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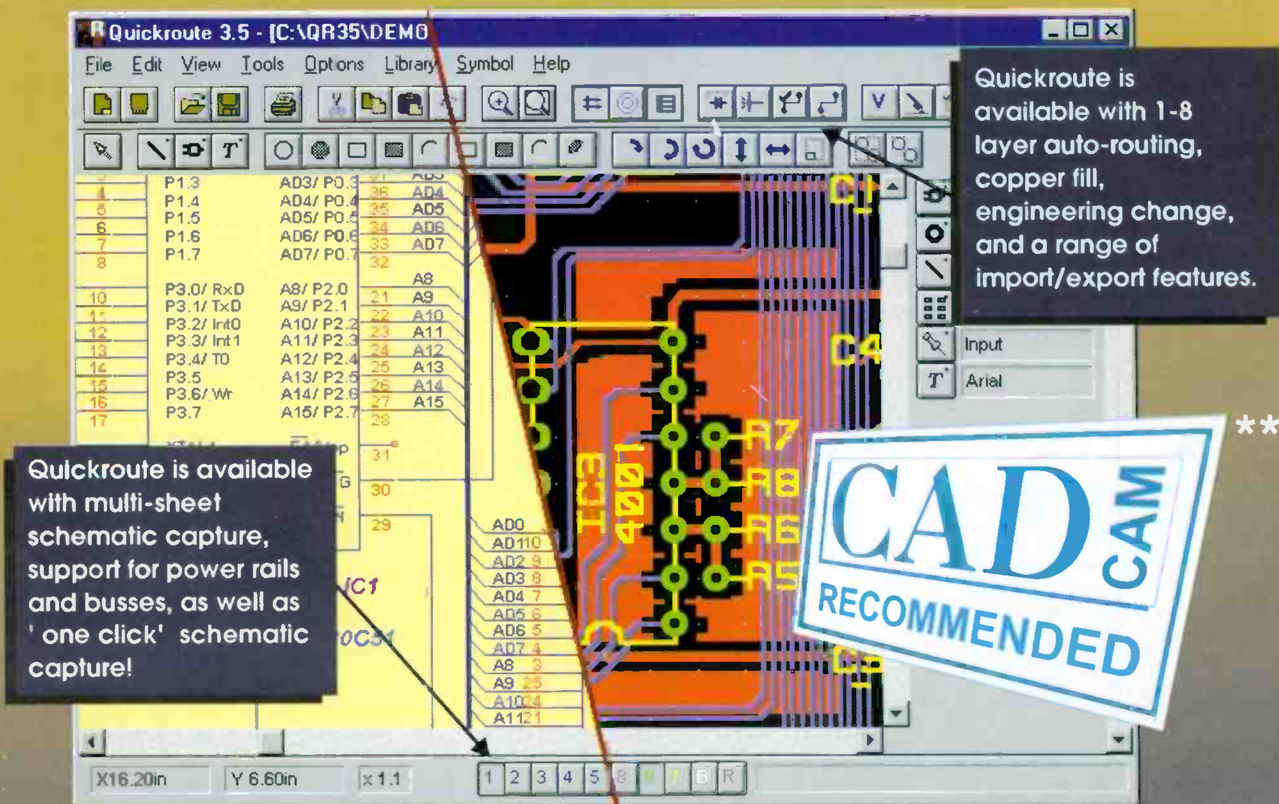

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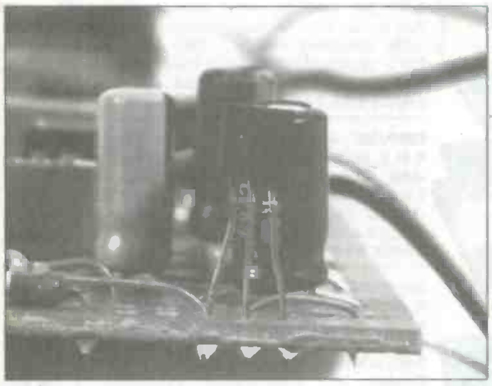

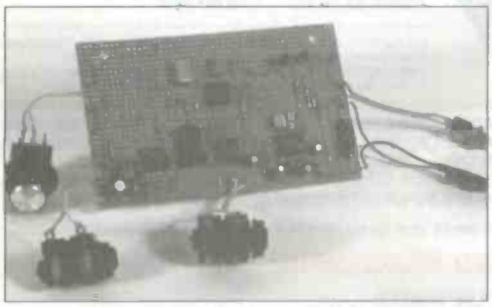

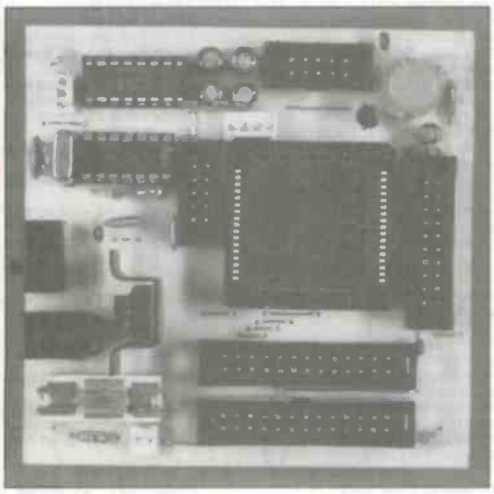

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NEW HIGH POWER MINI BUG With a range of 800 metres or more and up to 100 hours use from a PP3 this will be popular! Bug measures less than 1" square! £28 Ref LOT102

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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.

REMOTE CONTROLTANDATA TD1400 MODEM/VIEWDATA Complete system comprising 1200/75 modem, auto dialler, infra red remote keyboard, (could be adapted for PC use?) psu, UHF and RGB output, phone lead, RS232 output, composite output. Absolute bargain for parts alone! £9.95 ref BAR33

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20 character 2 line, 83x19mm £3.99 ref SM2020A
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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.

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

COMPUTER DISC CLEAROUT We are left with a lot of software packs that need clearing so we are selling at disc value only! 50 discs for £4, thats just 8p each!!(our choice of discs) £4 ref EP66

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

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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

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

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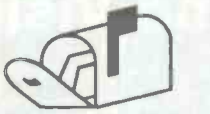
COMPLETE PC 200 WATT UPS SYSTEM Top of the range UPS system providing protection for your computer system and valuable software against mains power fluctuations and cuts New and boxed, UK made Provides up to 5 mins running time in the event of complete power failure to allow you to run your system down correctly. LAST FEW TO CLEAR AT £49 SAVE £30 ref LOT61

BIG BROTHER PSU Cased PSU, 6v 2A output, 2m o/p lead, 1.5m input lead, UK made 220v. SALE PRICE £4.99 REF EP7



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

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.

4.6mw LASER POINTER. BRAND NEW MODEL NOW IN STOCK!, supplied in fully built form (looks like a nice pen) complete with handy pocket clip (which also acts as the on/off switch.) About 50 metres range! Runs on 2 AAA batteries. Produces thin red beam ideal for levels, gun sights, experiments etc. just £39.95 ref DEC49 TRADE PRICE £28 MIN 10 PIECES

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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

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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.

PLUG IN POWER SUPPLY SALE FROM £1.50 Plugs in to 13A socket with output lead. three types available, 9vdc 150mA £1.50 ref SA19, 9vdc 200mA £2.00 ref SA20, 6.5vdc 500mA £2 ref SA21.

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

TALKING COINBOX STRIPPER COMPLETE WITH COINSLOT MECHANISMS originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? SALE PRICE JUST £2.50 REF SA23

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

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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.

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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.

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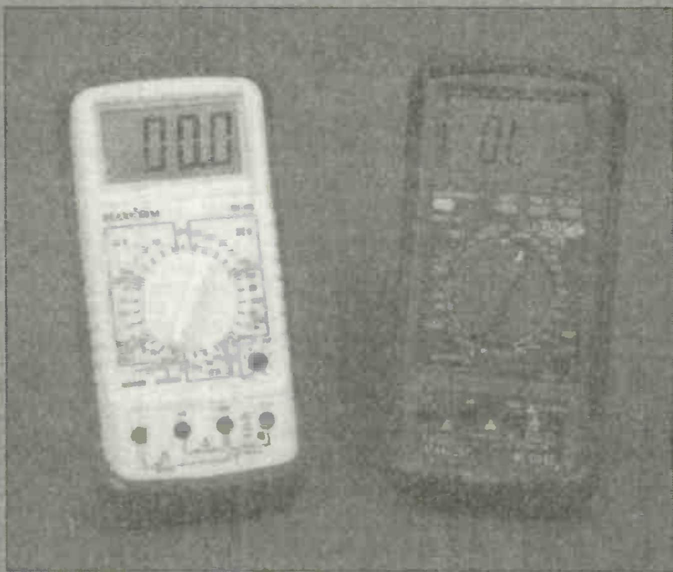
ETI ELECTRONICS TODAY INTERNATIONAL News...

Handheld meter measures capacitance



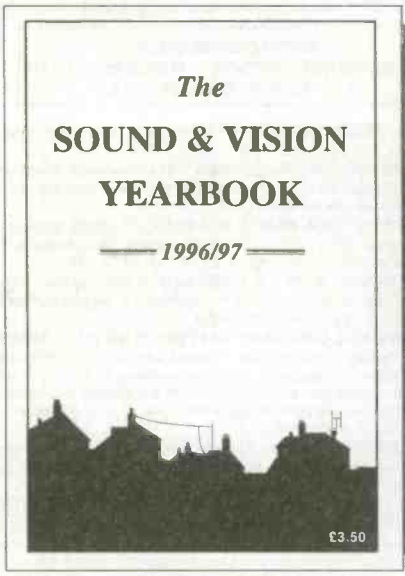
Two new handheld portable multimeters from Vann Draper are good value at £35 and £59 each.

The MX450 (£35) has a large 3.5-digit display and includes an annunciator giving the range and the facility currently in use. The facilities include AC and DC voltage and current with a basic accuracy of 0.6% with data hold; peak hold; capacitance measurement to 200 microfarads; resistance measurement to 200 megohms; logic test; continuity buzzer and transistor range.

The MX620 (£59) is particularly good value in that it has frequency measurement in addition to the other facilities and an increased set of annunciators.

Both meters have full overload protection and double insulated safety jack sockets for the protection of the equipment and the user. The input impedance of both is 10 megohm minimising circuit loading. The meters weigh 10.6 oz each and come complete with two safety probes, battery and a holster.

Vann Draper of Leicestershire at Unit 5, Premier Works, Canal St., South Wigston, Leicester LE18 2PL.
Tel 0116 2771400 Fax 0116 2773945.



Sound and Vision Yearbook

The 1996/1997 Sound and Vision Yearbook is a handy sourcebook for electronics hobbyists and collectors, especially constructors and collectors interested in vintage wireless. By no means only for the historian, however, the yearbook lists clubs, publications, suppliers and general useful contacts in amateur TV, satellite and radio, in-car entertainment, CB, cinema, classic films, computers, cult TV, ephemera, film and TV music, gramophones and phonographs, the Internet, jukeboxes, magic lanterns, offshore and pirate radio, optical toys, photography, pop music, radar, scientific instruments, former state secrets, telephones, vintage radio, weather satellites and x-ray apparatus - to take just a selection of samples from the contents index.

The Sound and Vision Yearbook, edited by Andrew Emmerson and published by Jonathan Hill (author of Audio! Audio!, the guide to classic value amplifiers) costs £3.50 from Sunrise Press, 2-4 Brook Street, Bampton, Tiverton, Devon EX16 9LY.
Tel 01398 331532

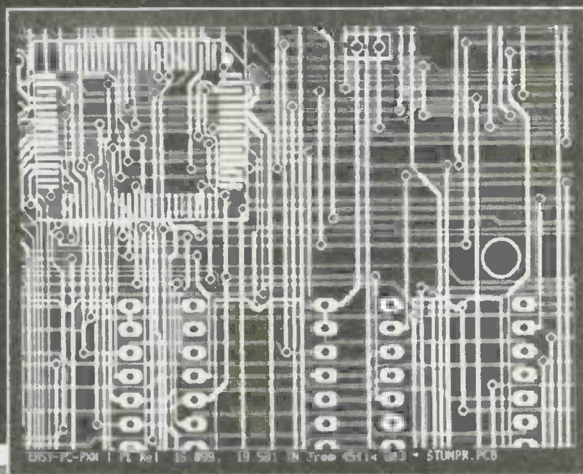
MicroP Course in Manchester

The Manchester Metropolitan University is running a short introductory course to designing with microcontrollers, based on the Arizona PIC16C54 microcontroller. The course requires no previous knowledge of microprocessors, microcontrollers or assembly language, but some knowledge of logic gates is useful. The course covers specification of the microcontroller, the instruction set, programming and building a circuit on a custom project board. The cost is £125, which includes a reprogrammable 16C54 and prototype board. Further courses based around other PICs are planned, and courses run year-round, including the summer.

For more details contact Course Tutor Dave Smith. Tel 0161 247 5437. Fax 0161 247 6377. Email D.W.Smith @ mmu.ac.uk at the Manchester Metropolitan University, Alsager Campus, Hassall Road, Alsager, Stoke on Trent ST7 2HL.

Multirouter is fast, cheap and smart

Multirouter is a fast, low-cost autorouter for Number One Systems popular Easy-PC Professional XM PCB CAD package. Multirouter aims to "get tracks through the design where other autorouters fail", using the latest fine-line routing technologies. Using gridless routing enables difficult components like D-connectors and surface mount packages to be included while making the maximum use of available space. The routing algorithm used is shape-based, referring to the chosen design rule clearances and track width limits as the only limitations on its routing. As each net is routed, existing tracks are moved over, or "shoved aside" as Number One Systems vigorously put it, to make more room, and if all routes appear to be blocked, Multirouter will perform a "rip up and re-try" in problem areas until a solution is found. Multirouter uses multiple-passes to organise a route through a difficult board allowing layout constraints to be altered and adjusted according by the user quickly and tried again until 100% routing is achieved if this is physically possible. Manual routing and autorouting can be combined, giving the user maximum control of the board design.. Once the nets are routed, Multirouter performs smoothing passes to widen tracks wherever possible, mitre corners to 45 degrees to minimise high frequency signal reflections, and eliminate unwanted track segments and vias. Via holes can be compelled to a grid for users who need a design capable of automatic testing, and routes can be specified to change board side only where there are component pins, to remove the need for plated vias where necessary. Multirouter handles surface mount shapes on both sides of the board, and repetitive memory arrays.



Number One Systems also offers lifetime support and free upgrades for six months. Multirouter costs £295, and works with EASY-PC Professional XM (£245). Prices are UK, ex carriage and VAT. USA prices are £305 (US$575 including airmail) and £255 (US$475 including airmail). For information contact Roger Wareham Tel 01480 461779 email rmw@numberone.com.

Memory book on CD-ROM

Hitachi has updated its CD-ROM product databook to include data on all the company's microcontroller and memory products. The disc will allow flexible searching of all the data, as well as the speed, shipping and storage advantages of CD-ROM. If a developer is concerned about specific parameters in a set of devices, the search facility will list all devices that are suitable, and print out datasheet if required. Information on the ROM is displayed as text, graphics and photos in a hybrid CD-ROM format readable by Macintosh and Windows users. Current CD-ROMS use Adobe's Portable Document Format (PDF) which allows documents to be read by Windows, DOS, Macintosh and Unix systems, and used directly on the World Wide Web. The increasing move to CD-ROM is part of Hitachi's programme to get the company's product information distributed to as wide an audience as possible. Information from Vince Pitt, Hitachi Europe Ltd., Whitebrook Park, Lower Cookham Road, Maidenhead, Berks SL6 8YA. Tel 01628 585163 Fax 01628 585160.

In Short

RADIO-TECH now has a World Wide Web site on the Internet at HTTP://WWW.RADIO-TECH.Co.UK. You can look at new products and data sheets, enter competitions, join in customer surveys, access their overseas distributors list and place orders by email. Tel 0181 368 8277 for any other information. The 1996 National Vintage Communications Fair is on at Wembley Conference Centre, London, on Sunday 1st December from 10.30am to 4pm. Admission is £5 (under-14s are free). About 300 dealers and collectors from Britain and Europe are currently expected to be exhibiting at the fair. For more information contact Jonathan Hill Tel 01398 331532. The Public Domain and Shareware Library - Software Reference Guide issue 21 supplement 1 costs £1.95 and lists hundreds of low-cost programs on disk or CD ROM.

The list includes technical drawing, spreadsheets, CAD, communications utilities and games, among others. Shareware is a good way of building up a library of starter software at low cost. Winscome House, Beacon Road, Crowborough, Sussex TN6 1UL. Tel 01892 663298 Fax 01892 667473 BBS (8n1) 01892 661149. The Bull Electrical Newsletter issue 961 is now out. Featuring unusual kits, fascinating devices and some down-to-earth practical items like batteries, air rifle shooting and sighting equipment and surveillance telescopes, the newsletter is available from Bull Electrical Tel 01273 203500. See also advertisements in this issue of ETI.

William Hughes Ltd. of Dorset have brought out a new range of gass bead test-points and PCB terminals for the easy testing of prototype boards. The glass beads provide a colour-coding, and the choice of shapes gives a close fit to the board without damaging plated through holes. This type of test point can also be used as a soldering base for high-temperature and often-replaced components. There are three sizes and eight colours available. Tel: 01963 363377.

Amateur bands worry

Radio amateurs in the USA are concerned because wavelengths within the 2-metre and 70-cm bands have appeared on a Government report as possible frequency allocations for low earth orbit communications satellites.

Both the ARRL and the RSGB report that they are not at present very worried that heavily-used amateur bands will be lost in the USA or the UK. The ARRL, however, is concerned enough to have asked amateurs in the USA to make their voices heard in defence of the 2m and 70cm bands, which are among the most widely-used. by amateurs. In Europe 433.92MHz (in the 430 to 440MHz amateur band) is allocated to keyless entry systems for cars and industrial applications in some European countries. It has been reported that in some cases when cars have been parked near repeater sites, it has been impossible to disarm the alarms or immobilisers.

The insistence of the authorities that the frequency allocation will not be revised has caused concern in the industry, as well as urgent receiver selectivity improvement. Newspaper reports have blamed radio amateurs for the problems, though the choice of frequency allocation for keyless entry was not theirs. There is now increasing disquiet among amateurs at rumours of the possible curtailing or removal of allocations on 2m and 70cm in Britain and Europe.

MODS MODS MODS MODS

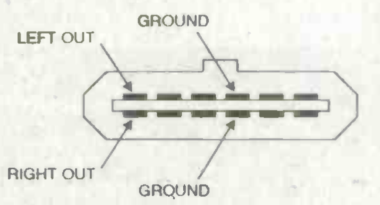
High Voltage Electrolytic Capacitor Reformer July 1996

On the circuit diagram: R4 = 100R, 2.5W D4 = 1N5374B 75V zener. The text below M1 = "Voltage reading *1 0 = output current (mA)."

Computer Game Headphone Adaptor July 1996.

On the circuit diagram, C201 should be connected between the +13V and the 0V rails, and C202 between the -13V and the 0V rails. On the circuit board layout (figure 2) move two tracks to the right: cathode D202/anode D201; cathode D204/anode D203; all the leads from the transformer(9V/0V/9V).

The article shows the Sega Megadrive socket. The instructions are also for the SNES socket, shown below:



Overseas Readers

Tel To call UK telephone numbers, replace the initial 0 with your local overseas access code plus the digits 44.

Valve radios restored

"Valve Radio Restoration" author Paul Stenning has compiled a list of suppliers to help radio restorers.

Dealers and services

- "Anode Electronics: 80D Hyde Park Road, Plymouth, PL3 4RQ. My usual supplier of valves, components, spares and related items - a vast range is available. Valve radios bought and sold. Manufacturer of the Stenode Battery Eliminator, for battery powered valve sets. Please write for details, enclosing SAE.
- "S.W. Chaplin - 43 Lime Avenue, Leigh on Sea, Essex, SS9 3PA. Traditional Loudspeaker Cloth. A good range. Send £1 for samples.
- "Paul Stenning, 1 Chisel Close, Hereford, HR4 9XF. I do valve radio repair and restoration and valve testing. Some components available. No lists are produced, so please write with SAE.

Magazines (subscription only)

- "405 Alive - Magazine and enthusiasts group: Andrew Emmerson, 71 Falcutt Way, Northampton, NN2 8PH. Vintage television
- "British Vintage Wireless Society: c/o Alan P Carter, Lime Tree Cottage, Loxhill, Hascombe, Godalming, Surrey, GU8 4BQ.
- "Radio Bygones: Geoff Arnold, 9 Wetherby Close, Broadstone, Dorset, BH18 8JB. Vintage wireless magazine, covering mainly military and communications equipment.
- "Radiophile: Chas Miller, 'Larkhill', Newport Road, Woodseaves, Staffs, ST20 0NP. Vintage wireless magazine, covering domestic sets. Technical and historical information, plus some lighthearted moments.
- "Radio Review: P.O. Box 46, Romford, RM1 2QE. Regular newsletter style publication covering modern broadcasters, pirate radio, listening figures, and related news and gossip.

Clubs and Groups

- "Sound & Vision Yearbook: Sunrise Press, 2-4 Brook St., Bampton, Devon EX16 9LY. Tel 01398 331532. Hobby and heritage directory for collectors of sound and TV technology. Annual.
- "Vintage Radio Circle (Swindon area): c/o M Williams, 28 Barton Lane, Cirencester, Gloucestershire, GL7 2EB.

