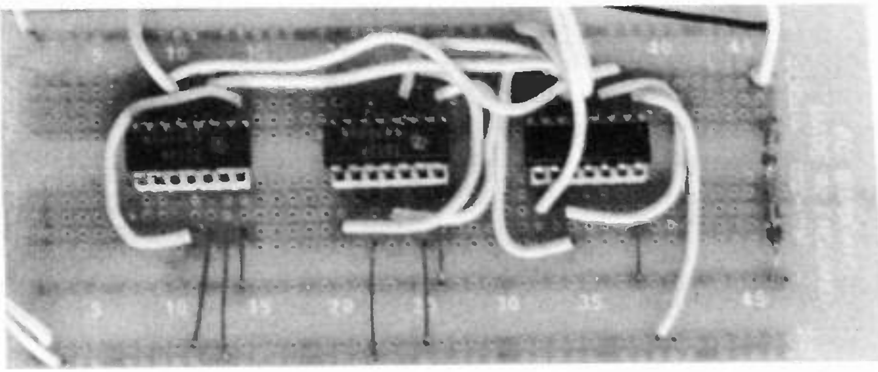
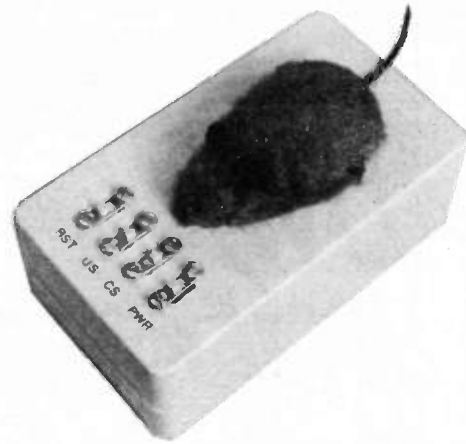


Fig. 10. Component layout for the P.C. Bimboard version of Psycho Rat.





switch S1 is operated, and the rat's eyes light up.

The (ultimately) conditional stimulus is initially neutral prior to conditioning, and can be demonstrated to have no effect at this stage. However, if the unconditional stimulus is presented at the same time as the conditional stimulus, thereafter the conditional stimulus will also light the rat's eyes – it has been conditioned.

Psycho Rat has been successfully used with students on courses from GCSE to undergraduate level. It is a very simple system. The cross-impact of electronics and behaviourist psychology is known as "stenobehaviourism". □

SHOP TALK

with David Barrington

Mains Failure Warning

As we are dealing with mains supplies here, the first comment we must make regarding the *Mains Failure Warning* project is: *exercise extreme care when building this unit and make sure the METAL case is safely "earthed"*.

The effectiveness of the warning depends largely on the choice of buzzer and it should be a good quality type. It must be capable of producing a high sound output from a supply of only 7V and have a small current requirement of around 5mA to 10mA.

The p.c.b. mounting buzzer used in the model came from **Maplin** (☎ *01702 554000*), code KU56L, and is rated for 3V to 15V d.c. operation, with an internal drive circuit. A suitable remote mounting sounder would be their "High Power", 3V to 24V version, code FK84F.

The p.c.b. mounting mains transformer was purchased from **Electromail** (☎ *01536 204555*), code 209-140. The 3V/11mAh p.c.b. mounting batteries are RS types and were also ordered through the same source, code 593-552.

The printed circuit board is available from the *EPE PCB Service*, code 126.

Theremin MIDI/CV Interface

Like last month's *EPE Theremin*, some of the parts called-up for the *Theremin MIDI/CV Interface* are special items and will not be generally available.

The author/designer, Adam Fullerton, is able to supply the pre-programmed PC87C51FB microcontroller for the sum of £45 each, inclusive p&p. Orders should be sent to Adam at **The Dene, Hindon, Salisbury, Wilts., SP3 6EE**. Make cheques payable to **Adam Fullerton**.

So that readers can select their own requirements, Jake Rothman (author of the *EPE Theremin*) has put together a range of kits for the MIDI/CV. He is also able to supply a ready-programmed micro for the same price. *See his advertisement on page 51 for details. – Note the new address and phone number.*

The printed circuit board set is available from the *EPE PCB Service*, code 130.

Earth Resistivity Meter

Apart from the ingenuity of constructing the probes, the only items which may cause concern to constructors of the *Earth Resistivity Meter* are some of the specified semiconductor devices.

The 2072/81/82 op.amps are Texas devices that do not appear to be stocked by any of our advertisers. However, they appear to be up-grade versions of the readily available TL072, TL081 and TL082 series and these can be used in this circuit, in fact, almost any op.amp will probably work, and this will result in a significant saving.

The TIP29A and TIP30A power transistors seem to be "old hat" now and not that easy to find, but the 5A 40W TIP31A and TIP32A versions can be substituted instead.

A copy of the author's program written in QBasic (for PC-Compatible computers), is available from the Editorial Office for the sum of £2·50 UK, £3.10 overseas surface mail or £4.10 airmail. This is to cover admin costs and postage, the software itself is *free*. You are welcome to copy this program and give it to your friends. See *PCB Service* (page 67) for ordering details.

The program can also be downloaded *free* from our FTP site: **ftp://ftp.epemag.wimborne.co.uk**, in the sub-directory: **pub/PICS/Earth.Meter**.

The printed circuit boards are available as a set from the *EPE PCB Service*, codes 131 (Current Gen.) and 132 (Amp/Rect.).

Psycho Rat

The only component problem likely to cause any local sourcing difficulties for the *Psycho Rat* is the P.C. Bimboard. This is a "hard-wiring" version of the component plug-in prototyping block and is currently listed by Maplin as a Plugblock PCB, code YR87U. You can, of course, transfer the layout to stripboard if you wish.

The choice of "rodent" is left to individual choice, but at this time of year most toy shops should be able to come up with a suitable subject.

PLEASE TAKE NOTE

Central Heating Controller **November '96**

We have received an E-Mail communication from Mr. David Lilley, who has successfully completed and installed the Central Heating Controller from our Nov '96 issue, highlighting a solution to a problem which other readers may encounter. He writes:

The programmer worked fine during testing with no load connected to the relay outputs. However, when installed, it ceased to function when one of the relays had operated – highlighted by a blank display. The only way to restore function was to remove and reconnect all power.

My CH system makes use of motorised valves to control water flow and I guessed that these were creating mains interference when operating, which was being fed back to the controller housing by the relay connections, and corrupting the microcontroller memory.

A 220nF ***X-Class capacitor*** *connected across the pole of each relay and the mains* Neutral *connection solved the problem, and the programmer now functions flawlessly.*

Many thanks for an excellent and practical article. David Lilley.

BUILD YOUR OWN PROJECTS

Alan Winstanley **Part 3**

IN THIS short series of articles, we are describing modern methods for constructing your electronic projects. This third part discusses the handling of stripboard and the process of fabricating your own single-sided printed circuit board. It's easier than you might think!

Future parts will look at case and enclosure preparation, workshop tips and tricks – in fact, everything you need to know to get satisfying results when building your latest *EPE* project!

Alan is, of course, Surgeon-in-Chief at *Circuit Surgery*, and enjoys all aspects of electronics.

IN Part Two of *Build Your Own Projects*, various methods for constructing electronic circuits were outlined, for building a quick prototype or assembling it in a more permanent form. The all-important topic of soldering was described, too.

This month, we look in more detail at the methods of fabricating circuits and also means of producing printed circuit boards (p.c.b.s) at home or in the workshop. So let's get down to the "nitty gritty" of assembling circuit boards!

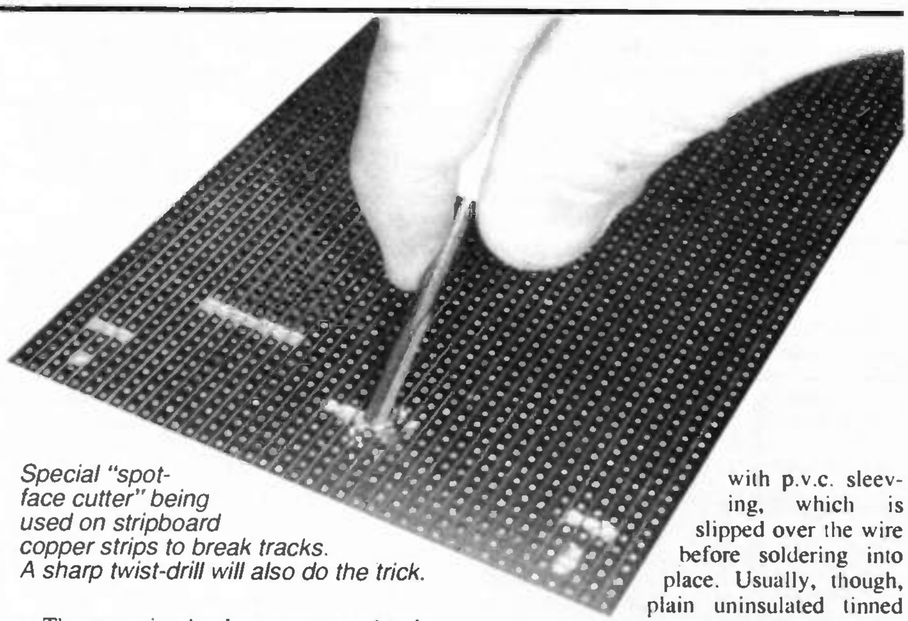
Some years ago, stripboard was the standard "bread-and-butter" medium with which most hobbyist circuits were assembled, and it was unusual to see a printed circuit board on our projects pages. The reverse is now true, because affordable personal computer software packages (see our advertising pages) have made the design of p.c.b.s simpler than ever before.

Never-the-less, stripboard *does* still have a role to play, but it tends to be used more during the prototyping stages or for building fairly small projects where the time and trouble of fabricating a p.c.b. couldn't really be justified. Stripboard is also useful for gaining general soldering practice, perhaps using surplus components.

GET STRIPPING

Stripboard can be snapped to shape by scoring it, holding it over a sharp edge and breaking it along a row of holes, then filing the edges till smooth; I prefer to use a junior hacksaw though, for more accurate results. It's worth examining the cut edges closely to ensure that no copper swarf is present which may short adjacent strips together. Clean up any potential trouble spots using a fine file.

If necessary, clean up the copper strips with an abrasive rubber block specially made for removing tarnish. If you are working from a published design, check with the component layout master to see whether any mounting holes are needed to carry the board. These will usually be M3 (3mm) or so, diameter, but they should not be drilled too close to a corner or the board will probably break.



Special "spot-face cutter" being used on stripboard copper strips to break tracks. A sharp twist-drill will also do the trick.

The mounting hardware may need to be insulated from the underside copper strips of the board, especially if steel nuts, bolts and spacers etc. are used. This is easily done using a special "spot face cutter" or even an ordinary handheld twist drill.

Drill away the copper strip (there's no need to go through the entire board!) at the appropriate places, to ensure the mounting hardware isn't in contact with the rest of the circuit. Continue by making the remaining breaks, in the copper strips as required, perhaps as you go along.

SOLDERING ON

Now it's possible to progress by soldering all the components into place on the surface-side (topside) of the stripboard, using the advice given in last month's article. It's best by far to start with the smallest, "fiddly" components while you still have an uncluttered board to work on, so start with link wires, then small resistors and other discrete components.

Link wires may be formed from tinned copper wire (e.g. approximately 20s.w.g.) which is bent to length using long-nose or round-nose pliers. If any link wires require insulating, this can easily be effected with p.v.c. sleeving, which is slipped over the wire before soldering into place. Usually, though, plain uninsulated tinned copper wire is used and you simply need to ensure that it's pulled reasonably tight at one end with pliers before soldering, to produce a neat straight wire which doesn't touch anything nearby.

Soldering continues by fitting in the remaining components, ensuring that all polarised parts (e.g. electrolytic capacitors and bridge rectifiers) are correctly orientated. Delicate semiconductors should not be overheated or they risk being damaged – but in any event it should take only a couple of seconds to make the perfect joint, as described last month. Some parts (e.g. large axial-lead capacitors) may benefit from being secured with a dab of hot melt glue, to help protect them against vibration.

BE ON GUARD

Never forget, CMOS devices are sensitive to static discharge and special measures are needed to handle them. The idea is to prevent any lurking electrostatic voltages from "zapping" the CMOS part, by diverting the static to ground (electrical earth) instead.

Preferably insert CMOS components into place last of all, after all other soldering etc. has been completed. Also, ensure your soldering iron is well earthed so that no charge is carried over by the iron to the CMOS device. Before handling a CMOS component itself, discharge any static on your body by touching a well-earthed part (e.g. a water pipe or an earth terminal).

More ambitious users may want to wear an anti-static wrist strap which is plugged into an earthing point (e.g. a mains outlet Earth) via a special adaptor (which usually includes a one megohm (1M) resistor to ground). Anti-static bench mats are also available which prevent any static charge accumulating, since the mat is electrically earthed and partly conductive.

Integrated circuits – whether CMOS or bipolar – are often best used in conjunction with d.i.l. (dual-in-line) sockets to prevent thermal damage arising, and to enable faulty i.c.s to be swapped out if necessary. Unless you are using a p.c.b. assembly frame, possibly hold the sockets flush against the board with a little insulating tape while you solder their pins underneath.

Parts which may become warm (e.g. some higher-power resistors) should be "stood off" the board slightly, to allow air to circulate. Remember to finish with the largest parts last of all.

Take care not to heat the copper strips excessively or the adhesive will be damaged and the copper will lift away. You should *always* check the board very closely for errors afterwards.

Common oversights include components soldered into the wrong location, missing wire links and breaks, or incomplete breaks. Soldering defects include excess solder being applied (often with tiny "whiskers" of solder shorting adjacent strips), or the occasional "dry joint" (see last month).

FLYING LEADS

With the components now in place, the board will invariably require connection wires to be soldered to it. You can solder these "flying leads" directly to the board, or use a solder terminal-pin and solder the wire to that instead.

Flying leads are always potential weak spots because vibration may cause the wire joint to "work harden" in due course and it will then fracture, even if you use multi-stranded flexible connecting wire.

Final options for the completed strip-board include using a flux-remover to clean up the solder-side of the board, and then to spray on a coating of aerosol lacquer to help prevent the copper from oxidising.

Anti-static wrist-strap is preferable when handling CMOS devices.

PRINTED CIRCUIT BOARD

In preference to stripboard, the most popular form of construction now used at the centre of most of our projects is the printed circuit board. (Commonly referred to as the "p.c.b.")

The constructor has two options: either purchase a ready-made p.c.b. from our *PCB Service*, or alternatively, fabricate the board from scratch. The first option is easy – see our p.c.b. listing elsewhere in this issue!

Hopefully, though, you will wish to try to make your own boards, and we encourage everyone to "try their hand" if they can afford it. Do-it-yourself production has the added benefit of allowing you to make modest batch runs of boards if needed, and you can also modify the design within reason and produce an updated board at a later date.

Printed circuit boards are usually made using glass reinforced fibre board which is immensely strong. It's fairly easy to produce boards to close tolerances but it does require the use of at least one noxious chemical (usually Ferric Chloride) which should be treated with respect.

Also, the preferred way of fabricating boards requires some additional equipment, in the form of an ultra-violet exposure unit, which may be priced beyond more modest budgets. A low-voltage "mini drill", capable of accurately drilling holes of roughly 1mm diameter, is another essential requirement. (See the Expo Drills & Tools Catalogue which is *free* with this issue.)

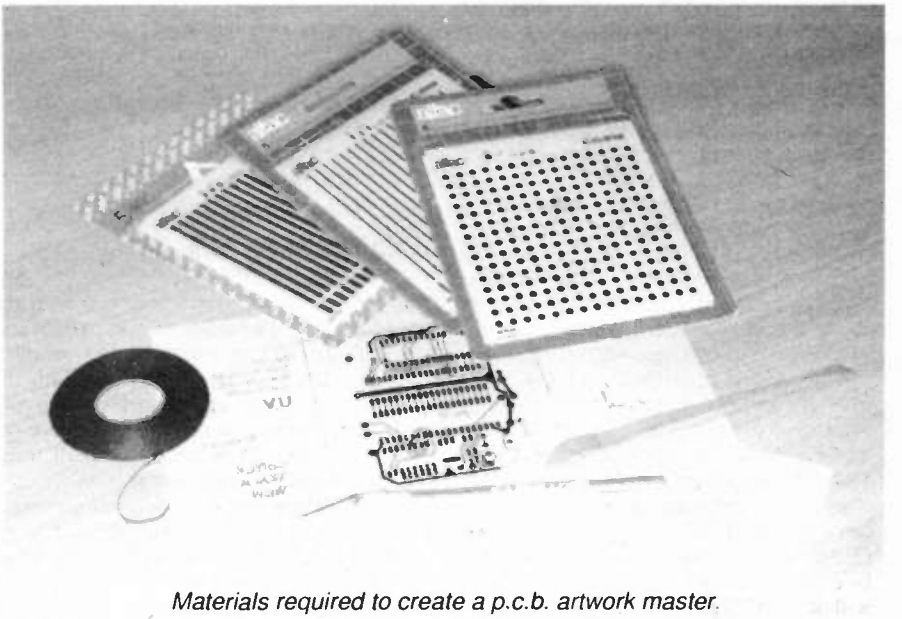
All the major catalogues have a section on "PCB Fabrication" or similar, and you should refer to these to obtain some idea of the product availability and their prices.

GETTING STARTED

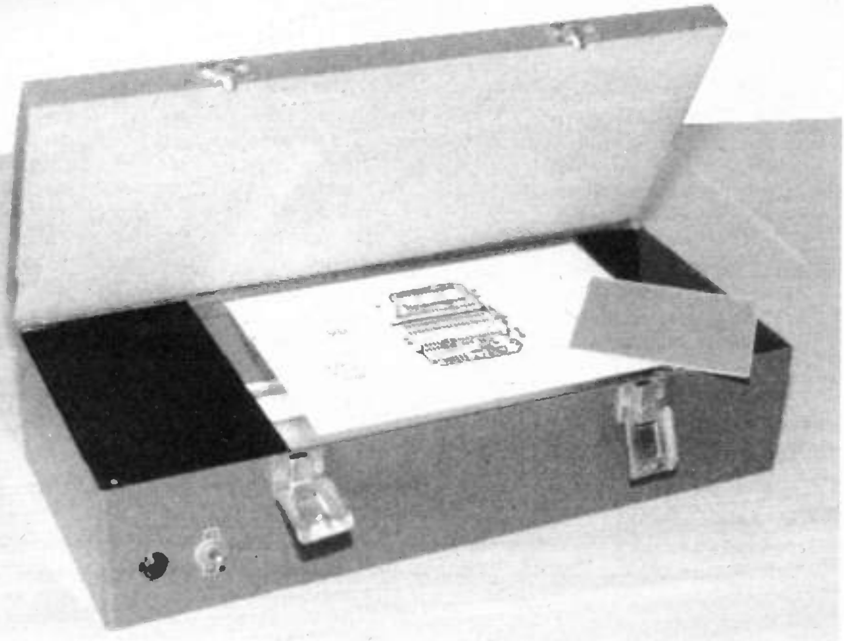
How do you make printed circuit boards? Well, the normal method involves using a "blank" copper-clad board which is coated with an ultra-violet light-sensitive chemical, often called "UV resist". You may purchase the boards ready-coated (something I normally do, mostly to save time) which you cut to size – an electric jigsaw is useful – or you can try to coat your own blank boards using an aerosol spray UV resist.

This latter option requires practice and I don't always obtain consistent results: it's worth a try if you have some spare copper-


"Hot-melt" glue is useful for protecting larger parts from breaking loose due to vibration.



Materials required to create a p.c.b. artwork master.



Placing the artwork on a UV exposure unit. (Protect eyesight from UV.)

clad board available which you would like to use with the ultra-violet process to be described next.

One way or another, the p.c.b. master pattern has to be translated onto a stable clear film (normally a polyester sheet) as "positive" artwork. The black areas of the film represent the copper in the layout.

Almost every *EPE* project using a p.c.b. includes a 1:1 copper track pattern from which a photographer can produce a photo-positive for you, or you can trace the design onto film for yourself, using special p.c.b. drafting symbols and tapes. *(Photocopies of the artwork can also be transparentised using special sprays available from office stationers. Ed.).*

With more complex boards, the tracing option is a lengthy job which takes some practice and dexterity, but which can be a satisfying and creative task. A range of p.c.b. drafting materials is available in a variety of shapes (round pads, dual-in-line pads, straight lines, curves, etc.) from the larger mail-order houses, and the constructor has to physically place self-adhesive die-cut symbols, or rub transfers down onto the film, using the magazine artwork as a guide.

Copper tracks are formed by physically cutting line transfers to suitable length using a scalpel, and then rubbing these down to trace the routes of the tracks. Larger black areas can be outlined with transfer lines and the central areas filled in with matt black enamel paint, for example.

It is important that the centres of component leadouts are accurately copied onto the artwork, especially those of d.i.l. integrated circuits and p.c.b. mounting capacitors etc., or the parts will mis-align and won't fit the board. Any mistakes in the artwork can be corrected by removing the the transfers with Sellotape or lifting off the die-cut materials with a scalpel. Eventually, the constructor will produce an accurate copy of the p.c.b. artwork onto film which can now be transferred onto the copper clad board.

One tip: clearly label which side of the artwork is which, or you risk producing a mirror image of the board by accident! So label the appropriate side *"This Side Copper Track View"* or similar. The artwork can then be stored for repeated use or modification in the future: keep it away from any sources of heat because this may distort the film.

LIGHT WORK

The next stage of processing involves using the artwork as a "mask", by exposing a sensitised (UV resist-coated) copper clad board to ultra-violet light, with the artwork placed over the board. The UV light source *MUST* be shielded from vision when in use as it is potentially harmful to stare directly at the source. A UV light box is best for consistent results, though some constructors build their own versions using UV lamps.

The artwork will prevent the UV light from passing through any black areas, but the clear regions of the artwork permit UV light to pass onto the resist-coating. It may take between 2 to 20 minutes for the resist to be fully exposed, depending on several factors, but do be prepared to experiment when you prepare boards this way for the first time.

When exposure is complete (and note that it's not necessary to use a darkroom when processing UV board), the board is placed into a liquid developer. This will quickly remove all the UV-exposed areas of the resist, leaving you with a perfect copy of your artwork made in the resist layer of the board, with raw copper everywhere else.

Exposed p.c.b. immersed in developer to remove unwanted resist.

The board is then dipped into a suitable etching liquid, which is usually Ferric Chloride solution held in a photographer's developing tray. This will completely etch away all of the raw copper in a process which takes say 15 to 30 minutes or so, depending on the age of the etchant and its temperature *(warming it before use is recommended. Ed.).*

After etching is complete and all the unwanted copper has been removed, the board is carefully washed down with water and the now-redundant UV etch-resist is then stripped away with a solvent or an abrasive block, to reveal the copper track pattern itself. Finally, the board is drilled to accept the components, after which the printed circuit board is ready for soldering.

The UV method is extremely accurate, and it will reproduce every imperfection in the artwork. It's often a good idea to examine and "touch up" the etch resist pattern prior to dipping into the Ferric Chloride: small quantities of acetone (e.g. nail varnish remover) can be used on a cotton bud to remove any unwanted resist, and conversely, an etch-resist pen can be used to add small areas of resist by hand, if necessary.

OTHER METHODS

Readers may hear of other "unofficial" methods of p.c.b. processing, and these are worth experimenting with. In the simplest applications, it's possible to use the transfers as etch-resist, by applying them directly onto plain copper board, which can then be etched straight away.

Materials needed for developing and etching printed circuit boards: Ferric Chloride crystals, developer, photoresist, caustic soda, plastic tongs, plastic tray, disposable gloves and photoresist copper board.

The so-called "toner transfer" system involves taking a good-quality photocopy of the (magazine) artwork onto clear acetate film, and then literally ironing this onto plain copper clad board! The gentle heat from the clothes iron will re-melt the toner which will now adhere to the copper, to form an etch resist. *(See the news item about Press-N-Peel on our* Innovations *page. Ed.)*

Computer users sometimes experiment by outputting p.c.b. artwork from screen onto clear film using an inkjet printer, but results are not always consistent. The creation of the artwork is often the greatest hurdle, and it is definitely worth experimenting with other techniques of artwork "origination". The most advanced techniques use CAD packages which output computer files directly to computer-aided manufacturing systems, and will not be discussed here.

RIGHT CHEMISTRY

Most mail order sources will provide the chemicals required to process printed circuit boards. Ferric Chloride is usually shipped in granular form, to which water must be added in accordance with manufacturer's recommendations.

The solution can be re-used many times, *but must only be stored in plastic or glass containers, firmly sealed with the correct plastic cap* (not metal). Being toxic and corrosive the fluid ***must be stored away from children or pets.***

You must not allow etchant to come into contact with metal fittings (e.g. kitchen taps) since the product will indelibly stain many materials. **Great care must be taken to ensure that it is not splashed onto skin or in the eyes.** Disposable gloves and splash-proof goggles are sensible precautions when in use.

These days, there is more emphasis on the "environmental friendliness" of chemical products, and the disposal of corrosive Ferric Chloride may understandably prick the conscience of some readers. First, the etchant will not be accepted at domestic refuse sites in the UK, and it is irresponsible to pour it on soil.

Since only very small quantities are involved, however, opinions generally seem to favour fully diluting it down and then letting it run to waste by pouring it down an outside drain, accompanied by plenty of running water. I view this as currently the most realistic and safest method of disposal, though constructors in Holland and Germany may have further restrictions due to their Special Chemical Waste regulations.