Museums

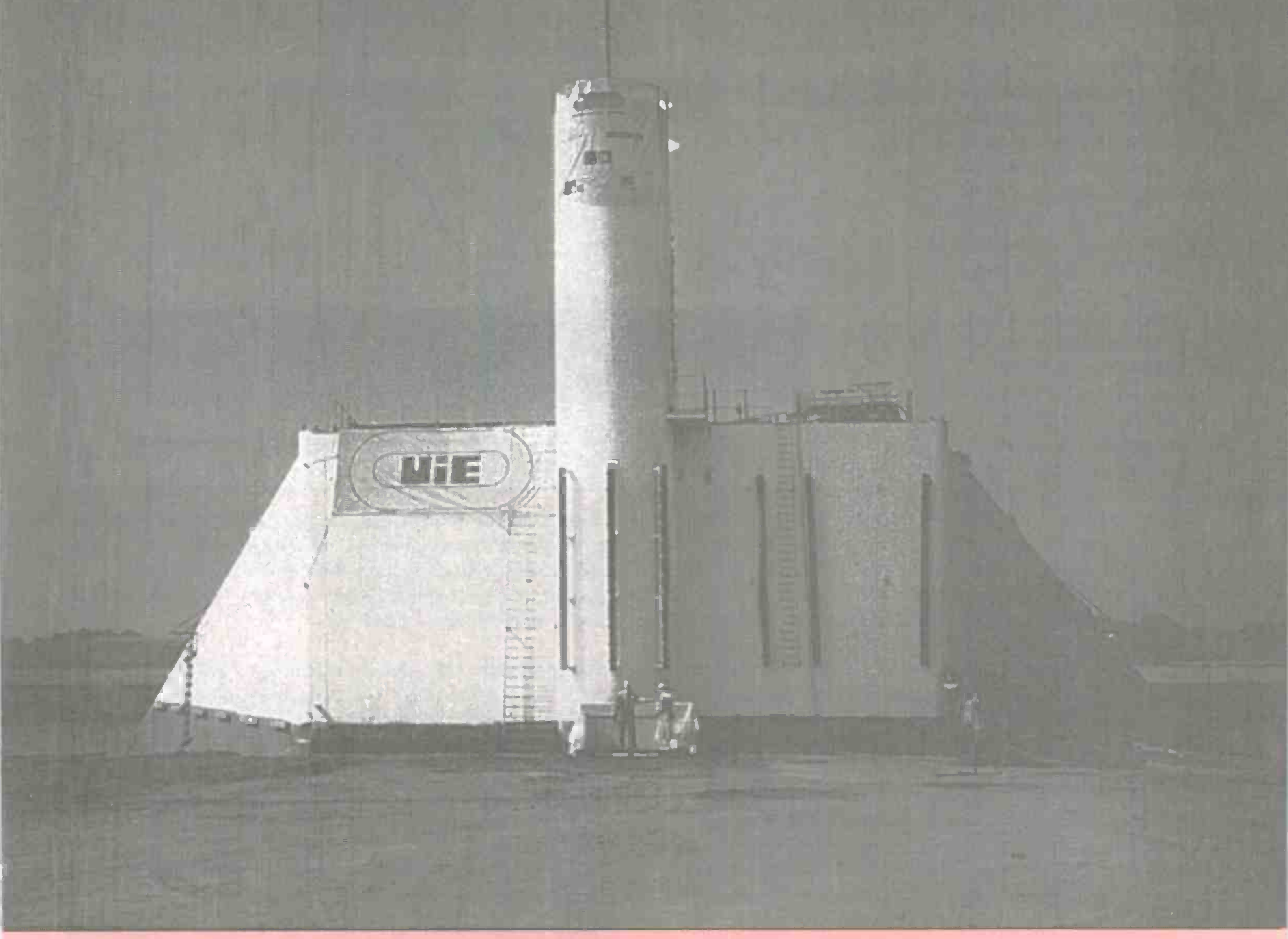
- "Vintage Wireless Museum, 23 Rosendale Road, London, SE21. Tel 0181 670 3667. Visitors welcome by appointment only.
- "Lindfield Vintage Wireless Museum, Old Brewery, 53 High Street, Lindfield, West Sussex. Tel 01444 484552. Telephone for opening times.
- "On the Air: 42 Bridge Street Row, Chester. Sets bought, sold and repaired. Museum.

Woodcare products

- Colron: Sterling Roncraft, 15 Churchfield Court, Barnsley, S70 2LJ. Manufacturer of woodcare products for furniture restoration, available from most DIY stores. Write for details of full range.

Information correct at the time of writing. No liability is accepted for the outcome of any dealings.
Corrections and additions are welcomed.

Figure 10: ART Osprey at launch



The Life in the OCEAN WAVES

Douglas Clarkson describes how the world's undervalued wave resources are being investigated

While techniques of using wind power as both a means of ship propulsion and as a land based power source via windmills have a relatively long documented history, the era of obtaining power from ocean waves is only a few decades old. Also, while the technology challenges of solar photovoltaic and wind power are relatively well defined and appreciated, the intricacies of wave power have revealed a new and intriguing area of endeavour.

The field of wave power is already diverse and numerous designs have been devised and tested at a computational or wave tank level though relatively few designs have been built as demonstrational systems. It is not possible to cover all the lines of investigation being pursued though it is hoped that this article will give a flavour of the current initiatives.

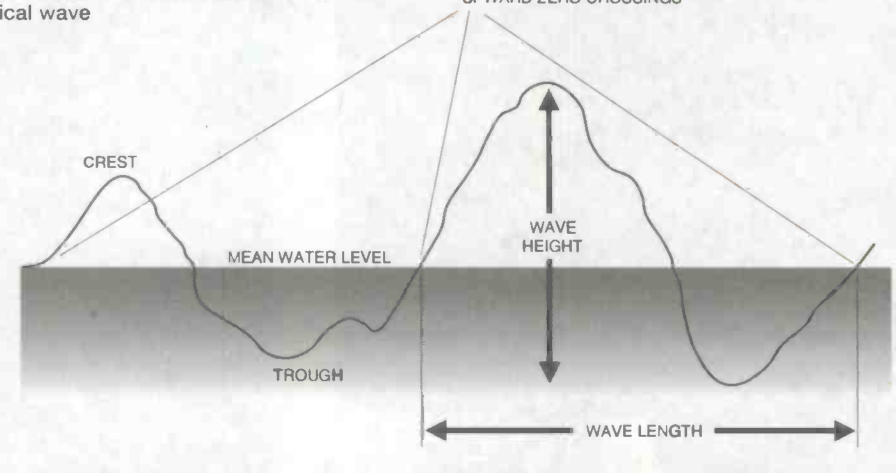
All about waves

It can be said that the best way to understand wave power is to understand waves. Reviews of wave studies have given credit to Thomas Stevenson, the father of Robert Louis Stevenson, for pioneering work in the study of wave heights around the coasts of Britain. This was in many ways natural, since as a builder of lighthouses and harbour defences, it was appropriate for him to assess the worst sea conditions to which such structures could be subjected. Waves are, of course, principally derived from the wind and can also be considered as a means whereby wind energy becomes stored in another energy form. As the wind blows on the surface of water, it causes the surface layers to move. The exact mechanism of wave generation is unclear. The role of thin layers of chemical agents, natural and man-made, is thought to have a significant effect in coupling wind action into wave energy. The restoring force for wave motion is gravity. Surface tension effects apply only to waves of much smaller amplitude. The raising of water above a mean level causes gravity to restore the water level and, as a result, the water level accuires a sinusoidal motion.

The size of waves produced depends on the 'fetch' or distance over which the waves are blown. The dimensions associated with a typical wave are indicated in figure 1. The expression widely used In wave studies is 'significant wave height'. This is taken as the mean value of wave height of the highest 1/3 of all waves present in a sample series. In this context, a wave height is the distance crest to trough.

Linked to this definition is the significant wave period, which is the mean period of the waves involved in the significant height definition. Wave data can be displayed in a variety of forms. For many conventional purposes, a display of wave height alone is adequate as indicated in figure 2, where the significant and maximum wave heights are referenced. In this format, the percentage exeedance is the percentage of observing time during which the specific wave height is exceeded. Table 1 provides data relevant to wind speed, the 'fetch' or distance over which the wind blows and the corresponding wave height.

Figure 1: Structure and definitions of the typical wave



Wind Speed	Beaufort	fetch	significant wave height
(m/s)	Scale	km	approx.(m)
5	3	250	0.6
5	3	500	0.7
5	3	1000	+ 0.8
10	5	250	1.7
10	5	500	1.9
10	5	1000	2.0
15	7	250	3.25
15	7	500	3.5
15	7	1000	3.7
20	8	250	5.1
20	8	500	5.5
20	8	1000	5.8

Table 1 (below left): Variation of significant wave height as a function of 'fetch' of wave and wind speed in metres per second and also corresponding Beaufort Scale value. (Conversion factors relevant are 1 knot = 0.5144 m/sec and 1 nautical mile = 1.852 km.)

For moderate to high winds, most energy is picked up in the first 250 km of the 'fetch'. Over long values of 'fetch' this produces a limiting wave height with a given wind speed. The wave climate, therefore, is a complex interaction of wind speed, direction and duration. Waves created by a storm can readily propagate out of the area of immediate adverse weather as 'swell' and influence sea conditions thousands of kilometres away.

Typical data for waves in deep water is shown in table 2. Thus longer waves travel faster.

Period (T) seconds	1	2	4	8	16
Wavelength (m)	1.56	6.2	25.0	100	400
Wave speed (m/sec)	1.56	3.1	6.2	12.5	25.0

Table 2: Characteristics of deep water waves.

At a location remote from a storm, it will tend to be the largest waves that will arrive, followed by waves of lesser size. Also, it tends to be the waves of shorter wavelength that are dispersed more readily as they dissipate their energy while propagating.

Waves of longer period, for example storm waves with period around 15 s which are generated in the Atlantic, have their energies diminished as they approach the shore due to the

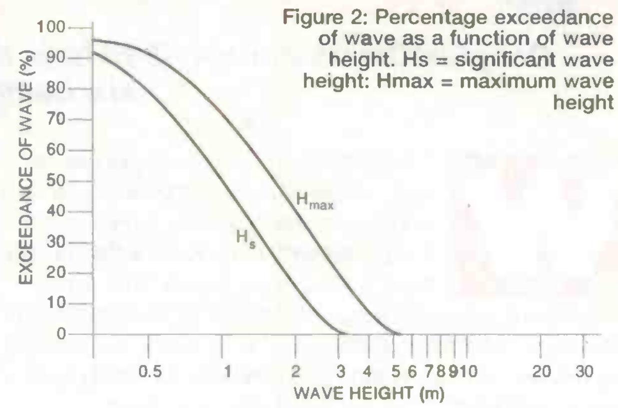


Figure 2: Percentage exceedance of wave as a function of wave height. Hs = significant wave height: Hmax = maximum wave height

Figure 3: Variation of wave power per metre of wavefront as a function of wave height for specific values of wave period.

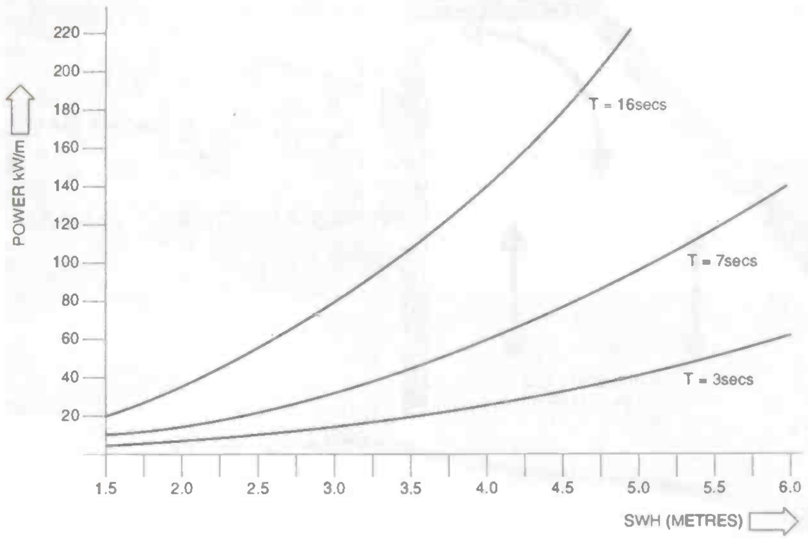
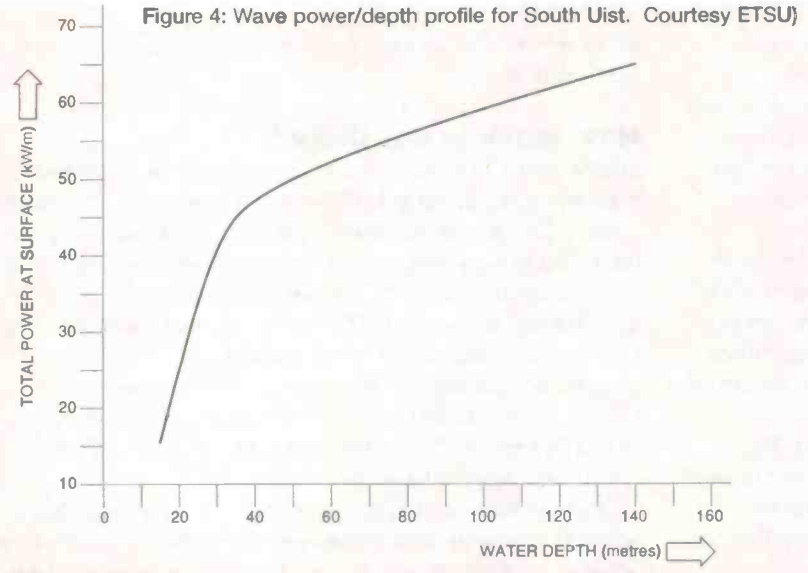


Figure 4: Wave power/depth profile for South Uist. Courtesy ETSU)



mechanism of seabed friction. A wave of 4 metres and period 15 s will be begin to disturb fine sediments on the sea bed at a depth of 140 metres. This is why there is specific interest in wave power technology in seeking to abstract power from ocean waves in deep water where wave energies are greater.

The power in the wave

Within a wave, energy is exchanged between potential energy of gravity and kinetic energy of motion. At the boundary of a wave on the sea floor, the motion of water is oscillating backwards and forwards. In higher sections of the wave, the motion of water particles is elliptical. Over recent years, the basic properties of waves has been rigorously investigated in order to determine the most efficient and effective means of abstracting the power that is present.

The power in a wave can be expressed as :-

$$P = 0.55\ H^2\ T\ kW/m$$

where H is the significant wave height T is the period of the wave in seconds.

Thus, the term varies as the square of the wave height and the period of the wave. Figure 3 shows the variation of power per meter of wavefront as a function of wave height for specific values of wave period. The actual distribution of wave amplitudes and periods, however, will tend to vary from one wave to the next. It will only be with a well-defined dominating swell or a continuous local wind-generated wave pattern that waves will be regular and 'well behaved'. Thus, very high waves from a distant storm will propagate with a characteristic velocity and wavelength with the amplitude slowly reducing with distance of propagation. This can be imagined in the graph as sliding down the contours from right to left for waves of a specific wavelength.

The energy reserve

Estimations of available energy from wave power have come from extensive analysis of wave data. Prior to the launch of satellites, wave data had been collected primarily by weather ships and specialist observing stations. In relatively shallow water; one simple method is to mount a pressure recorder on the sea bed and record the variations in pressure as waves of different heights pass over the observation site. In a more recent development, buoys tethered on the sea bed transmit their positional perturbations via radio link. A long-standing method for deep sea vessels was to combine an underwater pressure monitor with an accelerometer to obtain relative wave height. Satellites such as ERS-1 and ERS-2 have the ability to scan almost all of the world's oceans at regular intervals to provide much more extensive wave height data. Such global surveys provide insight into the global distribution of wave energy. The southern oceans have the highest mean significant wave heights at around 4.75 m in winter and 4.5 m in summer. In the North Atlantic the corresponding figure for winter is 4.5 m and 2.0 m for summer.

The 50 year wave

All ventures that are at the mercy of the sea plan for the largest waves that might be expected. This is of crucial importance for ship design and off-shore oil and gas installations. This wave size is often referenced as the 50 year wave. In terms of probability, it is the largest wave that is likely to be produced in a storm that lasts 12 hours within a 50 year time period and corresponds to a relative probability of 0.0000274. This value can readily be predicted from analysis of wave date of one or two years at a specific site. In the North Sea, values range between 15 and 25 metres. In the Atlantic west of the Outer Hebrides, the 50 year maximum wave height is estimated to be 35 m. Such freak waves, however, tend to exist not as a single entity but as the reinforcement in a moment of time of a multitude of individual waves of varying heights and wavelengths - after the fashion of constructive wave interference. Such apparently robust predictions, however, should be treated with caution. Recent studies, especially in Norway, indicate that storm frequencies have significantly increased during the 1980s and that, consequently, 50 year wave predictions may have to be increased.

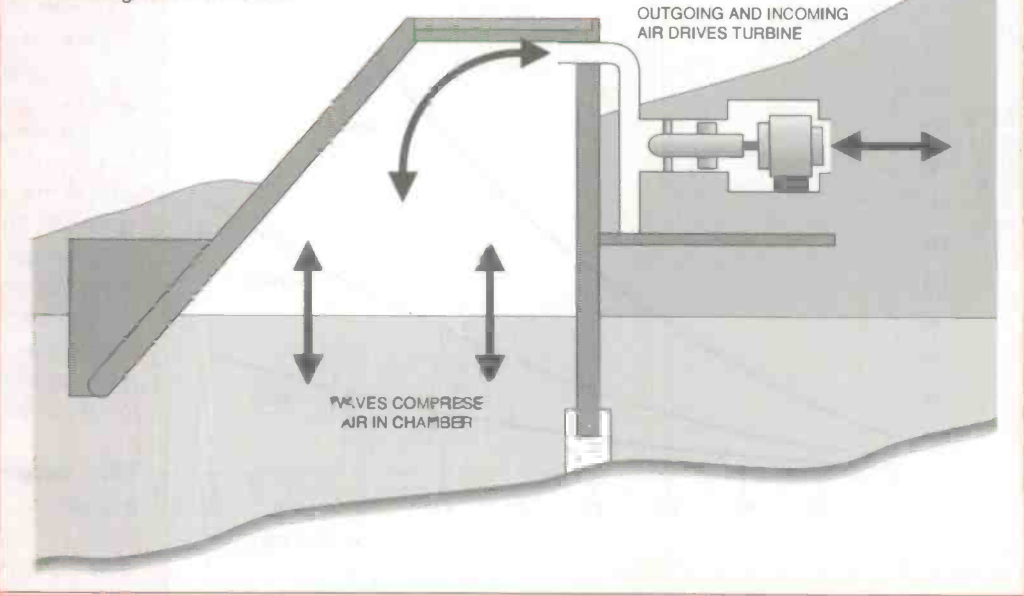


Figure 5: Design of the Islay Oscillating Wave Converter

Mapping the UK wave energy resource

A key aspect of any future utilisation of wave energy is to accurately evaluate the size of the resource. An 18 month project was initiated in 1989 to assess the near shore (around 20 m depth) and shoreline (5 to 10 m depth) of the UK's western seaboard. Assessment was carried out by the Queen's University of Belfast and chiefly used the Meteorological Office's wind-wave computer model in association with actual data from wave observational sites. The effect of sea depth was introduced by means of data from Admiralty Charts. While the annual power density of waves in the North Atlantic in more than 100 m of water is approximately 70 kW/m, the available energy decreases progressively with reducing water depth. This effect is principally due to sea bed friction.

Figure 4 indicates the wave power/depth profile for South Uist. In the favourable wave climate of the western side of the Outer Hebrides, the near-shore power density falls to around 20 kW/m. The location of shoreline or near-shore installations needs to be carefully researched in order to locate schemes at optimised sites.

The full contractor's report is available from ETSU. The combinations of wave direction, topography of sea and ocean bottom, alignment of cliffs etc can interact to produce so-called 'hot spots' or areas of heightened wave activity. Factors of two or three can be introduced by this mechanism.

In coastal landscapes for example, the location of gullies tend to coincide with area of heightened wave activity, with the shore line becoming eroded where it is subject to higher wave activity. Also, such areas tend to coincide with areas of active fishing.

How much is out there?

In estimations of levels of wave power available, consideration is usually given to the good sites of wave energy off the North West of Scotland where energy densities in excess of 50 kW per metre of wavefront are estimated to be present. Assuming a total collection length of 400 km and an efficiency of 30%, then this corresponds to 6000 MW or about 10% of the UK's total current installed generation capacity.

With the inclusion of other localities, such as west of Cornwall and possible improvements in conversion efficiencies, values as high as 25% of the UK's total current installed generation capacity have been referenced.

There is also, no doubt, the potential to collect significant amounts of energy off the West coast of Ireland. It is very clear, however, that the UK has the most significant reserves of wave energy in Europe and hence the most to gain from developing them. At a global level, the resource is estimated at 400 GW.

In terms of recovering successfully such a large energy resource, it will tend to be technology and not environmental sensitivity (as with windfarms) that will be the limiting factor. Wavepower is therefore a vast engineering challenge. As device efficiencies improve, however, then the size of the available resource will increase also.


Figure 6 View of Islay OWC showing column structure, turbine housing and switch plant (Courtesy ETSU)

On-shore, near-shore and off-shore

With on-shore systems, such as the Oscillating Water Column system, the generating unit and associated grid connection is land based. Access for construction and maintenance is relatively convenient. Near-shore systems would generally be in water up to 40 m depth but reasonably accessible for maintenance and power take off. Off-shore systems, however, while able to access potentially greater levels

Continued on p. 14

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BU126	65P	BU508D	90P	IRF610	150P	MJE15029	200P
BU133	125P	BU508DF	115P	IRF630	150P	MJE15030	250P
BU137	150P	BU508DR	130P	IRF640	400P	MJE15031	400P
BU180	100P	BU508V	110P	IRF730	175P	MJE18004	125P
BU184	100P	BU508VF	100P	IRF740	400P	OC28	350P
BU204	65P	BU801	70P	IRF820	150P	OC29	250P
BU205	70P	BU806	70P	IRF830	225P	OC35	350P
BU206	100P	BU807	60P	IRF840	200P	OC36	250P
BU207	150P	BU2508A	130P	IRF9530	400P	S2000A3	175P
BU208	70P	BU2508AAF	130P	IRF9540	300P	S2000AF	175P
BU208A	75P	BU2508D	130P	IRF9610	200P	S2055A	175P
BU208AT	200P	BU2508DF	150P	IRF9620	225P	S2055AF	200P
BU208D	130P	BU2520AF	225P	IRF9630	325P	2N3053	18P
BU209	90P	BU2520DF	225P	IRF9640	375P	2N3054	40P
BU225	120P	BU2525AF	325P	IRFBC30	200P	2N3055	38P
BU226	120P	BUH315	200P	IRFC40	400P	2N3055H	50P
BU312	90P	BUH515	200P	MJ2501	100P	2N3440	45P
BU325	55P	BUH517	275P	MJ2955	55P	2N3441	175P
BU326A	75P	BUH715	425P	MJ15003	250P	2N3442	85P
BU406	60P	BUT11AF	55P	MJ15004	300P	2N3771	85P
BU406D	85P	BUT12	80P	MJ15015	250P	2N3772	90P
BU407	55P	BUT13	310P	MJ15016	350P	2N3773	100P
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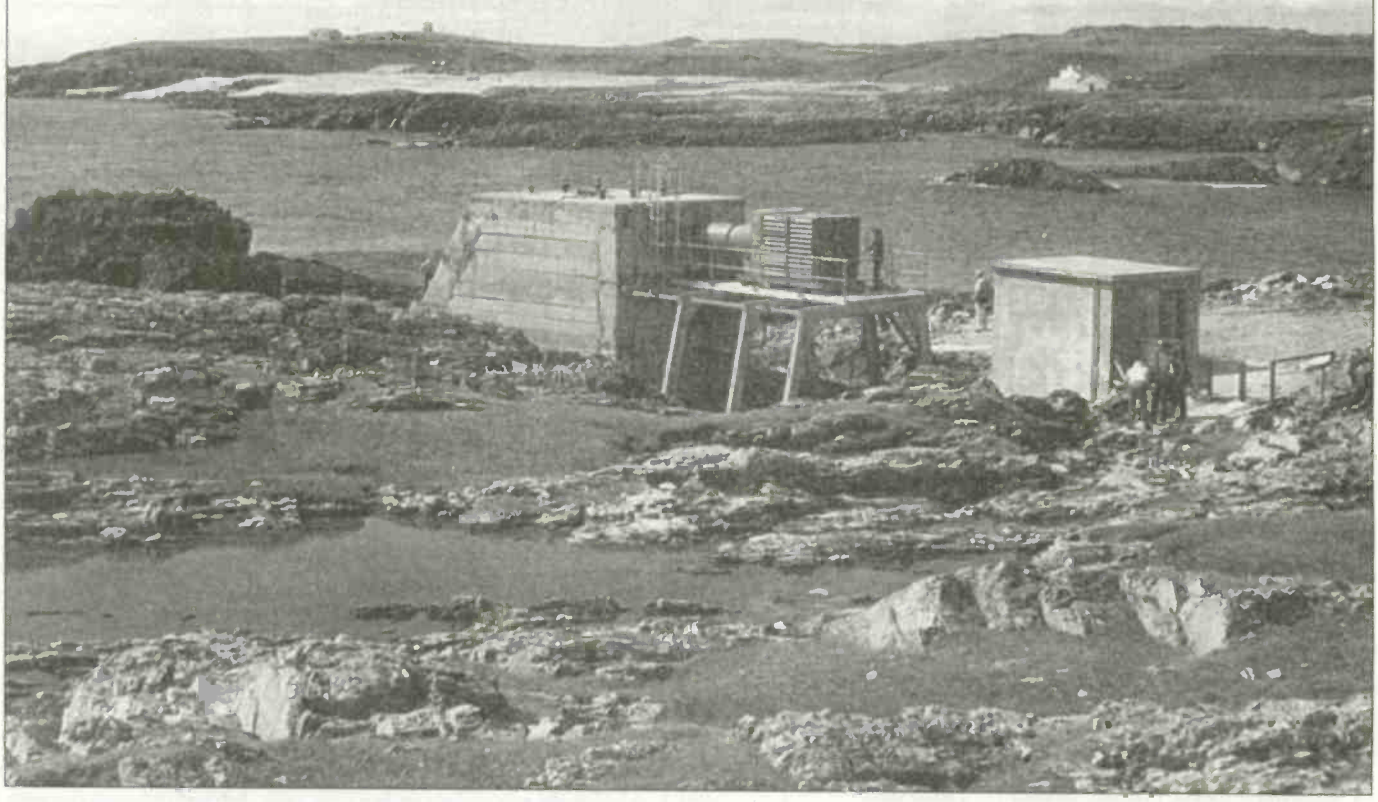
Figure 8: View of Wells turbine of Islay System during construction (Courtesy ETSU)



Continued from p. 12

wave activity, are more at the mercy of all vagaries of the weather. Some off-shore systems are designed to operate in a submersed mode and so are less vulnerable than surface floating constructions.

Environmental considerations

Studies of wave power systems have anticipated generally positive environmental impact. Coastal erosion would, for example, be reduced behind off-shore devices. Marine colonies could also find the relative shelter of off-shore structures a benefit. There would also be safer conditions for shipping and fishing.

Mechanisms of wave energy conversion

What is apparent in the field of wave energy is the range of energy conversion devices. It makes sense, however, to describe initially the most widely used device so far, the Oscillating Water Column (OWC) for on-shore and near-shore systems.

The Islay Oscillating Water Column

A device such as that shown in figure 5 represents a system currently operating on the Isle of Islay. The water level in the chamber rises and falls due to wave action and outgoing and in coming air is driven through a Wells turbine.

This design of turbine allows air with oscillating velocity to drive the turbine in a constant direction and was invented by Professor A. Wells of Queen's University, Belfast.

Construction of the Islay wave station was begun in 1987 with the unit being connected to the grid in early 1991. In good conditions, the station generates around 20 kW, though in better conditions around 50 kW can be produced. Figure 6 shows the system on the Islay shoreline and figure 7 the system as viewed from the adjacent shore. Figure 8 shows the Wells turbine during construction work.

It was the successful implementation of a similar wave power system in Norway during 1985 that rekindled interest in wave power within the UK context and subsequently also within a wider European framework.

Systems such as the one at Islay have not only to cope with the anticipated greatest wave heights, but it also has to cope with the tidal variations. Such Oscillating Water Columns would be simpler to build in areas with smaller tidal variations and, in fact, systems have been installed in islands in the Pacific - by Norwegian companies. Here, perhaps, is a clue to an underlying economic reality within the wave power scenario.

The efficiency of the Islay system has been less than anticipated. This, however, has been partly attributed to the roughness of the sides of the gully along which waves are propagated. Also, the tidal currents tend to reduce wave amplitude. The Islay system, however, has been built as a demonstration project and has provided extensive data to enhance efficiencies of future systems. In particular, it is now appreciated that the constructing of 'harbour walls' could enhance the efficiency of such systems by a factor of four as wave energy from a wider aperture is collected and converted.

ART Osprey

It is, of course, understood that there is more in the way of wave energy off-shore. One of the main difficulties to deep water implementation of OWCs is that the whole structure would tend to bob up and down with the waves and so efficiency would be significantly reduced. Also, exposed structures would be vulnerable to large seas.

A compromise system would be to develop a device that was seated on the sea bed in relatively shallow water and which could tap into the higher wave energy off-shore compared to an on-shore based device.

This was the concept behind the development of Osprey - Ocean Swell Powered Renewable Energy. The final design of

Continued on p. 16

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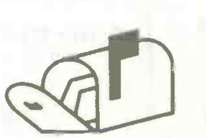

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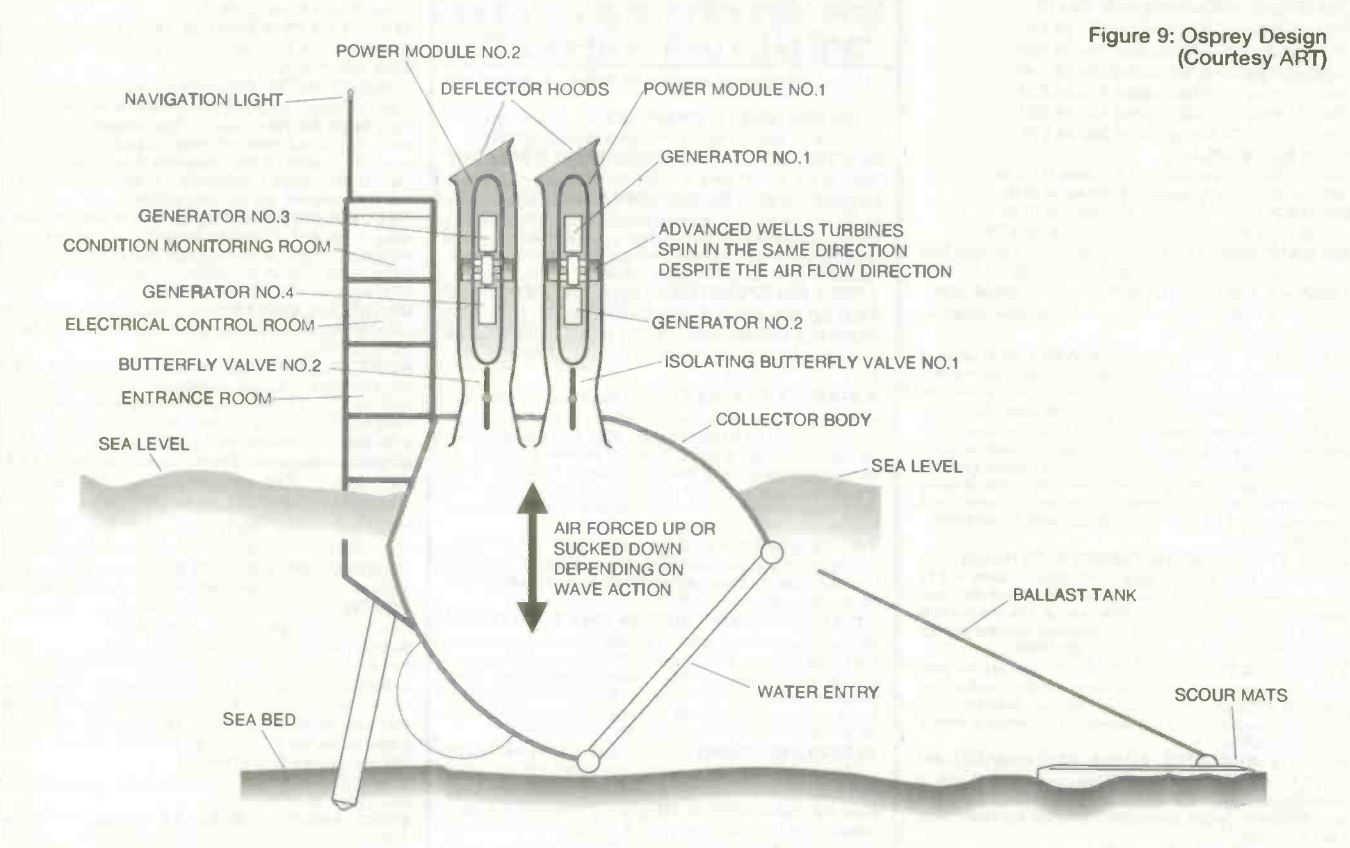


Figure 9: Osprey Design (Courtesy ART)

Continued from p. 14

Osprey is shown in figure 9. The device is some 28 m high with mean sea level some 14 m high. Osprey could be described as a near-shore device. Wave energy is designed to be converted to electrical power as the rising and falling column of water in the collector body drives air in alternating directions through a series of Wells turbines. The Osprey has been a widely reported project since it was essentially the first one to leave the security of land. It has been developed as a demonstration project, however, in order to assess the viability of general design and obtain data based on power generation in an area with well documented wave data.

The planned deployment of Osprey in the Pentland Firth is, in part, due to the level of interest from the former Atomic Energy Authority at Dounreay, near Thurso. This group have made detailed studies of wave profiles and mapped the sea bed at the location where Osprey was to be commissioned. Also, an existing on-shore substation would have allowed power to have been conveniently fed to the National Grid.

The Osprey saga, however, is yet to be successfully completed. While the craft was being loaded with ballast in the Pentland Firth off Dounreay, a large three metre swell buckled the device and plans are afoot to build another structure - hopefully for commissioning during 1997. One of the annoying features of the sequence of events is that if delays had not developed in towing the structure North due to problems with tugs, then Osprey would have been safely loaded with ballast and be quite likely contributing between 1 and 2 MW to the National Grid. The Osprey project has attracted the practical involvement and contribution from major industrial groups. GEC Alsthom, for example, is contributing induction generators that can generate constant frequency power from the variable energy source of Osprey's set of Wells turbines.

With a core of commercial backers for the project developed by Allan Thompson of Applied Research and Technology (ART) of Inverness, the European Union contributed around £435,000 to the project under the umbrella of the Joule initiative. The long experience of ART of off-shore technology in North Sea oilfields, provided a core of experience in working in such conditions.

Figure 10 shows the ART Osprey during its launch on the 2nd of August 1995 on the Clyde. One of the most dynamic references on the subject of wave power was provided by Allan Thompson's speech at this event.

The Salter Duck

While it is anticipated that on-shore and near-shore devices will be the first system to be developed, the Salter Duck is primarily designed as an open sea device designed to capture the higher power levels available in such conditions. From its initial conception during 1974, the system has undergone a process of continual refinement and development - especially in the energy conversion system. It is certainly the system

Continued on p. 18

Figure 11: Basic design of Salter Duck

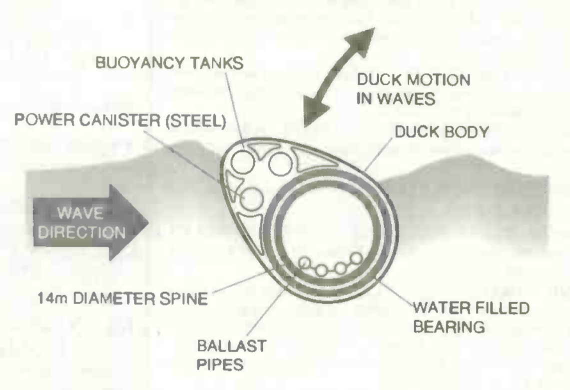
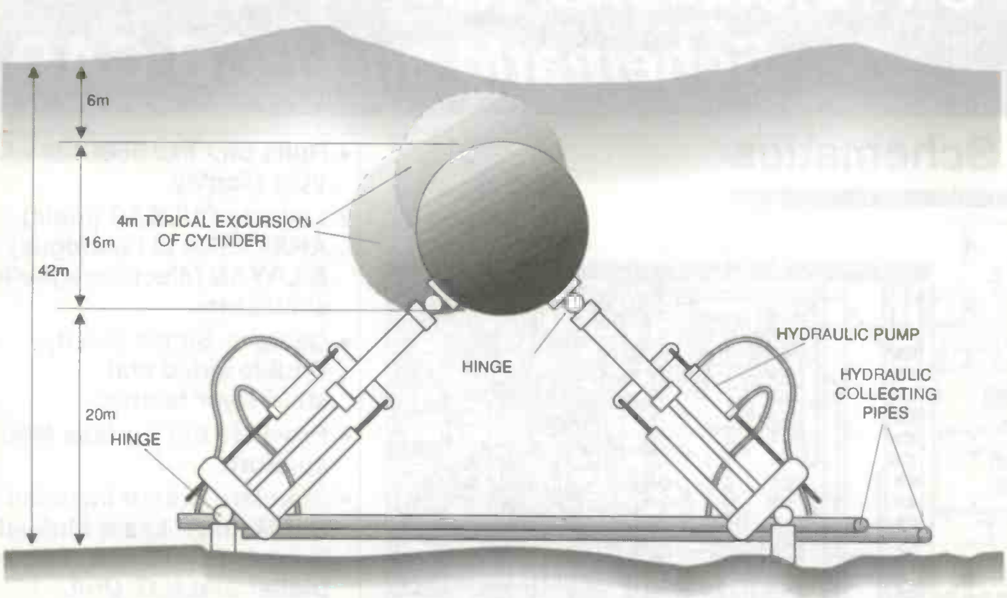


Figure 12: Diagram of the Evans cylinder



Continued from p. 16

which has undergone probably most external scrutiny and review. A detailed review of the system is available from Professor Salter's Department - Changing the 1981 Spine Based Ducks. A cross-section of the Duck is shown in figure 11. In a large-scale implementation, the individual Ducks will pivot relative to a common spine, which will act as a rotational reference point. A novel means of storing energy within the Salter Duck was twin gyroscopes that spun in a vacuum environment to minimise energy losses. While this provided good smoothing of delivered power, an alternative lower cost design using high pressure pumps is currently used. The concept of a suitably tethered 'Solo Duck' is also now receiving consideration. Also, the use of thinner concrete and alternative joints between units and the re-use of concrete shuttering between modules has significantly reduced estimated costs. According to an independent reputable source, the cost per kWh of power from such structures has fallen from the value of 16p of the 1992 Thorpe review to a figure more like between 4 to 5p. With further design and material developments, this figure will likely continue to fall.

The Canary Island Initiative

In recent years, the trans-Europe co-operation in Wave Power has come of age. An advanced Oscillating Water Column is currently nearing structural completion in the Canary Islands (which belong to Spain), with the contract work undertaken by ART in Scotland and a company in Lisbon, Portugal. The wave tank testing of the system was undertaken in Cork, Ireland, with aspects of advanced design of components being undertaken in Professor Salter's Department in Edinburgh, Scotland.

According to Professor Salter, the Oscillating Water Column design being developed is hoped to achieve significantly higher efficiency than standard designs using Wells turbines. New components of the system being developed in Edinburgh include a fast shutter that can close or open in 1/20th of a second and a variable pitch turbine that can have its blade angle adjusted to abstract a maximum amount of energy from individual waves. Initially, a standard turbine will be fitted, followed by the shutter mechanism and then finally the variable pitch turbine. The use of the shutter allows 'latching' in order to abstract maximum energy from the oscillating columns of sea water and also by switching the column to the appropriate turbine for maximum energy extraction. The rated power of the system will be around 400 kW. The features for latching and variable pitch turbines should increase considerably the efficiency of power extraction of such OWC systems for both on-shore and near-shore locations.

The Evans Cylinder

In this design, shown in figure 12, the submerged cylinder is moved by wave action and alternately compresses hydraulic pumps attached to the cylinder. The mathematics of this design was initially extensively studied and subsequent tank tests have validated the theoretical basis. It is estimated that the typical movement or excursion of the cylinder would be around 4 metres.
Sea water compressed by the pumps on the unit would be used to rotate a large Pelton Wheel shared by other units. One advantage of this design is that it mostly would be submerged and would not be exposed to the worst sea activity.

Other designs

A range of other designs, principally of UK origin, have also manifested. These include the Air Bag of Professor Michael French of Lancaster University, the Circular Clam of Coventry University and the Lillypad. David Ross's book provides a useful account of these. An extensive wave tank study of a 'swirling' cylinder unit has recently been completed by Dr. Chris Retzler at the City University in London.

The Norwegian perspective

The energy balance of Norway is, however, completely different from that of the UK. Almost all of Norway's power is produced by hydroelectricity. Water from melting snow produces maximum output in the spring and summer and water is stored in reservoirs for the following winter.

In the Norwegian context, the additional interest in wave monitoring has revealed a dramatic increase in storm frequency in the years 1988 to 1993. Observations, however, reveal the significant variability of wave power even over relatively short time periods. The average for a winter month can be some five or ten times that of a summer month. The higher availability of energy, however, coincides with higher demand for power. Within Norway, companies and agencies have developed systems for analysis of wave climate. The Norwegian company OCEANOR can assess wave climate over any region of the world's oceans by abstracting data from a broad range of sources. Also, the company NORWAVE has developed software to compute levels of wave activity in coastal areas as a

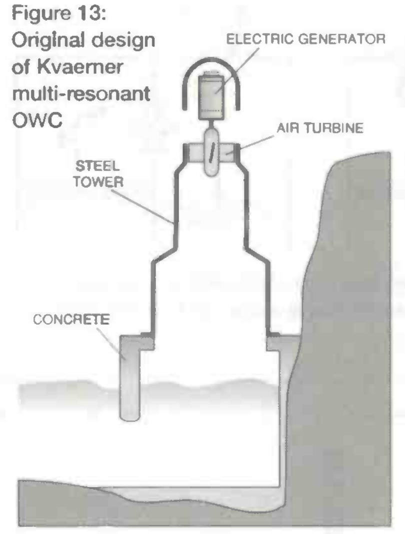


Figure 13: Original design of Kvaerner multi-resonant OWC

function of meteorological data and sea bed topography.

The Tapchan

Nature has given some clues about how some of the energy from the sea can be captured on shore. Natural blow holes, some distance inland from the coast, occur when wave action penetrates along gulleys and then breaks through layers of rock to the tops of cliffs.

The concept of the Tapchan was apparently initiated by physicists in Oslo who were working in general aspects of wave focusing. In normal optics, for example, waves are bent by changing their velocity by means of refractive components, such as glass lenses. Controlled alteration of the sea depths can also be used to focus waves towards a point of convergence. The original design of the Tapchan planned a system with a power capacity of 200 MW and, in one scheme, involved the construction of a lens some 10 km from the shore and a smaller one in-shore. The wave energy would be focused onto a single aperture some 200 metres wide. Water would be collected in a reservoir with a head of 12m and with a maximum water flow of 2000 m/s - quite a frothing inferno. Such a system would probably also have acted as an automatic fishing machine. It was decided, however, to build a demonstration system to verify the concepts as basic engineering techniques. The so-called Tapchan or 'tapered channel' as developed by Norwave in Norway, focuses waves over an entrance aperture or frontage of some 60 metres to rise up a tapered channel - gaining in height until the wave breaks over the walls of the channel into a raised lagoon of area 8000 square metres. Water from the lagoon can then be released through a 350 kW Kaplan hydroelectric turbine to generate electricity across a 3 m head. Around 40% of the incident wave energy is converted to electric energy. This system has operated entirely satisfactorily since 1985. The system has been subsequently modified to verify that a significant reduction in channel length will not adversely affect the system efficiency. It is likely that Norway will capitalise on its pioneering Tapchan development and sell its technology to numerous sites around the world. Currently a 'Tapchan' wave power plant of power capacity 1.1 MW is being constructed by a Norwegian company on the south coast of Java.

Figure 7: View of Islay OWC from adjacent shore (Courtesy ETSU)

Oscillating Water Column: demonstration system

An initial design study of a wave plant of 200 MW was undertaken by Kvaerner Brug of Oslo which involved OWC units of 8 MW each. It was subsequently shown that smaller units rated at 0.5 MW would be more economical. Initially the larger units would have been 160 m apart along the coast. An installation of total capacity 200 MW using 0.5 MW units and 125 metres apart would take up some 50 km of coast.

It was decided to build a demonstration system. The design of the original Kvaerner multi-resonant OWC is shown in figure 13 at Toftestallen, 40 km north west of Bergen. The base is constructed of concrete with a steel upper chamber. The unit was initially completed during 1985. The power output of the system varied between 100 kW and 500 kW. The structure was, however, dislodged from its cliff position late in 1988 by two of the severest storm ever encountered in the region.

After the demise of the original structure in 1988, Kvaerner Brug planned to rebuild the structure in concrete with the power take off system securely on land. This, however, was not to be since, In 1990, Kvaerner Brug merged with Kvaerner Eureka and it was decided to shelve this wave power project.

Trondheim University Wave Group

While Norway has 'got its feet wet' in wave power, funding for basic research is still difficult to get. A key centre for wave development is the University of Trondheim, Norwegian Institute of Technology. In the Oscillating Water Column, the basic design involves one single column of water and one single Wells turbine. Part of the problem of efficiency matching with such systems is that the wave periods are often longer than the resonant frequency of the water columns in the OWC and this reduces the conversion efficiency. By having two chambers with valves that can be opened and closed independently by appropriate control, as indicated in figure 14, it has been predicted that significant additional efficiency can be achieved. The 'appropriate control' would be a microcomputer that could predict the best times to open and shut the control valves. Also, the turbine used need not be of the self-rectifying Wells type and so a more standard and economical unit can be utilised. Such a system has been extensively studied at one tenth scale in Norway. The costs of construction of the more complex unit would be somewhat larger than a single chamber though energy recovery would be greater.