IN THE BAG

If disposal is indeed a problem then one excellent alternative which is worth considering seriously is the Seno/GS "Etch in a Bag" system. I strongly recommend it for home or hobby use, because the Ferric Chloride is always kept in a heavy gauge sealed polythene tube and, if used correctly, it's virtually impossible to come into contact with the harmful liquid itself.

Special sliding seals are used to "sectionalise" the poly tubing, releasing the etchant over the board in a closed environment. It will accommodate up to a standard "Eurocard" 160mm × 100mm, and etching can be accelerated by warming the poly bag with a hair drier. A special neutraliser powder is included which permits safe disposal of exhausted etchant, with a completely clear conscience!

This ingenious product is available from **ESR Electronic Components** ***(Tel. 0191 251 4363 Fax 0191 252 2296)*** and **ElectroValue Ltd.** ***(Tel. 01784 442253, Fax 01784 460320).*** In my view, the Seno/GS is a *must* for the hobbyist working at home.

Other chemicals which will be needed include the developer solution, and etch-resist remover. For developer, I generally use Sodium Hydroxide solution which I make up as needed by adding about 10 grammes of domestic Caustic Soda granules (available from chemists) to a litre of warm water, though this sometimes requires some trial and error. Common-sense precautions are necessary when handling caustic soda solution: avoid splashing the eyes or skin.

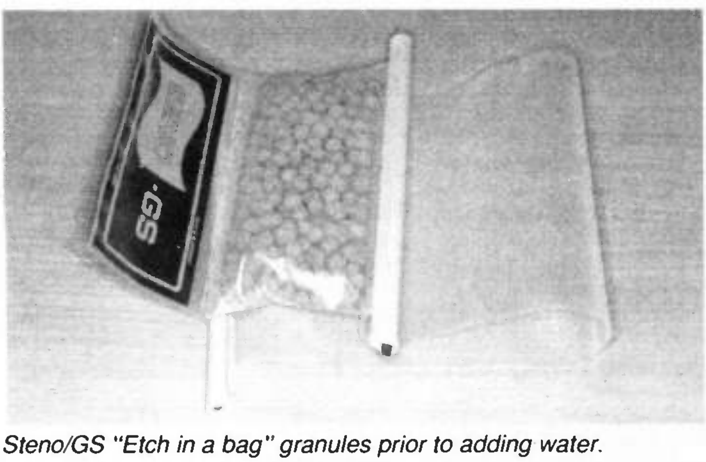
You can also buy a ready-made developer solution which is more convenient and will give consistent results. Etch-resist removal is easily effected with acetone used on a cotton-bud or a swab; it's readily available as nail varnish remover from the same chemist, whom by now will be giving you funny looks!

PERSEVERE WITH UV

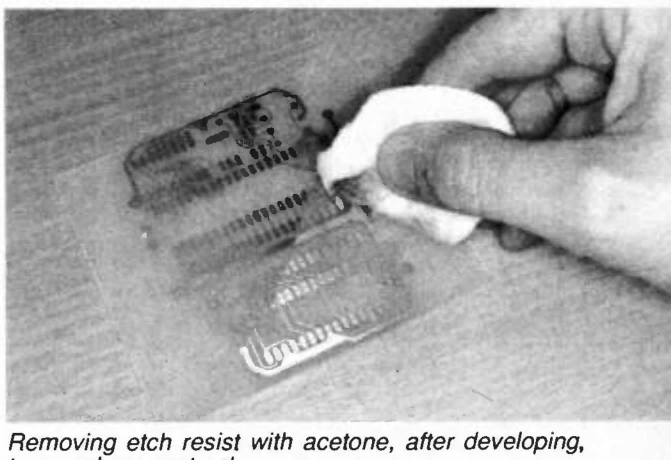
My advice is to persevere with the UV system because it does sometimes need practice before acceptable results are evident. Success depends on ensuring that the exposure time is just right. This depends on how thick and sensitive (or "fast") the resist itself is, how far away the UV source is, and the strength of the light.

- *Not enough UV* (under exposure), and the etch-resist will not be exposed all the way through its depth: it will then be impossible to develop the board fully.
- *Too much UV* (over exposure) and the finest copper tracks may be undermined by the UV light, and they will disappear during developing. In precision layouts, this would obviously be unacceptable. However, it is usually not a bad idea to over-expose slightly since you would have to be quite unlucky to cause any damage this way.

Under-exposure is a real nuisance which only becomes apparent during developing. It is virtually impossible to return the board to the UV source and expose the board for a further period, whilst trying to maintain the accuracy and alignment of the track pattern at the same time.

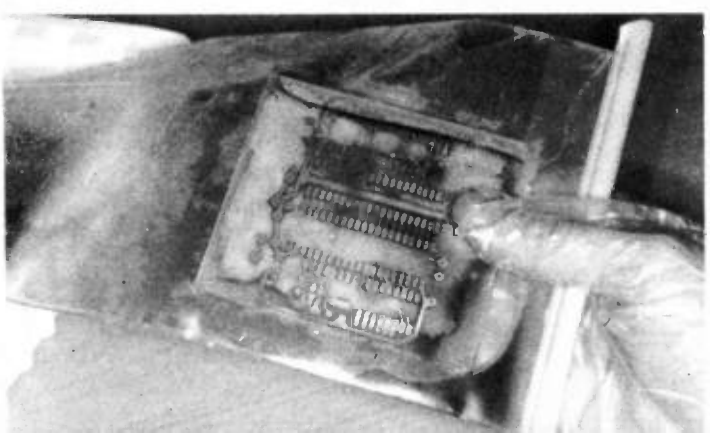


Steno/GS "Etch in a bag" granules prior to adding water.

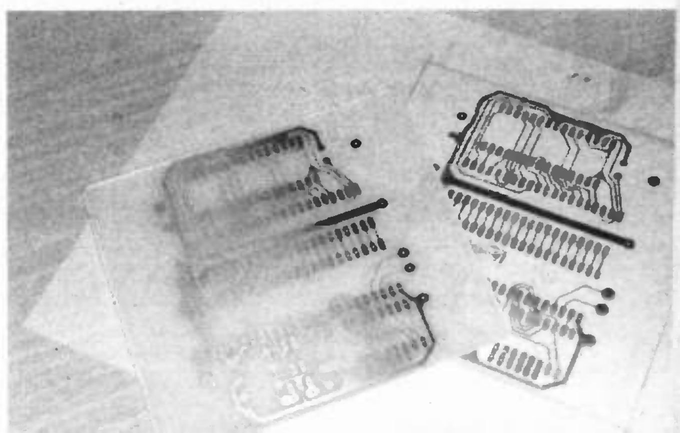


Removing etch resist with acetone, after developing, to reveal copper track.

Etching the p.c.b. in the "sealed" bag.



From artwork master to board ready for drilling.



The only real answer to this may be to remove the resist, and to spray on an aerosol resist coating, and try again. Personally, I often experience very inconsistent results with spray-on resist, due to the variations in the thickness of the final coating, but it's still worth a try.

Generally speaking though, using off-the-shelf products and a ready-made UV exposure unit, there is no real reason why you can't obtain perfect results, and p.c.b. production is a technique which adds another dimension to the hobby. Using the materials shown in the photos, I processed the p.c.b. first time as shown, and the final results were very rewarding.

FOLLOW THE DRILL

Having removed the etch resist, the final phase of p.c.b. fabrication is to carry out the necessary drilling. It's at this point that you suddenly appreciate why there is a small hole in the middle of every solder pad on the artwork.

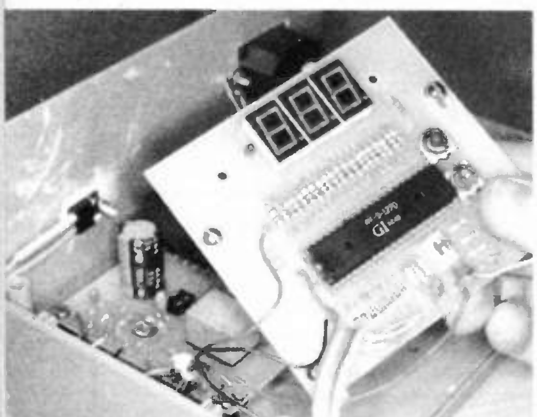
The centre of the pad is etched away, leaving a tiny drilling centre which acts as a starting point for the whirring drill. Without it, the drill will "wander", with possible disastrous results, and it becomes very much harder to drill the hole precisely.

There's no real substitute for buying a low-voltage d.c. drill with power supply. These are the best and most accurate way of drilling holes through the board, as ordinary electric drills really are too massive for this precise task. A drill may cost £15 to £30 or more and the power supply may double this cost. (Consider using your bench power supply if it is suitably rated.)

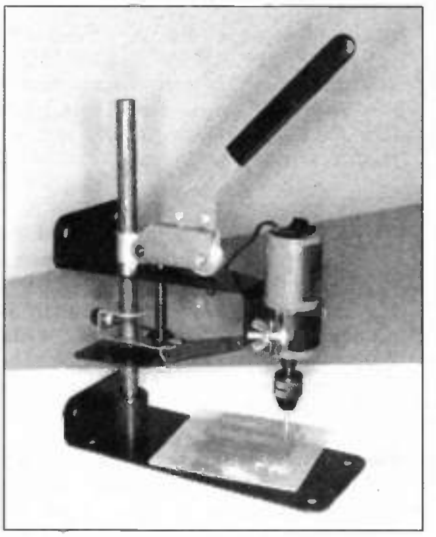
Which type of drill to buy, depends on your budget and interest, but ideally select a reasonable d.c. drill fitted with proper bearings inside, to ensure smooth running. The cheapest drills are nothing more than simple d.c. motors fitted with a chuck, and they can be quite crude to use, but at least they will help you make a start.

An extremely useful accessory for your p.c.b. drill is a vertical drill stand. This will be specially made to fit your machine and it allows you to set the height and cutting depth of the drill. They are worth investing in if you are at all serious and you need more precise control over your work; I managed for years without one.

However, cheaper drill stands (say, £30 or so) may not be as consistent or as easy to use as their more expensive counterparts which have twin pillars and are more



Completed p.c.b. with all parts soldered into place.



Low voltage drill in a stand, for more accurate control.

accurate and smooth-operating. Check the supplier's catalogues carefully.

BIT OF A TWIST

Turning to the "business end" of the p.c.b. drill itself, you will need to buy a small selection of drills which are specially made for fine work. P.C.B. drilling machines use miniature "collets" or chucks to accept them.

Usually, most holes are drilled at 1·0mm diameter, though 0·8mm may be used for dual-in-line chips and other finer wires. For larger devices, such as the larger tags of p.c.b. mounting potentiometers, or transformers, relays, etc. 1·3/1·4mm diameter is the common choice. Handy sets of drills can be bought which offer a selection of common sizes: top these up with individual items when they wear out.

Usually, drills (or more correctly, *twist drills* or *drill bits*) are made of high-speed steel ("HSS") which is adequate for p.c.b. work. However, it is a sad fact that glass-fibre boards wear down their cutting edges very quickly, so treat HSS drills as consumable items and always keep some spares.

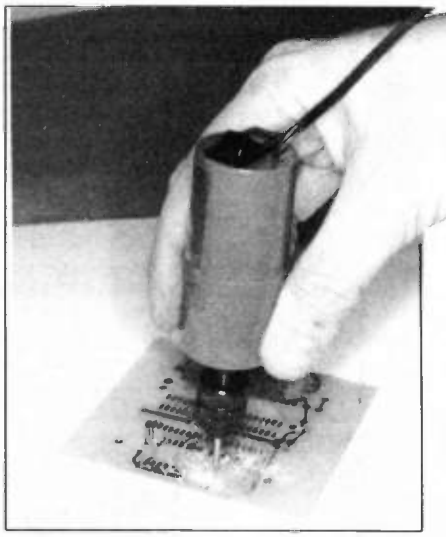
Be wary of tungsten carbide drill bits, which are up to ten times more costly: although they are much harder, they need to be run at high speeds and are extremely brittle. They will readily snap under hand pressure unless you use them in conjunction with a drill stand, but they do slice through glass-fibre with great ease.

Don't forget that you can buy other accessories for your drill, including cutters, grinding stones and polishing wheels, which you might find useful for model-making or other hobbies.

There's nothing more annoying than discovering an undrilled copper pad just as soldering commences, so check the board for omissions, and finish by drilling the larger diameter holes for the mounting hardware if used. Readers should be aware that the dust particles resulting from drilling glass-fibre boards can be intensely irritating to sensitive skins, so try to avoid skin contact and certainly do not inhale the product – also wear gloves if necessary.

SOLDERING P.C.B.s

The techniques for soldering a p.c.b. are very similar to those described earlier for stripboard. Extra care is needed



Drilling a p.c.b. by hand using a low voltage drill.

with finer tracks or smaller-diameter copper pads, though, since these will lift off if heated excessively. (Super Glue could be used as a repair.) It will take longer to solder joints positioned in large copper areas, due to the heatsinking action of the copper: a higher-capacity iron is sometimes useful at these times.

As before, start with the smallest parts first and finish with the bulkiest items. Large parts (e.g. transformers) must be completely flush against the board, otherwise vibration or knocks in use may cause the components to loosen the underside copper tracks and damage the copper foil permanently; hot melt glue will again act as a bonding agent to help protect flying leads and large parts (that don't become hot!) from vibration damage. An optional coat of spray-on lacquer will help protect the copper foil from corrosion and moisture.

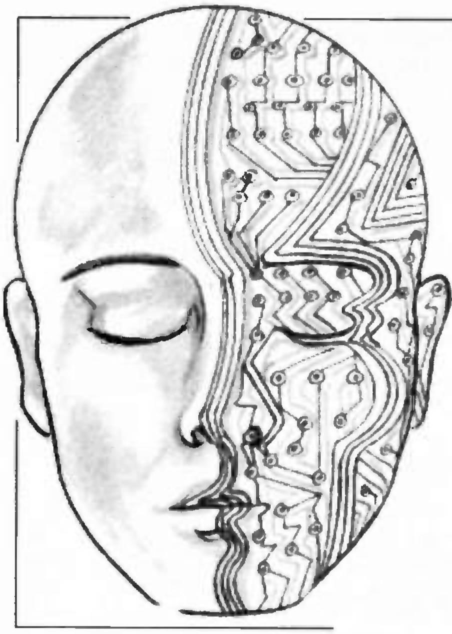
As with stripboard, flying leads can be soldered directly to the board or to solder-in terminal pins. In the case of mains-voltage connections, by far the safest and most reliable method of connecting these to a p.c.b. is to use screw-terminal blocks soldered to the board. Because the mains wire itself remains unsoldered, it will not become brittle through flexing or vibration (or, more dangerously, break off from the board completely) and will remain reliable in service. More of this next month.

All in all, with modern materials which are readily available today, there's no reason why you can't produce results which you can be really proud of.

NEXT MONTH

In Part Four, next month, we examine workshop techniques related to plastic and metal enclosures used to house your project. We'll also check out basic metal-working methods plus case preparation, along with other tricks and tips to help you enjoy assembling your electronic prototypes.

● Internet users may like to know that a "Soldering FAQ" (Frequently Asked Questions) is currently under construction, condensed from this series. It will offer an on-line resource to help beginners with the "Art of Soldering". Check our web site for the latest news.



INGENUITY UNLIMITED

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

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

Bicycle Mileometer – Pedal Power

THE simple circuit design shown in Fig. 1 can be used along with a ready-made l.c.d. counter module, to form a Bicycle Mileometer with an accuracy of approximately five per cent.

A reed switch, S1, is affixed to one of the forks of the cycle and a magnet is fixed to the wheel rim. The magnet causes the reed to close with each revolution, and with a wheel size of between 24 inches to 26 inches, a distance of 100th of a mile is travelled after eight revolutions of the wheel.

The circuit counts the eight pulses and then advances an l.c.d. counter each time the cycle travels 0·01 miles. Resistor R1, R2 and capacitor C1 debounce the pulse from switch S1, and each pulse then clocks IC1, a 4017 decade counter.

On the eighth pulse, pin 6 of IC1 goes high which drives transistor TR1 and causes the opto-isolator to "clock" the counter – increasing the count by 1/100th of a mile. On the next count, pin 9 goes high which resets the counter at pin 15, and the "count to eight" process re-starts.

The counter is a small battery operated unit available from Maplin, Tandy, etc. I added a Letraset "decimal point" to the left of the two least-significant digits on the display to give a direct readout in miles, which is permanently displayed. The circuit itself can be driven by a 9V PP3 battery. *(The ILD74 opto-isolator is a dual type, available from* ***Farnell*** *(Tel. 0133 263 6311) as Stock Code 325-909, but a single channel type e.g. TIL191 may be a suitable alternative. A.W.)*

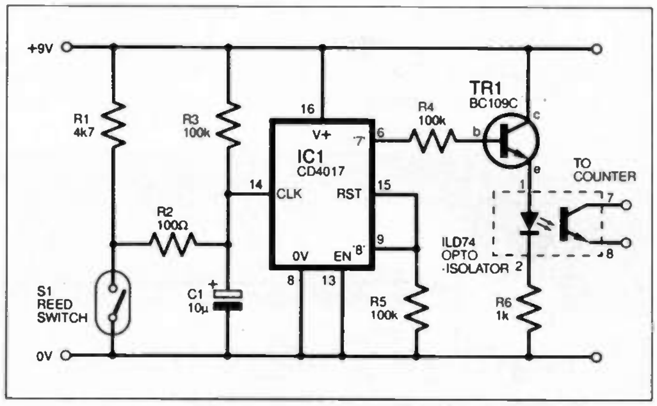


Fig. 1. Circuit diagram for the Bicycle Mileometer.

Nick Dossis,
Middlewich,
Cheshire.

Simple Stereo Amplifier – Undercover Sounds

I WAS once asked to build a Stereo Amplifier to permit a personal stereo to provide music in a trailer tent, and my simple solution is shown in circuit diagram Fig. 2. The circuit uses two TDA7052 bridge amplifiers, one per channel.

A stereo dual-ganged potentiometer VR1 acts as a Volume control, whilst capacitors C1 and C2 decouple the signal input. Resistors R1 and R2 are needed by some personal radios or stereos. Capacitors C3 and C4 decouple the 6V power supply.

I used four D-cells to power the unit. The two loudspeakers must have a minimum impedance of 8 ohms, as shown. (I selected two low cost Maplin 1·5W speakers).

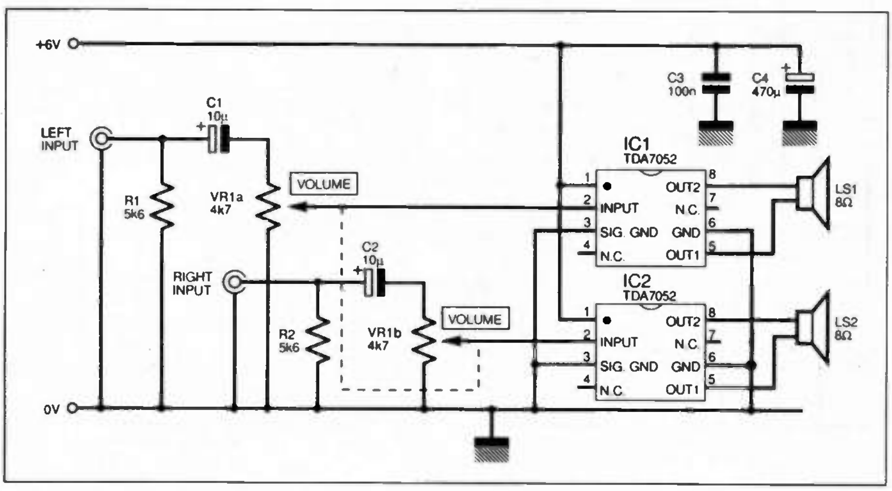


Fig. 2. Circuit diagram for a Simple Stereo Amplifier.

Alan Bradley,
Belfast.

THIS novelty circuit utilises the Holtek HT82231 PCM speech synthesis chip *(Maplin Order Code AE12N – A.R.W.)* which is preprogrammed with eight animal sounds, the best six of which are used in this application. To add further to the novelty, the sounds are initiated using touch-sensitive switching, each being based around a pair of NAND gates.

In Fig. 3, IC7 is the sound generator i.c.; VR1 and R9 control the internal oscillator speed whilst the output (pin 19) drives a single transistor buffer TR1. This in turn drives the loudspeaker LS1, and the l.e.d. D1 provides a visible indication of operation.

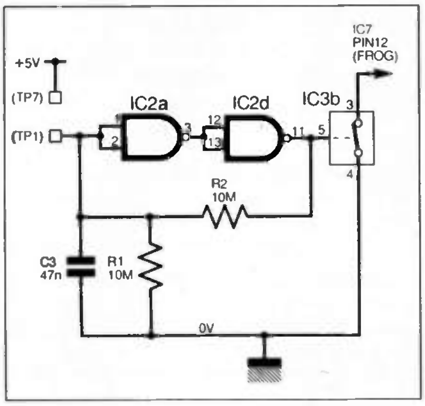


Fig. 4. Touch switch circuit.

Touch Tones

The animal tones are selected by grounding pins 7 to 15. By using two NAND gates as a pulse generator (see diagram of a single touch switch in Fig. 4), it is possible to select any of the control pins via a transmission gate. When the touch pads are shorted by skin resistance, the resulting voltage on the gate input is inverted and then inverted back by the following NAND to drive a transmission gate. This causes the respective control pin of the sound chip to be grounded.

The touch switch is latched on by resistor R2 and the capacitor C3 charges in about 47ms, then discharges through R1 in around 470ms, thus resetting the input at the first NAND gate and toggling the switch.

Three 4011 chips (IC2, IC4, IC5) and two 4066 chips (IC3, IC6) provide the six touch switches in total. Note that one touch pad (TP7) is common to all switches, being at the positive rail.

Power was derived from a 9V battery using a 5V regulator (IC1). In the final assembly the touch pads were made from six 10mm squares of 1mm copper sheet with a 160mm long strip for TP7. Copper clad board could perhaps be used.

D. Stringwell,
Scunthorpe, North Lincolnshire.

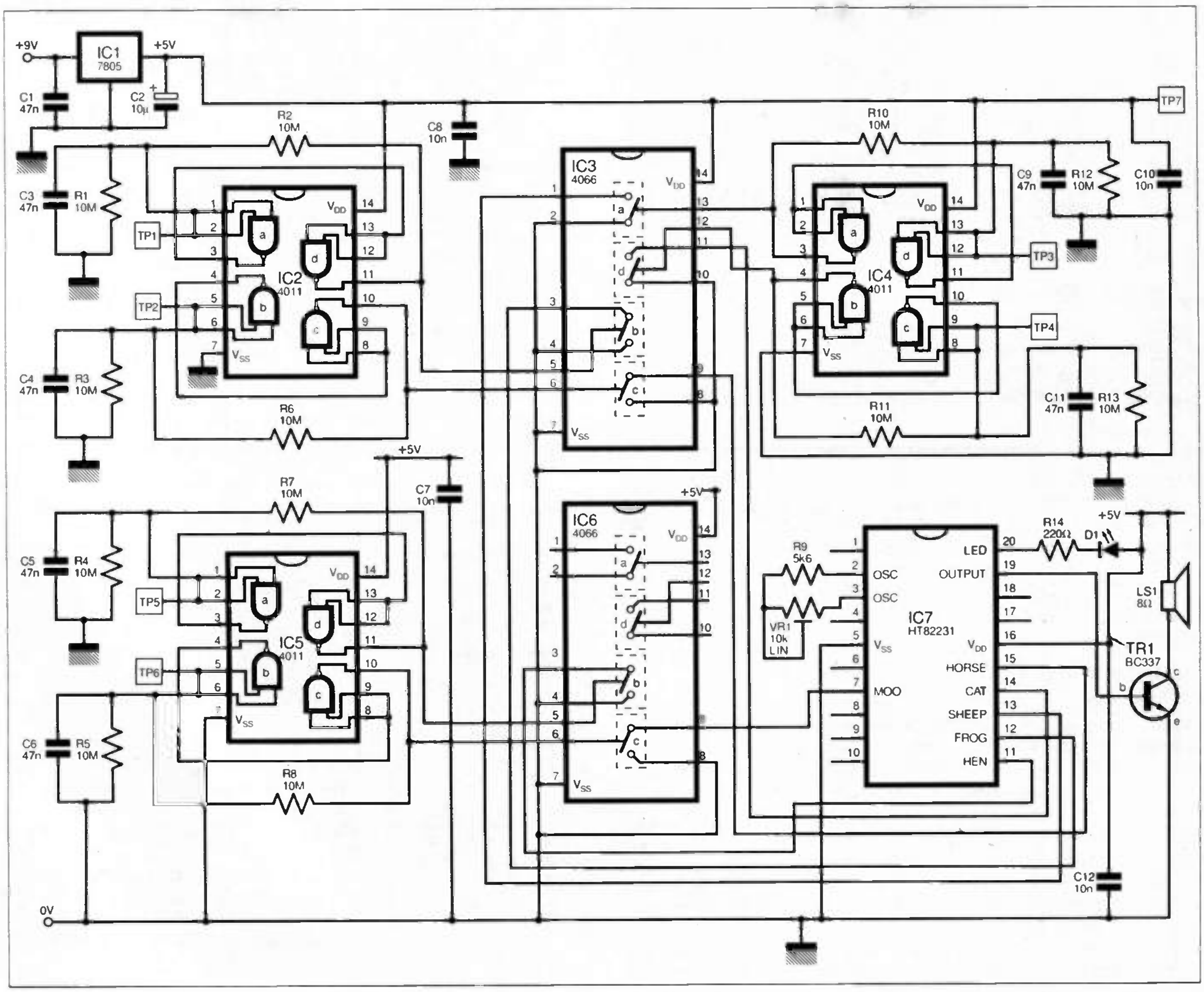


Fig. 3. Main circuit diagram for the Animal Sound Generator. Note that touch pad TP7 is common to all switches.