Point absorbers

One of the refreshing things about research into wave power is the diversity of ideas that surface within separate national programmes. While Norway has achieved some notable firsts in Europe with on-shore devices such as the Tapchan and OWC at Toftestallen, a significant amount of research has been undertaken by the physics group at Trondheim University. Many of the current projects of this group were initiated by the late K. Budal. Currently, the principal researcher is Dr. Johannes Falnes. In particular, the Norwegian group has analysed in considerable detail the performance of so-called 'point absorbers'. In the early development of wave power, energy converters tended to be considered as devices that converted the energy of the waves over the linear distance of wave incidence upon them. Theoretical studies subsequently have shown, however, that a so-called 'point absorber' can abstract energy from a wider 'aperture' than just its physical dimension. In more formal terms, the maximum power that can be captured is equal to the incident wave transport associated with a wave front of width one wavelength divided by two times pi (value 6.28). Experiments have confirmed that 50 percent of incident energy can be absorbed under best conditions by such point absorbers. Results with one tenth scale model buoys have indicated that values around 43% for energy conversion can be achieved. Thus a long period wave with a wavelength of 100 m will be able to present a capture aperture of around 15 metres with a maximum recovery level of 50%. The model of available power is complex, however, and the collectible energy is very much a function of the incident wave spectra.

The advantage of the point absorber, however, is that such devices do not have to be as large as the cross-section of devices such as the Salter Duck to capture and convert the same amount of energy. Figure 15 indicates the typical design of a near shore oscillating buoy system. As the waves pass over the buoy position, the buoy takes up an oscillating motion. The buoy runs up and down the vertical support by means of rollers. Various modes of energy take off have been proposed. One of the simplest is to form a cylinder along the axis of the buoy with vertical movement of the buoy compressing air into a pressure reservoir from which a turbine can generate electricity.

Latching action

A key design feature of such a system, however, is the implementation of 'latching', a process referenced by various wave power researchers. In this process, the motion of the buoy is intelligently controlled so that it can derive the optimum output from the incident wave stream. Such control is principally achieved by periodically clamping the buoy to the vertical support structure so that its subsequent motion can abstract additional energy. The latching mechanism is crucial to the efficiency of such a wave converter design. In a wave tank study, the estimated average power production of a buoy unit was calculated to be 14.0 kW with latching control, and 5.3 kW without it. While extensive tests have been undertaken in test tanks and also in the sea with models, so far no commercial sponsor in Norway has provided resources for funding research into developing a demonstration sea-going buoy unit. In the 'small is beautiful' philosophy of Dr Falnes, a 200 MW near-shore wave converter system would best be implemented by an array of 2,000 such devices, each of rated capacity 0.1 MW. While Norwegian wave research is forward looking, there is the impression that research and development has not progressed to a stage which would give confidence to construct devices for deployment in real seas. On paper, the figures look good. What is needed is more commercial interest to resolve aspects of engineering design.

Summary

After the Energy Crisis of the early 1970's, Wave Energy in the UK soon was seen by various key figures in the Electricity Supply industry as a viable option as a sustainable resource for the future. Within ten years, however, Wave Power was out of favour - at a political level. It is regrettable that a considerable degree of academic effort from the UK Wave Power community had to be expended to counteract government commissioned reports on wave power of questionable scientific and economic correctness. Where funds have been spent by the UK government on 'Wave Research', this has tended to fund 'reports' of the status of developments and designs without acting to actively develop the effectiveness of such systems. Because of the large potential energy resource that wave power represents for the future, as well as its potential as a wealth creating industry, there is every justification for greater levels of investment than are being committed at present. Also, there seems a bizarre conflict of financial models where nuclear power stations are built at great cost initially and with the prospect of future crippling cost to decommission them and render their radioactive cores 'safe'. Is this even sensible within the confines of 'market forces'?

There does appear, however, to be a greater openness on the part of the UK government to accept the case that wave power has potential. The contribution of Tom Thorpe while at ETSU is widely acknowledged as regaining 'the respect of the entire wave community'. More and more, however, commercial players unfettered by political baggage are beginning to participate in wave power development. It is Europe, however, that is at present funding the significant element of current research in wave power in the UK. As the pendulum swings towards obtaining power from renewable,

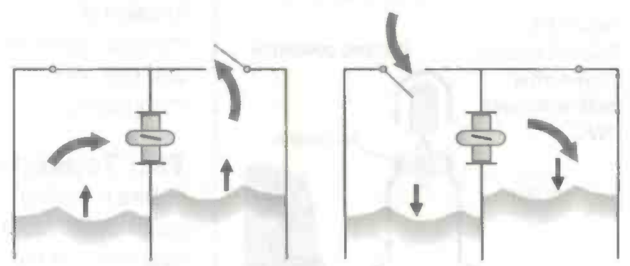


Figure 14: Design of two chamber OWC unit: on the left, arrows indicate air flow with rising water, and on the right, falling water

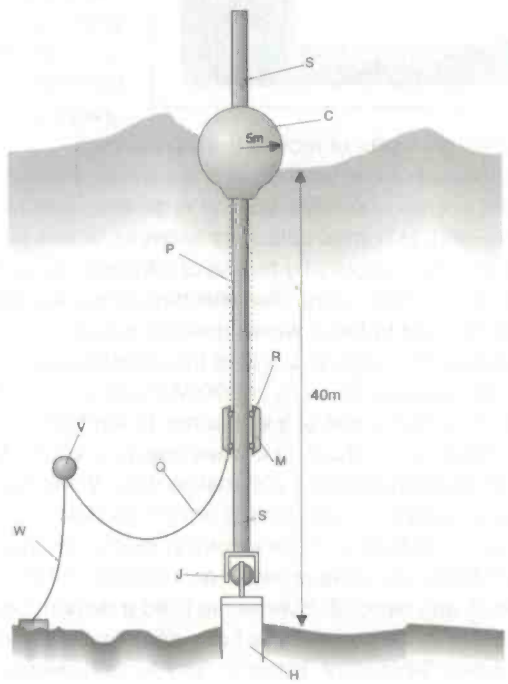


Figure 15: Design of oscillating buoy: S = vertical column; C = buoy; Q = power take-off cable; H = mooring base; J = attachment point

non-polluting sources, wave power is well placed to play a significant part in helping to stabilise our existence within an increasingly fragile biosphere.

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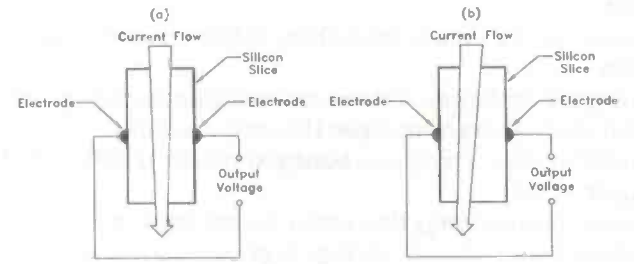
50Hz MAGNETIC FIELD SENSOR

Find magnetic field overloads with Robert Penfold's mains hum tracker

The presence of magnetic fields in the modern environment was something that seemed to be taken for granted for many years, with no serious questioning of whether these fields had any harmful effects. This situation has changed in recent years, with numerous claims about potential problems due to various types of electromagnetic radiation. Even humble 50 Hertz mains hum from ordinary power cables, transformers, etc. has come under suspicion. Electro-magnetic fields have become a major news story, with substantial coverage in the national press. It remains a highly controversial subject, and seems likely to be so for some years to come.

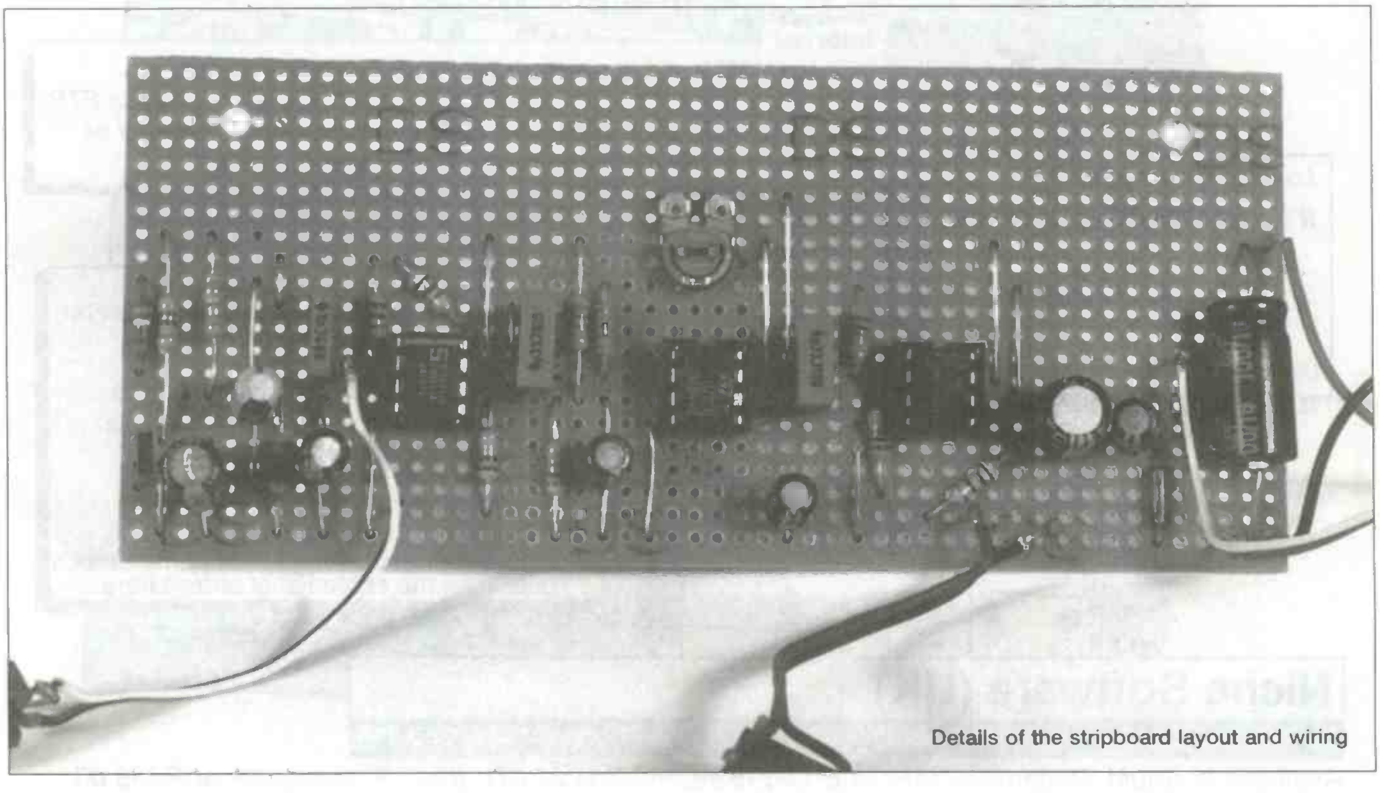
This project is a sensitive but inexpensive 50 Hertz magnetic field detector. While it is not intended to act as a highly accurate scientific instrument, it does enable relative field strengths to be gauged reasonably accurately. It is interesting to check the field strengths around cables, transformers and so on, and results are often not what one would expect. If you have any "hot-spots" around the house, it should be easy to track them down using this unit. Due to the small size of its Hall effect sensor, the unit can be used to map out complex magnetic fields quite accurately. It can also act as a mains cable locator. The field strength is indicated via a moving coil panel meter, and there is also an output socket that can be used to drive a pair of medium impedance headphones.

Figure 1. A hall effect sensor is basically just a munite bar of silicon fitted with two electrodes



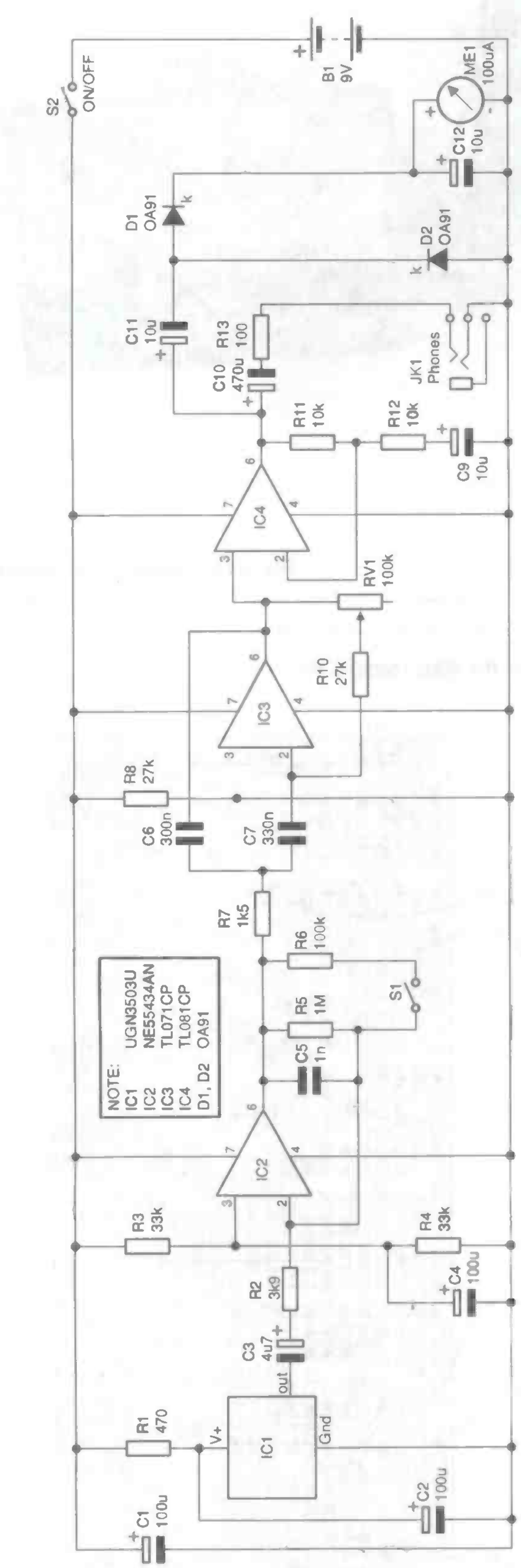
Hall effect

The magnetic field is detected using a UGN3503U linear Hall effect sensor. The Hall effect was discovered by E.H.Hall in 1879, but it is only relatively recently that Hall effect devices



Details of the stripboard layout and wiring

Figure 3. The 50Hz magnetic filed sensor circuit.



have become widely available. This effect is very simple in essence, and figure 1 helps to explain the way in which a Hall effect sensor functions. The sensor is basically just a minute bar of silicon with electrodes fitted on opposite faces. A current is passed through the piece of silicon, producing a potential gradient. In other words, the potential varies from 0 volts at the bottom of the silicon chip to the full applied voltage at the top. The electrodes are about halfway up the bar of silicon, and about half the applied voltage is present at each electrode.

The important point to note here is that the same potential is present at each electrode, giving a differential output voltage of zero. This all assumes that there is no magnetic field applied to the sensor, giving a uniform flow of current through the piece of silicon, as in figure 1(a). If a magnetic field is applied at one side of the silicon bar, the current carriers are deflected, giving increased current flow through one side of the bar and decreased current flow through the other. This is often likened to the beam of a cathode ray tube (crt) being deflected by a magnetic field.

Figure 1(b) represents the distorted current flow caused by the application of a magnetic field. This very simple setup can act as a magnetic sensor because the deflected current flow causes a distortion of the potential gradient. This in turn results in a higher voltage at one electrode, and a lower voltage at the other. This produces a small voltage difference across the electrodes. The output voltage is proportional to the strength of the magnetic field, and its polarity is dependent on the polarity of the magnetic field.

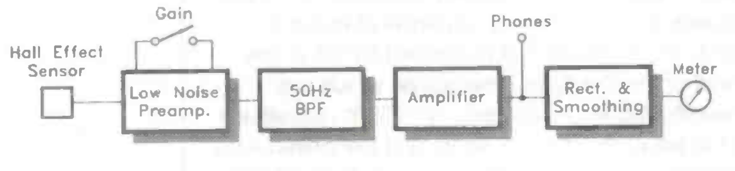
It is important to realise that the sensor will only detect a magnetic field applied to one side or the other of the silicon bar. A field applied to the top, bottom, front, or rear (as viewed in figure 1) will affect the current flow, but not in a manner that will cause an imbalance in the potentials at the electrodes. In practice this means that the orientation of the sensor must be adjusted to produce maximum reading from the unit if meaningful results are to be produced. Practical Hall effect sensors invariably include some on-chip signal processing, such as an amplifier or some form of switching circuit. In this application it is a linear device having a built-in amplifier that is required. Some linear Hall effect sensors have differential outputs, while others have a single-ended output stage. Differential outputs are not needed in the present application, and a simple three terminal sensor is perfectly adequate.

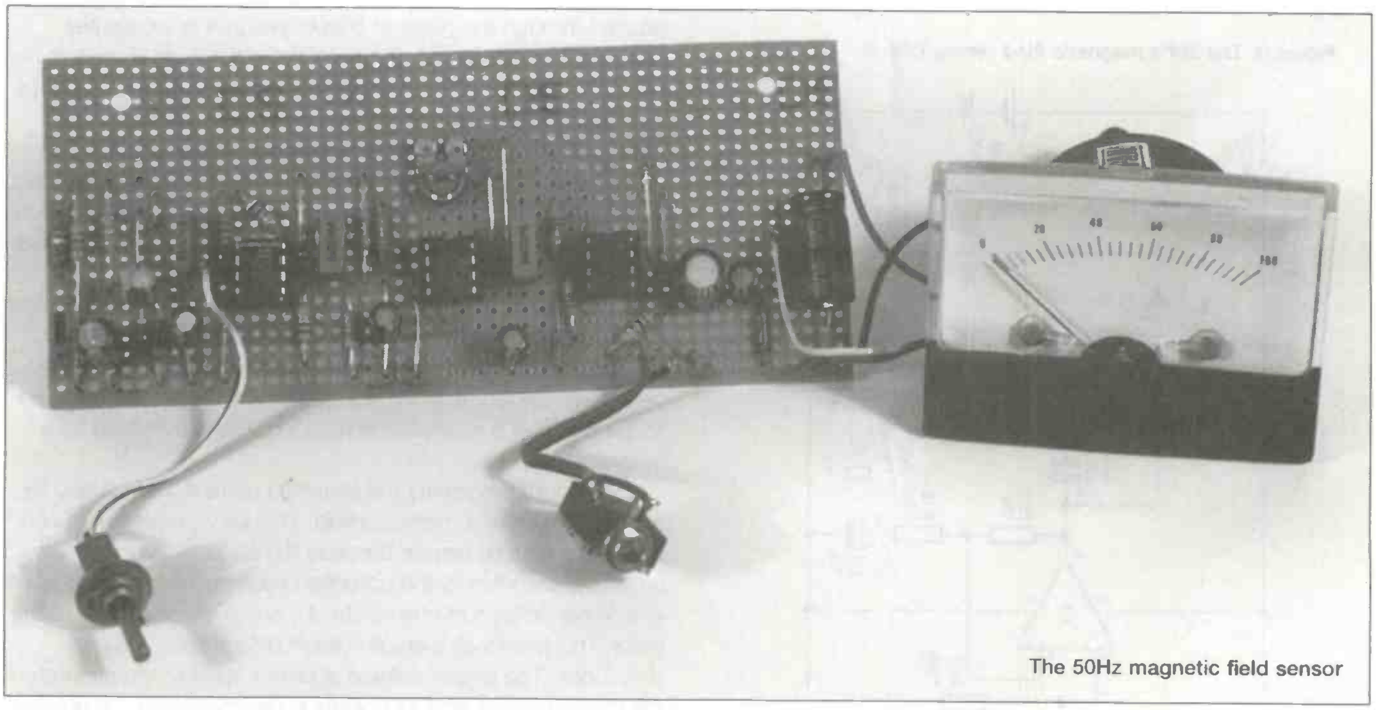
This unit is based on the UGN3503U Hall effect sensor, which is inexpensive but offers good sensitivity. It is a small three-terminal device which looks very much like a transistor in an "E-line" flat plastic encapsulation. The UGN3503U is very simple to use, with the supply being connected to two of its terminals, and the output signal being taken from the third. The output terminal is at half the supply voltage under quiescent conditions. The supply voltage should be within the range 4.5 to 6 volts.

System operation

The block diagram (figure 2) shows the general arrangement used in the magnetic field sensor. The integral amplifier of the sensor gives a useful boost in sensitivity, but the raw output of the sensor is still far too low to drive the meter circuit.

Figure 2. The block diagram for the 50Hz magnetic field sensor





The 50Hz magnetic field sensor

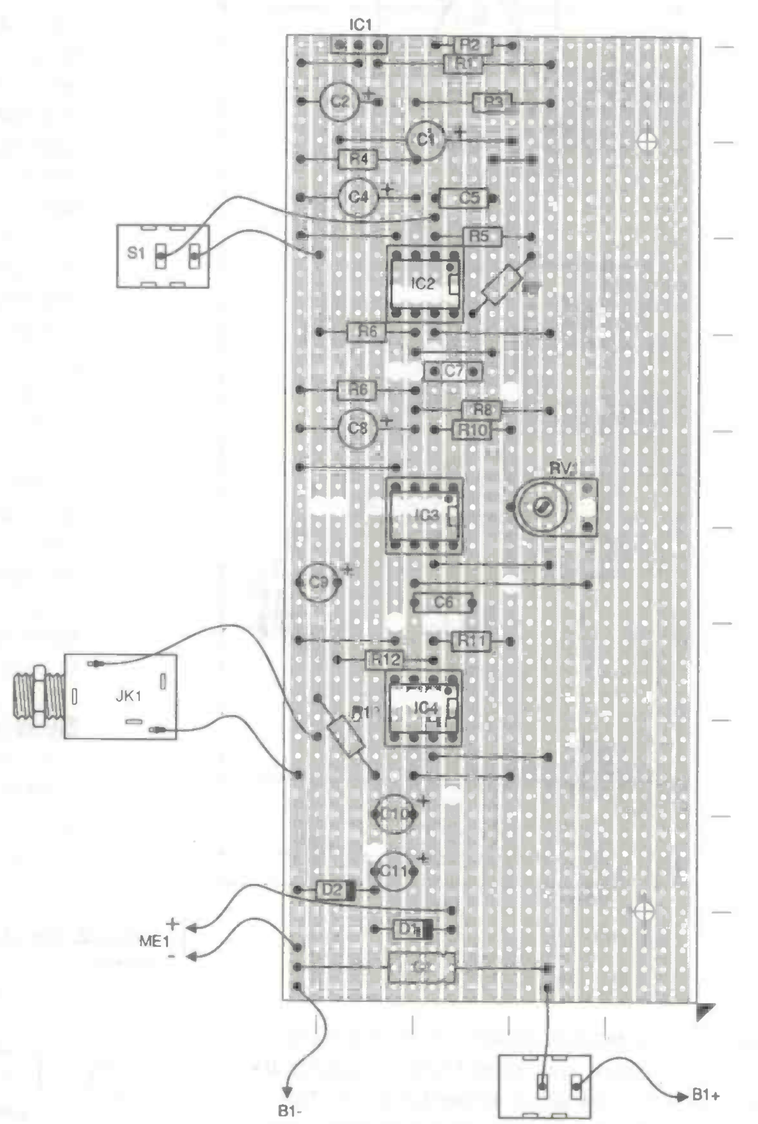
A low noise preamplifier stage is therefore used to boost the output of the sensor by more than 200 times. The sensor has a fairly wide bandwidth, with its actual operating range being from dc to 23kHz. The output from the preamplifier contains a large amount of noise across this frequency range. This gives a high output level from the preamplifier even under standby conditions, and any weak 50 Hertz hum will obviously be lost in the background noise.