PCS32 STORAGE OSCILLOSCOPE INTERFACE

ROBERT PENFOLD

A three-in-one module for your PC that really measures-up to the "real" thing!

WHILE the idea of virtual instruments is not new, it is only recently that sophisticated systems have become available at affordable prices. The basic idea of a virtual instrument is to utilize a computer plus suitable software and an interface of some kind to replace a complex piece of measuring equipment.

The modern trend is to have on-screen "virtual" controls operated via the mouse, rather than having "real" controls on the Interface Unit. It is from this that the virtual instrument name is derived.

Systems of this type are used for all sorts of weird and wonderful things, including electronic test equipment. The "virtual instrument" reviewed here is the Velleman PCS32 Storage Oscilloscope for PCs.

Scope For A PC

Provided you already own a suitable PC, this unit offers a 2-Channel Storage Scope having a 32MHz sampling rate and an 8-bit vertical resolution for just £324·99. Furthermore, it can be switched to operate as a Spectrum Analyser or a transient recorder. (Better still, if you are a "dab hand" at soldering, you can select a Single Channel Kit for £173·39, add a Second Channel Kit for £66·29 and a Upgrade Software for £25·49. In addition, a Demo Disk is available for £3·05 – the Demo is also available free on the Internet).

It does not require a particularly advanced PC. The minimum requirement is a 80386 processor, VGA display, mouse, and 460k of free conventional memory. The spectrum analyser program and the oscilloscope's r.m.s. readout additionally require a maths co-processor (which is built into 80486DX and Pentium microprocessors).

What You Get

The version of the PC Scope supplied for review is ready-made, and is supplied complete with a soft carrying case, manual, two probes with cables and plugs, parallel cable for connection to the computer, and a mains power supply adaptor. The accompanying A5 size manual has 98 pages, but includes instructions in four languages. It tells the experienced user everything he or she needs to know in order to get the system "up and running", but those who are new to oscilloscopes will need to obtain a book or two on the subject.

The probes are standard oscilloscope type which connect to the BNC connectors on the front panel of the interface. Both include an "× 10" facility which extends the system measuring range.

The power supply unit is of the oversize mains plug variety, and the one supplied with the review system had a continental two-pin plug. However, units sold in the UK will be supplied with proper three-pin supply units for direct connection to UK mains outlets. The Interface can be powered from rechargeable batteries (not supplied as standard) if portable operation is required.

The Interface connects to printer port one (LPT1), and there is no option to use port two. As most PCs will probably have a printer already connected to port one, either a printer sharer will be needed, or the printer must be relegated to port two.

Operating software is supplied on a 3·5 inch high density disk, and is easy to install. A set-up program copies everything onto the hard disk for you. The program runs under MS/DOS, and does not require Windows. It should run from within Windows if required, provided there is sufficient free memory available. The mouse driver must be loaded before running the program via the batch file copied to the hard disk.

Facts and Figures

A maximum sampling rate of 32MHz is very respectable, but it does not mean that the unit has a bandwidth of 32MHz. As with any sampling system, the sampling rate must be at least two or three times higher than the maximum input frequency. The effective bandwidth is therefore about 10MHz or so.

While this is rather less than that of most conventional oscilloscopes, it is still adequate for most purposes, including the display of PAL video signals. The two channels operate independently, and the maximum sampling rate therefore remains at 32MHz when both channels are used.

Input impedance is the usual one megohm, and this is shunted by about 30p (picofarads) of capacitance. The maximum input voltage is 100 volts a.c./d.c. The timebase range is switchable from 100ms per division to 100ns, with the usual 1 – 2 – 5 – 10 sequence. Triggering can be on the positive or negative edge of

The complete PCS32 outfit, minus carrying case.

the waveform, and can be from channel one or channel two. There is no provision for external triggering.

Input sensitivity is switchable from 10 millivolts to 5 volts per division, again with the usual 1 – 2 – 5 –10 sequence. The × 10 setting on each probe provides additional ranges of 20V and 50V per division. It also boosts the input impedance to 10 megohms, and reduces the input capacitance.

Software and Interface

The software is really three different programs, one for each function the system provides, but on-screen switches enable you to move quickly and easily from one to another. The oscilloscope program provides an on-screen representation of an oscilloscope front panel and c.r.t., complete with controls that are operated via the mouse.

For example, to operate one of the pushbutton switches you simply place the pointer over it and "click" on it with the mouse. With the rotary controls you simply "click" on the appropriate number around the on-screen control knob. The other two sections of the software operate in essentially the same fashion, but with suitably modified control layouts.

Although most of the action takes place on the screen, there are actually a few controls on the interface itself. For each channel there is a "Y" position control, and a three-position miniature toggle switch which offers a.c. and d.c. coupling, or the option of "earthing" the input. The only other control on the interface is the on/off switch on the rear panel.

I found little difficulty in adjusting to the use of a combination of virtual and actual controls. This is certainly made easier by the fairly convincing on-screen representation of a scope front panel together with the use of mouse control.

The PC532 Interface is housed in a tough plastic case having silver anodised front and rear panels. It has standard BNC connectors for the Y1 and Y2 inputs. It seems to be well made, and should stand up to many years of use.

"I have no hesitation in recommending the system, and might even be tempted to buy one myself."

Scope

Probably the vast majority of users will buy this system primarily as an oscilloscope, and will regard the Transient Recorder and Spectrum Analyser as useful "extras." The eight-bit resolution of the oscilloscope gives a vertical resolution of 256 pixels, which is high enough to show complex waveforms in a fair amount of detail. In this respect it seems to be a fair match for the modestly dimensioned c.r.t.s fitted to most conventional 'scopes.

At very fast sweep speeds the horizontal resolution suffers due to the relatively small number of samples taken per sweep. This can give a rather ragged looking waveform using the normal (linear) interpolation, but there is the option of using "smoothed" interpolation to give a better looking waveform. This option only operates on the three highest sweep speeds.

Triggering can be positive or negative, and there is the option of continuous triggering or single-shot operation. The trigger level is set using two virtual pushbuttons, and an on-screen marker, left hand side of the display, shows the selected trigger level. Triggering can be switched off if a free-running timebase is required.

On-Screen

In addition to the Y position controls on the interface, there are on-screen X position controls. The system takes more samples than the screen can display at one time, and the X position controls enables the "missing" right hand section of the waveform to be scrolled onto the screen.

There is a "SAVE" control which writes the screen display to the hard disk in TIFF format. The file can then be loaded into a TIFF compatible program, which includes many illustration programs, word processors, and desktop publishing programs. I had no difficulty in loading saved files into programs such as Corel Draw! and Micrografx Designer. See Fig. 1.

The top section of the "c.r.t." screen shows the selected input sensitivities and sweep rate. The bottom section shows the calculated r.m.s. voltage of the signal on channel one. There are also three other figures which operate in conjunction with two pairs of moveable on-screen markers. The basic idea is to move the markers so that they tightly enclose one complete cycle. The figures in the bottom part of the "c.r.t." area then show the period of one cycle, input frequency, and peak-to-peak input voltage.

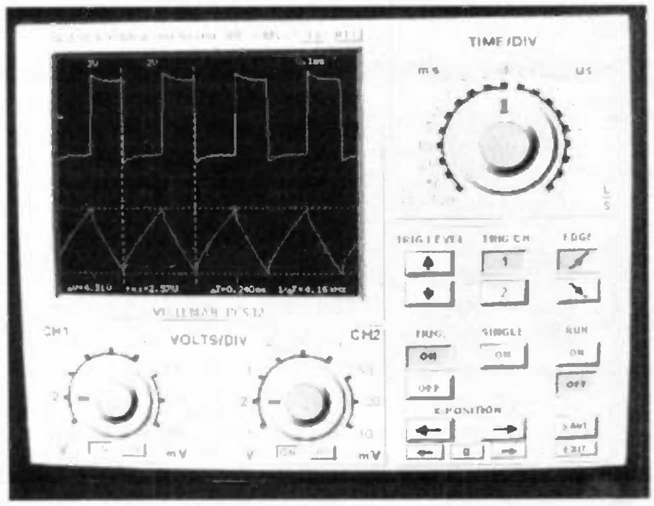
Oscilloscope Specifications

Minimum system requirements

IBM compatible PC with 80386 processor and maths co-processor
VGA display
Free Printer port LPT1
Mouse
460Kb free conventional memory

Technical Data

Vertical Deflection	
Sensitivity:	10mV to 5V/Div
Frequency Range:	D.C. to 16MHz
Input Impedance:	1MΩ//30pF
Input coupling:	D.C. – A.C. – Gnd
Input voltage:	100V max (D.C. + peak A.C.)
Horizontal Deflection	
Timebase	100ns to 100ms/Div
Triggering	
Trigger mode:	single, automatic or free running
Slope:	positive or negative
Level:	adjustable in steps of ½ division
Trigger Channel:	Channel 1 or Channel 2
Digital Storage	
Resolution:	8-bit
Sampling rate:	32MHz (max)
Memory size:	4Kb/channel
Interpolation:	linear or smoothed



PC screen picture showing the "virtual" controls for the Storage Oscilloscope. The scope "screen" displays stored signals from a simple triangular/squarewave oscillator. Imperfections on both signals are clearly displayed.

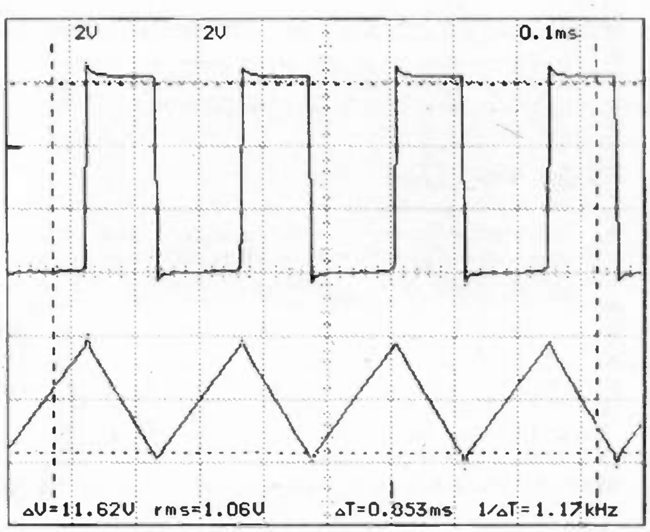


Fig. 1. Screen printout via Corel Draw.

PCS32 PC Scope Interface front panel layout.

The frequency display is useful, and saves wear on your pocket calculator. It would be better still if the program worked out the input frequency and peak-to-peak voltages for you.

Spectrum Analyser

The Spectrum Analyser function shows the frequency components present in a signal, and their relative strengths. A repetitive signal such as a squarewave or a triangular signal consists of a fundamental frequency plus various harmonics (multiples of the fundamental frequency).

Using the Spectrum Analyser it is possible to determine which particular harmonics are present, and their strength relative to the fundamental signal. It will also show any signals at non-harmonically related frequencies caused by imperfections or noise on the signal.

When switched to the Spectrum Analyser mode the screen display is similar to the one used for the Oscilloscope mode. However, only one channel or the other can be active at any one time, and the timebase operates in terms of the maximum display frequency. There are seven ranges from 800Hz to 16MHz.

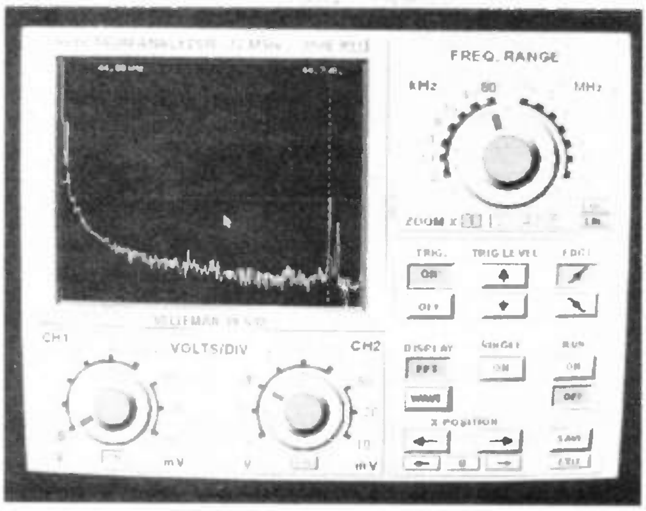
The X-axis represents frequency, and can have either logarithmic or linear scaling. The Y-axis represents amplitude, and the amplitude scaling is always logarithmic (10dB per division). The display can be switched to a conventional waveform display if required.

A conventional spectrum analyser is based on a swept bandpass filter, but this is not the method used in this case. Instead, some advanced mathematics are used to analyse the digitised signal and calculate its frequency content. It is for this reason that this facility requires a PC which has a maths co-processor.

Results from the Spectrum Analyser seem to be very plausible, giving suitable displays for a range of test waveforms. Even using a relatively slow PC (a 33MHz 30386DX) it only took about two seconds for the signal to be analyzed and the results to be displayed.

"The use of 'virtual' controls is not simply a gimmick, it really does help to make the systems quicker and easier to use."

The display shows the amplitude difference between two vertical axis screen markers. More usefully, it also shows the frequency represented by a horizontal screen marker. To determine the frequency of a peak in the display you simply move the marker over the peak, and read-off the frequency.



Spectrum analysis of a 1kHz sinewave showing high frequency noise.

Transient Recorder

A somewhat different screen layout to the other two is shown by the Transient Recorder Program, but it still uses what is broadly the same method of control. The "c.r.t." area occupies the full width of the screen.

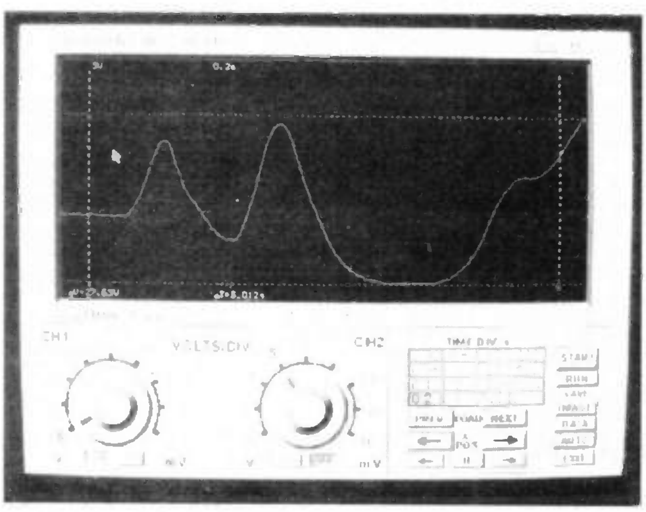
A Transient Recorder is really just a form of low frequency oscilloscope. The one in this system operates with a timebase range of 50ms to 200s per division. The required speed is selected via sixteen on-screen pushbutton controls.

The storage scope function operates by first taking in a full set of readings, and then producing the display. The Transient Recorder operates in "real-time", with transients being displayed as they occur.

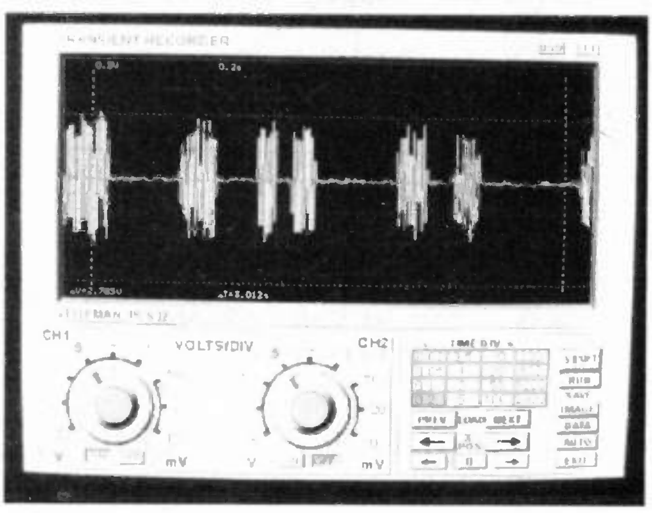
This is obviously a more specialised function than the standard storage scope function, but it does have its uses. For example, it can be useful when testing envelope shapers in electronic music equipment, and it can also be used for such things as recording data from temperature sensors over a long period of time. In fact the type of thing where a conventional oscilloscope is mediocre or completely useless.

Conclusion

I did not have a chance to use the PCS32 system over a long period of time, but during a test period of two or three weeks it always functioned well. It did not work properly with a 75MHz Pentium PC, but this seemed to be due to a lack of free memory. A boot-up disk which omits any unnecessary drivers should cure problems of this type.



Recording a low frequency signal using the Transient Recorder.



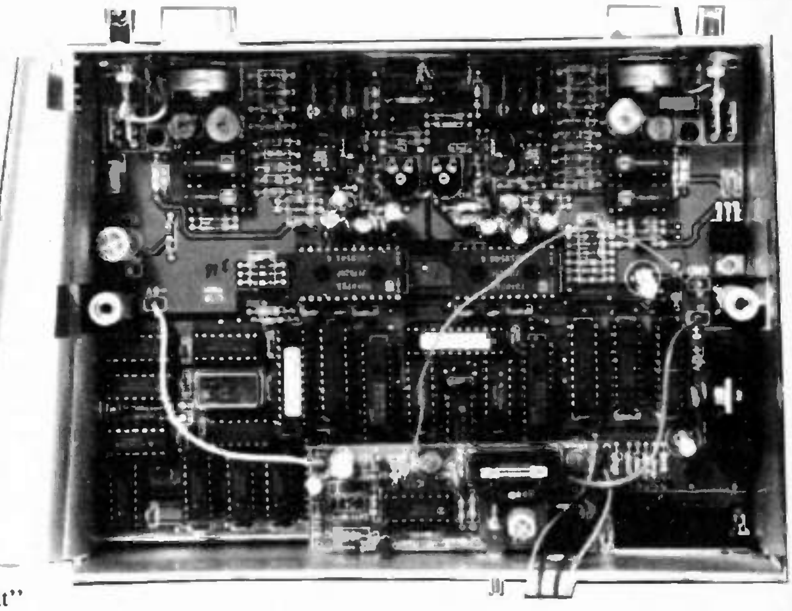
The Transient Recorder used to monitor intermittent bursts of signal.

AVAILABLE OPTIONS

Full PCS32 System	51950	£324-99
Single Channel Kit	51268	£173-39
Second Channel Kit	51270	£66-29
Upgrade Software	51949	£25-49
Demo Disk	51269	£3-05 (Inc. P&P)

(The Demonstration software is also available free on the Internet – **http://www.maplin.co.uk/velleman/velleman.htm**)

These prices include VAT, – carriage is Free on orders over £30.



Judging by this internal shot of the PC Scope Interface, the task ahead looks fairly daunting if you undertake the DIY approach – but the rewards will be most satisfying.

Provided you are familiar with oscilloscopes, the system is very straightforward to use. In fact, it is so straightforward to use that the information on the back of the box tells you practically everything you need to know in order to use the equipment effectively. The use of virtual controls is not simply a gimmick, and it really does help to make the systems quicker and easier to use.

Although PC prices are falling, the cost of a "ready-built" PCS32 system *and* a suitable PC is still considerable, and likely to total £1000 or more. At this sort of price the system still represents quite good value for money, but virtual instruments are most attractive to those who *already own* a suitable computer system.

A Dual-Beam Storage Scope, Spectrum Analyser, and Transient Recorder, with the ability to print out results from any of them, are all here for just £324-99. This represents a remarkable bargain. I have no hesitation in recommending the system, and might even be tempted to buy one myself!

For around the same price or less it is possible to obtain a few ready-made oscilloscopes, but they have relatively limited specifications. For some types of servicing a conventional oscilloscope might still be a better option. If you just require a basic oscilloscope, a conventional instrument provides a simpler and less cumbersome alternative to this system. If you require anything more than basic scope functions and have a suitable PC, there seems to be no conventional instrument that offers a similar specification at a comparable price.

Prices

The system reviewed here is the complete and ready-built version of the PCS32. For those who have the necessary experience there is a single channel kit version which has only the storage scope software. A second channel upgrade kit is available, as is a software upgrade to provide the spectrum analyser and transient recorder functions. Finally a demonstration disk is available, and this should help to give prospective purchasers the "feel" of the system. All items are available from Maplin Electronics, PO Box 3, Rayleigh, Essex, SS6 2BR (Tel. 01702 554000). The order codes and prices are listed in the Options Panel.

INTERFACE

Robert Penfold

TWO or three recent *Interface* articles have been devoted to computerised test equipment of the measuring variety. Computers are also used to control signal generation, which is the subject of this month's article.

There are two basic approaches to the problem, one of which is to use purely digital techniques to generate the basic signal, with linear circuits only being used if some waveform conversion is required (a squarewave being converted to a sinewave for example). This method has the advantage of producing what are normally very accurate output frequencies, but practical circuits are usually quite complex. It is an interesting subject, and one that will be covered at a later date.

Going Digalogue

The second and more simple method uses a combination of digital and analogue techniques ("digalogue" circuitry?). The basic technique is to use a digital-to-analogue converter to generate the control voltage for a v.c.o. (voltage controlled oscillator).

A high degree of linearity is available from modern digital-to-analogue converters, but the linearity of v.c.o.s tends to be not so good. Also, v.c.o.s often have large offset voltages that can complicate matters.

However, a simple setup of this type can provide reasonable accuracy. In fact, the accuracy should be at least as good as that obtained from a conventional signal generator having a calibrated control knob.

One slight drawback of this method is that suitable frequency measuring equipment is needed in order to get the finished unit working accurately.

Stepping Up

Of course, any form of digital control produces an output signal that is incremented in steps, rather than having the fully variable output frequency of a conventional signal generator. Provided there are a sufficient number of steps this should not be of any practical significance, and the resolution of the system will be adequate for any normal testing. Eight-bit resolution gives 256 output frequencies per range, which is adequate for all but the most critical of testing.

The circuit diagram for a simple 8-bit Digital-to-Analogue Converter, based on a ZN426E (IC1), is shown in Fig. 1. Converters based on the ZN426E DAC have been covered in previous *Interface*, articles, and so we will not dwell on this part of the unit. Any 8-bit latching output port should drive the circuit properly, including a PC printer port.

The maximum output voltage from IC1 is 2·55V, but this is boosted to around 9V by the simple non-inverting amplifier based on IC2. Note that the CA3140E used for IC2 is a type that can operate as a single supply d.c. amplifier.

Most other operational amplifiers (741C, LF351N, TLO71CP, etc.) will not work in this circuit. The CA3140E has a PMOS input stage, and the standard anti-static handling precautions should therefore be observed when dealing with this component.

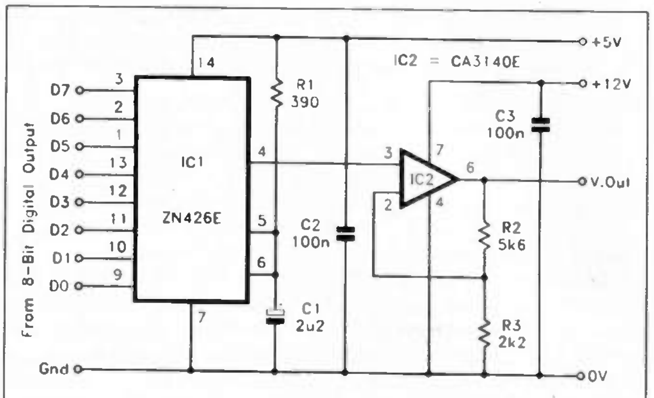


Fig. 1. Circuit diagram for the D/A Converter. The full scale output is about 9V.

Signal Processing

Circuit details for the v.c.o. and signal processing stages appears in Fig. 2. IC3 is a CMOS 4046BE "micropower" phase-locked loop, but in this circuit only the v.c.o. section is utilized.

No connections are made to the other sections of the device, apart from the input to the phase comparator (pin 3) which is connected to the 0V rail. This is done simply to avoid spurious operation of the unused stages.

The analogue-to-digital converter circuit (Fig. 1) provides the control voltage to pin 9 of IC3. C4 is the timing capacitor, and the timing resistance is provided by resistor R5 and preset VR2. The latter is adjusted so that an output frequency of 255kHz is obtained with the output voltage from the converter at maximum.

With perfect linearity and no offset voltage, this would give an output frequency range of 0Hz to 255kHz with a resolution of 1kHz. In practice the linearity of IC3 is far from perfect, and there is a small offset voltage. In other words, a small input voltage is needed before IC3 will start to oscillate.

A resistance from pin 12 to "ground" (0V) can be used to trim out the offset and to some extent improve the circuit's linearity. This is the purpose of resistor R4 and preset VR1.

Two basic approaches are possible when adjusting preset VR1. You can either opt for a slightly restricted output frequency range but with very good linearity, or a wide frequency range with reduced frequency accuracy.

Setting-Up

In either case it is a matter of first setting preset VR2 for the correct full scale output frequency. In other words, write a value of 255 to the converter (IC1) and then adjust VR2 for an output frequency of 255kHz.

Next the converter's output is set at a low voltage, and VR2 is adjusted for the appropriate output frequency. For example, a value of 25 could be written to the converter, and VR2 would then be set for an output frequency of 25kHz. This procedure is repeated a few times until good accuracy is obtained at both ends of the frequency range.