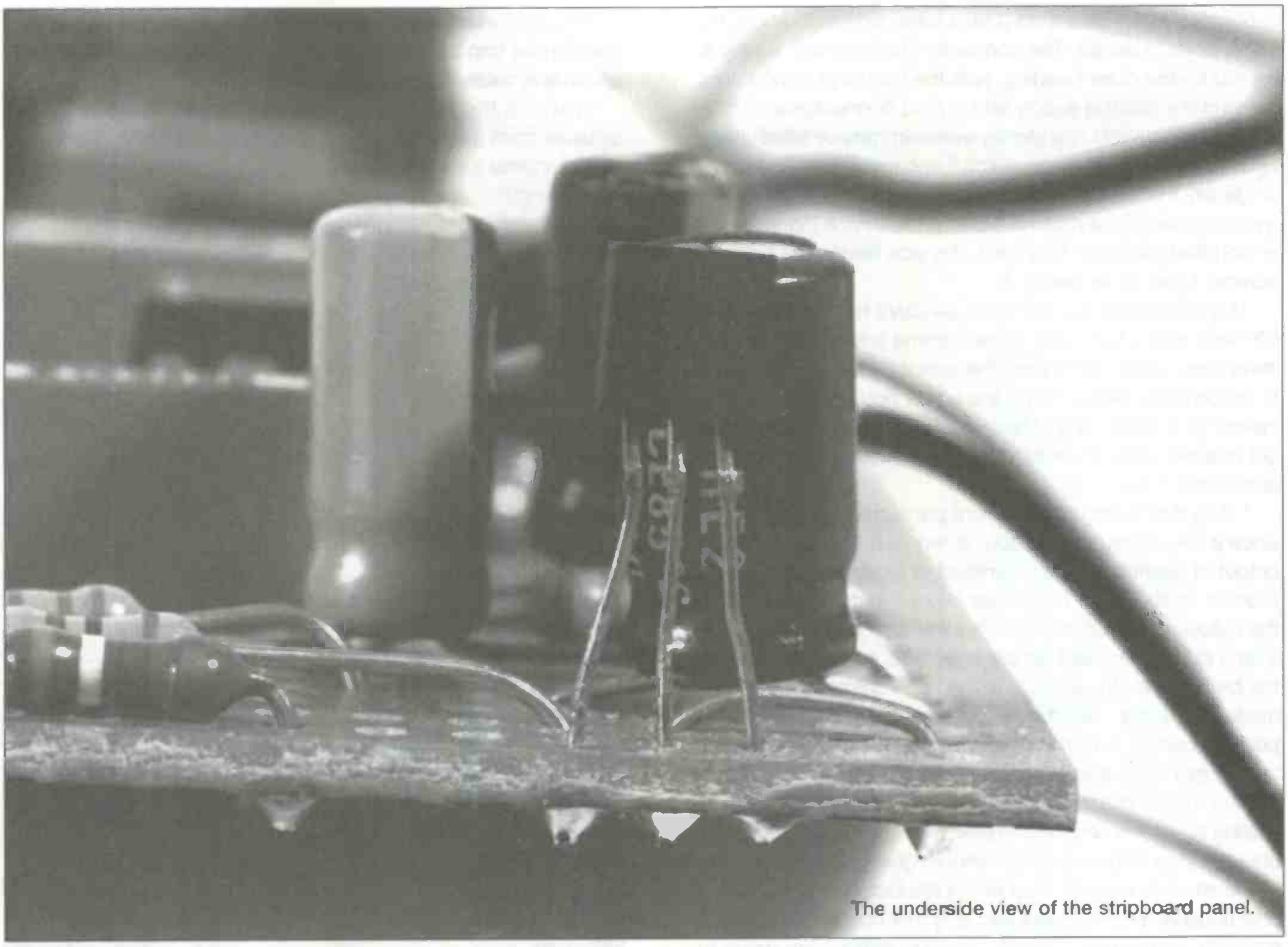
As we are only interested in 50 Hertz mains hum in this application, a bandpass filter can be used to restrict the bandwidth of the unit, removing much of the noise in the process. Obviously the unit would be more versatile if it was left with its full 23kHz bandwidth, but only a relatively low sensitivity could then be used. Restricting the unit to 50 Hertz mains hum enables much higher gain to be used, and really weak magnetic fields to be detected. Presumably most users will only be interested in detecting 50 Hertz fields anyway. A certain amount of amplification is provided by the bandpass filter, and an amplifier stage then provides a further boost to the signal. However, this amplifier has a voltage gain of just two times, and its main purpose is to provide buffering at the output of the filter. It enables the output of the unit to be monitored via headphones, and it also drives the moving coil panel meter via a rectifier and smoothing circuit.

Circuit operation

Figure 3 shows the full circuit diagram for the 50 Hertz magnetic field sensor. IC1 is the Hall effect sensor, and this is powered from the 9 volt battery supply via R1 and decoupling capacitor C2. These provide IC1 with a supply potential of about 5 volts. The output of IC1 is coupled by C3 to the input of the low noise preamplifier, which is an inverting mode circuit based on IC2. In normal use S1 is set to the open position, and the closed-loop voltage gain of the circuit is then set at about 250

The block diagram for the 50Hz magetic field sensor.




The underside view of the stripboard panel.

times by R2 and R5. The sensitivity of the circuit may sometimes be too high, and S1 is then closed. This shunts R6 across R5, giving a roughly tenfold reduction in the closed-loop voltage gain of IC2. C5 provides a certain amount of high frequency attenuation, and this helps to reduce noise problems. The bandpass filter is a conventional operational amplifier circuit based on IC3. The operating frequency of the filter is determined by the values of C6, C7, R7, R10, and VR1. The latter effectively operates as a tuning control, enabling the filter to be set for optimum results with a 50Hz input signal. The value of R7 is low in comparison to the series resistance of R10 and VR1, which provides the filter with a high Q value and a moderate amount of voltage gain. IC4 is used as the output amplifier and buffer stage. This is a non-inverting mode circuit which has its closed-loop voltage gain set at two times by R11 and R12. C10 couples the output of IC4 to the headphone socket via R13. The headphones should be a medium impedance stereo type, as sold as replacements for use with personal stereo units. JK1 is connected so that the two phones are driven in series. R13 provides some attenuation at the output, and also reduces the load impedance on IC4 to a more suitable figure. C11 couples the output of IC4 to a simple half-wave rectifier circuit which uses D1 and D2 in a standard configuration. Using germanium diodes for D1 and D2 minimises problems with non-linearity due to the forward voltage drop through the diodes, but it does not give truly linear scaling. This does not really matter since the unit is intended only to permit relative field strengths to be gauged, rather than to permit precise measurements to be made. A small amount of non- linearity in what is really arbitrary scaling is therefore of no consequence. It would be possible to use a precision rectifier circuit and to give the unit an accurate scale, but this is only practical in the unlikely event that you have some means of accurately calibrating the unit. The current consumption of the circuit is approximately 15 milliamps. This can be provided by a PP3 size battery, but it is advisable to use one of the "high power" versions. If the unit is likely to receive a great deal of use it would probably be more economic to use a higher capacity battery, such as six HP7 size cells in a plastic holder.

Construction

Figure 4 provides details of the stripboard component layout and the hard wiring. The underside of the component panel is shown in figure 5. The board has 50 holes by 21 copper strips, and this can conveniently be a strip cut from a standard five inch (127 millimetre) wide piece of stripboard. The two mounting holes in the board should be about 3.2 to 3.3 millimetres in diameter, and they will accept 6BA or metric M3 mounting bolts. The breaks in the copper strips can be made using the special tool, but a hand-held twist drill bit of about 5 millimetres in diameter seems to do the job quite well. Make sure that the copper strips are cut across their full widths, but be careful not to cut so deeply that the board becomes seriously weakened. Although none of the integrated circuits are static-sensitive, it is still advisable to use holders for the three 8-pin dil types. D1 and D2 are germanium diodes, and not silicon devices. They are relatively easily damaged by heat, and extra care should therefore be taken when fitting these components. Make sure that both diodes are fitted with the correct polarity.

IC1 is shown as being mounted on the circuit board, but the unit will be easier to use if it is mounted off-board and connected to the board via a twin screened cable about half a metre or so in length. The connection to the 0 volt supply is carried by the outer braiding, with the two inner conductors carrying the positive supply and output connections.

The UGN3503U is a slightly awkward device which has what appears to be a symmetrical encapsulation. The only way to identify the leadout wires is to use the face which carries the type number as the notional front of the device (figure 6). If IC1 is mounted direct on the board, the side having the type number faces away from C2.

The circuit board is obviously sensitive to stray pick-up of 50 Hertz mains hum, and there is some advantage in using a metal case which will screen the board. However, results seem to be perfectly satisfactory if the unit is housed in an inexpensive plastic box. The exact layout used is not critical, but choose one that enables the leads to S1 to be kept reasonably short.

Fitting the meter onto the front panel may be awkward, since a very large round cutout is required. For most meters a cutout of diameter of 38 millimetres is required, but it would be prudent to check the barrel size of your meter before making the cutout. It can be made with a fretsaw or an "Abrafile", but a tank cutter (also sold simply as a "hole cutter") is probably the best tool for the job. Once the large cutout has been made, the meter itself can be used as a template to locate the positions of the 3.3 millimetre diameter holes for the meter's built-in mounting screws. It is acceptable to use an inexpensive "tuning" meter in an application such as this, where accurate scaling is not involved. Any meter with a full scale sensitivity of about 100 to 250 microamps should give good results. Details of the small amount of hard wiring are included in figure 3. The only unusual aspect of this wiring is that no connection is made to the earth tag of JK1. The connections are made to the two non-earth tags, so that the headphones are used in series. The jack socket used on the prototype has a pair of switch contacts, but these are not needed in this application and are left unconnected. Stereo 3.5 millimetre jack sockets vary significantly in style, but the retailer's catalogue should provide connection details if you are using a socket which is different from the one fitted on the prototype.

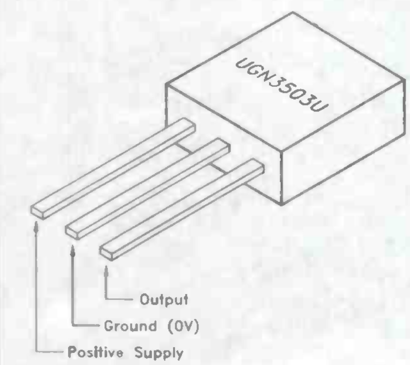
In use

Start with the wiper of VR1 at a middle setting. When the unit is switched on there will probably be a very small deflection of ME1's pointer. This is caused by internally generated noise and the inevitable background hum level. The sensitivity of the unit is very high with S1 open, and the prototype can readily detect the magnetic field generated around the mains cable of a 15 watt soldering iron. The field generated by such a low current is very weak, but it can still be detected at a range of about 10 to 20 millimetres. With a higher current appliance, such as a two kilowatt electric fire, the field can be detected at much greater distances. With some mains hum detected, adjust VR1 for maximum meter reading. Remember that IC1 is directional, and that it must be oriented so that the magnetic field is applied to one of the large surfaces. Holding the top end of IC1 (that is the end opposite the leadout wires) against a mains lead will give little or no deflection of the meter's pointer. Aiming one of the large surfaces towards the lead should provide much better results. When searching for mains leads in walls, remember that the lead can only be detected if it actually passing a current. The greater the current flow, the more easily the lead can be detected. In my typical "sixties semi" the 50 Hertz field levels seem to be very low in general.

Any appliance which is switched on and contains a mains transformer can be expected to produce a strong field, as will any mains cable that is carrying a heavy current.

However, the field strength reduces rapidly with increased distance from the source. Even as little as one metre from a strong source the field strength seems to be at the normal background level. This would seem to suggest that prolonged exposure to high field strengths is unlikely in the average home environment, and is easily avoided once you have identified the sources of strong 50 Hertz fields.

Figure 6. Pinout details for the UGN3503U



PARTS LIST FOR THE POWER SUPPLY INTERFACE

Resistors

R1,4	10KW (2 off)
R2	4K7
R3	22KW

Capacitors

C1,3,4	100nF Ceramic or Polyester (3 off)
C2,5	10mF / 25V Radial Electrolytic (2 off)
C6	2200mF / 25V Radial Electrolytic

Semiconductors

BR1	100V / 1.9A Bridge Rectifier
D1	1N4001
IC1	7805 +5V Voltage Regulator
TR1,2	BC547 NPN Transistor (2 off)
TR3	BFY51 NPN Transistor

Miscellaneous

F1	500mA 20mm Fuse
JP1	0.1" Jumper Link
MOV1,2275V	metal oxide varistor (2 off) *
RLA1	12V SPCO PCB Relay
T1	0-6-0-6 / 6VA PCB transformer
Fuseholder	20mm PCB fuseholder
Fuseholder Cover	Plastic Cover To Suit Above
Heatsink	Shallow Heatsink for IC1
Sensor	ORP12 Light Dependant Resistor (LDR)
Terminals	3-Way 10mm pitch PCB Terminal Block (2 off)
Connector	2-Way PCB Pin Header - 2.54mm pitch (2 off)
Connector	2-Way PCB Pin Header - 5.08mm pitch
Case	Enclosure to suit *
Hardware	General Fixing Hardware *
Cable	3-Core Mains Flex *
PCB	DTE Process Timer PSU / Interface

* These parts not included in the kit

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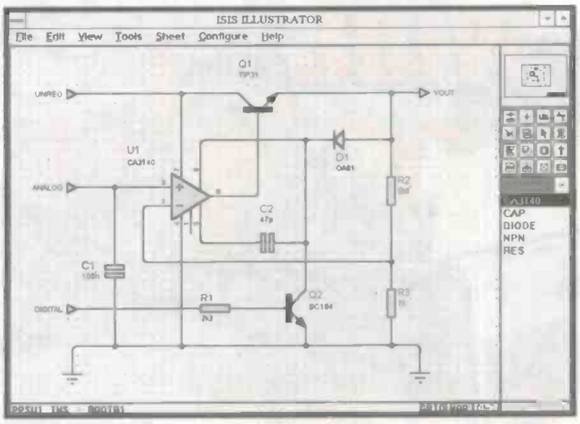

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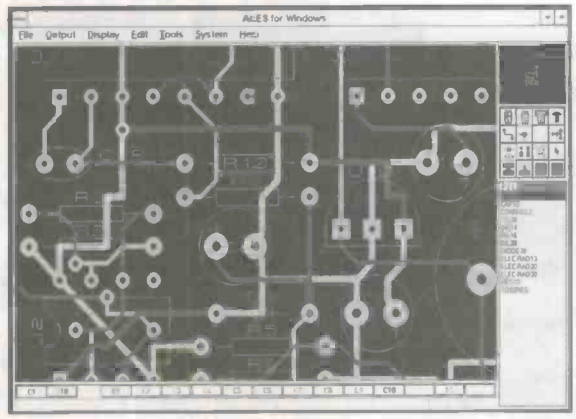

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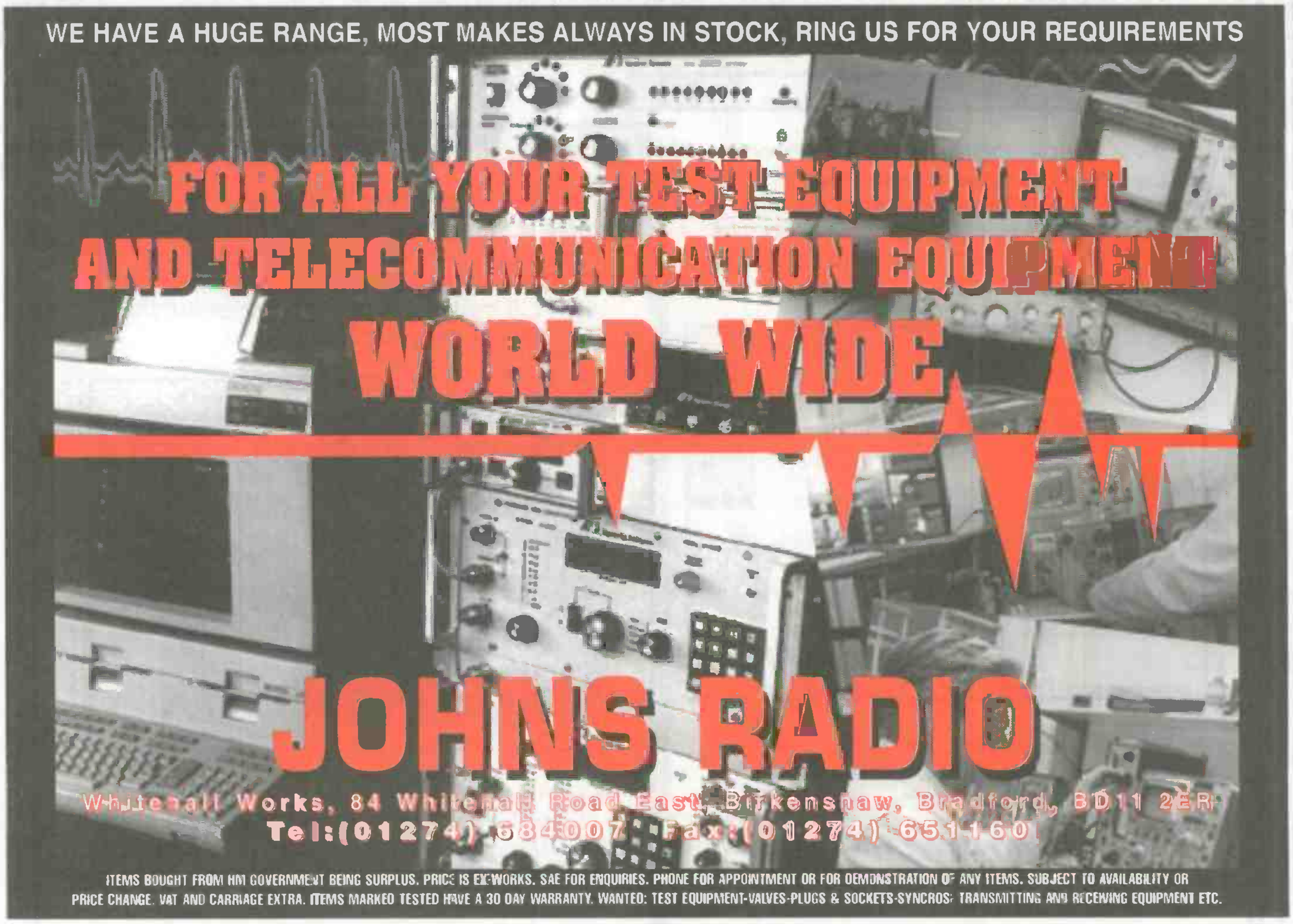

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FOOL'S PARADISE
KEYPAD ENCODER/ EMULATOR

Or How To Use a PIC Microcontroller to "fool" existing equipment by emulating old or obsolete devices. By Tim Parker

There is an aspect about the introduction and widespread use of the PIC microcontroller that seems, in general, to have been overlooked; its ability to be programmed to emulate the functions of some other devices.

As a sign that times are rapidly changing - perhaps more so now than ever before - the most impressive aspect is that it is now cheaper to buy a PIC microcontroller, and program it for a specific integrated task, than to actually purchase some of the dedicated counterpart devices for which it can replace.

To demonstrate this, I have chosen not one, but two devices which could be replaced by the same PIC16C55RC Microcontroller. Obviously the replacement cannot be a direct pin-for-pin substitute, but by building a small interface board which re-configures the signals from the PIC to those expected by the equipment, a jumper lead can be plugged between the two boards so that the equipment is 'fooled' into thinking that it is looking at the original device.

This is ideal for users or installers of older equipment, who do not have the facilities - or funds for that matter - to re-design a particular aspect of that equipment if it goes wrong, and the damaged part is no longer available. So, you might not have to write off equipment that has proved itself to be reliable for many years (and why should you?), just because one of the parts has now become obsolete.