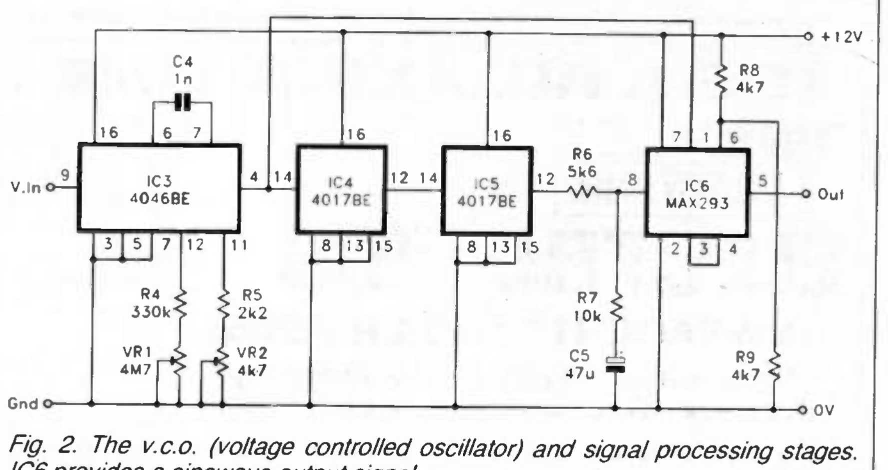


Fig. 2. The v.c.o. (voltage controlled oscillator) and signal processing stages. IC6 provides a sinewave output signal.

Using calibration frequencies of 25kHz and 250kHz gives a useful 10:1 frequency span, and good accuracy from 25kHz to 250kHz. Unfortunately, the accuracy on frequencies below 25kHz is not likely to be very good, especially at the lowest output frequencies.

Better accuracy at low frequencies can be obtained by using a calibration frequency of (say) 2kHz instead of 25kHz. The problem with doing this is that the mid-range accuracy is likely to suffer.

Since relatively few frequencies are available below 25kHz, there is little to be gained in using these frequencies, but a lot to be lost in terms of overall frequency accuracy. Consequently, it is probably best to opt for an accurate 10:1 frequency span having good accuracy, and leave frequencies below about 20kHz unused.

Increased Range

The output from pin 4 of IC3 is a reasonably good squarewave signal having a peak-to-peak amplitude of about 12V. IC4 and IC5 act as divide-by-ten circuits which provide two additional frequency ranges.

Maximum output frequency from pin 12 of IC4 is 25kHz, and the resolution is 100Hz. A maximum output frequency of 2·5kHz is available from pin 12 of IC5, and has a resolution of 10Hz. Both signals are 12V peak-to-peak squarewaves.

The output from IC5 is processed by IC6 to produce a form of sinewave output. A repetitive signal such as a squarewave type consists of a fundamental frequency plus harmonics (multiples) of that frequency. By using heavy lowpass filtering it is possible to attenuate the harmonics to an insignificant level, so that a reasonably pure sinewave is left. In this case the lowpass filtering is provided by IC6, which is a switched capacitor filter.

A normal *R/C* lowpass filter consists of a resistor and a capacitor connected in the manner shown in Fig. 3a. Resistor R_a limits the rate at which capacitor C_a can charge and discharge.

If the input frequency is low enough, this current limiting has no significant effect since only a very low current is needed in order to keep the charge on C_a equal to the input voltage. Above a certain frequency the limiting effect of R_a becomes very significant, and causes increasing losses through the circuit.

In fact, it ultimately results in each doubling of the input frequency causing the loss through the circuit to be doubled. The cutoff frequency is governed by the values of R_a and C_a, and it is inversely proportional to their values.

A Switch In Time

A higher attenuation rate can be obtained by using several filter stages in series. A variable cutoff frequency can be produced by using variable resistors or capacitors. However, a *C/R* filter having a large number of stages plus a variable cutoff frequency is rather impractical, especially where electronic control of the cutoff frequency is required.

A basic "switched" capacitor filter uses the arrangement shown in Fig. 3b. This is similar to the *C/R* lowpass filter, but the resistor has been replaced by a small capacitor (C_a) and an electronic switch.

The latter is controlled by a clock oscillator, and continuously alternates between its two settings. Capacitor C_b is the filter capacitor, and is the equivalent of C_a in Fig. 3a.

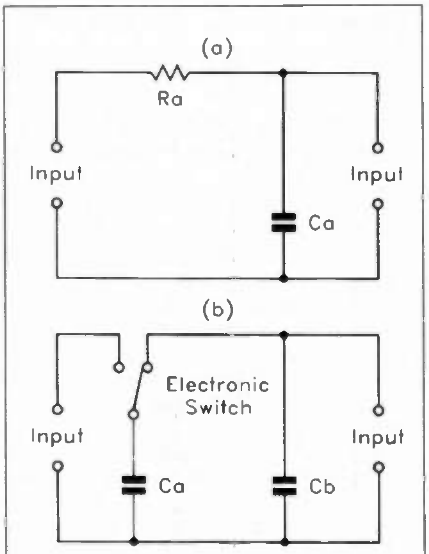


Fig. 3. Basic R/C lowpass filter (a) and switched capacitor (b).

Like R_a in the *R/C* filter, the switch and capacitor C_a provide a signal transfer from the input to the output of the circuit. If the input voltage rises, C_a is repeatedly charged from the input signal and discharged into C_b. If the input voltage falls, C_a is repeatedly charged from C_b and discharged into the signal source.

The main factors governing the cutoff frequency are the relative values of C_a and C_b, and the clock frequency. It is this second point that is of great practical importance, and in most practical circuits the cutoff frequency is one fiftieth or one hundredth of the clock frequency. The cutoff frequency can be varied by altering the clock frequency, and there is no difficulty driving a multi-stage filter from a common clock signal.

Sharp Filtering

Filtering a squarewave signal to produce a passable sinewave requires some pretty sharp filtering. The MAX293 used for IC6 is an 8th order elliptic filter which does the job very well. Its cutoff frequency is one hundredth of the clock frequency.

The clock signal is taken direct from the v.c.o., and the signal input of IC6 is driven with the divided-by-100 signal from IC5 via an attenuator. IC6 therefore allows the fundamental signal from IC5 to pass unhindered, but the harmonics (which are at upwards of 200 times the clock frequency) are severely attenuated. The output level from IC6 is approximately 10V peak-to-peak.

One drawback of this method of sinewave generation is that the output waveform is a stepped type, although the stepping can be removed using conventional lowpass filtering. This method does not produce highly pure output waveforms anyway, and the distortion level is comparable to a simple Function Generator at about one per cent.

Switched Range

The simplest way of providing additional sinewave frequency ranges is to replace capacitor C4 with two or three switched capacitors. A value of 10nF will provide a maximum output frequency of 255Hz with a resolution of 1Hz.

Due to the self-capacitance of the 4046BE, a value of 33pF rather than 100pF provides a maximum output frequency of 25·5kHz. The resolution is then 100Hz.

The 4046BE cannot be guaranteed to operate right up to the frequency of 2·55MHz needed to produce a 25·5kHz sinewave, but the three devices tested all just about managed it. In order to obtain good accuracy on all three ranges R4, R5, VR1, and VR2 should be duplicated for each range, and selected via the range switch.

Each range of the circuit can then be individually calibrated.

THEREMIN MIDI/CV INTERFACE

ADAM FULLERTON **Part 1**

Retro-fit your Theremin into a MIDI chain for 21st Century music control!

SINCE the birth of the Theremin some 78 years ago, there have been few variations on the basic theme, and the design philosophy on which they are based has remained relatively unchanged. As such, it is fair to say that the Theremin has for some years been thought of, if at all, as a product of a bygone era, a veritable dinosaur in the world of the silicon chip.

However, things are changing. Since the advent of the microprocessor, technology has exploded at an exponential rate. Many old ideas and concepts have received the "retro-refit" treatment thereby bringing them into line with today's technology. It is an all-encompassing process from which nothing can escape indefinitely, not even Theremins.

This project gives the Theremin its long awaited "refit". It is hoped that it may be a step towards attracting the new interest which will be necessary for the continued development of this unique musical instrument into the 21st century.

DESIGN OBJECTIVE

The objective was to produce a generic MIDI/CV interface that could be used with any existing Theremin without the necessity for modification or a special interface connector. It is an ideal complement to the *EPE Elysian Theremin* of Nov/Dec '96. (MIDI, by the way, stands for Musical Instrument Digital Interface, and CV stands for Control Voltage.)

It seemed like the best way to do this was to analyse the Theremin's audio signal. The resulting design is a combined hybrid of analogue and digital electronics.

This MIDI/CV Interface is not only useful for Theremins, but it can be used to interface any monophonic (one note at a time) musical instrument to MIDI. The human voice is no exception to this, so into the domain of pitch to MIDI!

PROJECT OUTLINE

It is stressed that this design is too complex to be tackled by newcomers to electronics. Although the project appears straightforward to construct, if any trouble-shooting does turn out to be required, beginners could find themselves in difficulties.

The Theremin MIDI/CV Interface (MCV for short) is a pitch/amplitude to MIDI and CV interface. There are 128 user patches which can be loaded from the front panel, or footswitch or remotely via the MIDI program change message. Each patch contains detailed setup parameters, including Octave Range, Pitch Bend Range, Amplitude Sensitivity, Velocity Sensitivity, Volume Sensitivity, Tone Offset, Program Change, and more!

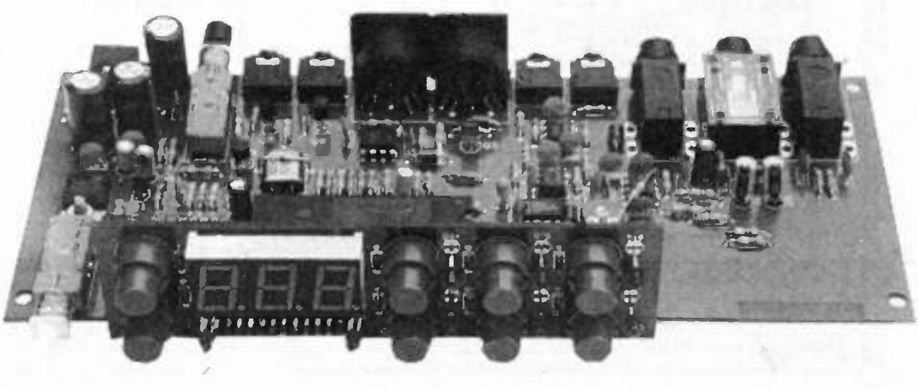
A Hold footswitch is available to allow a note to be held. Two Control Voltage outputs are provided for Pitch and Amplitude. The Gate and Trigger signals are amplitude threshold switched, with control of the switch threshold. The source signal of the CV interface may also be switched to incoming MIDI, to allow use as a standard MIDI to CV converter.

The MCV is capable of simultaneous Theremin to MIDI and MIDI/CV conversion. The Pitch Bend controller (1 to 48 semitones definable) is used in conjunction with the RPN 54H (Registered Parameter Number 54 hex) Portamento control to follow the pitch of the Theremin. Pitch is resolved down to ±2·5 cents over eight octaves, with 10 cents hysteresis (to reduce the amount of useless MIDI data transmitted from "wobbly hand syndrome").

The Channel Volume message is used to control the amplitude, and can be assigned to Channel Pressure (aftertouch), poly-pressure and virtually any other MIDI controller. An Echo-back facility is provided since there is no MIDI THRU terminal. This merges the Theremin MIDI data with incoming MIDI data, allowing the user to control sequencers with a Theremin.

SPECIFICATIONS

- ★ Interfaces to any Theremin
- ★ Pitch and amplitude sensitivity
- ★ 128 user-programmable patches
- ★ Real-time pitch readout
- ★ 8-octave pitch tracking
- ★ ±2.5 cents pitch resolution
- ★ 14-bit pitch bend data
- ★ Octave range control to 1 semitone
- ★ Glissando and Portamento options
- ★ Auto-octave switching
- ★ Velocity sensitivity
- ★ Volume sensitivity
- ★ Octave and tone transpose control
- ★ Tone offset
- ★ MIDI merge Theremin sequence control
- ★ 4-function footswitch control
- ★ CV voltage and scaling control
- ★ Two 1V/octave voltage outputs
- ★ Gate and Trigger 5V/15V and switch definable
- ★ Aftertouch and Poly-pressure assignment
- ★ Echo-back facility
- ★ 3-digit 7-segment l.e.d. display
- ★ 19-inch rack case, 1/2 width 1U



HOW IT WORKS

The project is shown divided down into its basic blocks in Fig. 1, allowing each part to be discussed in bite sized chunks.

Each of the blocks could be divided down further to provide a more complex and accurate block diagram, but given the simplicity of the circuit concept, the basic block diagram is sufficient to explain the operation.

As indicated by this diagram, the CPU (Central Processing Unit) block is the core of the design; the analogue and digital hardware are carefully bound together by the software executed by the CPU.

Pre-programmed CPUs (microcontrollers) are obtainable as detailed later.

Throughout this article, reference is made to various software listings of the control codes used by the CPU. These are partial extracts from the main software and may be of interest to programmers.

Space prevents their inclusion here, but they are available on 3·5inch. PC-compatible disk from the Editorial office (see the *EPE PCB Service* page – you get all sorts of other software on this disk as well!). The listings are also available *FREE* from our web site: **ftp://ftp.epemag.wimborne.co.uk** in sub-directory **pub/PICS/MIDICV.**

For copyright reasons, the *full* software code listing for the MCV is not available for examination.

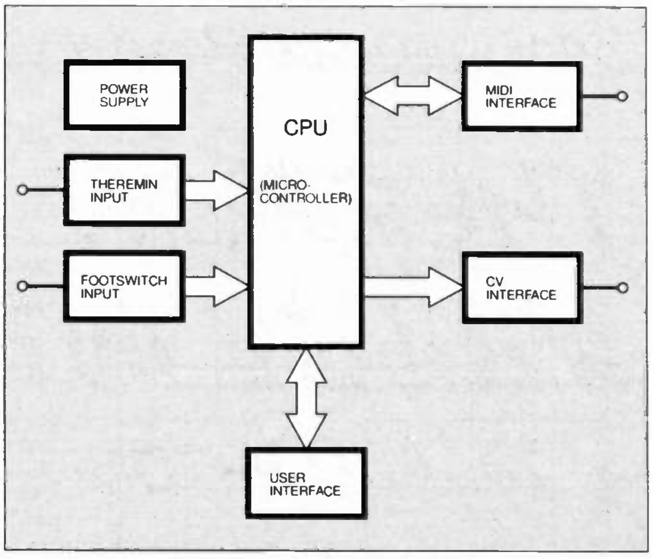


Fig. 1. Block diagram for the Theremin MIDI/CV Interface.

THEREMIN INPUT

The Theremin input block must extract the pitch and the amplitude of the incoming signal, and present it in a form that can be readily understood by the CPU. Pitch or frequency may be equally represented by time since t = 1/f (t = time and f = frequency); the conversion is simple, and time is easily measured by a CPU.

If the Theremin produces a complex waveform, it may require heavy low-pass filtering or a DSP (Digital Signal Processor) running a Fast Fourier Transform (FFT) algorithm to extract the fundamental harmonic. However, the Theremin output is close to that of a sine wave so the fundamental harmonic is readily available.

The Theremin signal is fed into two separate circuits, one to extract the amplitude of the signal, and one to extract the pitch. The changing amplitude of the Theremin signal is referred to as the envelope.

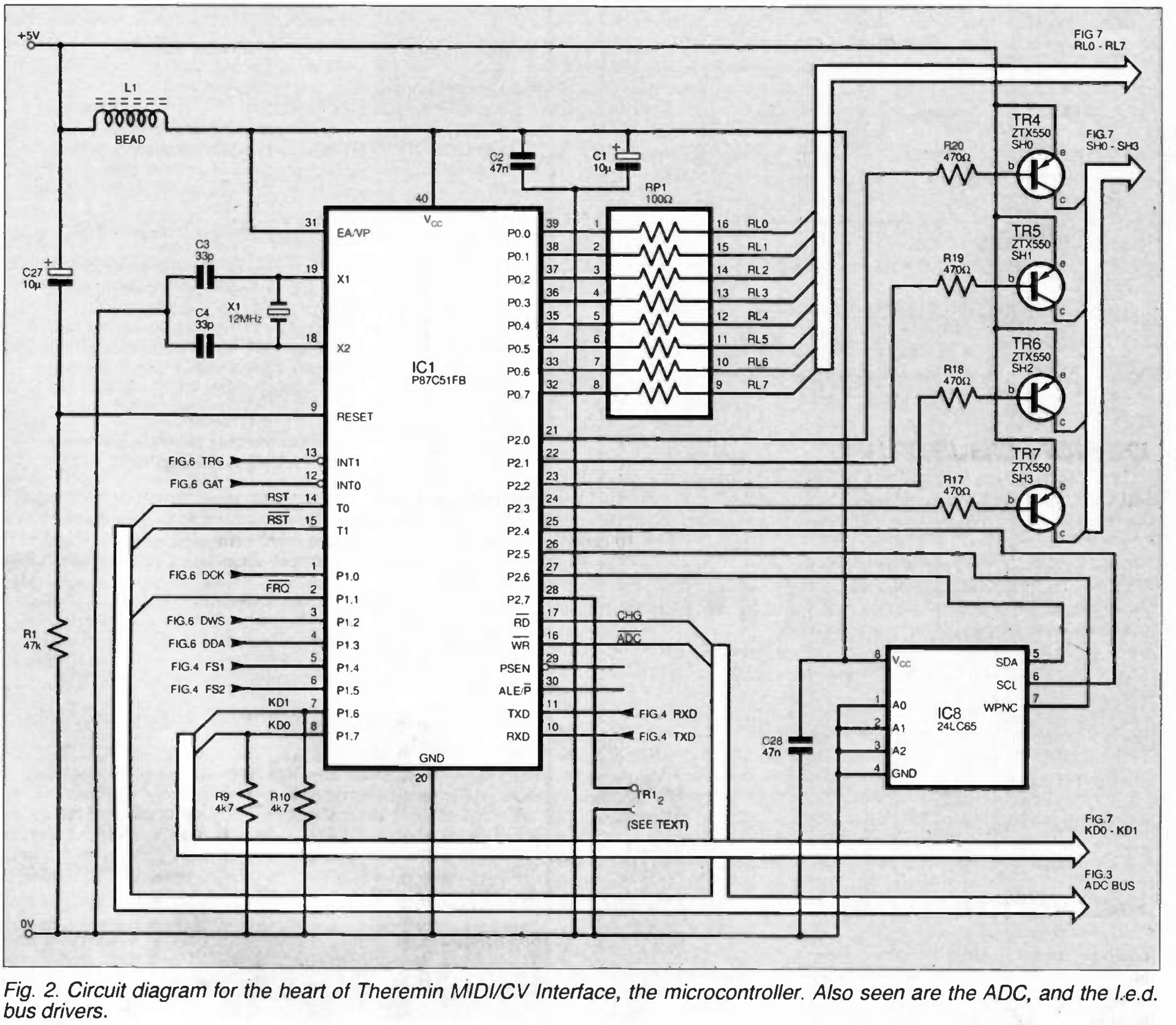


Fig. 2. Circuit diagram for the heart of Theremin MIDI/CV Interface, the microcontroller. Also seen are the ADC, and the l.e.d. bus drivers.

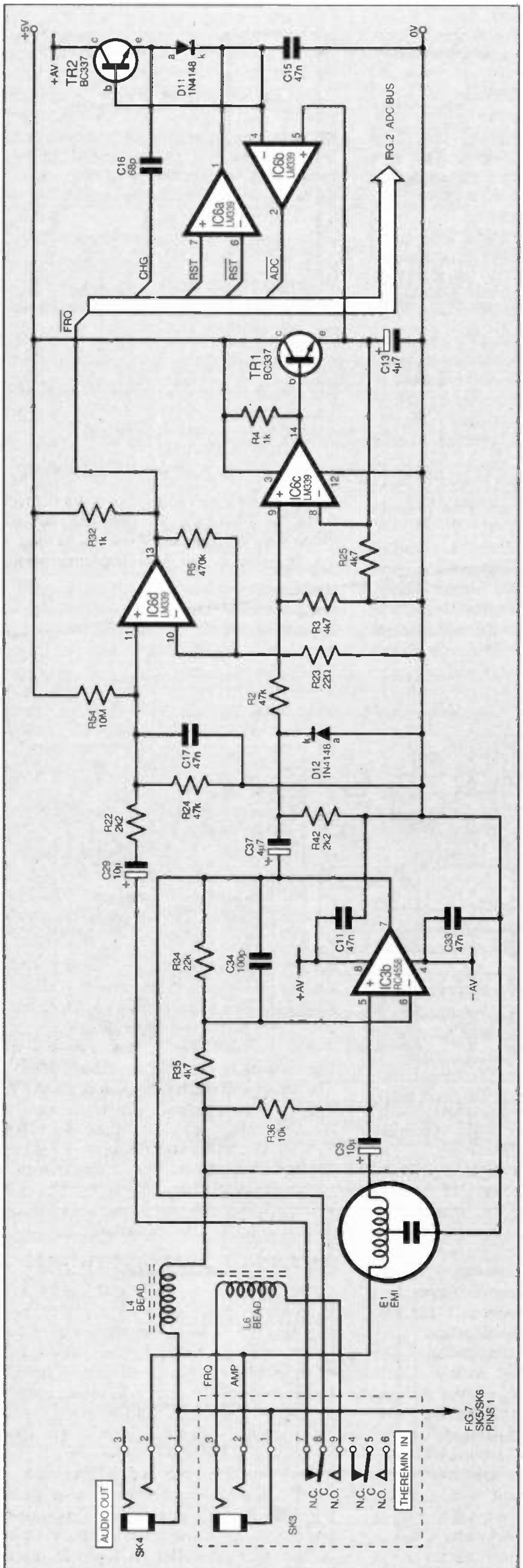


Fig. 3. Circuit diagram for the Theremin input stage.

COMPONENTS

See SHOP TALK Page

Resistors

R1, R2, R24	47k (3 off)
R3, R9, R10, R14, R25, R35, R37, R38, R41, R44, R51, R52	4k7 (12 off)
R4, R8, R12, R15, R32, R43, R45, R46, R53	1k (9 off)
R5	470k
R6, R7, R11, R48	220Ω (4 off)
R13, R36, R39, R40	10k (4 off)
R16, R26, R27, R47	33Ω (4 off)
R17 to R20, R28, R29	470Ω (6 off)
R22, R30, R31, R42, R49, R50	2k2 (5 off)
R23	22Ω
R34	22k
R54	10M
RP1	100Ω 8-resistor module

All resistors 0·25W 5% carbon film or better

Potentiometer

VR1	10k horizontal preset

Capacitors

C1, C26	10μ tantalum, 6.3V (2 off)
C2, C6 to C8, C10 to C12, C15, C17 to C25, C28, C32, C33, C35, C36	47n ceramic, 63V (21 off)
C3, C4	33p ceramic, 63V (2 off)
C5, C9, C27, C29, C38	10μ radial elect. 16V (5 off)
C13, C37	4μ7 radial elect. 16V (2 off)
C14, C30, C31	470μ radial elect. 35V (3 off)
C16	68p ceramic, 63V
C34	100p ceramic, 63V
C39	47μ radial elect. 16V

Semiconductors

D1, D2, D14 to D16, D18 to D20	red l.e.d. (8 off)
D3 to D12, D17, D24, D25	1N4148 signal diode (13 off)
D21 to D23	1N4001 rectifier diode (3 off)
D26	BZX79C16 16V 500mW Zener diode
D27	BZX79C5V1 5V1 500mW Zener diode
TR1, TR2, TR8 to TR10	BC337 *npn* transistor (5 off)
TR3 to TR7	ZTX550 *npn* transistor (5 off)
IC1	P87C51FB microcontroller, pre-programmed (see text)
IC2	LM7805 5V 1A voltage regulator
IC3 to IC5	RC4558 dual op.amp (3 off)
IC6	LM339 quad comparator
IC7	6N138 opto-isolator
IC8	24LC65 8K serial EEPROM
IC9	TDA1543 dual serial ADC

Miscellaneous

E1	EMI filter
L1 to L6	ferrite beads, mini, general purpose r.f. (6 off)
SK1	RCA power input socket, p.c.b. mounting
SK2, SK4, SK9	¼in. stereo jack socket, p.c.b. mounting (3 off)
SK3	multi-pole ¼in. jack socket, p.c.b. mounting
SK5 to SK8	3·5mm stereo jack socket (4 off)
SK10, SK11	5-way 180° DIN socket, p.c.b. mounting (2 off)
S1, S2	s.p.d.t. latching pushswitch, p.c.b. mounting (2 off)
S3 to S10	s.p. push-to-make switch, p.c.b. mounting, large button (8 off)
X1	12MHz crystal
X2	3-digit 7-segment l.e.d. display, p.c.b. mounting, common anode

Printed circuit boards (3 off) available as a set from the *EPE PCB Service*, code 130; d.i.l. sockets (see text); 19-inch rack mounting case, 1/2 1U; 12V a.c. 500mA mains adaptor; red filter for display; switch caps for S1 and S2 (2 off); nuts; bolts; washers; solder, etc.

Approx Cost Guidance Only **£135** **excl. case**

MICROCONTROLLER

One of the Intel MCS-51 single chip microcontroller family is used as the "brains" (CPU) of the circuit, designated as IC1 in Fig. 2. Timing is set by the 12MHz crystal, X1; capacitors C3 and C4 are the additional components required to complete the oscillator circuit.

Between them, components C27 and R1 provide a reset signal when power is applied. Everything else in the way of control is provided by the microcontroller, giving a "plug in and go" solution.

Device IC8 is a serial electrically erasable programmable read-only memory (EEPROM). This provides the microcontroller with a non-volatile memory facility, and having just a simple three-wire interface.

The Microchip 24C65 EEPROM used as IC8 is an 8K byte device having a high endurance block of memory that may be written to and erased more than 10,000,000 times. This makes it particularly suitable for this application.

The software code for accessing the EEPROM is on the *EPE* disk as Listing 1.

INPUT CIRCUIT

Referring to the circuit diagram in Fig. 3, socket SK3 is the Theremin input point. When a stereo jack plug is inserted here, the tip of the plug is connected to the input buffer circuitry (for amplitude extraction), and the collar is connected directly to the pitch extraction circuit, to allow a continuous pitch signal to be injected.

Component E1 is a passive EMI (electromagnetic interference) filter that helps reduce any r.f. (radio frequency) entering the buffer circuit. Inductor L4, a ferrite bead, assists similarly.

Components C9 and R36 a.c. couple the input signal to IC3b, which is wired as a voltage follower with a gain of 5.6, as set by R34 and R35. Capacitor C34 helps with high frequency stability.

When a mono jack plug is inserted into socket SK4 and there is no plug in SK3, the pitch extraction circuit is fed directly from the output of the input buffer. The gain of the input buffer is quite high because of the simplicity of the pitch extraction circuit. Small amplitude signals are more difficult for it to deal with.

Inductor L6, also a ferrite bead, assists with r.f. immunity at SK3.

ENVELOPE EXTRACTION

From the output of IC3b, capacitor C37 a.c. couples the signal to the envelope extractor around IC6c, configured as a voltage comparator. Diode D12 prevents this signal from dropping below −0·6V while resistors R2 and R3 attenuate its positive aspect.

Resistors R4 and R25, transistor TR1 and capacitor C13 form the basis of a peak hold circuit. If the input voltage is greater than the voltage on C13, the open collector output of IC6c is in a high impedance state. Resistor R4 pulls the base of TR1 high causing C13 to be charged, capturing the peak input voltage on this capacitor.

When the voltage on C13 is a few microvolts greater than the input voltage, the open collector output of IC6c becomes low impedance, pulling the base voltage of TR1 down to 0V. This stops C13's charge current and holds the peak voltage, leaving R25 to set a time constant over which C13's voltage will fall to 0V.

The voltage on C13 is a crude half-wave rectified representation of the amplitude of the Theremin signal. The fact that it is crude does not really matter since the software can provide more complex digital filtering to smooth over the cracks.

The next part of the circuit allows the microprocessor to convert the voltage on C13 into a number. Rather than use an analogue-to-digital converter (ADC) chip, a "home baked" circuit was used for component cost reasons.

Capacitor C16, transistor TR2 and diode D11 form an "edge-to-voltage converter" in conjunction with integrator capacitor C15. The microprocessor applies a pulse to C16 from pin 17, which causes D11 and TR2 to dump a small lump of charge onto C15. Each pulse applied to C16 by the microcontroller is counted until comparator IC6b reports (via its output pin 2) that the voltage on C15 is greater than the voltage on C13.

The number of pulses applied represents the input voltage. Comparator IC6a is used to discharge capacitor C15 at the end of each conversion.

If you place an oscilloscope probe on pin 1 of IC6 you will see many "ramp" waveforms, each ramp waveform represents an amplitude sample. If you look carefully, you will also see little bright spots on the ramp line. This is because an interrupt service routine (ISR) briefly stops the microcontroller from executing the amplitude extraction function.

Since there is only a high impedance path to ground, the charge on C15 remains for quite some time, so this small interlude from the conversion function does not affect the result.

This unusual "edge-to-voltage" circuit evolved to allow frequency independent operation, making it possible for ISRs to occur within the conversion function.

The function that performs the analogue to digital conversion was written in assembler for speed and is on the disk as Listing 2. Notice in the Listing how the bit-addressable architecture of the microcontroller makes it easy to code.

It is also possible to implement this same "ADC" type circuit with a timer. Most microcontrollers have timer output pins that can generate clocks etc. Used in conjunction with the timer capture, the software overhead can be greatly reduced.

Since in this application processing time is not an element of great concern, a software implementation is preferred; this also allows easier printed circuit board (p.c.b.) routing, because it gives freedom of choice of the port pins used.

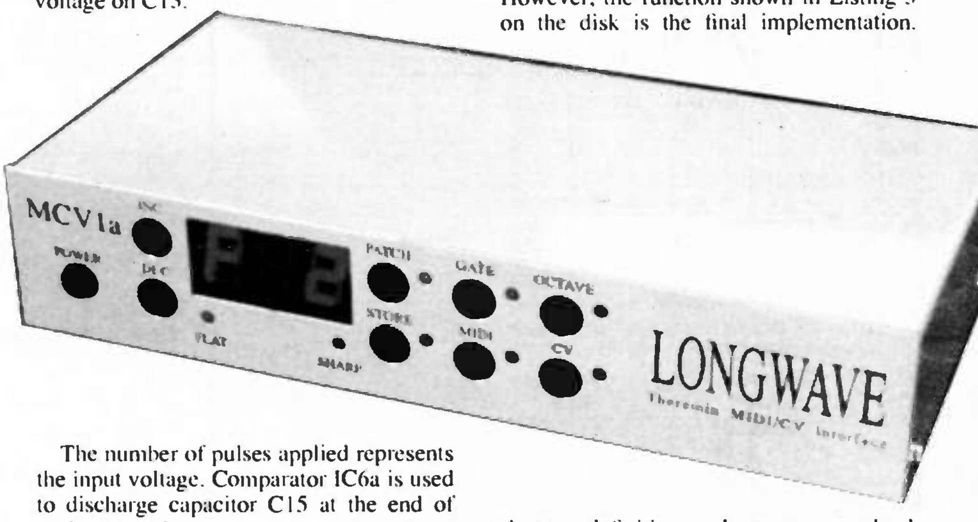
The use of a digital filter to process the samples adds a good "feel" to the performance of the circuit. The digital filter used was a simple implementation of an *R/C* low-pass filter written in C. The mathematics boils down to a multiplication, an addition and a subtraction. The following C code illustrates the implementation of this filter.

```
sampleo=(K * accumulator);
accumulator=accumulator − sampleo
   +samplei;
```

where:

K = cutoff frequency to sample rate coefficient
sampleo = output sample
samplei = input sample
accumulator = analogy of a capacitor

This shows how easy it is to implement a digital filter, simply two lines of C! However, the function shown in Listing 3 on the disk is the final implementation.



A type definition and structure evolved, and one low-pass filtering function. The C code has been taken from both the header and library files to illustrate this.

The gate should open (play a note) at an input signal level of approximately 80mV. The signal will reach saturation at about 6V. This gives the amplitude extraction circuit a dynamic range of 37dB, since the MIDI Volume Controller contains only seven bits of data. This allows a maximum dynamic range of 48dB. Thus this type of circuit is a fairly good way to provide adequate dynamics with a low component cost.

PITCH EXTRACTION

Still referring to Fig. 3, the pitch extraction circuit behaves as a zero crossing detector, turning the input waveform into a square wave from which the period of the waveform can be accurately timed. Capacitor C29 and resistor R24 a.c. couple the signal. Then R22 and C17 form a first order low-pass filter that feeds to the non-inverting input of IC6d.

Between them, R5 and R23 provide a small amount of hysteresis to give clean transitions to the signal edges. This square wave is connected to a timer capture input on the microcontroller (IC1 pin 2). Each high to low transition on this pin causes a 16-bit timer read, allowing the software to calculate the time of each cycle.

Calculating the MIDI note number and pitch bend values from the cycle time is the interesting bit. The algorithm in disk Listing 4 was the one ultimately used. The entire calculation is performed by a scaling function and a look-up table. This is often referred to as the "Blue Peter" approach to maths (and here is one I did earlier!).

The software look-up table is in 2.5 cents (musical intervals of time), rather than frequency as might have been expected. The scaling function manipulates the cycle time to fit the table, producing an "octave" offset value. A binary chop or successive approximation function then looks up the note number and cent offset. Job done!

Rather than use a calculator to derive the table, the easy option of a Perl script was taken. If you are unfamiliar with Perl, disk Listing 4 may look a bit cryptic, but close examination should reveal how the table calculation is performed. The table generated by the Perl script is shown in disk Listing 5.

The scaling function that fits the cycle time to the table was written in C and is detailed in disk Listing 6.

MIDI INTERFACE

Referring back to Fig. 1, the MIDI Interface block provides the standard MIDI connections. The MIDI THRU facility was omitted, though, since a software implementation that could merge incoming MIDI data with data generated by the Theremin was preferred, leaving only MIDI IN and MIDI OUT terminals.

The MIDI circuits as implemented in Fig. 4 are fairly standard. IC7 provides the MIDI IN optical isolation. Transistor TR3 is the MIDI OUT driver, rather than the more commonly used gate driver circuit. The footswitch part of the circuit is referred to shortly (User Interface). Since the microcontroller has a fully featured asynchronous serial port no other hardware is needed.

The software MIDI handlers are fairly simple with only small buffers allocated to the THRU and OUT data, since the incoming MIDI data is processed on "the fly". The MIDI IN translation function breaks down into a "jump into a jump table" function written in assembler for speed. The code in disk Listing 7 illustrates how the incoming MIDI data is translated.

In Listing 7, the macro named %STATE is a routine that puts the address of the data processing function in the MIDI_H and MIDI_L registers, so that when the data is received the microcontroller can execute the required data processing function.

Real-time MIDI messages have further meaning which is translated in the same way. The assembler in disk Listing 8 details further translation, in which MIDI_Idle is the address of a RETurn. Entering the address of MIDI_Idle into MIDI_H and MIDI_L will throw away any further incoming MIDI data bytes.

Although little of the incoming MIDI data is received, functions for all of the messages itemised in a rather out-of-date copy of the MIDI specification were implemented to allow the software to validate each MIDI message as it is received. This is because the software has a THRU emulation mode and it is the easiest way of preventing corrupted or bad MIDI data from being re-transmitted.

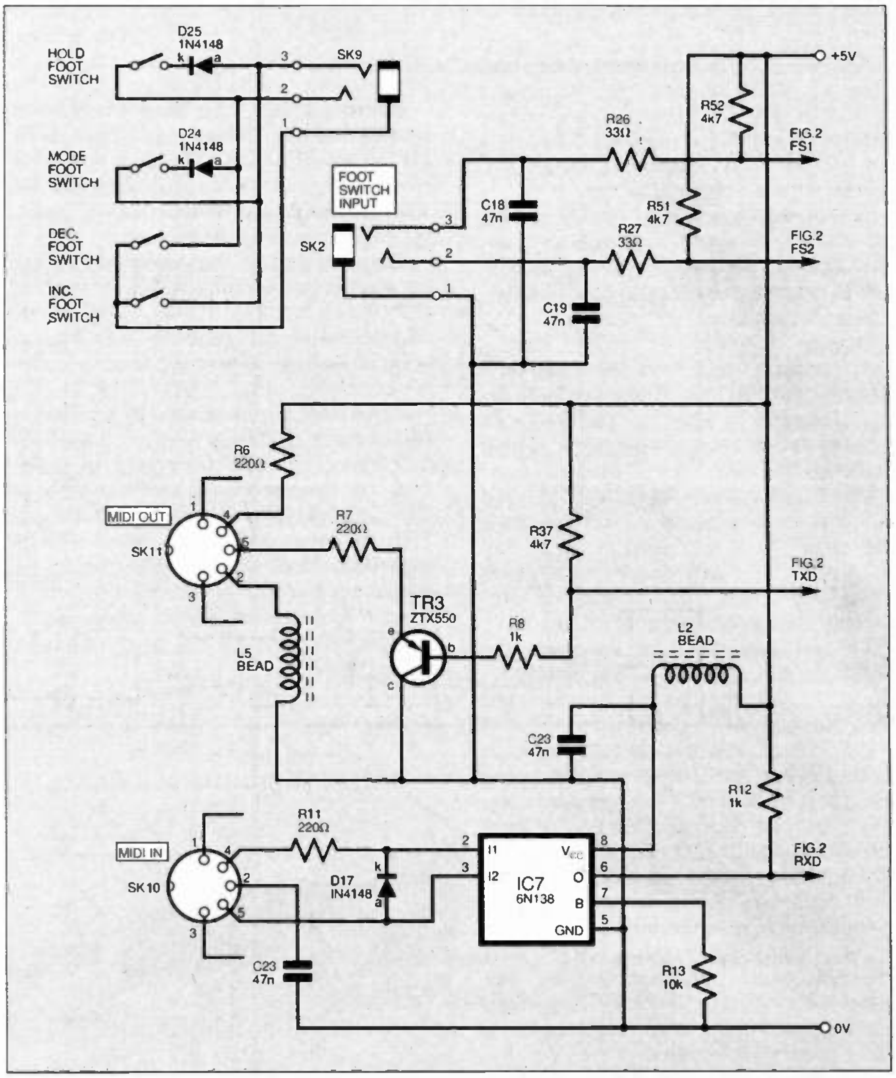


Fig. 4. MIDI ports and footswitch interface circuits. IC7 is an opto-coupler.

The MIDI transmit function is more simple but interwoven with the microcontroller's serial interface hardware. The serial port is set to interrupt the program execution on both transmission and reception of MIDI data. The code in disk Listing 9 shows the transmit data buffering and the interrupt vector MIDI processing.

CV INTERFACE

The CV Interface block can be broken down into several smaller building blocks, as shown in Fig. 5. Most of the commercial MIDI to CV designs over the past few years have utilised circuits capable of producing 0-5 volts from an 8-bit DAC (digital-to-analogue converter). Since the range of the *EPE Elysian Theremin* is greater than five octaves, and many synthesizers accept voltage ranges greater than 0-5V, it seemed necessary to design a CV interface with a little more "guts".

For the CV output, a dual 16-bit DAC was chosen. Measurements made, though, would suggest that its performance in this application gives only 12 bits of resolution. This is still better than most.

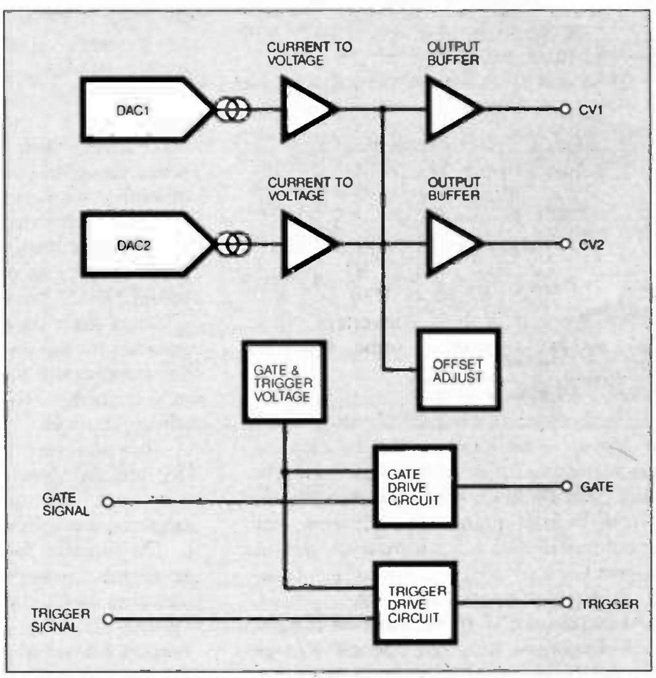


Fig. 5. CV Interface block diagram.

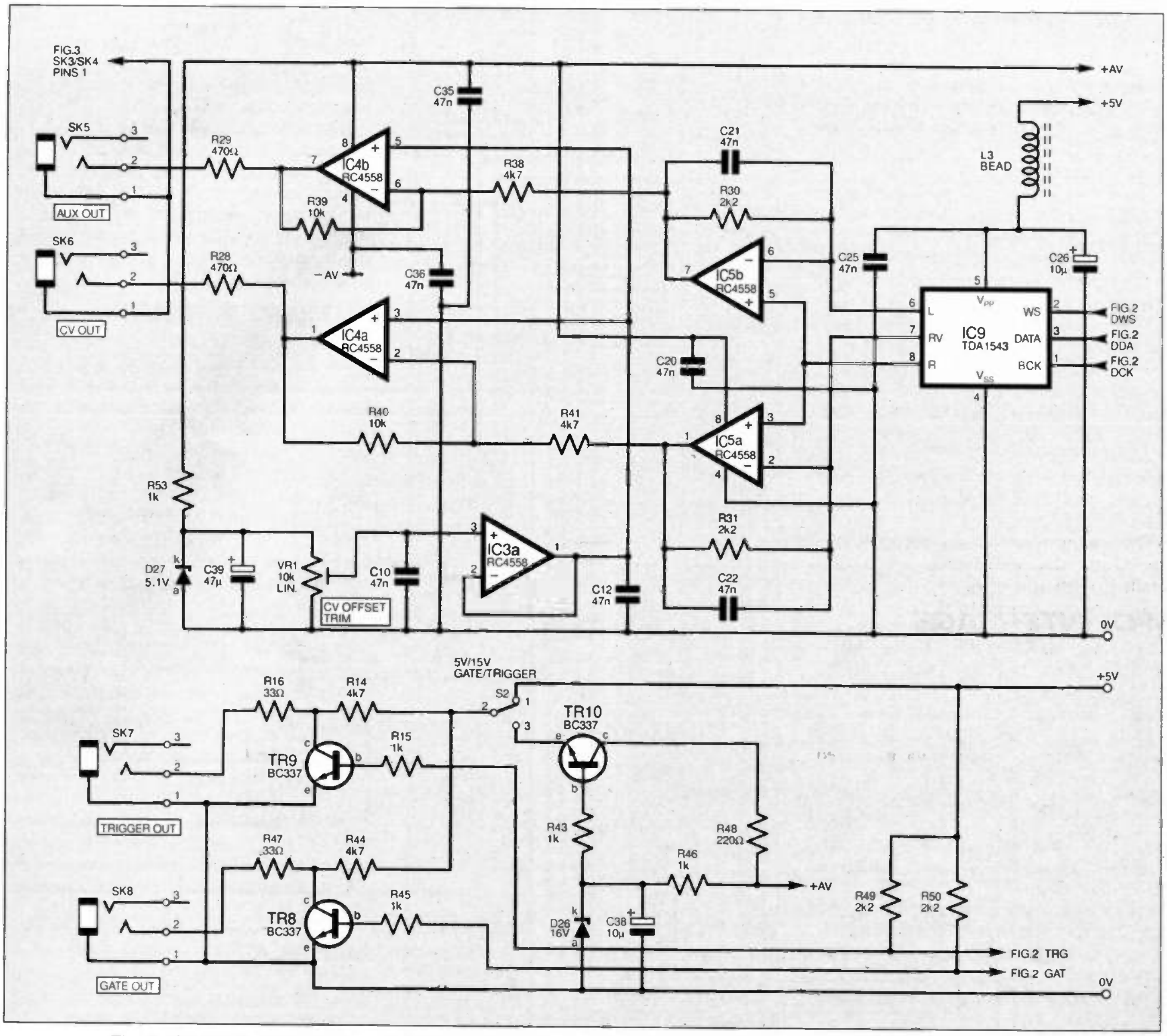


Fig. 6. Circuit diagram for the CV Interface, comprising the ADC plus the Trigger and Gate pulse circuits.

The DAC's circuit diagram is in Fig. 6. In it, the dual 16-bit DAC, IC9, is serially interfaced with the microcontroller by only three connections, from pins 1, 2 and 3.

Currents output from IC9 pins 6 and 8 are converted into voltages by op.amps IC5a and IC5b. Resistors R30 and R31 control the gain of these converters, while C21 and C22 provide some low-pass filtering.

Resistors R38 to R41 set the gain of the output buffers IC4a and IC4b, to give an output voltage range of 10V (ten octaves at 1V/octave). IC3a is used in conjunction with preset potentiometer VR1 to provide offset adjustment, allowing the output voltages to be trimmed, to give maximum flexibility. Output current limiting is provided by R28 and R29.

The Gate output signal must be capable of generating both voltage and switch-type signals. This is done by a single transistor, TR8, and a pull-up resistor, R44. Transistor TR8 is a robust BC337 type, and R47 is a current limiting resistor to prevent accidental damage.

Pull-up resistor R44 provides the voltage which is switched by S2 from either a +5V or a +15V reference. A 16V reference is provided via R46 and Zener diode D26. Then TR10, R43 and C38 form a capacitance multiplier to provide a smoothed +15V reference. R48 is a current limiting resistor to protect TR10.

Similarly to Gate output control, Trigger output control is provided by the circuit around TR9.

The Gate and Trigger signals are provided by the microcontroller. Because the port pins of the microcontroller cannot source current (they only have weak pull-up resistors of about 40k), R49 and R50 provide the current to turn transistors TR9 and TR10 on/off as required.

On testing the prototype, it was found that there was a minor problem inherent in the p.c.b. design layout. The offset adjustment circuit caused small voltage variations from the +5V rail to be added to the CV outputs. This was cured by adding components R53, C39 and Zener diode D27, as shown in Fig. 6. These components do not have allocated positions on the p.c.b. and need to be added separately. How this is achieved is detailed when p.c.b. assembly is discussed (next month).

The software that drives the CV interface was written to accept MIDI note numbers and pitch bend data to simplify the software development. Because the whole interface only requires connection to five port pins, the software implementation was easy.

The most complex part was writing the port pin driver routines for the DAC. Because DAC conversion occurs frequently, it was necessary for the function to be as fast as possible. The assembler code used is given in disk Listing 10.

As 16 bits are transmitted, the function is called twice, taking 120µs to send both bytes. It could have been made fractionally faster by making a trade with code space, but this often results in difficult to maintain "spaghetti" code.

USER INTERFACE

The User Interface circuit diagram is shown in Fig. 7. It is designed around eight pushbutton switches (S3 to S10), a 3-digit 7-segment l.e.d. display (X2) and eight individual l.e.d.s. (D1, D2, D14 to D16 and D18 to D20).

Transistors TR4 to TR7 (see Fig. 2) drive the four column signals (SH0 to SH3) of the matrix. Both the l.e.d.s and the switches share the same column driver signals but the rows (RL0 to RL7) are different.

The l.e.d. matrix is driven one column at a time by the microcontroller, with the corresponding l.e.d. data being placed on the

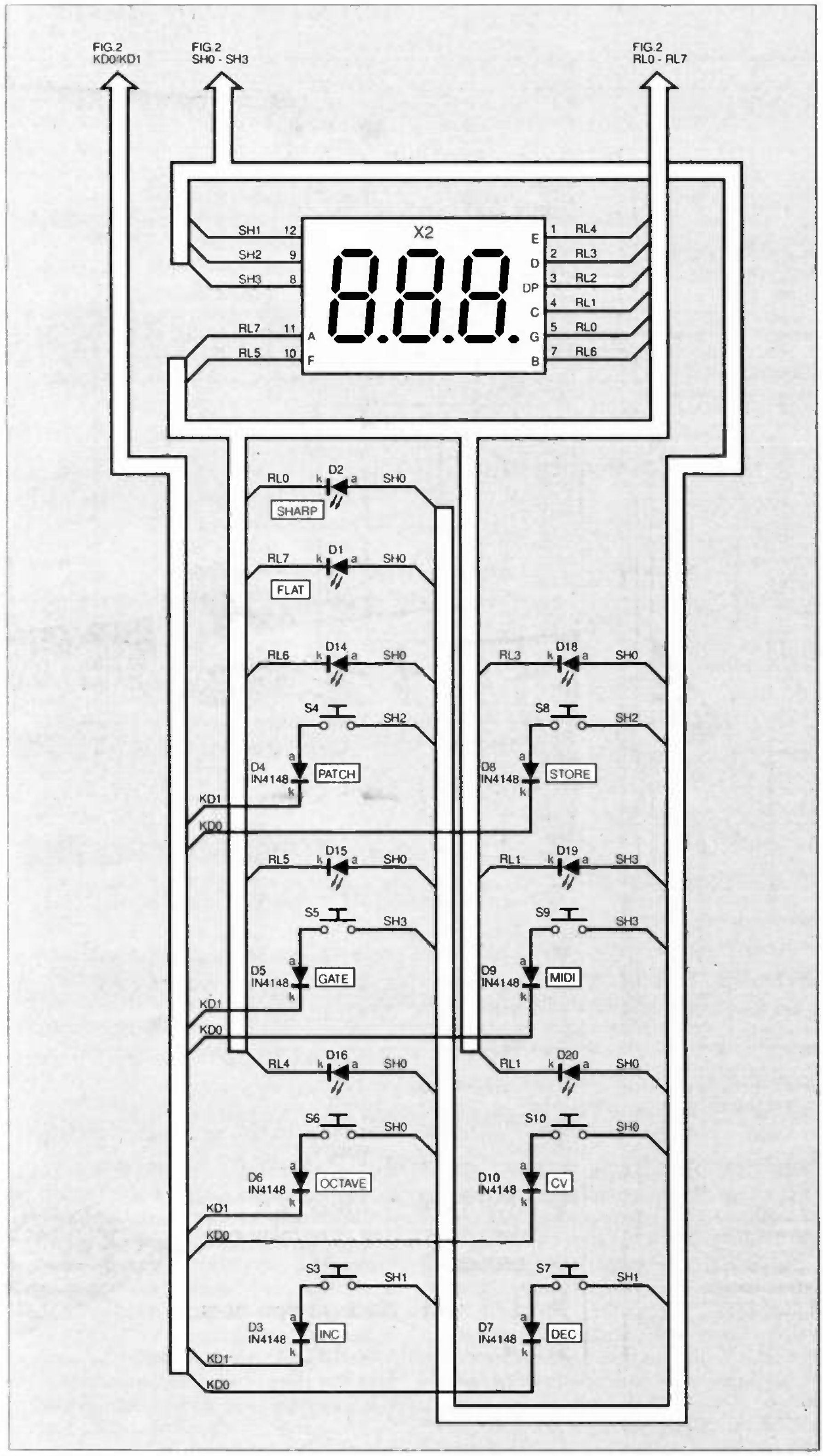


Fig. 7. The User Interface circuit diagram.

port pins connected to the resistor module RP1 (in Fig. 2), which limits the maximum intensity of the l.e.d.s.