The two devices concerned (and it must be stressed that no bias or malice is intended or implied. Many other devices could have been the subject of this article, and the two used here are just examples) are the 74C922 and the 74C923, both of which are keypad encoders that are used to scan an XY keypad matrix, and produce a binary output corresponding to the current button being pressed. The single main difference between the two devices is that the '922 is a 4 x 4 matrix encoder, and the '923 is a 5 x 4 matrix encoder. Although

Figures 1a and 1b: The old way: different devices had to be used for 4 x 4 matrix keypads and 5 x 4 matrix keypads

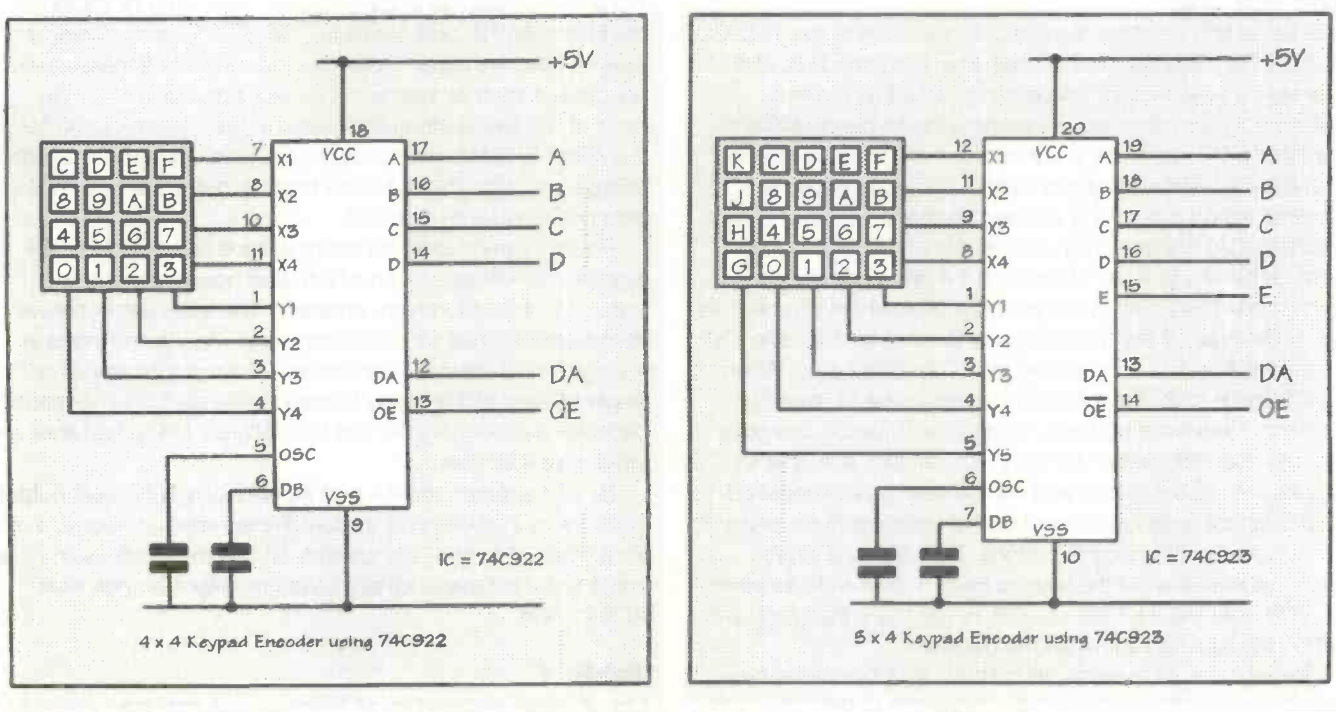
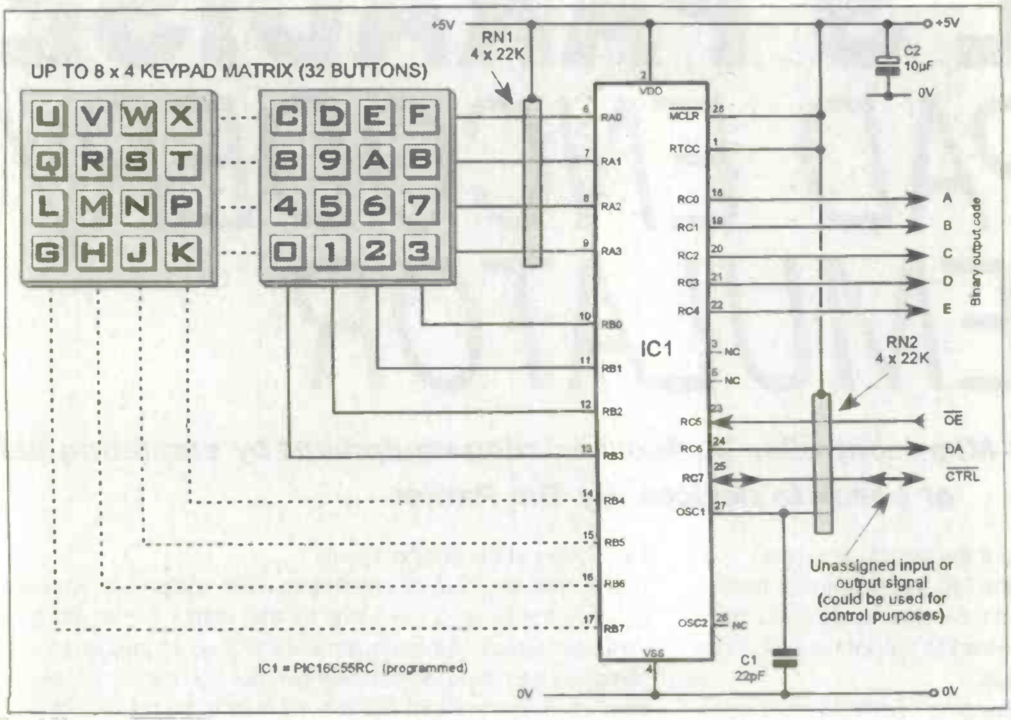


Figure 2 : The new way: one PIC 16C55 is more powerful and programmable, and it can emulate either of the old devices.



on the other hand requires a 5th binary output to cater for the additional 4 buttons, but only codes from 00h to 13h are used, which means that the remaining 12 codes that are available on 5 bits - 14h to 1Fh - are wasted because there aren't any further scan lines available for a larger keypad. But, as you will see shortly, we can overcome this restriction with our emulator version.

A new idea

Figure 2 shows how, with an appropriately programmed PIC16C55, both 4 x 4 and 5 x 4 matrix keypads can be accommodated. In fact, due to the programmability, it is possible to encode any size keypad from 1 x 1 (pointless!) up to a maximum of an 8 x 4 matrix. There is no need to make full use of all available matrix lines, only utilise the ones you need for your own purposes. There is also no need to change in any way the hardware configuration, because generating only the codes you require is achieved entirely through software alterations, just ensure the keypad is connected correctly across the X and Y axis input terminals, but not in any particular order. That is, don't connect two adjacent X or Y co-ordinates of the keypad to one X and one Y connection of the emulator board. No damage will result if you do, it simply won't work properly.

these devices may not be quite so well known among the analogue oriented enthusiasts, they will certainly be recognised by the digital fraternity, not only for the fact that they were once widely used for decoding data entry keypads on early microprocessor systems (in fact some of the very early ones were primarily stamped with an 8080 series MPU interface device number), but more possibly for the fact that they started life as expensive devices, came down in price very slightly (but not much), and then rocketed back up again to the point where now the price is now about £14 and £16 respectively, and can be very difficult to obtain due to their age and the usual lack of supply and demand aspect.

The old way

Figures 1a and 1b show the basic connections to the 74C922 and 74C923 respectively. Although the connections to each look very similar, neither device can be used as a direct replacement for the other, since one is an 18 pin device and the other a 20 pin, and the connections are made to different pins anyway. The operational side of things, however, is identical. When a button is pressed on the keypad the Data Available (DA) line goes high for the duration of that button press, returning to a low state once it is released, and the binary code representing the button is latched onto the A-D (or A-E in the case of the '923) outputs. If the Output Enable (OE) line is low, the data can be read from the output pins. When the OE line is high, the A-D or A-E outputs are tri-stated or 'floating'. Even if the button is released and the DA line goes low, the code for the last button press remains available as long as the OE line is low, and can be read again if required.

The binary codes generated do not necessarily correspond to the codes written on the buttons. This depends on the wiring configuration of the keypad itself, and how those wires are connected to the '922 or '923, which more than likely will not be the same as shown in the diagrams.

Because the '922 scans 16 buttons, all 4 bits of the binary output are used to produce codes from 00h to 0Fh. The '923

How it works

To scan the keypad matrix, four inputs - RA0 to RA3 - and eight outputs - RC0 thru RC7 are used. Each output line of the RC port is pulled low in turn, and the input data bit pattern is read from the RA port. Since the RA port consists of only the lower 4 bits, the upper 4 bits (the top nibble) are masked off, and always read as zero's. If the resulting data is 0Fh then none of the four buttons is pressed in the column connected to the currently active output bit, so the next column is scanned, and so on, until either a button press is detected, or all of the columns have been scanned.

Pressing any button will return a value less than 0Fh, the exact value will depend on which, and how many of the buttons in that column are pressed. The table below shows the values returned for all combinations of button presses in the right hand column. The same values apply to any other single column of the keypad matrix, but a distinction is made between each one by the fact that different RB output lines are used to enable them.

By manipulating the RA port input data and RB port output code, or by incrementing a counter each time a check is made for a different button, it is possible to use the result as an offset into a look-up table of binary codes to output on port lines RC0 to RC4.

Table 1

List of codes returned for all combinations of button presses in

Table 1: The list of codes retuend for all combinations of button presses in any one signle column (the right-hand column is an example. All other columns produce the same codes.)

BUTTONS PRESSED	BINARY	HEX	DECIMAL
3 7 B F	0000 1111	0F	15
3 7 B F	0000 1110	0E	14
3 7 B F	0000 1101	0D	13
3 7 B F	0000 1100	0C	12
3 7 B F	0000 1011	0B	11
3 7 B F	0000 1010	0A	10
3 7 B F	0000 1001	09	9
3 7 B F	0000 1000	08	8
3 7 B F	0000 0111	07	7
3 7 B F	0000 0110	06	6
3 7 B F	0000 0101	05	5
3 7 B F	0000 0100	04	4
3 7 B F	0000 0011	03	3
3 7 B F	0000 0010	02	2
3 7 B F	0000 0001	01	1
3 7 B F	0000 0000	00	0

Table 2: The pin re-configurations needed for emulating the two devices.

PIN RE-CONFIGURATION REQUIRED FOR EMULATING EACH DEVICE						
PIC16C55		74C922	SIG	PIC16C55		74C923
PIN 18	to	PIN 17	A	PIN 18	to	PIN 19
PIN 19	to	PIN 16	B	PIN 19	to	PIN 18
PIN 20	to	PIN 15	C	PIN 20	to	PIN 17
PIN 21	to	PIN 14	D	PIN 21	to	PIN 16
PIN 22	to	NONE	E	PIN 22	to	PIN 15
PIN 23	to	PIN 13	OE	PIN 23	to	PIN 14
PIN 24	to	PIN 12	DA	PIN 24	to	PIN 13
THESE ARE ALL ACCOMMODATED ON THE PRINTED CIRCUIT BOARD LAYOUT						

any one single column (Right hand column used as example. All other columns produce the same codes)

BUTTONS PRESSEDBINARYHEXDECIMAL - - - -0000 1111 0F 15 - - - F0000 1110 0E 14 - - B -0000 1101 0D 13 - - B F0000 1100 0C 12 - 7 - -0000 1011 0B 11 - 7 - F0000 1010 0A 10 - 7 B -0000 1001 099 - 7 B F0000 1000 088 3 - - -0000 0111 077 3 - - F0000 0110 066 3 - B -0000 0101 055 3 - B F0000 0100 044 3 7 - -0000 0011 033 3 7 - F0000 0010 022 3 7 B -0000 0001 011 3 7 B F0000 0000 000

PIN RE-CONFIGURATION REQUIRED FOR EMULATING EACH DEVICE
PIC16C55 74C922 SIG PIC16C55 74C923
PIN 18toPIN 17A PIN 18toPIN 19PIN 19toPIN 16B PIN 19toPIN 18PIN 20toPIN 15C PIN 20toPIN 17PIN 21toPIN 14D PIN 21toPIN 16PIN 22to NONE E PIN 22toPIN 15PIN 23toPIN 13 OE PIN 23toPIN 14PIN 24toPIN 12 DA PIN 24toPIN 13

THESE ARE ALL ACCOMMODATED ON THE PRINTED CIRCUIT BOARD LAYOUT

Once all of the necessary signals required for emulation purposes have been catered for, there is a spare port line - RC7 - available on the PIC16C55 (figure 2). This can be freely programmed for input or output and used for external control purposes. As an input, you could, for example, detect a low signal on this pin and invert the binary output code to the RC port. This is useful for existing applications which expect to read negative (as opposed to positive) binary codes from (say) a thumbwheel switch.

As an output, you could utilise this pin as a complimentary DA signal, which would go low when the original DA line - RC5 - goes high, and vice versa. This could have a current limited LED connected to it so as to indicate when a button is being pressed. You could even modify the software such that it functions as a self-contained security keypad, with a pre-programmed user code stored as part of the program. This spare output could then be used as an 'unlock' output to signal to an external device that the correct security code has been entered.

These are just some examples. No doubt you can think of, or maybe you already have, other purposes to suit your own needs. In our application, this bit is programmed as an input, but has no function assigned to it, and is not checked by the software.

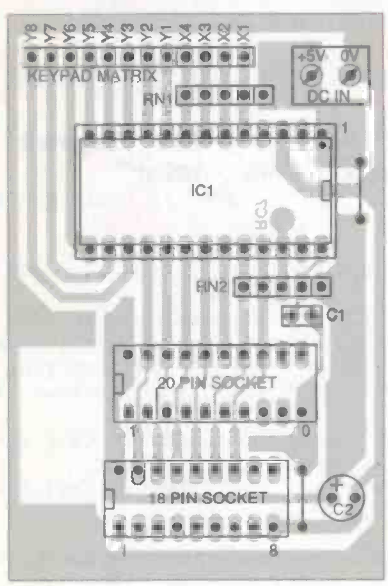
Figure 3 shows the PCB layout. The keypad connections are in a logical order down the left hand side, with up to four 'X' rows at the top, and up to eight 'Y' columns below them. It doesn't matter how you connect the keypad, just so long as the X-to-X and the Y-to-Y connections are made in some form or other, because the binary output codes can be altered in software to suit your needs.

You may have difficulties locating a source for the 4-way (5 pin) SIL resistor networks. Although they are a standard item, they are not stocked by many suppliers. However, you can purchase the 7 or 8 way versions, and either cut off the unused pins, or actually cut the whole resistor network to the required length - 5 pins - but don't cut it from the wrong end, the 5 pins must include the one with the pin 1 marker dot, otherwise you're going to end up with a 2-way or 3-way version, which will prove to be of little use for anything.

Connection

The 18 pin and 20 pin IC sockets to the right of the IC1 (notice these face the opposite direction to IC1) can be connected to the '922 or '923 positions respectively on the target system via a DIL header jumper lead. Assuming the target system is powered from +5V, this, together with the 0V line, will be transferred via the ribbon cable, and can be used to power the emulator board. Alternatively, if you wish to use the board as a stand alone keypad encoder unit, you can omit the IC sockets and fit a pin header to the left hand set of holes of the 20 pin socket, and take your signals from this, but remember you

Figure 3: The component layout for the PCB



Figures 5: Pin for pin connections between the two boards (see also figures 2 and 4)

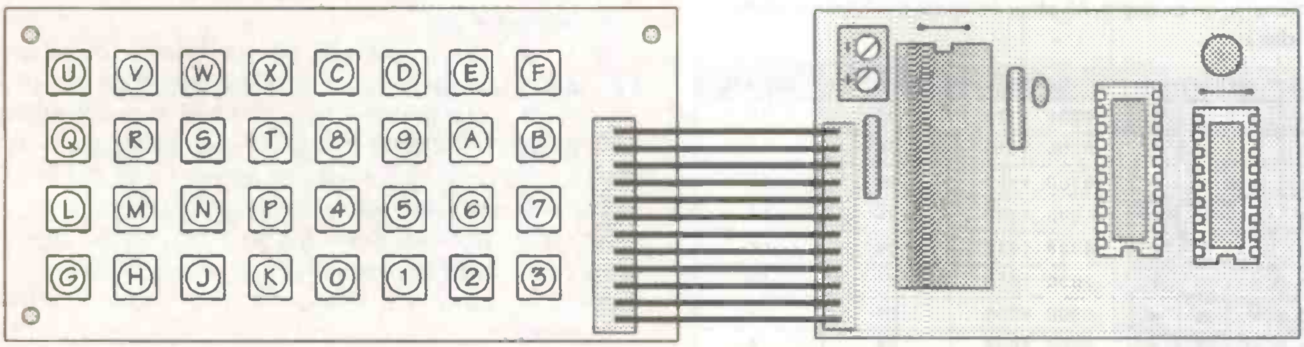
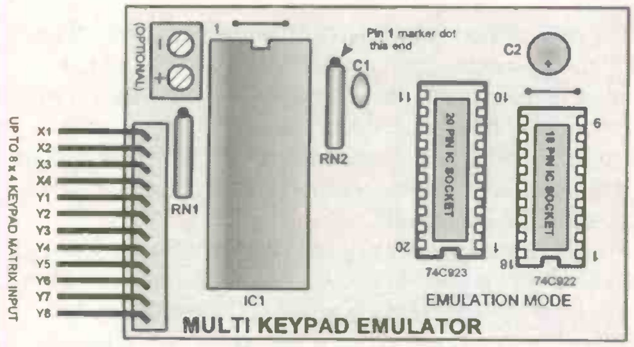


Figure 4: Emulation modes and connection details



are going to need the +5V and 0V connecting via the optional power input terminals at the top left of the board. See figure 4 for full details.

Software

There are usually two main reasons why designers make use of readily available keypad encoders, of any sort, not just the two mentioned here. Either they haven't got sufficient I/O lines available on their system to connect all the X and Y terminations, or, if they have got enough, they simply don't know how to actually scan the keypad, and to then convert the data in such a way to produce a usable binary output code. Well the software listing as presented will give you at least one idea of how to do it.

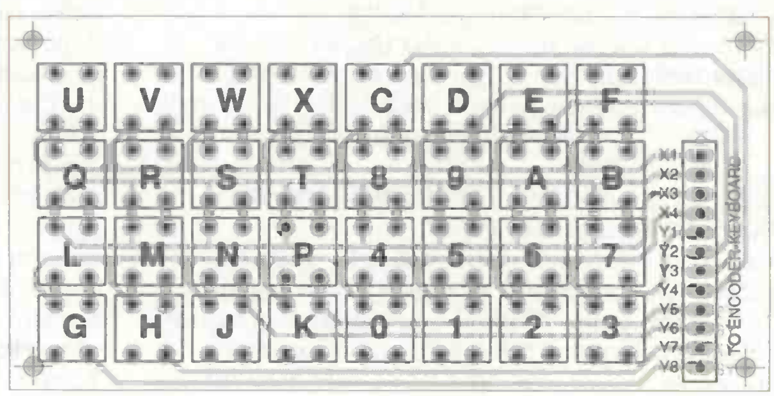
LIST P=16C55, N=38, C=132, R=DEC

""'Fools Paradise' Keypad Encoder/Emulator"

```
; Define the general registers and I/O
port addresses

RTCC EQU01 ; Real Time Clock/Counter
register address
PC EQU02 ; Program Counter address
STATUS EQU03 ; Status register address
FSREQU04 ; File Select Register address
PORTAEQU05 ; I/O Port A (lower 4 bits
only available)
PORTBEQU06 ; I/O Port B (all 8 bits
available)
PORTCEQU07 ; I/O Port C (all 8 bits
available)

; Assign labels to programming constants
used in PIC assembly language.
; These are used by all instructions which have a
choice of destination
; register for the result of their operation,
where 'd' can be 1 or 0.
; Doing this makes program listings more logical
and easier to read.

WEQU0; Destination register becomes 'W' (acc. )
FEQU1; Destination register becomes 'F' (file)

; Assign labels to the various bit numbers of the
STATUS register (03h)

CARRYEQU0; carry bit
DCARRY EQU1; digit carry bit
ZERO EQU2; Zero bit
PDOWNEQU3; power-down bit
WATDOG EQU4; watchdog time-out bit

; Assign basic pin labels to the bit numbers for
I/O port A.

RA0EQU00 ; Port A I/O bit 0
RA1EQU01 ; Port A I/O bit 1
RA2EQU02 ; Port A I/O bit 2
RA3EQU03 ; Port A I/O bit 3

; Assign basic pin labels to the bit numbers for
I/O port B.

RB0EQU00 ; Port B I/O bit 0
RB1EQU01 ; Port B I/O bit 1
RB2EQU02 ; Port B I/O bit 2
RB3EQU03 ; Port B I/O bit 3
RB4EQU04 ; Port B I/O bit 4
RB5EQU05 ; Port B I/O bit 5
RB6EQU06 ; Port B I/O bit 6
RB7EQU07 ; Port B I/O bit 7
```

Continued on p. 34

Figure 6: The overlay for the keypad PCB



Continued from p. 32

```
; Assign basic pin labels to the bit numbers for I/O port C.

RC0EQU00 ; Port C I/O bit 0
RC1EQU01 ; Port C I/O bit 1
RC2EQU02 ; Port C I/O bit 2
RC3EQU03 ; Port C I/O bit 3
RC4EQU04 ; Port C I/O bit 4
RC5EQU05 ; Port C I/O bit 5
RC6EQU06 ; Port C I/O bit 6
RC7EQU07 ; Port C I/O bit 7

; Assign labels to the various (RAM) data file registers used

 ORG08 ; Set base address for RAM

COUNT1 RES1; General purpose counter
IPBUFF RES1; Input buffer status byte
LASKEY RES1; Previous offset into look-up table
OFFSET RES1; Current offset into look-up table
OPBUFF RES1; Binary output code for RC0 to RC4
STROBE RES1; Column strobe line value

; END OF EQUATES SECTION

;**************************************************************************

; Start of program memory area (ROM)

 ORG0000 ; SET ORIGIN ADDRESS

;**************************************************************************

; Scan the Keypad and put the data in "IPBUFF".
; If a button is pressed, copy "OFFSET" to "LASKEY"
; To protect against possible 'glitches' causing the DDRs to change states,
; the DDRs for port A and port B are constantly updated by this routine.

SCANKP
 CLRF OPBUFF ; START WITH "OPBUFF" EMPTY
 CLRF OFFSET ; RESET OFFSET COUNTER TO ZERO
 MOVLWB'11111111'
 TRIS PORTA; SET PORT A FOR INPUT
 TRIS PORTB; INITIALLY SET PORT B FOR INPUT
 MOVWFPORTB; PRESET ALL PORT B LINES HIGH
 MOVLWB'11111110'
 MOVWFSTROBE ; PREPARE COLUMN STROBE LINE
SCAN2
 MOVF STROBE,W ; GET CURRENT STROBE VALUE IN 'W'
 MOVWFPORTB; PREPARE THE PORT LINES FIRST
 TRIS PORTB; NOW ENABLE THE OUTPUTS
 NOP
 NOP ; ALLOW I/O LINES TO STABILISE
 NOP
 MOVF PORTA,W; GET BUTTON PRESSED COLUMN DATA
 MOVWFIPBUFF ; SAVE IT IN "IPBUFF"

; Now, starting from the top row of the column we have just sampled,
; check each button in turn to see if any of them was pressed. After
; each test, increment the "OFFSET" value to adjust the offset into
; the look-up table of binary output codes - used later.

 BTFSSIPBUFF,RA0 ; SKIP IF NOT THE TOP ROW
 GOTO SCAN4; OTHERWISE SORT IT OUT
 INCF OFFSET ; ADD 1 TO LOOK-UP TABLE OFFSET
 BTFSSIPBUFF,RA1 ; SKIP IF NOT THE 2nd ROW
 GOTO SCAN4; OTHERWISE SORT IT OUT
 INCF OFFSET ; ADD 1 TO LOOK-UP TABLE OFFSET
 BTFSSIPBUFF,RA2 ; SKIP IF NOT THE 3rd ROW
 GOTO SCAN4; OTHERWISE SORT IT OUT
 INCF OFFSET ; ADD 1 TO LOOK-UP TABLE OFFSET
 BTFSSIPBUFF,RA3 ; SKIP IF NOT THE BOTTOM ROW
 GOTO SCAN4; OTHERWISE SORT IT OUT
 INCF OFFSET ; ADD 1 TO LOOK-UP TABLE OFFSET

; No buttons were pressed in this particular column, but we need to
; check any remaining columns that have not yet been scanned.

SCAN3
 BSFSTATUS,CARRY ; SET THE CARRY FLAG
 RLFSTROBE ; PREPARE STROBE LINE FOR NEXT COLUMN
 BTFSCSTATUS,CARRY ; SKIP IF ALL COLUMNS COMPLETED
 GOTO SCAN2; ELSE GO BACK FOR THE NEXT COLUMN

; All columns have been scanned, no buttons were found to be pressed.
; In this situation the "OFFSET" location contains 20h (32 decimal)
; and cannot be converted, so exit with "LASKEY" intact from last time.

 GOTO CONVERT; EXIT WITHOUT UPDATING "LASKEY"

; A button is pressed, and "OFFSET" holds the unique offset value for it
; (after keypad prioritisation, of course, i.e. lowest column/row address).
; Set the Data Available 'DA' line high, and copy the value into "LASKEY".

SCAN4
 BSFOPBUFF,RC6 ; PREPARE 'DA' LINE HIGH IN "OPBUFF"
 MOVF OFFSET,W ; GET CURRENT "OFFSET" VALUE
 MOVWFLASKEY ; AND UPDATE "LASKEY" WITH IT

;**************************************************************************

; Convert the value in "LASKEY" into a binary code for output on port C.
; These codes can be modified to suit your own needs. The characters on
; the right correspond to the keypad layout shown in Figure 2 of the text.

CONVERT
 BCFSTATUS,CARRY ; CLEAR THE CARRY FLAG
 MOVF LASKEY,W ; GET OFFSET VALUE IN 'W'
 ADDWFPC,F ; ADD IT TO THE PROGRAM COUNTER
 RETLWH'00'; CODE FOR 'F' BUTTON - RA0 to RB0
 RETLWH'01'; CODE FOR 'B' BUTTON - RA1 to RB0
 RETLWH'02'; CODE FOR '7' BUTTON - RA2 to RB0
 RETLWH'03'; CODE FOR '3' BUTTON - RA3 to RB0
 RETLWH'04'; CODE FOR 'E' BUTTON - RA0 to RB1
 RETLWH'05'; CODE FOR 'A' BUTTON - RA1 to RB1
 RETLWH'06'; CODE FOR '6' BUTTON - RA2 to RB1
 RETLWH'07'; CODE FOR '2' BUTTON - RA3 to RB1
 RETLWH'08'; CODE FOR 'D' BUTTON - RA0 to RB2
 RETLWH'09'; CODE FOR '9' BUTTON - RA1 to RB2
 RETLWH'0A'; CODE FOR '5' BUTTON - RA2 to RB2
 RETLWH'0B'; CODE FOR '1' BUTTON - RA3 to RB2
 RETLWH'0C'; CODE FOR 'C' BUTTON - RA0 to RB3
 RETLWH'0D'; CODE FOR '8' BUTTON - RA1 to RB3
 RETLWH'0E'; CODE FOR '4' BUTTON - RA2 to RB3
 RETLWH'0F'; CODE FOR '0' BUTTON - RA3 to RB3
 RETLWH'10'; CODE FOR 'X' BUTTON - RA0 to RB4
 RETLWH'11'; CODE FOR 'T' BUTTON - RA1 to RB4
 RETLWH'12'; CODE FOR 'P' BUTTON - RA2 to RB4
 RETLWH'13'; CODE FOR 'K' BUTTON - RA3 to RB4
 RETLWH'14'; CODE FOR 'W' BUTTON - RA0 to RB5
 RETLWH'15'; CODE FOR 'S' BUTTON - RA1 to RB5
 RETLWH'16'; CODE FOR 'N' BUTTON - RA2 to RB5
 RETLWH'17'; CODE FOR 'J' BUTTON - RA3 to RB5
 RETLWH'18'; CODE FOR 'V' BUTTON - RA0 to RB6
 RETLWH'19'; CODE FOR 'R' BUTTON - RA1 to RB6
 RETLWH'1A'; CODE FOR 'M' BUTTON - RA2 to RB6
 RETLWH'1B'; CODE FOR 'H' BUTTON - RA3 to RB6
```