When a scan line is high, the microcontroller can establish if a switch is pressed by examining its respective return line (KD0 and KD1). Diodes D3 to D10 prevent reflections when more than one switch is pressed simultaneously, allowing "shift function" operations to be performed by the software.

The footswitch (see Fig. 4) works in a similar multiplexed way, providing four switched modes (Hold, Mode, Decrement, Increment) via only three wires, through jack socket SK9. Diodes D24 and D25 are steering diodes that allow the Hold and Mode footswitches to be read by the microcontroller.

The software maps the keys into two registers, one remembers the last reading of the keyboard, and the other holds the current reading. An Exclusive-OR of the two registers reveals the changes, while an AND with the last reading masks "key offs", providing a quick and easy way to identify "key on" events.

POWER SUPPLY

Looking now at Fig. 8, the circuit diagram for the power supply, a 12V a.c. power source is fed in via socket SK1. Diodes D22 and D23 half-wave rectify the a.c. to provide +Ve and −Ve power supply rails of approximately ±17V.

Capacitors C14, C30 and C31 provide power line smoothing. IC2 regulates the +17V down to +5V. Diode D21 minimises the risk of voltage drop on the +AV (+17V) power rail when the digital part of the circuit consumes bursts of current on the +5V line.

Physically, C7 is placed very close to SK1 since this capacitor helps remove noise spikes that may prevent correct operation of the digital circuitry. Further decoupling capacitors are placed close to the power pins of the i.c.s to reduce power rail noise.

The i.c.s that consume current in a noisy way have ferrite beads in series with their power pins, to help reduce the amount of high frequency noise (h.f.) on the power rails (L1/IC1, L2/IC7, L3/IC9). It has already been seen that such beads are used at SK3 (L6) and SK4 (L4), another is used at SK11 (L5).

Extensive use of ground planes on the p.c.b. further helps to reduce the transmission of h.f. noise, particularly to the analogue circuitry. It also provides good earthing and helps remove "hum loops".

It is intended that mains-derived 12V a.c. power for the unit is supplied by a commercial a.c. power adaptor. It should have a rating of at least 500mA, and preferably higher if you want very brightly glowing l.e.d.s.

RESOURCE

Pre-programmed microcontrollers for this project are available, see *Shoptalk*.

PART TWO

It is recommended that you do not begin p.c.b. assembly until you have read the concluding part of this project next month.

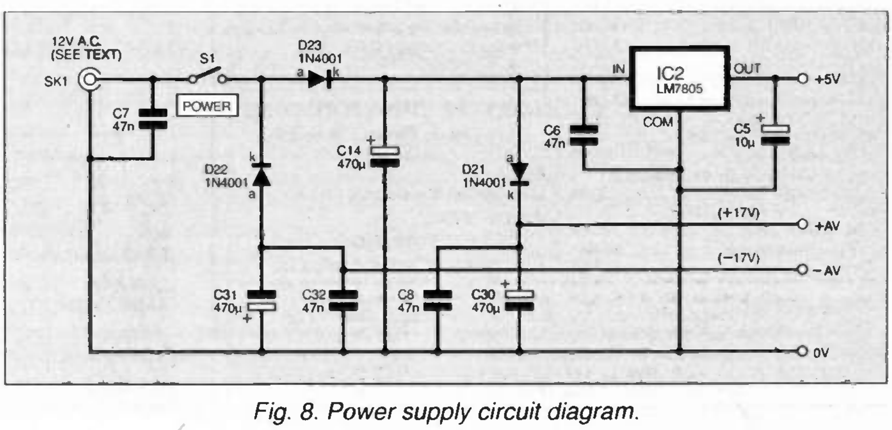


Fig. 8. Power supply circuit diagram.

FOX REPORT

by Barry Fox

Out-of-line ISDN

Early modems ran at 300 bits per second and cost £200. The first 2400 bps designs cost nearly £1000. Now 28·8 kilobits per second is the *de facto* standard, with fax capability thrown in, for around £100. The latest work at 33·6 kbps, which is near the theoretical limit for an analogue speech line.

Now we are seeing ISDN modems, which are not really modems at all. They act as an interface between digital equipment (e.g. a PC) and a digital phone line that carries data at 64 kbps, and higher multiples. The interface responds to the same Hayes "AT" commands as an analogue modem, so most users think of an ISDN interface as a modem. An ISDN terminal adaptor works like a modem in reverse. It converts digital line pulses into analogue signals, so that an ordinary phone, fax or modem can work with an ISDN line.

First interfaces and adaptors cost around £1000. The price is now down to around £400. It will drop like a stone as soon as the price of using an ISDN line falls and more people can afford the connection. But high hopes of a price cut were recently dashed.

Imaginative Marketing

Until recently the cheapest way to sign up for ISDN was to pay BT £400 (plus VAT) for an ISDN-2 connection and then pay £336 a year for line rental. In June, Oftel, the telecommunications watchdog, told BT to be more "imaginative" in its marketing. BT responded with what it quaintly called a "flexible approach". The rental on existing lines went up by £16 a year and new users faced a bewildering range of options, which bundle a "free" call allowance with rental and installation costs.

June Campbell, BT's Marketing Manager of ISDN services, said it was "good news for small businesses". Jo Baxter, BT's Pricing Manager, told me that the new tarriffs made ISDN "more affordable".

Oftel disagreed and gave BT "a few days" in which to come up with a better deal. Director General Don Cruickshank threatened legal action if BT did not comply.

Fielding Objections

BT claimed that it costs over £1000 to install a line. It is hard to see how this can be because the connection is made using existing copper pair wires and a new connector box. Perhaps BT is trading the low cost of most intallations against bizarre exceptions. Recently BT tried to back out of an installation which cost £25,000 because it involved digging a trench to bury a new cable for four miles, crossing three roads and a river, and then completing the last 200 metres of the run with an overhead cable wrapped in a steel coating to protect it from shot gun pellets on a farmer's land.

BT has now juggled its "flexible" figures and Don Cruickshank is happy. He says that BT's revised tariffs include "worthwhile price cuts". The Telecommunications Users Association is not happy. In fact it is "very disappointed" at Oftel's capitulation. As an ISDN user, so am I.

"All BT has done is move the figures around and introduce complex tariffs" says TUA Chairman Bill Mieran. "ISDN is still too expensive. We thought Oftel wanted to do something about it, but it hasn't".

Out of three new options, the cheapest connection charge is £199 (plus VAT), with free calls worth £105 a year, but users must pay £535 a year rental for a minimum of two years. If people do not use all their free calls they get no refund. Another option leaves connection at £400 and increases the rental to £352.

Home Office Barrier

Pharmaceuticals giant Zeneca typifies the way both small and large businesses could benefit from ISDN, if only prices were lower. Zeneca has divisions scattered around the country and linked by an office network. The company encourages some researchers to spend one or two days a week working from home and using a laptop PC and phone line. They get more work done because they are undisturbed. Using an ISDN line, instead of an analogue line and fast modem, doubles the speed at which a researcher can download a large reference file.

"ISDN removes the barrier between home and office working" says Phil Barton, Zeneca's Telecoms Strategy Manager. "But at BT's rates the typical cost to Zeneca is £1000 a year. So some staff have to use analogue lines."

Germany Calling

BT will not say how many people are connected to its ISDN-2 service, but Racal-Datacom, which makes ISDN connection equipment, estimates 0·2 million by the end of the year. In Germany, Deutsche Telekom has connected nearly 2 million people. It is not hard to see why.

Deutsche Telekom will switch on a new subscriber for 200DM (around £85), with the cost halved if the subscriber fits the wires to the connection box instead of calling out an engineer. Line rental is then 138 DM (£60) a quarter. Special offers bundle over a hundred pounds' worth of free calls with the purchase of ISDN hardware.

Phil Barton warns that it is unfair, and counter-productive, to use the giveaway prices in France and Germany as a stick with which to beat BT.

"Those countries still have monopoly providers which can afford to subsidise ISDN and charge ridiculously low prices. It is fairer to look at prices in Scandinavia and North America, where there has been de-regulation. We expect to pay a reasonable premium, say twice the business rental rate for an analogue line, because of the higher cost of the network technology. But BT already charges four times the rate and is now raising the hurdle to around six times."

Cable Improves the Rate

The latest news is that cable TV companies are offering subscribers the chance to use a cable modem. This uses a spare analogue TV channel for digital data. Nynex has just signed a deal with Motorola to supply equipment for a trial in Manchester. The data rate is 10 megabits per second downstream into the home or office, with a 768 kbps return path back to the cable head end. The return path can be used to send compressed video of teleconference quality, while the downstream data pipe can carry VHS quality video or hifi stereo at faster than real time for local storage and replay. If the cable service starts to offer a high speed interconnect for business users, you can be sure that BT will suddenly find a way to cut ISDN pricing.

BT SHOUTS BACK

BT and VIAG Intercom have launched legal proceedings in Germany to prevent the telecoms company Global One from trading in breach of European competition rules.

Global One is a joint venture between Deutsche Telekom (DT), France Telecom (FT) and Sprint Corporation. DT is the monopoly operator in Germany and the largest telecoms company in Europe; FT is the monopoly operator in France and the second largest operator in Europe.

A BT spokesperson said, "As a result of being owned by two monopolists, Global One has an unfair advantage in comparison with its competitors".

The creation of Global One was cleared by the European Commission subject to the company's competitors being able to obtain supplies from two operators in addition to DT and FT. This was intended to create a level playing field for third-part operators.

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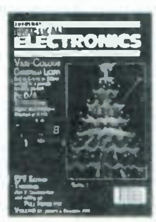

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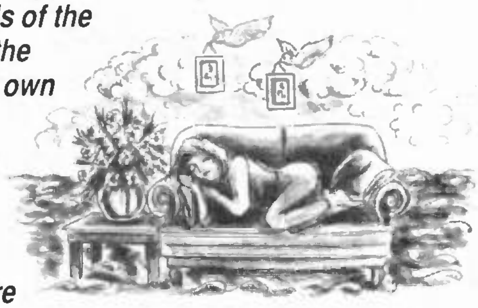
NEXT MONTH

PACIFIC WAVES



In these days of high stress, why not relax to the soothing sounds of the "high seas" in the comfort of your own home!

There can be little doubt that one of the most relaxing sounds of nature is that of ocean waves breaking along a wide shore. It calms the soul, and in these stress-filled times a stroll along such a beach isn't simply a pleasure, it's a therapy.

The "Pacific Waves" project described next month is designed to create surf sounds as realistically as possible for playing through any ordinary domestic stereo system.

HOW TO USE INTELLIGENT L.C.D.s

The ability of intelligent liquid crystal display modules to show not just numbers, but also letters, words and all manner of symbols, makes them a good deal more versatile than the familiar 7-segment light emitting diode displays.

However, getting them to work properly can often pose problems for those who are unfamiliar with the techniques required. Once you do *know how they should be programmed, though, they are remarkably simple to use and can enhance the capabilities of all manner of constructional designs.*

In this two-part series of articles, we present an utterly practical guide to interfacing and programming the character-based l.c.d. modules which use the Hitachi HD44780 (or compatible) controller chip, as do most modules which are available to the hobbyist.

PsiCom EXPERIMENTAL CONTROLLER

This project should allow owners of the Psion Series 3a *"palmtop" computer to use it for controlling external equipment with simple software programs, either by switching, or with an analogue control voltage.*

The technique employed might also be usable with other devices employing an l.c.d. screen. It requires no electrical connection to the controlling equipment.

EVERYDAY PRACTICAL ELECTRONICS

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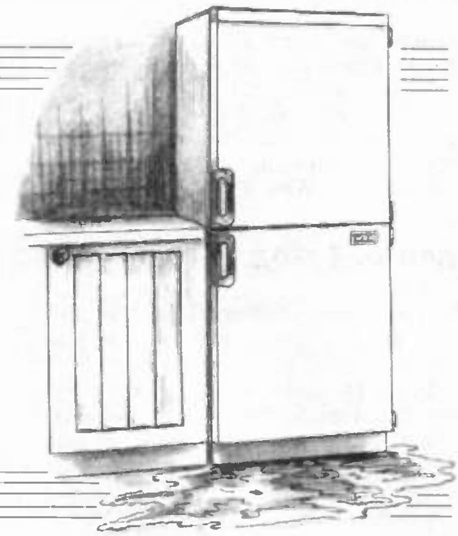
FEBRUARY '97 ISSUE ON SALE FRIDAY, JANUARY 3

MAINS-FAILURE WARNING



TERRY de VAUX-BALBIRNIE

An audible alarm for fridges and freezers.

THIS simple Mains-Failure Warning project will be of interest to anyone wishing to guard against mains appliances being switched off accidentally.

Fridges and freezers are obvious targets but some readers will wish to protect such items as aquarium and reptile heaters, greenhouse equipment and emergency water pumps. It may also have applications with medical and scientific apparatus.

ENJOY YOUR TRIP

Common causes of mains failure are blown fuses, tripped RCD units, children playing with switches and people pulling on wires. However, it often happens that an appliance is accidentally switched off when it is plugged into one of a row of sockets and the wrong one is disconnected.

Another frequent cause is when the appliance is unplugged to allow the socket to be used for some other purpose – such as for the vacuum cleaner – and it is not plugged back in afterwards.

The Mains-Failure Warning provides an alarm by sounding a pulsing tone if the supply is disconnected for any reason. In the prototype, the sounder was mounted on the circuit board inside the case. However, it would be possible to connect it remotely so that, for example, a signal could be provided in the house if the supply in the garage failed.

CONNECT AND FORGET

The unit is built in a small aluminium case with a neon indicator mounted on the side which confirms that the supply is connected. An on-off switch is provided on the circuit board inside the box and is only accessible when the lid is removed.

This prevents inadvertent operation which would prevent the circuit from working and defeat its purpose. It will probably be used only when the device is removed from service for some reason (since otherwise it would sound continuously because the supply would be disconnected).

In use, the appliance to be protected is connected to the mains through the Mains Failure Warning unit. While a supply exists, a set of small nickel-cadmium cells is maintained in a charged state.

When the supply fails, the circuit obtains power from these cells which then operate the audible warning device. Using a rechargeable supply in this way has the advantage of there being no conventional batteries to check and replace – the unit can be connected up and forgotten.

There is a switch (also accessible by removing the case lid) which provides "boost" charging if the alarm has been required to sound over a long period and this allows the batteries to be re-charged in a short time. In the prototype, the specified buzzer operated for 12 hours approximately on a full charge although the sound becomes weaker towards the end.

Important Warning: Constructing this project requires mains connections to be made. Any reader who is uncertain of being able to make a safe job must seek the help of a competent electrician.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Mains Failure Warning project is shown in Fig. 1. A sub-miniature mains transformer, T1, provides a nominal 12V d.c. output using the conventional arrangement of bridge rectifier D1-D4 and smoothing capacitor C1.

While the mains supply is on, transistor TR1 receives base (b) current via resistor R1 and will be turned *on*. Thus, the collector goes *low* so keeping the reset input, pin 4, of timer IC1 low also. This disables the i.c. which has no further effect.

Assume that On-Off switch S2 is *on*. The 7·2V nickel-cadmium battery pack (consisting of two separate 3·6V units, B1 and B2, connected in series) is charged by current entering via diode D5 and resistor R5 alone or R6 connected in parallel with R5 when the Boost switch S1 is on.

Connecting the resistors in parallel in this way will lower the effective value and

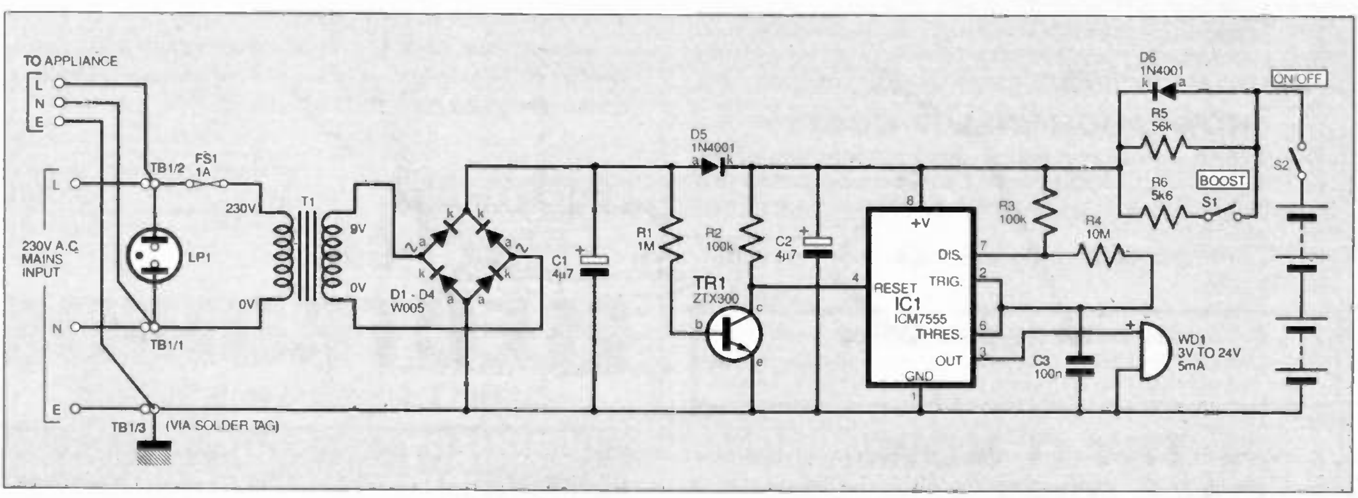


Fig. 1. Complete circuit diagram for the Mains-Failure Warning. S1 and S2 are d.i.l. switches mounted on the circuit board.

increase the current. Diode D6 is reverse-biased with respect to current entering the battery and so has no effect.

Resistor R5 limits the current to 100μA approximately which is low enough to prevent overcharging when current flows continuously. With S1 set to Boost, the charging current rises to about 1mA.

MAINS FAILURE

When the mains supply fails, transistor TR1 no longer receives base current so it switches *off*. Its collector (c) therefore goes high and with it, IC1 Reset pin 4.

Diode D5 prevents base current entering TR1 from the battery pack. However, IC1 does receive a supply from this with current flowing through diode D6 which is now forward biased as far as current flowing out of the batteries is concerned.

SOUND ADVICE

With IC1 pin 4 high, the timer is enabled. Since it is configured as an astable its output, pin 3, will constantly switch on and off at a rate dependent on the values of resistors R3, R4 and capacitor C3.

With the values specified this will be about once per second and, because it is not thought to be particularly critical, no adjustment is provided. If a faster rate is preferred, resistor R4 may be reduced in value and *vice-versa*. The output of IC1 operates the audible-warning device (solid state buzzer) WD1 direct.

The effectiveness of the warning depends largely on the choice of sounder and how it is situated. It must be as loud as possible combined with a small current requirement (5mA to 10mA). Moreover, it must be capable of producing a high sound output using a supply of only 7V.

Readers are warned against using small cheap devices which may not be loud enough to attract attention. Good coverage is obtained by mounting the sounder flat on the printed circuit panel as shown in the photograph. For louder results, it could be mounted on short stalks so that its top lies level with the surface of the box.

It is also possible to use a buzzer attached to the box externally. This should be of the panel-mounting type and chosen to have a sound output at least equal to that specified in the parts list. The same type of audible warning device could be used if it is to be situated remotely and more will be said about this later.

CONSTRUCTION

The Mains-Failure Warning is built on a small, single-sided, printed circuit board (p.c.b.) and the component layout, interwiring and underside copper foil master pattern are shown in Fig. 2. This board is available from the *EPE PCB Service*, code 126. All components except terminal block TB1 and neon indicator LP1 are mounted on-board which makes construction particularly straightforward.

Prepare the p.c.b. by drilling the four holes to mount it in the case later. Add the soldered components in the following order. First, transformer T1, fuseholder FS1, the i.c. socket (but do not insert the i.c. itself yet), d.i.l. switches S1 and S2 (both set to *off*) and all resistors and capacitors.

Note that resistors R3 and R4 are mounted vertically against the board. Take care over the polarity of electrolytic capacitors C1 and C2.

Follow with the bridge rectifier, diodes, transistor, nickel-cadmium batteries and audible warning device taking care over the orientation of all these components. Attach the plastic cover to the fuseholder.

Complete construction of the circuit board by soldering 10cm pieces of *mains-type* wire of 3A rating minimum *direct* to the lower transformer primary winding tag and the adjacent fuseholder tag (see Fig. 2) on the *copper track* side of the board. ***For safety reasons, make certain that these wires are secure and cannot dislodge in service.***

Finally, solder a piece of stranded wire 5cm long to the "earth point (E)", about half-way along one side of the p.c.b. in line with the warning buzzer. This lead

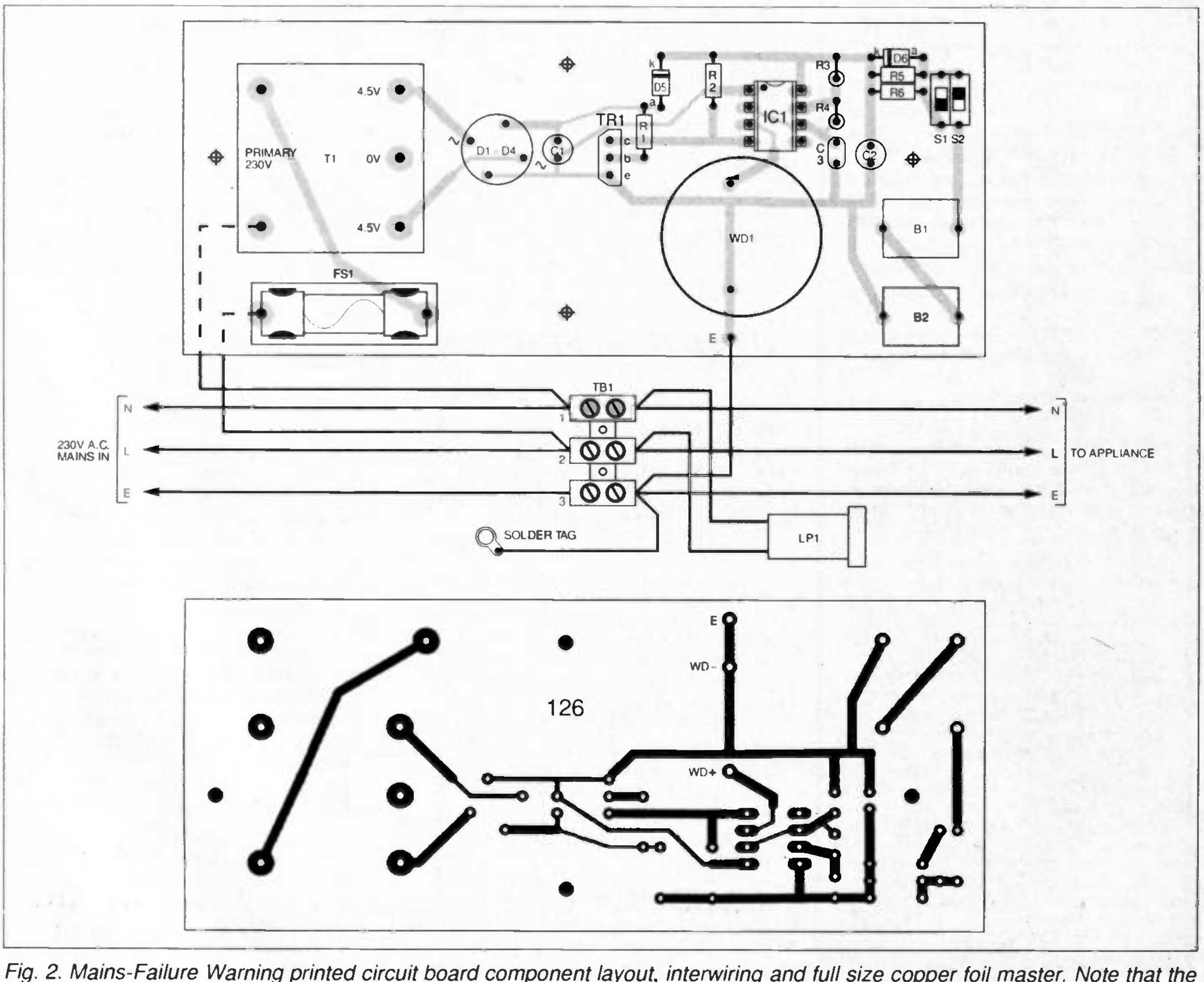
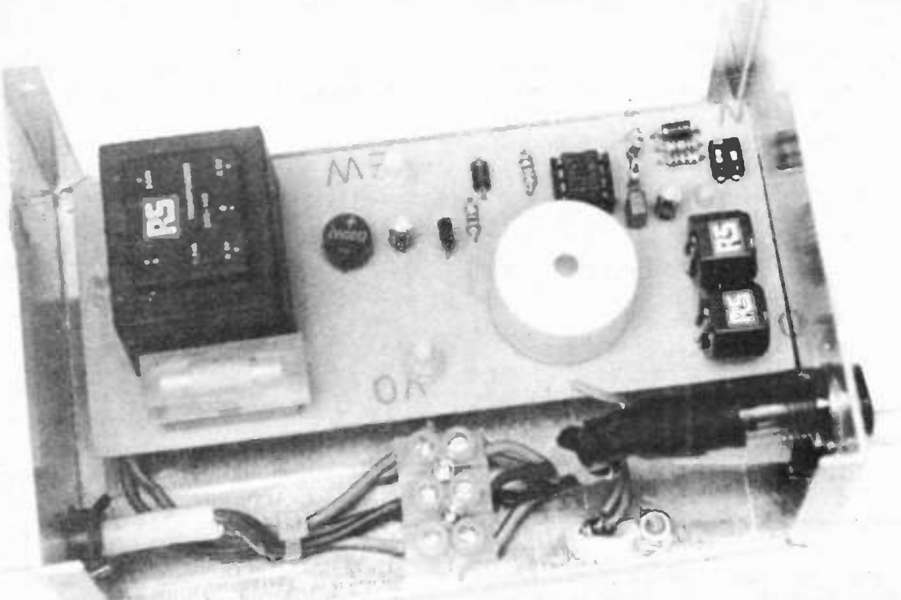


Fig. 2. Mains-Failure Warning printed circuit board component layout, interwiring and full size copper foil master. Note that the leads from TB1 to the transformer primary and the fuse FS1 should be rated at 3A and be soldered directly to the **underside** *copper pads as indicated.*



Layout of components inside the metal case. Make sure the p.c.b. is mounted on nylon spacers and secured with nylon screws and nuts. You must use strain relief grommets for the mains leads, protective sleeving over the neon leads at TB1 and cover the top of TB1 with some insulating tape.