Continued on p. 36

Continued from p. 34

```
 RETLWH'1C'; CODE FOR 'U' BUTTON - RA0 to RB7
 RETLWH'1D'; CODE FOR 'Q' BUTTON - RA1 to RB7
 RETLWH'1E'; CODE FOR 'L' BUTTON - RA2 to RB7
 RETLWH'1F'; CODE FOR 'G' BUTTON - RA3 to RB7

;*****************************************************
**************************

; Sort out the I/O signals and binary output code
required on port C.
; Location "OPBUFF" holds the binary code for
keypad data, plus the 'DA'
; bit status for RC6. Port lines RC0 to RC4 must
only be set for output
; if the OE input on RC5 is low, otherwise they
must be set as inputs.

OUTPUT
 MOVF OPBUFF,W ; GET BINARY OUTPUT VALUE
 MOVWFPORTC; PREPARE PORT C BEFORE ENABLING IT
 MOVLWB'10111111'; INITIALLY SET JUST RC6 FOR
OUTPUT
 BTFSSPORTC,RC5; SKIP IF 'RC5' IS HIGH
 MOVLWB'10100000'; ELSE USE KEYPAD CODE TOO
 TRIS PORTC; ENABLE THE OUTPUTS

; Add a short switch debounce period to the whole
process. This
; will compensate for any worn or 'iffy" contacts
on the keypad.

DBOUNC
 DECFSZ COUNT1 ; WAIT . . .
 GOTO DBOUNC
 RETLW0; TIME UP - RETURN

;*****************************************************
**************************

; Beginning of the main program (PROGRAM ENTRY
POINT)

START
 MOVLWB'00000000'
 MOVWFPORTC; PREPARE ALL PORT C LINES LOW
 MOVLWB'10111111'
 TRIS PORTC; INITIALLY SET JUST RC6 FOR OUTPUT
 MOVLWH'20'
 CLRF COUNT1 ; CLEAR KEYPAD DEBOUNCE TIMER
 CLRF LASKEY ; SET "LASKEY" TO ZERO

;*****************************************************
**************************

COMMAND
 CALL SCANKP ; SCAN THE KEYPAD MATRIX
 BCFSTATUS,CARRY ; CLEAR THE CARRY FLAG
 ADDWFOPBUFF,F ; ADD CONVERTED CODE TO "OPBUFF"
 CALL OUTPUT ; SORT OUT THE OUTPUT CODE
 GOTO COMMAND; DO IT FOREVER

;*****************************************************
**************************

; Set up the reset vector for the type of
processor used.
; This varies between devices but is at 1FFh on
the 16C55

 ORGH'1FF'
 GOTO START
ZZZ; END OF PROGRAM MARKER
 END
```

A complete kit of the above parts, which includes the PCB and a pre-programmed
PIC16C55RC/P, is available for £14. 50 from the author at the following address
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IN 5363B	20 for £1
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IN 5386B	20 for £1
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IN 6072A	20 for £1
2N 1711	10p each
2N 2369A	10p each
2N 2484	10p each
2N 2894	10p each
2N 2905	10p each
2N 2906	10p each
2N 3419	16p each
2N 3700	10p each
2N 3725	20p each
2N 3824	16p each
2N 4117A	20p each
2N 4918	20p each
2N 5038	20p each
2N 5039	20p each
2N 5179	16p each
2N 5192	20p each
2N 5320	20p each
2N 5322	20p each
2N 5323	20p each
2N 5486	20p each
2N 6288	20p each
2N 6386	20p each
BC 108	5p each
BC 109	5p each
BC 161	5p each
BC 179B	5p each
BC 477	10p each
BC546	5p each
BC 558	5p each
BCY 59	10p each
BCY 791X	10p each
BD 175	20p each
BD 237	20p each
BD 238	20p each
BD 239	20p each
BD 240C	20p each
BD 436	20p each
BD 707	20p each
BD 909	20p each
BDW 84A	20p each
BDW 91	20p each
BDW 93C	20p each
BDW 94A	20p each
BDX 54	20p each
BDX 87C	20p each
BF 257	10p each
BF 258	10p each
BFR 36	20p each
BFR852	5p each
BFR856	5p each
BFW 43	20p each
BFW 44	20p each
BFX 38	20p each
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BFX 86	20p each
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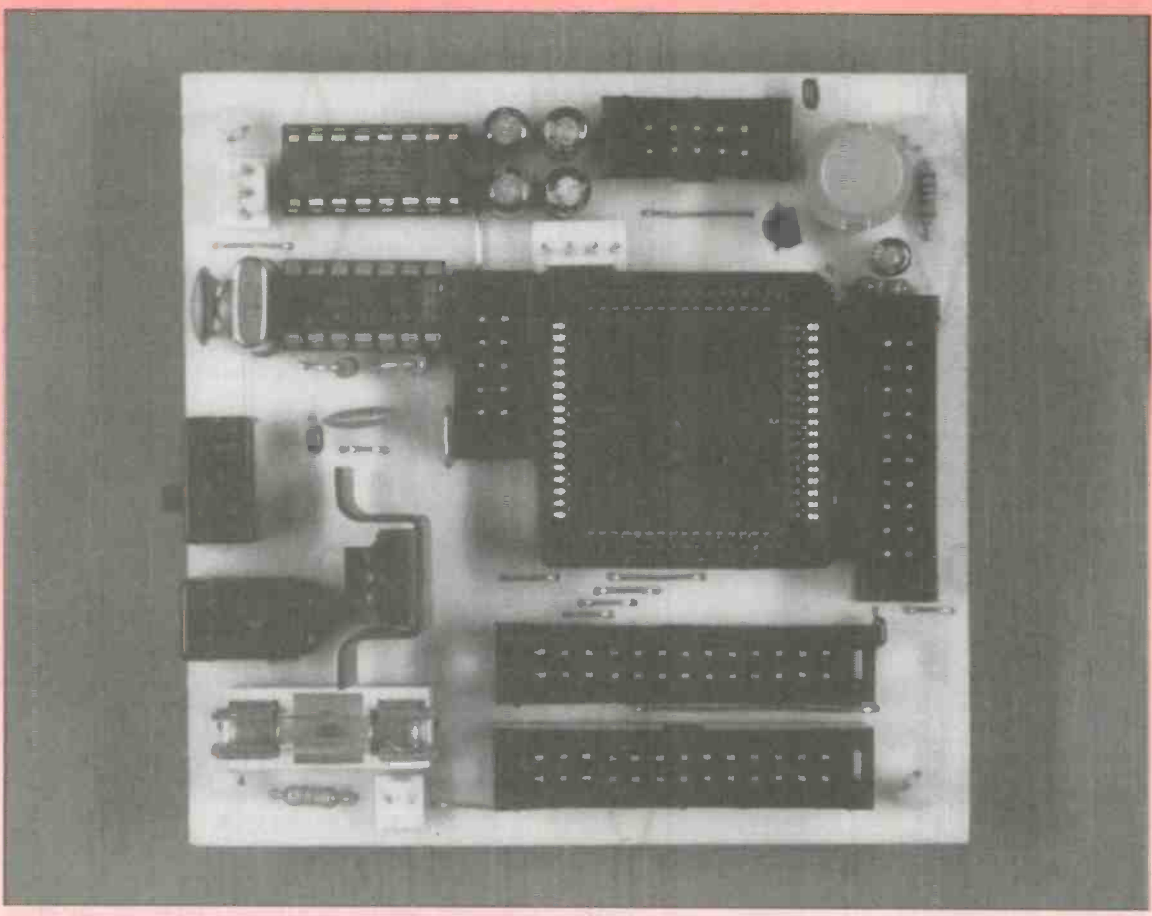
8031 & 80C535 Single Board Computer

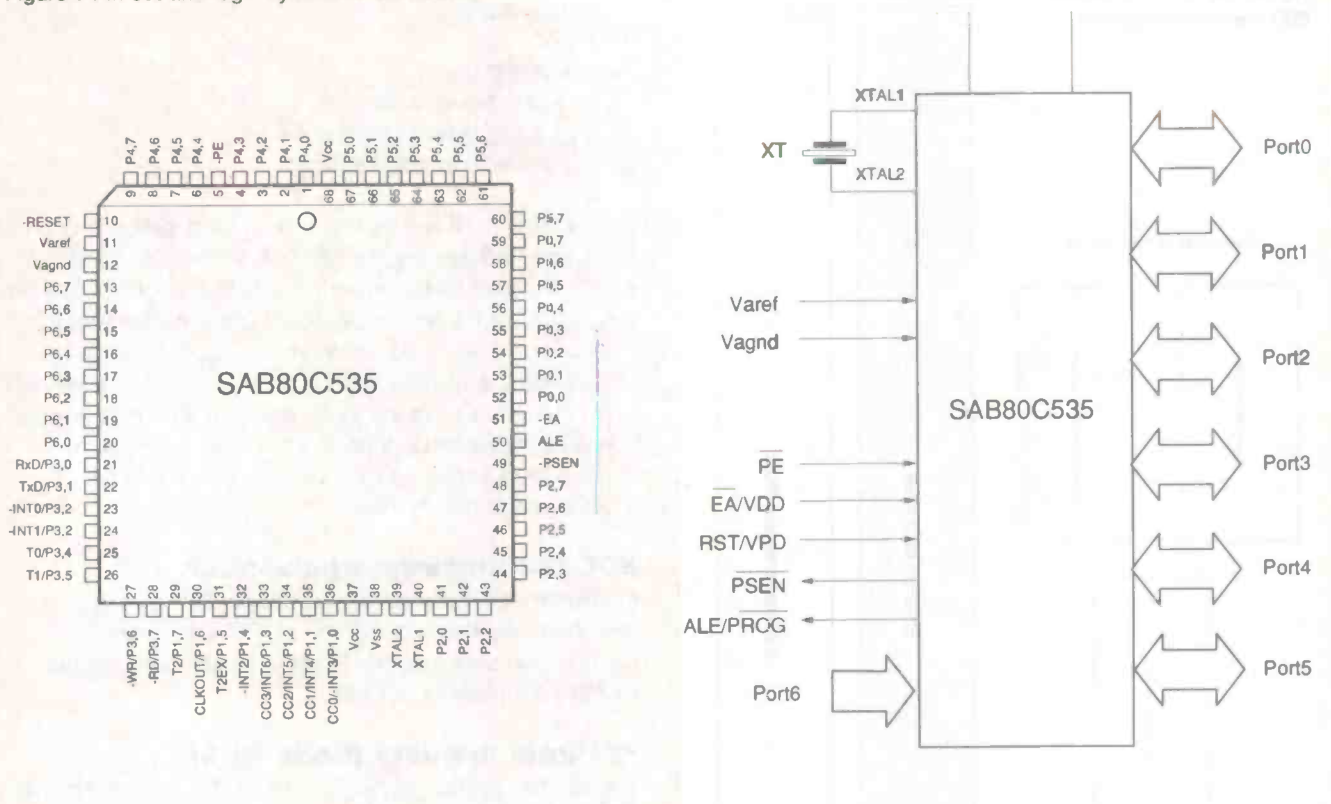
PART 5

Dr. Pei An concludes this project by adding extra power with the 80C35 motherboard.



The 80C535 is a high-performance single-chip microcontroller developed by Siemens and is based on the MCS-51 architecture. It has 100% hardware and software compatibility with MCS-51 microcontrollers and incorporates a number of enhancements which significantly increase overall system performance. These enhancements include increased numbers of I/O ports and timer/counters, an 8-channel A/D converter, extensive interrupt facilities, and others. The 8031 single board computer system was described in the April and May issues, and the construction and operation of the SBC were given in June and July issues. The present article describes an 80C535 motherboard that could directly replace the 8031 motherboard, forming an even more powerful 80C535 single board computer system. The complete 8031/80C535 single board computer system is available in kit and in assembled form from the author. Details are given at the end of this article.

Figure 1 Pin out and logic symbol of the 80C535



(a) Pin out of the 80C535

(b) Logic symbol of the 80C535

80C535 single chip microcontroller

The 80C535 architecture is based on the MCS-51 microcontroller family and the instruction set is fully compatible with MCS-51. The 80C535 has 68 pins and a PLCC-68 package. The pin-out of the 80C535 is shown in figure 1a. Figure 1b gives the logic symbol. Some of the pins are fully compatible with those of the 8031 microcontroller. They include:

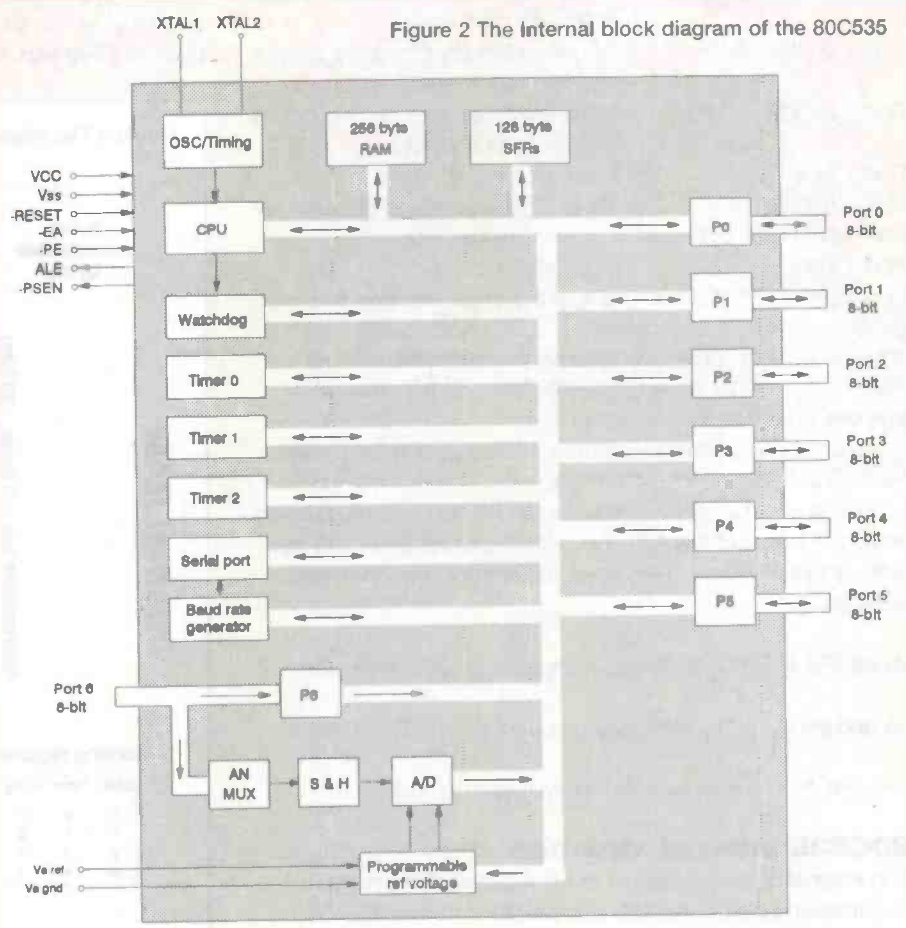
Port 0 (P0,0 - P0,7, Pins 52 to 59)
Port 2 (P2,0 - P2,7, Pins 41 to 48)
Port 3 (P3,0 - P3,7, Pins 21 to 28)

ALE/PROG	(Pin 50) -PSEN
	(Pin 49) -EA/Vpp
	(Pin 51)
XTAL1, XTAL2	(Pins 40 and 39)
RESET	(Pin 10);
VSS	(Pin 38)
VCC	(Pin 37 and 68)

Please refer to Part I of this project for the description of the pin functions. Pins that are special to the 80C535 are described below:

Port 1 (P1,0 - P1,7, Pins 36 to 29): If this port is used as a general purpose 8-bit I/O port, it is the same as the one for the 8031 microcontroller. Each pin has a secondary function which is different from those on the 8031.

Figure 2 The internal block diagram of the 80C535



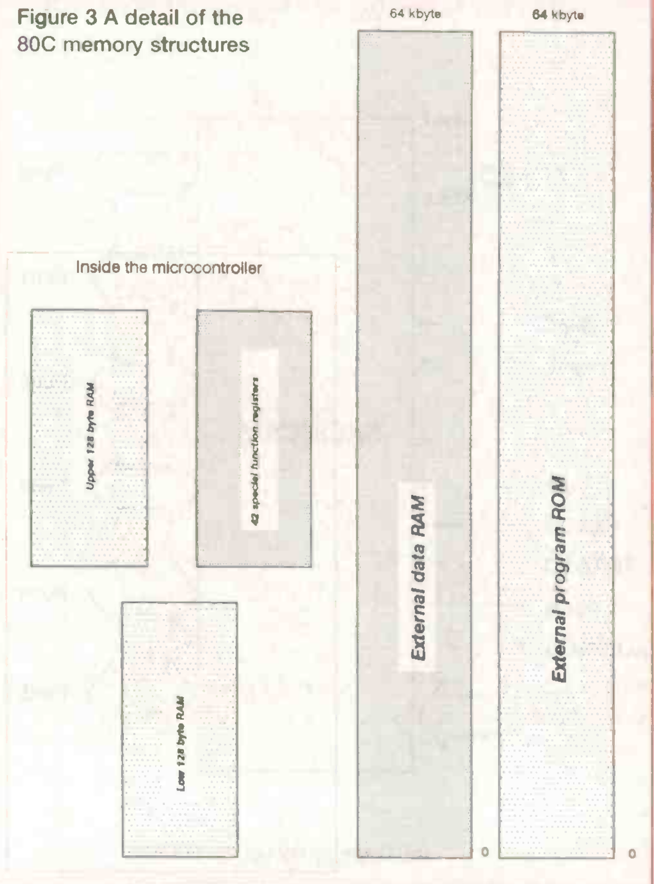


Figure 3 A detail of the 80C memory structures

Port 0 and Port 2 which form the external memory expansion interface
Serial port
Timer/Counter 0 and 1
Port 3 which provides alternate functions
The lower 128 bytes of internal ram
21 of the special function registers

The functions of these internal units were described in Part I of this article. Additionally, the 80C535 contains an extra 128 bytes of internal RAM area which results in a total of 256 bytes of internal RAM. It has a new 16-bit timer/counter with a 2:1 pre-scaler, reload mode, compare and capture capability. It also contains a 16-bit watchdog timer and an 8-channel 8-bit converter with a programmable reference voltage. It has two additional bidirectional ports (Ports 4 and 5). Furthermore, it has a powerful interrupt structure with 12 vectors and 4 programmable priority levels.

80C535 memory organisation

Identical to the 8031 memory structure, the 80C535 microcontroller has two memory portions, the program memory and data memory. Figure 3 shows the complete memory structure for 80C535.