COMPONENTS

Resistors

R1	1M	See SHOP TALK Page
R2, R3	100k (2 off)	
R4	10M	
R5	56k	
R6	5k6	

All resistors 0·25W 5% carbon film

Capacitors

C1, C2	4µ7 p.c.b. mounting radial elect. 16V (2 off)
C3	100n sub-min. metallised polyester

Semiconductors

D1 to D4	W005 50V 1·5A bridge rectifier
D5, D6	1N4001 50V 1A rect. diode (2 off)
TR1	ZTX300 *npn* silicon transistor
IC1	ICM7555 CMOS timer

Miscellaneous

B1	3·6V 11mAh nickel-cadmium, p.c.b. mounting, batteries (2 off)
T1	sub-miniature p.c.b. mains transformer. 230V a.c. primary and 4·5V-0V-4·5V secondary rated at 1·2VA (100mA)
LP1	mains neon indicator
WD1	piezo buzzer, p.c.b. mounting, 10mA 3V to 24V d.c. operation, 90dB output minimum – see text
S1/S2	dual s.p.s.t. d.i.l. switch
FS1	1A 20mm ceramic mains-type fuse, with 20mm p.c.b. fuseholder and plastic cover

Printed circuit board available from *EPE PCB Service*, code 126; aluminium box, size 125mm x 85mm x 60mm approx.; 8-pin d.i.l. socket; strain relief grommet (2 off); screw terminal block – 3 sections required; stand-off insulators (4 off); mains wire and plug for input lead; 3·5mm mono jack plug and socket or other small connector for remote sounder if required.

Approx Cost Guidance Only **£30**

will eventually go to the terminal block at point TB1/3.

SOUNDER

As mentioned previously, the audible warning device will normally be mounted on-board. However, if it is to be situated remotely, solder 8cm pieces of light-duty stranded connecting wire *direct* to the solder pads marked "WD+"; and "WD–", via the topside of the board.

The external connections can then be made through a small plug and socket – for example, a 3·5mm mono jack-type socket mounted on the side of the box. If the sounder itself is to be mounted on the side of the box, the flying leads already attached to it may need to be extended, a hole drilled and a rubber grommet used to prevent the sharp edges cutting the wires.

CASE PREPERATION

Prepare the aluminium case to receive the p.c.b. by drilling four holes in the base to correspond with those already made in the board. Drill a large hole in the case lid for the sound to pass through – this must be carefully measured so that it lies directly above sounder WD1 when the circuit board is in position.

Drill holes in the end panels for the strain-relief bushes to be used on the input and output mains wires. ***These are an essential safety requirement since they prevent the wires possibly pulling free in service which could be very dangerous.***

Choose a three-section piece of screw terminal block appropriate to the load (for example, 3A for up to 720W rating on 240V) and drill the holes to secure this. Drill holes for the neon indicator LP1 and solder tag. *Note that the solder tag is used to Earth the case and, for safety reasons, **it is essential to include it.*** Secure all these components.

ASSEMBLY

Mount the p.c.b. on the base of the box using 10mm long plastic stand-off insulators on the bolt shanks. *It is essential for the soldered connections to be maintained at least 5mm clear of the metalwork. This is particularly important for the mains connections at T1 primary. If necessary, place a piece of plastic between these and the base of the box as an additional precaution.*

Refer to Fig. 2 and connect the three wires leading from the board to terminals TB1/1, TB1/2 and TB1/3 on the screw terminal block as shown. If the buzzer is to be situated remotely, drill a small hole in the side of the box and mount the socket.

If one terminal of the socket makes electrical contact with the metalwork (the usual arrangement with some jack sockets) it is ***essential*** for this to be made the ***negative*** one. That is, the one connected to the copper pad marked WD– on the p.c.b. Attach self-adhesive plastic feet to the base of the box.

Insert IC1 into its socket observing the orientation. As a precaution, observe simple anti-static measures before handling it. The simplest method is to touch something which is earthed, such as a water tap, before touching the pins.

REDUCING THE STRAIN

Make up the mains input wire using a suitable length of 3-core wire (even if the appliance itself needs no earth connection) and of a rating appropriate to the load being used. Cut off the end 5cm and remove the piece of earth wire (yellow/green) – discard the other two.

Secure one end of the mains input wire through the strain relief grommet, trim the three wires to size and, referring to Fig. 2, connect them up to the terminal block TB1 along with the existing ones leaving a little slack. Use the short piece of the earth wire removed previously to connect the mains Earth at the terminal block to the solder tag.

Fit the other end of the mains lead with a plug. If this is of the standard UK type, choose the correct value of fuse for the appliance being used.

Connect the neon indicator LP1 to the mains Live and Neutral on the output side of the terminal block as shown. Use heat-shrinkable sleeving at LP1 tags to provide insulation and make them impossible to touch.

If the buzzer is to be situated remotely, connect it temporarily to a short piece of twin wire with the appropriate plug on the other end. Take care to observe the polarity or it will not work. Switch S2 *on*. If there is any charge in the cells, the buzzer should start bleeping.

Before proceeding, check that all mains connections, including those at the fuseholder and neon indicator, are shielded so that it is impossible for the fingers to touch them whilst the lid of the case is removed. The unit may now be tested since it does not need an appliance connected for it to work.

TESTING

Plug the unit in to the mains – the neon indicator should light and if the buzzer has been sounding it should now stop. If the buzzer did not sound before due to the batteries being discharged, set d.i.l. switch S1 to *boost* and leave the circuit on for about 30 minutes. This will allow sufficient charge to accumulate for testing to take place.

Now switch off the mains supply. The buzzer should start bleeping after a delay of about 20 seconds (that is, when capacitor C1 has discharged sufficiently to fail to maintain TR1 in the *on* state). When the supply is re-connected, the warning should stop immediately.

Unplug from the mains and switch S2 *off* to silence the sounder. If S1 was set to *boost*, switch it back to the normal charge rate.

Connect the appliance cable via the unused strain relief grommet to the terminal block TB1 along with the LP1 neon indicator connections and circuit board Earth wire, see Fig. 2. Switch S2 on, replace the lid and re-test. If all is well, the unit may be put into permanent service.

If the buzzer is to be connected remotely (such as from a garage or greenhouse), due to one lead being connected to the mains Earth, a double-insulated cable must be used for this purpose as, under exceptional fault circumstances, it could become "live" up to 230V a.c. Ordinary 2-cored mains cable is suitable (each core separately insulated with both jointly wrapped by an external insulating sheath). The buzzer should also be housed in a small plastic box with a hole drilled in the front for the sound to pass through.

ALARM CHECK

It would be a good idea to check the alarm by switching off the mains supply every few weeks. If the buzzer has ever sounded for a long period so that the batteries are flat, the Boost switch S1 may be used to restore them as quickly as possible. This takes 14 hours and the switch should *NOT* be left in the *on* position any longer.

With the Boost switch off, complete charging will take about six days although a useful amount of charge is accumulated in a few hours. It is suggested that S1 switch is not used unless the batteries are totally discharged due to the possibility of overcharging and consequent damage to them.

Remember that NiCad cells do not last indefinitely. Check each year for any sign of deterioration. Replacement may be necessary after about 5 years of service. □

Ohm Sweet Ohm

Max Fidling

Barking Mad

Rooting around in the shack the other day, near my pile of old washing machine motors and rusty biscuit tins containing various assorted electronic goodies, I came across the defunct remnants of an earlier project, when yours truly had declared war against some light-fingered members of the criminal fraternity!

I had decided that it was time to fit a burglar alarm to *Chez Fidling*, not that I've anything worth pinching, but not being one to spend money if I can "do it myself", I'd spent quite some time rummaging through various magazines in search of suitable circuits. As usual, I hoped to cobble something together on the cheap! However, I didn't relish the prospect of drilling holes through every wall in sight, feeding miles of wires everywhere and putting contact switches on just about everything including the toilet seat, so I'd decided on a more cunning plan instead . . .

One thing had caught my eye as I flicked through an advertiser's "surplus" pages in my favourite magazine, while munching my breakfast one morning. It appeared to be a small box containing the electronic circuitry to imitate the growl of a dog.

It was battery operated and when triggered was supposed to give the impression that your home was populated by a pack of fierce hounds, guaranteed to strike terror into the heart of any cotton-picking opportunists! Quite how it worked I wasn't sure, but guessing that it contained a sample chip which would be fun to play with, I duly wrote out an order and cycled off to the post box.

Padded Cell

Several days later, a padded bag arrived and I ambled over to the shack bearing my latest loot. It was rather a chilly morning and Piddles the cat was tucking into his grub in the shack, next to the old electric fan heater whose *whirr* punctuated the air and made the floorboards rattle like the inside of a throbbing Douglas Dakota.

The cat munched on blithely as I started to tinker on the bench with the *"Phantom Dog Woofer (batteries not included)"*. Ripping open the electronic canine's carton, the plastic plunder tumbled out onto the bench. It was quite an impressive box which had a grille on the front panel, presumably for the speaker or the horn.

Not being one to bother with batteries, I hooked up the bench power supply, which has been set to the usual 9V (give or take a few), and waited excitedly to see what would happen. Nothing! A quick wiggle of the wiring, a twiddle of the bench power supply – still nothing! Not a growl, not even a snivelling wet-nosed whimper! Hmmm . . .

If in doubt, always read the instructions, I guess, so I peered at the accompanying tiny bit of paper headed "Instruction Manual" for inspiration. Barely decipherable in a smudgy black ink, the voluminous Instruction Bit of Paper bore a mystical message:

"Placing Phantom Dog Woofer on door lever and battery switch red color is on for working properly", it said in a strange Taiwanese tongue, cross-referring to a thumbnail sketch, but I got the gist. *"Leave room immediately for Phantom Dog Woofer now protecting door handle if touched thereafter!"* it burbled. Aha! The plot "thinned".

Evil Eye

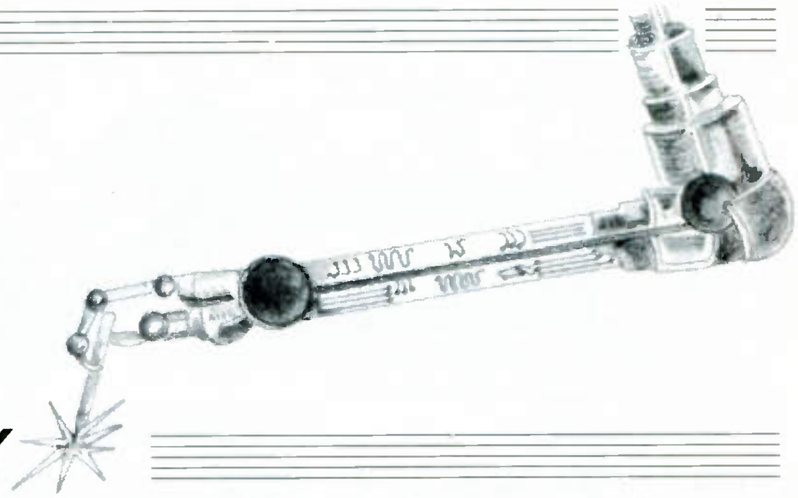
The cunning canine gizmo sat defiantly on the bench; I half expected a tail to pop out and start wagging, but instead the black box remained there, waiting to be taken the electronic equivalent of *walkies*. Examining the plastic moulding revealed that on the underside of the plastic hook, which I guessed hung onto a door knob, there was a large shiny metal contact, probably part of some kind of antenna which would trigger the circuit.

Anyway, I poked it with a screwdriver blade to see what would happen. Bark! Bark! ***WOOOF!! WOOOF!!*** The box unleashed a chorus reminiscent of the *Last Hound of the Baskervilles!* At this point, a petrified Piddles, in mid-munch, sat bolt upright and then with a squeal hurtled off towards the door!

WOOOF!! WOOOF!! The Taiwanese Terrier continued its "rappaw" with an absent Piddles. A small screwdriver slot was found on the casing which invited a twiddle with the screwdriver, and the canine clamour resolved itself more to a Chihuahuan "Yap!" as the meter on the bench power supply pulsed in sympathy.

By this time the cat had wised up to the fact that he'd been "had", and duly relieved (in more ways than one) he ambled back to his grub and started clattering the bowl noisily next to the fan heater, giving me an evil stare as usual. Meantime, having got the hang of the *Phantom Dog Woofer*, the next thing was to try it on the toilet door handle and see if I could catch the Boss at the operative moment! What a bargain!

CIRCUIT SURGERY



ALAN WINSTANLEY

Our monthly column for readers' queries and tips looks at a novel but effective reverse-voltage protection circuit, also "Zapping" of Nickel-Cadmium cells, linking l.e.d.s together, and how to Monitor a PSU output.

Simple Protection

HERE'S a further selection of readers' comments and queries, starting with a follow-up from September's column. *Geoff Kermode* of Whitley Bay, Tyne & Wear, shares these simple tips with us. Geoff writes:

Your reverse polarity protection system in September's Circuit Surgery *reminds me of a simple GCSE CDT circuit I developed some time ago. This was a lighting system for a model railway using four 12V 20W dichroic bulbs.*

I used a 13·8V CB power supply which had 4mm terminals (binding posts). There was the possibility of reversing the polarity, which would have damaged the lighting system.

As in many battery applications, it's necessary to minimise the voltage drop through the system to ensure maximum brightness at full power. Rectifiers couldn't be used because of this, so I designed the simple circuit of Fig. 1. The voltage drop arises through relay contact resistance. Thick-gauge wires, and plenty of solder minimises losses too.

At these high currents even the resistance of a fuse can be significant. An l.e.d. or buzzer can be added as shown in Fig. 2 to warn of incorrect polarity.

Thank you very much for two excellent columns!

Thanks for writing, and for the tips. With apologies to those who are less interested in batteries, but it's an immensely popular subject. Here are some tips from regular reader ***David Dewey*** of Bovingdon, Herts, who comments:

I use a NiCad Charger and some tricks of mine may interest your readers. Most gadgets need two or more cells in series and often one discharges before the remainder.

In order to prevent "memory build-up" I discharge the others individually through a diode in series with a resistor (about 22 ohms for AA batteries). Thus, they are all fully discharged without dropping below about 0·6V.

Sometimes, in general use, one cell falls to 0V and stays that way, even after trying to recharge it. This hints at an internal short. It is worth trying to "zap" the cell with a heavy current (many amps) for a **second** *or two.*

I use two or three charged cells in series, hooked in parallel to the "dud" cell with **thick** *wire. A voltmeter across the dud NiCad will hopefully jump from 0V after a few seconds, to about 1·2V. Then* ***disconnect immediately!***

Finally, I mark NiCads of the same batch when purchased, and use cells from the same batch wherever possible to make a stack. This ensures good rotation of cells.

"Zapping" of cells is sometimes practised prior to reading the Last Rites to a NiCad, it's a bit unofficial and you really *must only* "nuke" it for *one to two* seconds. The dendrites in the cell may form whiskers which can be fused away but it's a sure sign that the cell's on its way out!

Also, younger readers should know that a **cell** is one individual 1·2V NiCad, these may be joined together in series to form a **battery** but they should **not** ordinarily be connected in parallel, because their voltages will not be equal and one cell is likely to shunt the others.

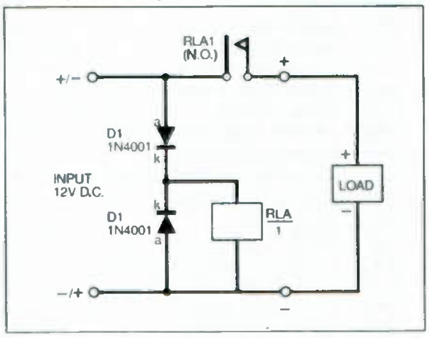


Fig. 1. Using a relay to minimise voltage drop losses while offering reverse voltage protection.

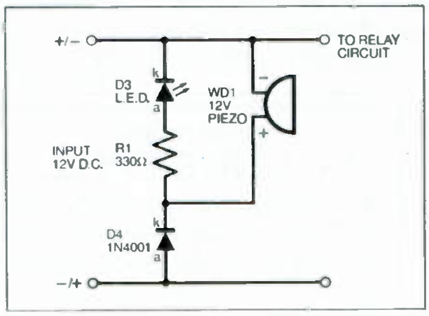


Fig. 2. Adding a buzzer to warn of reverse battery polarity.

Keeping Tabs on Batteries

In last September's column I commented on methods of soldering wires or tabs to batteries. From ***Mr Ken Maynard***, by E-mail:

With reference to soldering batteries, (Hot Batteries – September issue) *I only do this if they have tags already fitted. Soldering to any type of battery requires that the terminal top be cleaned with a file to remove the plating, then it's possible to solder the battery without overheating it.*

*Also **Ben Musson*** comments by E-mail: *Many times I've soldered lengths of cable onto NiCads without any problem, using standard tinlead solder. As long as the terminal surface is sufficiently roughened using sandpaper, the solder takes well and the cell does not get too warm.*

*And from **Christer Renberg*** of S-461 67 Trollhättan, Sweden, comes further advice if you're having a ticklish time soldering those stubborn substances.

My suggestion is to use a solder called "KR-19" that wets on stainless steel and other difficult materials. It's made by Almit of Japan with a very effective fluxing agent that wets on almost any metal without the need for excessive heat.

I learned this trick when I was involved in trying to grade and recycle surplus electronic equipment. I set my temperature-controlled iron to 370°C and wet both surfaces together with KR-19 super-solder. Good luck with your soldering!

Solder KR-19 isn't a product I've come across. Does anyone have any alternatives or further information? I'm also very pleased to see that p.c.b. holders are at last becoming available for coin cells, e.g. **Maplin** Order Code GU00A *et al*, or **Farnell** Stock Code 676-482. Maplin also stock a further range of snap-in battery clips for p.c.b. use.

(Open the new Maplin "*MPS*" catalogue and you could be forgiven for thinking you've picked up an RS Components catalogue by mistake: however, the MPS catalogue is, in my opinion, now easily the best one available in this market and I strongly recommend that you buy a copy.) Incidentally, coin cell dimensions are a topic I'm hoping to tackle in a future column.

General soldering tips were offered in the series *Build Your Own Projects* (Dec '96) which continues in this issue. I have, incidentally, been absolutely astonished by the interest shown in this series, and I thank everyone who's kindly contacted us to say how much they've enjoyed reading it.

We're hoping to put an "on-line" guide to soldering with extra photos onto the Internet at our World Wide Web site **(http://www.epemag.wimborne.co.uk),** following several requests from Internet users everywhere. If you have any queries or comments arising from the *Build Your Own Projects* series, why not share them and drop *Circuit Surgery* a line?

Parallel Bars

Mr. Soar of Doncaster raised a query concerning the use of light-emitting diodes (l.e.d.s) in parallel. He writes:

I recently saw a suggested circuit showing two l.e.d.s. being driven in parallel with each other, should they not be connected in series to prevent a "current hogging" effect?

Preferably, yes. Otherwise the one with the lowest forward voltage will "shunt" the others, and it will draw an unfair share of the available current.

The "hog" will often be the brightest l.e.d. whilst the others may not be as bright as they could be. The remedy is to ensure that each has its own series dropper resistor, or you could place the devices in series instead.

Interestingly, some super-large seven-segment displays (say 70 to 100mm high) use an internal combination of parallel and series l.e.d.s: e.g. Maplin's 100mm display (Order Code JX86T) uses no less than eight l.e.d. chips per segment: two l.e.d.s in parallel, then each parallel pair in series four times; if you see what I mean.

Bench Metering

Constructing a Bench Power Supply? ***Mr Alan McCusker*** is! A small problem with monitoring the output voltage and current is easily solved. Mr McCusker writes:

I enclose a circuit diagram of a 723-based power supply I'm making, to which I would like to add two meters (analogue, moving iron) to monitor the voltage and current. I would appreciate any help or advice to enable me to connect them.

No problem, ammeters are placed in *series* with the current being measured, whilst a voltmeter measures the potential *difference between two points*. Fig. 3 shows how. Also a double-pole single-throw switch is useful for isolating the power from the load instantly.

Usually, switching off the **mains** supply does not instantaneously power-down the load, because a voltage remains across the p.s.u.'s smoothing capacitors for a short period. Hence the d.p.s.t. switch *following* the p.s.u.

A cute trick is to add a "constant current" l.e.d. directly across the supply rails; this needs no resistor and will light whenever the d.c. supply is switched on, provided it exceeds a few volts. If the l.e.d. extinguishes, then you may have a direct short across your power supply. The trouble

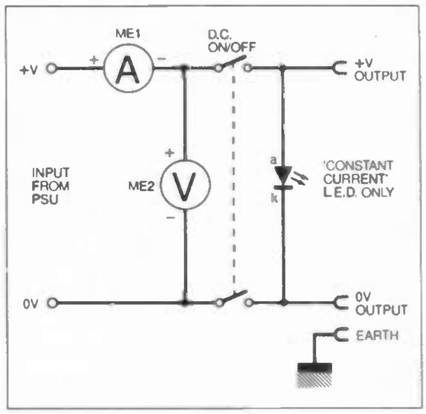


Fig. 3. Metering a power supply.

is, these l.e.d.s. suddenly seem incredibly hard to obtain. Can anyone help?

One quite important point though, concerns your choice of meter. Usually, moving *coil* types are used, or if you can afford it, a digital voltmeter instead. Not many constructors may be aware that if you bolt a moving *iron* meter to a **steel** panel, you may seriously affect the accuracy of the meter readings. Aluminium panels seem OK though.

At your service

Circuit Surgery is *your* page. If you have any questions to ask or comments to make, please write to Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. E-mail **alan@epemag. demon.co.uk**

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ELECTRONIC PROJECTS – BOOK 1
Published by *Everyday Practical Electronics* in association with Magenta Electronics.

Contains twenty of the best projects from previous issues of EE each backed with a kit of components. The projects are: Seashell Sea Synthesiser, EE Treasure Hunter, Mini Strobe, Digital Capacitance Meter, Three Channel Sound to Light, BBC 16K Sideways Ram, Simple Short Wave Radio, Insulation Tester, Stepper Motor Interface, Eprom Eraser, 200MHz Digital Frequency Meter, Infra Red Alarm, EE Equaliser Ioniser, Bat Detector, Acoustic Probe, Mains Tester and Fuse Finder, Light Rider – (Lapel Badge, Disco Lights, Chaser Light), Musical Doorbell, Function Generator, Tilt Alarm, 10W Audio Amplifier, EE Buccaneer Induction Balance Metal Detector, BBC Midi Interface, Variable Bench Power Supply, Pet Scarer, Audio Signal Generator.

128 pages (A4 size) **Order code EP1** **£2.45**

ELECTRONICS TEACH-IN 88/89 – INTRODUCING MICROPROCESSORS
Mike Tooley BA (published by *Everyday Practical Electronics*)

A complete course that can lead successful readers to the award of a City and Guilds Certificate in Introductory Microprocessors (726/303). The book contains everything you need to know including full details on registering for assessment, etc. Starting with basic terminology, integrated circuits, logic families and numbering systems the text builds in stages, with revision and assessments built in, up to programming, languages, flow charts, etc. The course is ideal for the newcomer to the subject.

80 pages (A4 size) **Order code T-88/89** **£2.45**

ELECTRONICS TEACH-IN No. 6 DESIGN YOUR OWN CIRCUITS
(Published by *Everyday Practical Electronics*)
Mike Tooley BA

This book is designed for the beginner and experienced reader alike, and aims to dispel some of the mystique associated with the design of electronic circuits. It shows how even the relative newcomer to electronics can, with the right approach, design and realise quite complex circuits.

Fourteen individual p.c.b. modules are described which, with various detailed modifications, should allow anyone to design and construct a very wide range of different projects. Nine "hands-on" complete DIY projects have also been included so readers can follow the thinking behind design, assembly, construction, testing and evaluation, together with suggested "mods" to meet individual needs. The practical projects have each been designed to stand on their own as complete items of equipment. P.C.B.s for all the modules and projects are available by mail order.

The subjects covered in each chapter of the book are: Introduction and Power Supplies: Small Signal Amplifiers: Power Amplifiers: Oscillators: Logic Circuits; Timers; Radio; Power Control; Optoelectronics.

The nine complete constructional projects are: Versatile Bench Power Supply; Simple Intercom; Bench Amplifier/Signal Tracer; Waveform Generator; Electronic Die; Pulse Generator; Radio Receiver; Disco Lights Controller; Optical Communications Link.

136 pages (A4 size) **Order code T16** **£3.45**

TEACH-IN No. 7 plus FREE Software
ANALOGUE AND DIGITAL ELECTRONIC COURSE
(Published by *Everyday Practical Electronics*)
Alan Winstanley and Keith Dye B.Eng(Tech)AMIEE

The highly acclaimed *Teach-In* series, which included the construction and use of the *Mini Lab* and *Micro Lab* test and development units, has been put together in book form. Additionally EPT Educational Software have developed a GCSE Electronics software program to compliment the course and a FREE DISC covering the first two parts of the course is included with the book.

DIRECT BOOK SERVICE

The books listed have been selected by Everyday Practical Electronics editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page. For another selection of books see next month's issue.

An interesting and thorough tutorial series aimed specifically at the novice or complete beginner in electronics. The series is designed to support those undertaking either GCSE Electronics or GCE Advanced Levels, and starts with fundamental principles.

If you are taking electronics or technology at school or college, this book is for you. If you just want to learn the basics of electronics then this is for you. If you are teaching electronics or technology you must make sure you see it. *Teach-In No. 7* will be invaluable if you are considering a career in electronics or even if you are already training in one. The Mini Lab and software enable the construction and testing of both demonstration and development circuits. These learning aids bring electronics to life in an enjoyable and interesting way: you will both see and hear the electron in action! The Micro Lab microprocessor add-on system will appeal to higher level students and those developing microprocessor projects.

152 pages (A4 size) **Order code T17** **£3.95**

Computers and Computing

HOW TO CHOOSE A SMALL BUSINESS COMPUTER SYSTEM
D. Weale

This book is for anyone intending to buy an IBM compatible computer system, whether it is their first system or a replacement. There are sections on hardware, application and systems programs and how to actually make your choice as well as sections on the law, ergonomics and a glossary of common terms.

The text contains many useful tips and some warnings (which could save much effort and expense).

114 pages **Order code BP323** **£4.95**

MAKING MS-DOS WORK FOR YOU (covers version 6.2)
N. Kantanis & P. R. M. Oliver

This book was written with the busy person in mind and, as such, it has an underlying structure based on "what you need to know first, appears first". Nonetheless, the book has also been designed to be circular, which means that you don't have to start at the beginning and go to the end.

The book explains: How to write customised batch files which allow you to display what you want on your screen, and in the form and order you want it, instead of being forced to use the DOS prompt on a blank screen. How to design and set up a fast interactive and professional looking menu system, so that you or anyone else can run utility applications or commercial software packages easily. How the ANSI.SYS display and keyboard commands can be used to position the cursor on any part of the screen, change the intensity of the displayed characters or change their colour. How the Edit screen editor or the Edlin line editor can be used to enter ESCape (ANSI.SYS) commands into simple ASCII files to allow control of both your screen display and your printer. How to control the operation of the two main types of printers in use today, Epson compatible dot matrix and HP compatible laser printers. How to use several routines, such as moving and finding files, protecting files from accidental erasure, a simplified backup process, a screen saver, and a disc cataloguing system.

The Debug program and how it can be used to create, see and change the contents of any file, including those of programs written in assembler code. This includes how to find your way around the names and tasks of the CPU registers and the meeting of some simple assembler mnemonics.

182 pages **Order code BP319** **£4.95**

MULTIMEDIA ON THE PC
Ian R. Sinclair

In this book, you'll find out what a CD ROM is, how it works, and why it is such a perfect add-on for a PC, allowing you to buy programmes, text, graphics and sound on a CD. It also describes the installation of a CD ROM drive and a sound card, pointing out the common problems that arise, and then shows how to use them to create a complete multimedia presentation that contains text, photos, a soundtrack with your own voice recorded as a commentary, even animation and edited video footage.

184 pages **Order code PC112** **£11.95**

A CONCISE INTRODUCTION TO MS-DOS
N. Kantaris
(Revised Edition Covers Version 6.2)

This guide is written with the non-expert, busy person in mind and, as such, it has an underlying structure based on "what you need to know first, appears first". Nevertheless, the guide is also designed to be circular, which means that you don't have to start at the beginning and go to the end. The more experienced user can start from any section.

176 pages **Order code BP232** **£3.95**

UNDERSTANDING PC SPECIFICATIONS
R. A. Penfold (Revised Edition)

If you require a microcomputer for business applications, or a high quality home computer, an IBM PC or compatible is often the obvious choice. They are competitively priced, and are backed up by an enormous range of applications programs, hardware add-ons, etc. The main difficulty for the uninitiated is deciding on the specification that will best suit his or her needs. PCs range from simple systems of limited capabilities up to complex systems that can happily run applications that would have been considered beyond the abilities of a microcomputer not so long ago. It would be very easy to choose a PC system that is inadequate to run your applications efficiently, or one which goes beyond your needs and consequently represents poor value for money.

This book explains PC specifications in detail, and the subjects covered include the following: Differences between types of PC (XT, AT, 80386, etc); Maths co-processors; Input devices (keyboards, mice, and digitisers); Memory, including both expanded (EMS) and extended RAM; RAM disks and disk caches; Floppy disk drive formats and compatibility; Hard disk drives (including interleave factors and access times); Display adaptors, including all standard PC types (CGA, Hercules, Super VGA, etc); Contains everything you need to know if you can't tell your EMS from your EGA!

128 pages **Order code BP282** **£4.95**

AN INTRODUCTION TO 6800 ASSEMBLY LANGUAGE
R. A. & J. W. Penfold

Obtain a vast increase in running speed by writing programs for 6800 based micros such as the Commodore, Amiga, Atari ST range or Apple Macintosh range etc., in assembly language. It is not as difficult as one might think and this book covers the fundamentals.

112 pages **Order code BP184** **£2.95**

Circuits and Design

PRACTICAL ELECTRONIC FILTERS
Owen Bishop
This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.
The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rythm sequencer and a multi-voiced electronic organ.
Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.
88 pages **Order code BP299** **£4.95**

ELECTRONIC ALARM CIRCUITS MANUAL
R. M. Marston
One hundred and forty useful alarm circuits, of a variety of types, are shown in this volume. The operating principle of each one is explained in concise but comprehensive terms, and brief construction notes are given where necessary.
Aimed at the practical design engineer, technician and experimenter, as well as the electronics student and amateur.
124 pages **Order code NE11** **£13.95**

DIGITAL GATES AND FLIP-FLOPS
Ian R. Sinclair
This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.
Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.
No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.
200 pages **Order code PC106** **£8.95**

ELECTRONIC CIRCUITS FOR THE COMPUTER CONTROL OF ROBOTS
Robert Penfold
Robots and robotics offer one of the most interesting areas for the electronics hobbyist to experiment in. Today the mechanical side of robots is not too difficult, as there are robotics kit and a wide range of mechanical components available. The microcontroller is not too much of a problem either, since the software need not be terribly complex and many inexpensive home computers are well suited to the task.
The main stumbling block for most would-be robot builders is the electronics to interface the computer to the motors, and the sensors which provide feedback from the robot to the computer. The purpose of this book is to explain and provide some relatively simple electronic circuits which bridge this gap.
92 pages **Temporarily out of print**

50 SIMPLE LED CIRCUITS
R. N. Soar
Contains 50 interesting and useful circuits and applications, covering many different branches of electronics, using one of the most inexpensive and freely available components – the light-emitting diode (LED). Also includes circuits for the 707 common anode display.
64 pages **Order code BP42** **£1.95**

BOOK 2 50 more l.e.d. circuits.
50 pages **Order code BP87** **£1.95**

CIRCUIT SOURCE BOOK 1
A. Penfold
Written to help you create and experiment with your own electronic designs by combining and using the various standard "building block" circuits provided. Where applicable, advice on how to alter the circuit parameters is given.
The circuits covered in this book are mainly concerned with analogue signal processing and include: Audio amplifiers (op.amp and bipolar transistors); audio power amplifiers; d.c. amplifiers; highpass, lowpass, bandpass and notch filters; tone controls; voltage controlled amplifiers and filters; triggers and voltage comparators; gates and electronic switching; bargraphs; mixers; phase shifters, current mirrors, hold circuits, etc.
Over 150 circuits are provided, which it is hoped will be useful to all those involved in circuit design and application, be they professionals, students or hobbyists.
182 pages **Order code BP321** **£4.95**

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold
This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world"
142 pages **Order code BP332** **£4.95**

CIRCUIT SOURCE BOOK 2
R. A. Penfold
This book will help you to create and experiment with your own electronic designs by combining and using the various standard "building blocks" circuits provided. Where applicable, advice on how to alter the circuit parameters is provided.
The circuits covered are mainly concerned with signal generation, power supplies, and digital electronics.
The topics covered in this book include: 555 oscillators; sinewave oscillators; function generators; CMOS oscillators; voltage controlled oscillators; radio frequency oscillators; 555 monostables; CMOS monostables; TTL monostables; precision long timers; power supply and regulator circuits; negative supply generators and voltage boosters; digital dividers; decoders, etc; counters and display drivers; D/A and A/D converters; opto-isolators, flip/flops, noise generators, tone decoders, etc.
Over 170 circuits are provided, which it is hoped will be useful to all those involved in circuit design and application, be they professionals, students or hobbyists.
192 pages **Order code BP322** **£4.95**

HOW TO USE OP.AMPS
E. A. Parr
This book has been written as a designer's guide covering many operational amplifiers, serving both as a source book of circuits and a reference book for design calculations. The approach has been made as non-mathematical as possible.
160 pages **Order code BP88** **£2.95**

Project Building

ELECTRONIC PROJECTS FOR EXPERIMENTERS
R. A. Penfold
Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different. No doubt many of the projects featured here have practical applications, but they are all worth a try for their interest value alone.
The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.
138 pages **Order code BP371** **£4.95**

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.
132 pages **Order code BP374** **£4.95**

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:
Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.
In fact everything you need to know in order to get started in this absorbing and creative hobby.
135 pages **Order code BP392** **£4.95**

45 SIMPLE ELECTRONIC TERMINAL BLOCK PROJECTS
R. Bebbington
Contains 45 easy-to-build electronic projects that can be constructed, by an absolute beginner, on terminal blocks using only a screwdriver and other simple hand tools. No soldering is needed.
Most of the projects can be simply screwed together, by following the layout diagrams, in a matter of minutes and readily unscrewed if desired to make new circuits. A theoretical circuit diagram is also included with each project to help broaden the constructor's experience and knowledge.
The projects included in this book cover a wide range of interests under the chapter headings: Connections and Components, Sound and Music, Entertainment, Security Devices, Communication, Test and Measuring.
163 pages **Order code BP378** **£4.95**

HOW TO DESIGN AND MAKE YOUR OWN P.C.B.S
R. A. Penfold
Deals with the simple methods of copying printed circuit board designs from magazines and books and covers all aspects of simple p.c.b. construction including photographic methods and designing your own p.c.b.s.
80 pages **Order code BP121** **£2.50**

A BEGINNER'S GUIDE TO MODERN ELECTRONIC COMPONENTS
R. A. Penfold
The purpose of this book is to provide practical information to help the reader sort out the bewildering array of components currently on offer. An advanced knowledge of the theory of electronics is not needed, and this book is not intended to be a course in electronic theory. The main aim is to explain the differences between components of the same basic type (e.g. carbon, carbon film, metal film, and wire-wound resistors) so that the right component for a given application can be selected. A wide range of components are included, with the emphasis firmly on those components that are used a great deal in projects for the home constructor.
166 pages **Order code BP285** **£3.95**

ELECTRONICS SIMPLIFIED – CRYSTAL SET CONSTRUCTION
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.
Especially written for those who wish to participate in the intricacies of electronics more through practical construction than by theoretical study. It is designed for all ages upwards from the day one can read intelligently and handle simple tools.
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PCB SERVICE

Printed circuit boards for certain EPE constructional projects are available from the PCB Service, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, *Everyday Practical Electronics*, Allen House, East Borough, Wimborne, Dorset BH21 1PF. Tel: 01202 881749; Fax 01202 841692 (NOTE, we cannot reply to orders or queries by Fax); E-mail: editorial@epemag.wimborne.co.uk**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only).**

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photostats of articles are available if required – see the *Back Issues* page for details.

Please check price and availability in the latest issue.
Boards can only be supplied on a payment with order basis.

Special KNOCK DOWN SALE of PCBs.

£2.00 EACH inc. VAT and p&p

We have a few p.c.b.s left from past projects these are being offered at the knock down price of **£2.00** each – *no matter what size they are* **(some of these boards are worth over £15.00 each)** while stocks last. This price includes VAT and UK post – overseas orders please add 50p postage (or £1 per board for airmail postage).

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Any of the above for just £2 each inc. VAT and p&p.

Back numbers or photostats of articles are available see the *Back Issues* page for details.

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Simple TENS Unit	MAY'94	875	£5.84
L.E.D. Matrix Message Display Unit **(Special Offer Price)** Boards 870, 871, 872 and 880		870/1/2/80	£18.00
Advanced TENS Unit	JUN'94	877	£6.56
Print Timer	JULY'94	874	£5.82
Watering Wizard		883	£6.60
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Stereo HiFi Controller – 1 Power Supply		886	£5.66
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Pump Controller		890	£5.41
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Dancing Fountains – 2	SEPT'94		
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Seismograph – 2	OCT'94		
PC-Compatible Interface (double-sided)		898	£10.72
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Hobby Power Supply		902	£5.00
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The Ultimate Screen Saver **FEB'95**	927	£5.66
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Audio Amplifier		
Light Beam Communicator (2 boards required)		
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* EPE Met Office – **JAN'96**		
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Mind machine Mk III – Tape Controller	989	£6.70
Midi Analyser	992	£6.74
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EPE SOFTWARE

Software programs for the *EPE* projects marked above with an asterisk (*) are available altogether on a *single* 3.5 inch PC-compatible disk, or as needed via our Internet site. The same disk also contains the following additional software: Simple PIC16C84 Programmer (Feb '96), PIC Disassembler (unpublished).
The disk (order as "PIC-disk") is available from the *EPE PCB Service* at £2.50 (UK) to cover our admin costs (the software itself is *free*). Overseas £3.10 surface mail, £4.10 airmail. Alternatively, the files can be downloaded *free* from our Internet FTP site: **ftp://ftp.epemag.wimborne.co.uk.**

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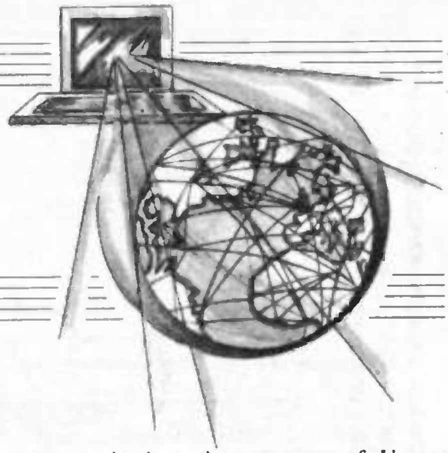
NET WORK

ALAN WINSTANLEY



WELCOME to our page for Internet users! First, an update of developments on our web site: the URL as always is **http://www.epemag.wimborne.co.uk** Now there is a *Back Issues Order Form* which enables you to place orders by E-mail, on line. This method is currently "insecure" until the *Secure Server* is running, but it provides a convenient and *reasonably* safe way of purchasing by credit card. You can browse the form to find out which back issues are available. Also, all you need to know about our *Fax on Demand* service (UK only), is now on **/epeonfax.htm.** Files for the *Earth Resistivity Meter* and *Theremin MIDI/CV Interface* are on our FTP site in the sub directory PICS.

Here is the News

Internet users often hear about "news", but in our context, "news" has nothing to do with reporting current affairs at all! More correctly called *Usenet* (Unix User Network), this system allows like-minded users to circulate topical comments, questions, and a whole lot more, to anyone "subscribing" to their particular "newsgroup".

There are some 20,000 different newsgroups now available covering virtually every topic imaginable. Newgroups do business under such prosaic names as **sci.electronics.basic** or **comp.infosystems.www.authoring, rec.antiques.radio + phono, rec.autos.makers.vw.aircooled,** and a whole lot more besides!

Usenet consists of global E-mail messages circulating around the planet, which will be delivered to the computers of everyone subscribing to those particular newsgroups, whenever they dial up to access the Internet. An individual newsgroup relates to one particular area of interest.

If you're into **alt.music.makers.theremin,** for example, you can raise a question ("start a new thread") and "post" it to that newsgroup. Your question will then be read by every other Usenet reader who subscribes to that same newsgroup. It's a bit like sending an E-mail to every other member of the same club.

Others may respond by posting a "follow up" to your query. You will be able to read this on your own screen when you download the latest news via your Service Provider. Other users too will join in by adding further follow-ups themselves. Thus, the thread develops and branches out, and it's not uncommon for a simple query to explode into a thread containing several hundred follow-ups, all of which you may choose to read on your own screen.

A Soft Line

Software makes life easy. It's very desirable to use an "off-line newsreader" (examples include *Turnpike* and *Forte Free Agent*) which will enable you to quickly dial up the Internet, send and receive news messages, and then hang-up. The act of physically browsing the news on-screen, can be performed while you are disconnected, in order to save the phone bill. You can compose your own follow-ups, off-line, too.

Most groups are unmoderated, so things are a bit of a free for all. Groups have a "charter" which is a mutually-agreed and formal policy of what may and may not be posted there – the idea being to discourage users from clogging up a newsgroup with unwanted or "off-topic" traffic. Very occasionally, things may become unpleasant when tempers fray.

Netiquette

Many newsgroups are discussion groups in which participants have a healthy respect for other readers of the group. The principles of so-called "netiquette" apply, which embrace the generally common-sense rules of courtesy and consideration. Failure to observe such netiquette may attract "flames" – hostile messages from disgruntled Usenet users, both publicly (in the newsgroup) and by personal E-mail! Thus, the system polices itself.

After a complete re-organisation, the structure of Usenet includes the following "top levels":

comp Anything to do with computer software or hardware e.g. **comp.lang.c + +**
news Usenet administration matters, e.g. **news.admin.misc**
rec Recreation, past-times, e.g. **rec.aquaria.marine.misc**
sci Science-related areas, e.g. **sci.agriculture.beekeeping**
alt "Alternative" newsgroups, e.g. **alt.alien.visitors** or **alt.animals.horses.icelandic!**

There are many more groups which were created outside of the formal Usenet structure but which circulate in much the same way. For example, **demon.service** is a place where customers of London-based Demon Internet Services Ltd. can voice their complaints. **Demon.local** is the equivalent of chatting at a bar somewhere in England, and so on. Thus, Usenet offers a fountain of worthwhile information which can help solve many thorny problems.

Usenet has another side which I will briefly mention, if only so that you can steer clear of it if you wish. Given that anything goes on Usenet, "each to their own" is definitely the golden rule. To be honest, whether some people approve of some newsgroups or not, is irrelevant as far as Usenet is concerned – don't subscribe to them if you don't like them.

Some notorious groups include the **alt.binary** and **alt.sex** ones. The "binary" tells you that material including very large binary or executable files (e.g. ***.zip** or ***.exe** files) may be posted there, and a number of groups exist for posting material in the form of graphical images (**.gif** or **.jpg** pictures) and movies, complete with soundtrack. You have been warned!

Usenet can be highly addictive, and before you know it, you are itching to log on again to see if anyone has followed up your own articles. Or you see an article with which you disagree strongly, so you spend an hour composing a reply. Usenet can steal your time and is best used with a strong sense of discipline, or it will take over your life! I strongly recommend "taking" a newsgroup for about two weeks to see what the general level is like, before you dip in with your own articles or follow-ups.

It takes all sorts on Usenet, and you will meet many of them! Both *Netscape Navigator* and *MS Internet Explorer* include a newsreader, and you could dabble by configuring either of them to read news. Have a great time.

Links

Here are this month's selection of links, which are ready-made for you on my *Net Work* page on our web site: *EPE Elysian Theremin* builders should visit Rosedene Audio's site at **http://www.fullerton.demon.co.uk**. Into the MAX038 function generator chip? Try Maxim's site **http://www.maxim-ic.com/** for Maxim application notes (in Adobe Acrobat format). A new and very promising technical data base of more than 70,000 component references complete with data sheets is at web site **http://www.tds-net.com.**

Valve (vacuum tube) fans should drop in on *Tube Dude's Webpage of Vacuum Tube Lore* on **http://www.cdc.net/~gesic**. Manufacturers 4 Q D are heavily into battery motor controllers, electric vehicles etc. and offer a handy resource of circuits and FAQs at **http://www.argonet.co.uk/users/4qd**.

A site of interest for the electronic engineer is to be found at **http://www.worldaccess.nl/~bema**. And finally, readers, a "welcome aboard" to our friends at ***Maplin***, and we wish them well with their new web site on **http://www.maplin.co.uk**. See you soon for more *Net Work!*

My E-mail address is **alan@epemag.demon.co.uk**

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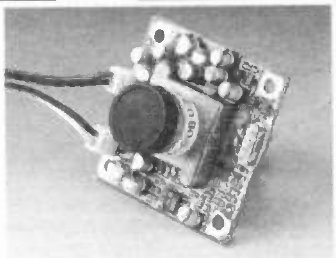

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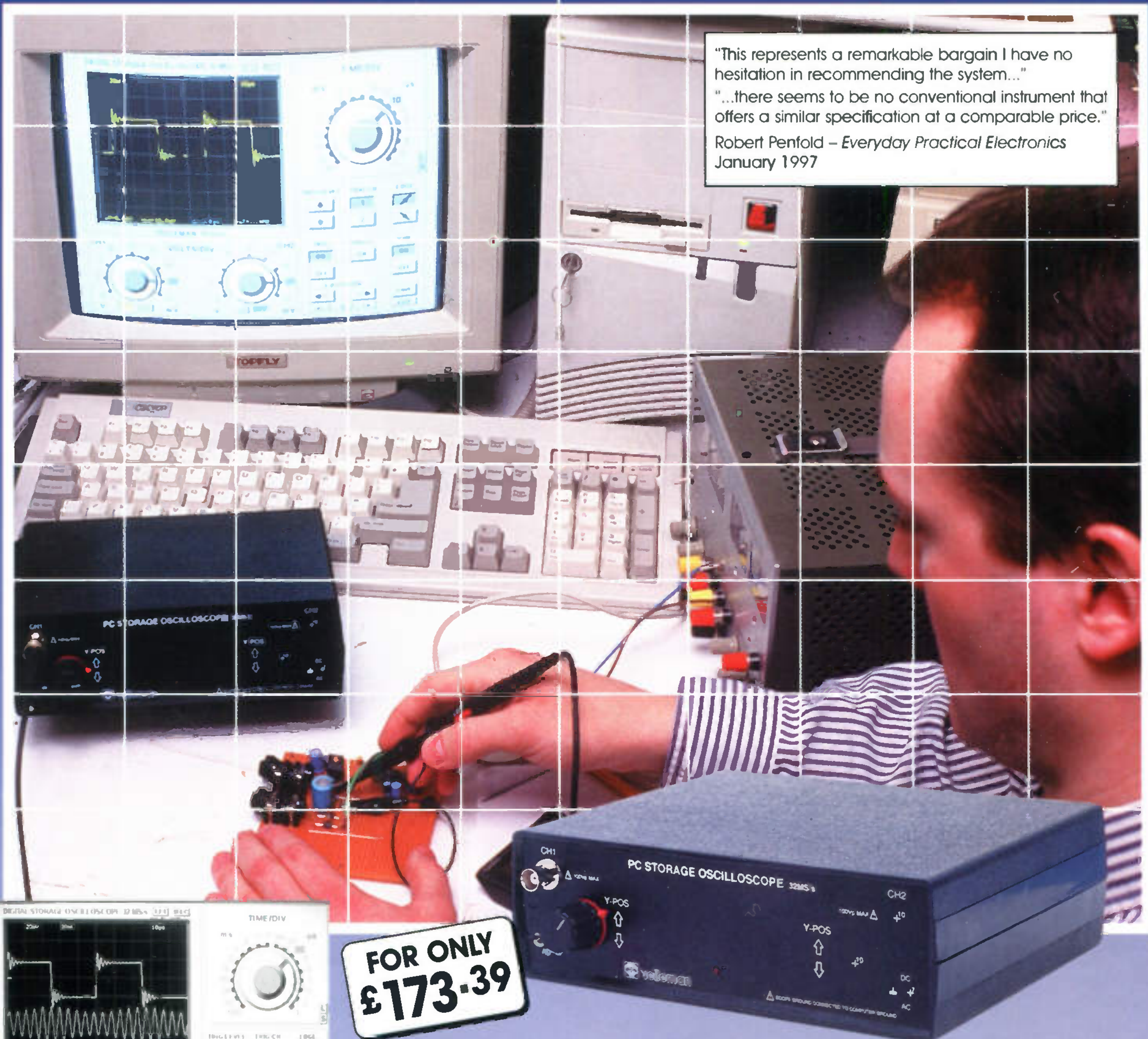

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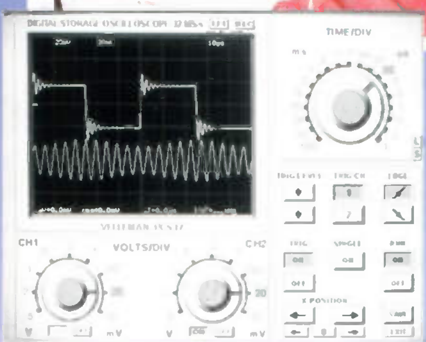

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