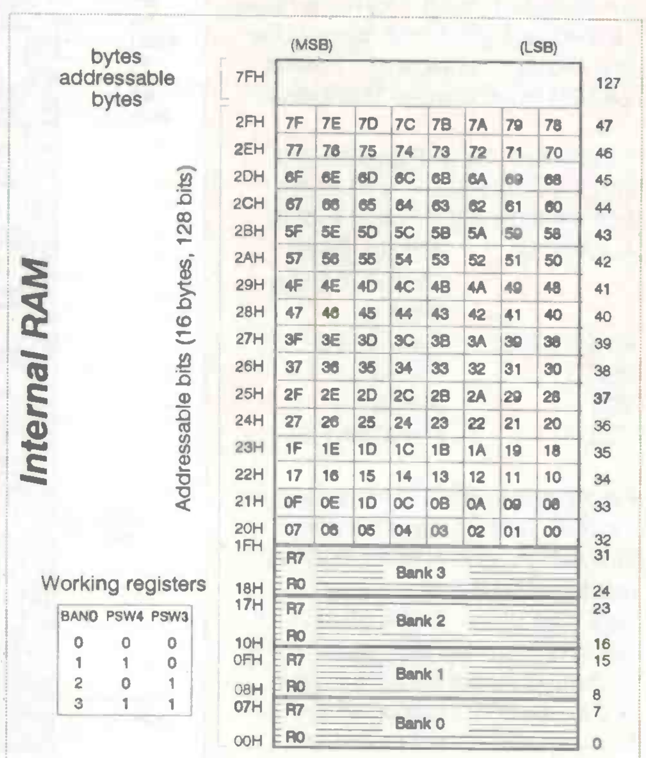
Program memory (Code ROM)

80C535 has no internal program ROM. The program memory can be expanded externally up to 64 kbyte.
This requires -EA pin to be tied low to enable the external rom.

Data memory

The data memory space consists of an internal and external memory space. The internal data memory is divided into three separate blocks: a lower 128 bytes of RAM, an upper 128 bytes of RAM and an 128 byte special function register (SRF)

Figure 4 The internal ram of the 80C535 microcontroller



Port 1,0/CC0/-INT3:	Compare 0 output, capture 0 input and interrupt 3 input
Port 1,1/CC1/-INT4:	Compare 1 output, capture 1 input and interrupt 4 input
Port 1,2/CC2/-INT5:	Compare 2 output, capture 2 input and interrupt 5 input
Port 1,3/CC3/-INT6:	Compare 3 output, capture 3 input and interrupt 6 input
Port 1,4/-INT2:	Interrupt 2 input
Port 1,5/T2EX:	Timer 2 internal reload trigger input
Port 1,6/CLOCKOUT:	System clock output
Port 1,7/T2:	Counter 2 input

Port 4 (P4,0 - P4,7, Pins 1 to 4 and 6 to 9): This port is a general purpose 8-bit bidirectional I/O port. It can be configured as an input or output port by software.
Port 5 (P5,0 - P5,7, Pins 67 to 60): This port is a general purpose 8-bit bidirectional I/O port.
It can be configured as an input or an output port by software.
Port 6 (P6,0 - P6,7, Pins 13 to 20):

This is an 8-bit unidirectional input port for eight multiplexed analogue inputs of the A/D converter. It can be also used for digital input if voltage levels meet the specification for digital voltages.

Va ref (Pin 11): The reference voltage for the A/D converter.

Va gnd (Pin 12): The reference ground for the A/D converter.

-PE (Pin 4): The enable pin for power saving mode.

80C535 internal structure

The internal block diagram of the 80C535 is given in figure 2. The following blocks are fully compatible with the MCS-51 microcontrollers.

Figure 5 The special function register area

Register	Address									
Port 5 (P5)	F8H	D7 FF	D6 FE	D5 FD	D4 FC	D3 FB	D2 FA	D1 F9	D0 F8	255
Register B (B)	F0H	D7 F7	D6 F6	D5 F5	D4 F4	D3 F3	D2 F2	D1 F1	D0 F0	
Port 4 register (P4)	E8H	D7 EF	D6 EE	D5 ED	D4 EC	D3 EB	D2 EA	D1 E9	D0 E8	
Register A (A)	E0H	D7 E7	D6 E6	D5 E5	D4 E4	D3 E3	D2 E2	D1 E1	D0 E0	
Port 6 input data register (P6)	DBH	byte accessible only								
A/D converter program register (DAPR)	DAH	byte accessible only								
A/D converter data register (ADDAT)	D9H	byte accessible only								
A/D converter control register (ADCON)	D8H	BD DF	CLK DE	DD	BSY DC	ADM DB	MX2 DA	MX1 D9	MX0 D8	
Program status (PSW)	D0H	CY D7	AC D6	F0 D5	RS1 D4	RS0 D3	OV D2	F1 D1	P D0	
Time 2, high byte (TH2)	CDH	byte accessible only								
Time 2, low byte (TL2)	CCH	byte accessible only								
Compare/reload/capture register, high byte (CRCH)	CBH	byte accessible only								
Compare/reload/capture register, low byte (CRCL)	CAH	byte accessible only								
Timer 2 control register (T2CON)	C8H	T2PS CF	I3FR CE	I2FR CD	T2R1 CC	T2R0 CB	T2CM CA	T2I1 C9	T2I0 C8	
Compare/capture register 3, high byte (CCH3)	C7H	byte accessible only								
Compare/capture register 3, low byte (CCL3)	C6H	byte accessible only								
Compare/capture register 2, high byte (CCH2)	C5H	byte accessible only								
Compare/capture register 2, low byte (CCL2)	C4H	byte accessible only								
Compare/capture register 1, high byte (CCH1)	C3H	byte accessible only								
Compare/capture register 1, low byte (CCL1)	C2H	byte accessible only								
Compare/capture enable register (CCEN)	C1H	byte accessible only								
Interrupt request control register (IRCON)	C0H	EXF2 C7	TF2 C6	IEX6 C5	IEX5 C4	IEX4 C3	IEX3 C2	IEX2 C1	IADC C0	
Interrupt priority register 1 (IP1)	B9H	byte accessible only								
Interrupt enable regitser 1 (IEN1)	B8H	EX2 BF	SWDT BE	EX6 BD	EX5 BC	EX4 BB	EX3 BA	EX2 B9	EADC B8	
Port 3 register (P3)	B0H	P37 B7	P36 B6	P35 B5	P34 B4	P33 B3	P32 B2	P31 B1	P30 B0	
Interrupt priority 0 (IP0)	A9H	byte accessible only								
Interrupt enable 0 (IEN0)	A8H	EA AF	WDT AE	ET2 AD	ES AC	ET1 AB	EX1 AA	ET0 A9	EX0 A8	
Port 2 register (P2)	A0H	P27 A7	P26 A6	P25 A5	P24 A4	P23 A3	P22 A2	P21 A1	P20 A0	
Serial I/O buffer (SBUF)	99H	byte accessible only								
Serial port control (SCON)	98H	SNC 9F	SN1 9E	SN2 9D	REN 9C	TB8 9B	RB8 9A	TI 99	RJ 98	
Port 1 register (P1)	90H	P17 97	P16 96	P15 95	P14 94	P13 93	P12 92	P11 91	P10 90	
Timer 1, high byte (TH1)	8DH	byte accessible only								
Timer 0, high byte (TH0)	8CH	byte accessible only								
Timer 1, low byte (TL1)	8BH	byte accessible only								
Timer 0, low byte (TL0)	8AH	byte accessible only								
Timer mode (TMOD)	89H	GAT	C/T	N1	N0	GAT	C/T	M1	M0	
Timer/counter (TCON)	88h	TF1 8F	TR1 8E	TF0 8D	TR0 8C	IE1 8B	IT1 8A	IE0 89	TC 88	
Power control (PCON)	87H	SM				GF1	GF0	PD	IDL	
Data pointer high byte (DPH)	83H	byte accessible only								
Data pointer low byte (DPL)	82H	byte accessible only								
Stack pointer (SP)	81H	byte accessible only								
Port 0 register (P0)	80H	P07 87	P06 86	P05 85	P04 84	P03 83	P02 82	P01 81	P00 80	

area. The upper 128 bytes of RAM and the 128 byte SRFs share the same address locations, but they are accessed through different addressing modes.

The lower 128 bytes of RAM are accessed through direct addressing (for example MOV A, direct; direct is an address ranging from 0 to 128) or register indirect addressing (MOV A, @R0; register R0 stores a RAM address ranging from 0 to 128).

The upper 128 bytes RAM can only be accessed through register indirect addressing (MOV A, @R0; R0 stores a RAM address ranging from 129 to 255). The special function registers are accessed through direct addressing.

The lower 128 bytes RAM has the same structure as that in the 8031 microcontroller (see figure 4). The external data memory can be expanded up to 64 kbytes. There are 42 special function registers in the SRF area (there are 21 special function registers on the 8031). All the registers in 8031 are in the 80C535 and they are located at the same address.

The extra registers, 21 in total, are used to control the expanded facilities such as the I/O ports, A/D converter and timers, etc. These registers are summarised in figure 5.

I/O ports

Ports 3, 4 and 5 can be used as three 8-bit programmable I/O ports (Port 3 also has secondary functions). Their associated registers have the following addresses: B0H, E8H and F8H, respectively. Each bit can be programmed either as an input or as an output.

When the CPU issue a write command, the data from the internal bus is latched into the output and appears at the pin. Outputting a byte to a port is achieved by writing a byte to the corresponding special function register. When the CPU issues a read command, the data at the port pin (read-pin mode) or at the port latch (read-latch mode) can be read into the CPU.

Reading is achieved by reading a byte from the port SRF. To configure a port bit as an input, 1 must be written to that port first. A pull-up resistor pulls the pin to high state, but the external circuit can pull the pin to low state.

Because of this, this type of port is called 'quasi-bidirectional' port. The details of the hardware and operation can be found in the user's manual of the components.

Serial interface

The serial port enables a full-duplex serial communication between the microcontroller and external components and it is compatible to that of the 8031. The serial interface can work in any of the four operation modes.

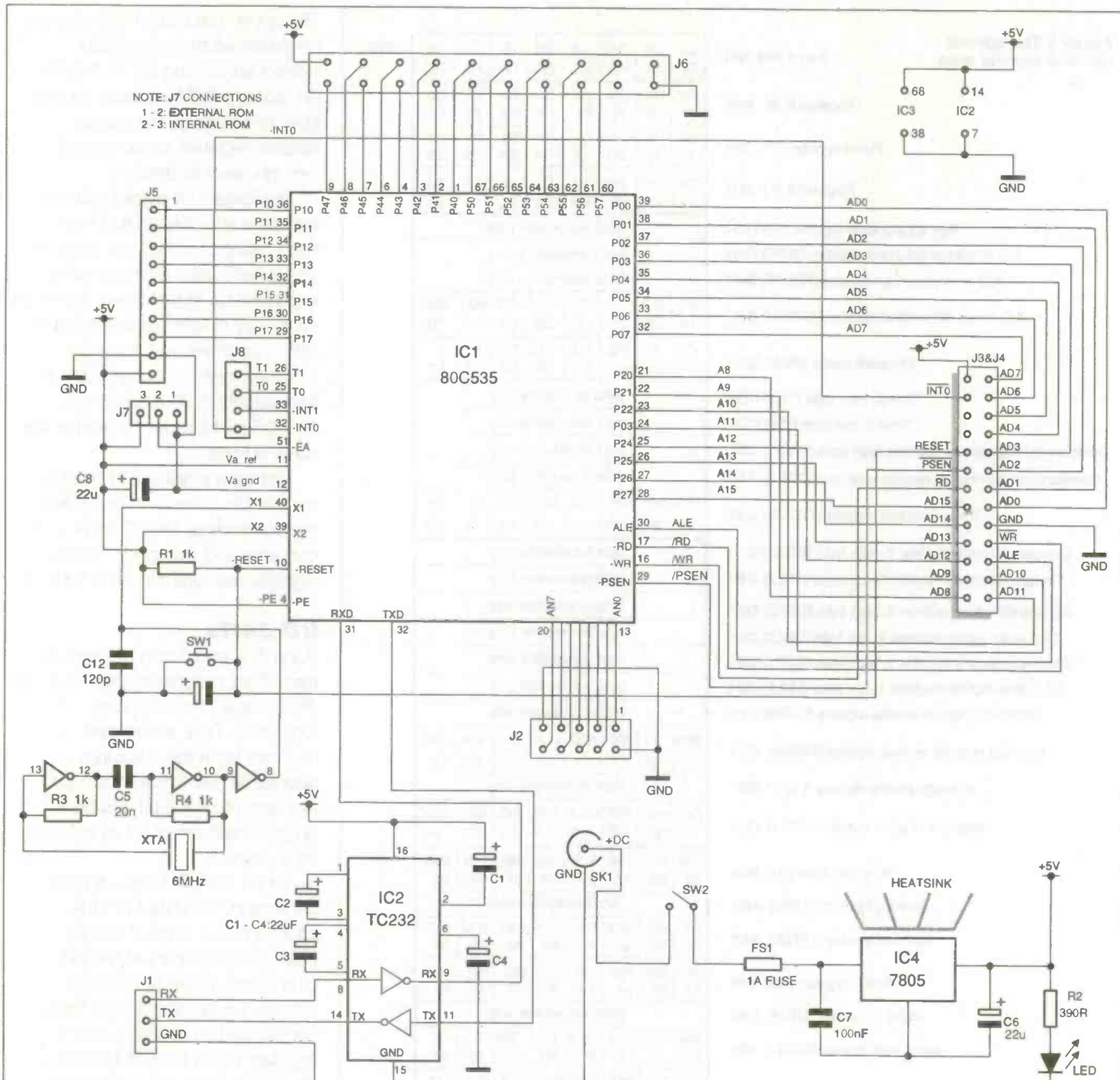


Figure 6 The circuit diagram of the 80C535 motherboard

Table 1 Operation mode of the RS232 interface

Modes	Name	Description
0	Synchronous	Serial data transmits through RxD, TxD is the synchronisation clock. The baud rate is 1/12 of the oscillator frequency.
1	8-bit UART, Variable baud rate	Data transmitted through TxD and received through RxD. 1 start bit (0), 8 data bits (LSB first) and 1 stop bit (1). Baud rate is variable
2	9-bit UART, fixed baud rate (can be used for multiprocessor applications).	Data transmitted through TxD and received through RxD. 1 start bit (0), 8 data bits (LSB first), programmable bit and 1 stop bit (1). Baud rate is fixed at 1/32 or 1/64 of the oscillator.
3	9-bit UART, variable baud rate. (can be used for multiprocessor applications).	Data transmitted through TxD and received through RxD. 1 start bit (0), 8 data bits (LSB first), programmable bit and 1 stop bit (1). Baud rate is variable.

There are four special function registers associated with the serial interface: the SCON(98H) for configuring the serial port, SBUF(99H) for buffering the transmitted or received data, PCON (87H) selecting the baud rate, and ADCON (D8H) being the other register for selecting the baud rate for Modes 1 and 3. The details of the hardware and operation of the RS232 interface can be found in the user's manual.

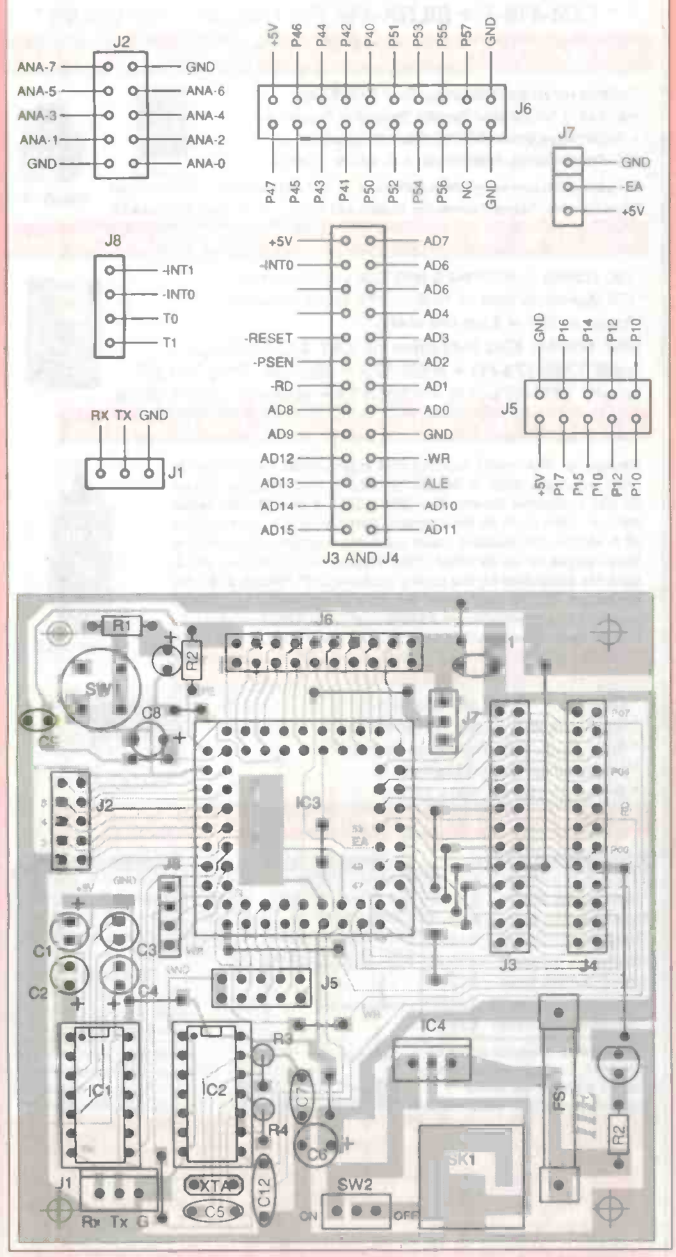
Timers

80C535 has three timers, timers 0, 1 and 2. Timer 0 and 1 are compatible to that for 8031.

They can be configured as timers or counters. In timer function, the counter register is incremented every machine cycle. Therefore the count rate is 1/12 of the oscillator frequency. In counter function, the counter register is incremented in response to a 1-to-0 at the external input pin, T0 or T1.

Each timer/counter has four modes. Timer 2 is a powerful peripheral unit of the 80C535. It combines the functions of compare, capture and reload and is used for applications such as digital signal generation (i.e. pulse generation and pulse width modulation) and event capturing (i.e. pulse width measurement).

Figure 7 The component layout of the 80C535 motherboard



On-board A/D converter

The 80C535 provides an A/D converter with the following features.

The A/D converter is of a successive approximation type and has an 8-bit conversion accuracy. It is equipped with eight multiplexed input channels.

The internal reference voltage (both the reference voltage and ground) can be programmed. An A/D conversion requires 13 machine cycles. There are three special functions register associated with it.

They are the ADCON register (A/D conversion control register), ADDAT (A/D converter data register) and DAPAR (A/D converter program register). A write-to-DAPR starts a new conversion cycle.

The conversion begins with the next machine cycle and a busy status (BSY) in ADCON becomes 1.

After 12 machine cycles, the conversion is completed, the result is written to the ADDAT register and BSY goes to 0. In continuous mode, a new conversion is triggered after a conversion is completed.

ADCOM register is allocated at D8H and is used for choosing single or continuous conversion mode for each analog channel. Bit functions of the ADCOM register are shown as follows:

Table 2 Bit functions and bit addresses of the ADCON register

Bit address	DFH	DEH	DDH	DCH	DBH	DAH	D9H	D8H
Function	//BD//	//CLK//	////	BSY	ADM	MX2	MX1	MX0

In this table, MX0, MX1 and MX2 select one of the 8 input analogue input channels (000 for AN0, 111 for AN7 etc). If ADM=1, a continuous A/D conversion is performed. If ADM=0, the conversion stops after one conversion.

BSY becomes high when the converter is busy. After a conversion it goes low. BD and CLK are not used for the A/D converter. The special function register ADDAT is located at D9H. It holds the conversion result. The data remains in the register until it is overwritten by the next converted data. Register DAPR has an address of DAH and it has two functions

Firstly, writing a data to this register starts the A/D conversion. Secondly, it controls the internal programmable voltage reference. Its bit function is shown below:

Table 3 Bit functions of the DAPR register

DB7 to DB4: Programming of V int AREF DB3 to DB0: Programming of V int AGND

The internal reference voltage can be programmed in 16 steps by the DB7 to DB4 of the register.

The internal reference ground is programmed in 16 steps by the DB3 to DB0.

The following equation is used for obtaining the internal reference voltage and ground:

$$V_{int,\ AGND} = V_{AGND} + \frac{\text{Value of DB3 to DB0}}{16}\left(V_{AREF} - V_{AGND}\right)$$

$$V_{int,\ AREF} = V_{AGND} + \frac{\text{Value of DB7 to DB4}}{16}\left(V_{AREF} - V_{AGND}\right)$$

It is required that the voltage between *V int AREF* and *V int AGND* should be not less than 1V.

80C535 motherboard

The circuit diagram of the 80C535 motherboard is shown in figure 6.

It consists of an 80C535 microcontroller (IC1), a RS232 line driver (TC232, IC2) and a 6 MHz clock generator built around 74LS04 (IC3). It has a +5V 1A voltage regulator (7805, IC4) and requires an external 8-15V DC power supply. An on/off switch, a 1A fuse, a LED indicator and a reset button are also contained on the board.

The MCS-51 bus (including data, address and control lines) is available from two 26-pin IDC connectors (J3 and J4). From there the memory and I/O expansion board and other I/O cards are connected. Digital I/O port, Port 1, is available from a 10-way IDC connector (J5).

Other two digital I/O ports, Port 4 and 5, are available from a 20-way IDC connector (J6).

Port 6 which is the analogue input port and a digital input port is available from another 10-way IDC connector (J2). J1 is the connector for the RS232 serial cable.

The pin functions of all connectors are shown in figure 7.

The board is also designed for use with other 80535 series microcontrollers, such as 80C515 which has an 8 kbyte on-board ROM. To enable the on-board ROM or the external ROM, a jumper switch (J7) is used.

If the microcontroller fetches data fROM an external ROM, Pins 1 and 2 of J7 should be connected using jumpers.

If it fetches data from the internal ROM (for 80C515 only), Pins 3 and 2 should be connected.

Construction

The motherboard is constructed on a single-sided PCB board. The component layout is shown in figure 7 and the completed board is shown in photograph 1.

General guidelines in constructing the board were given in 'Construction Notes' in Part 3 of this series.

As the complete SBC system consumes about 0.5 A, a heat sink must be installed on the voltage regulator to prevent it from overheating.

The board is simple to construct and there is no adjustment needed. Hence, it should work straight away once it is properly constructed.

Further references

For further information about the hardware and instruction set of the MCS-51 series and 80535 microcontrollers, please refer to the following books.

1. User's manual of MCS-51 microcontroller families. Siemens semiconductors

2. User's manual of SAB 80515/SAB 80C515 family 8-bit single-chip microcontrollers. Siemens semiconductors

Technical support

The complete 8031 single board computer is available in kit and assembled form from the author at a price of £97 including P&P.

The 80C535 motherboard costs £36.

Please direct your enquiries to

Dr. Pei An, 58 Lamport court, Manchester M1 7EG, U.K.
Tel/Answer/Fax: +44-(0)161-272-8279.

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"CHOPPER" TREMOLO EFFECT

A more extreme musical effects unit from Robert Penfold.

One of the advantages of the do-it-yourself approach to musical effects units is that you are not restricted to the "standard" effects. You are free to experiment with other effects, and they can be as mild or extreme as you desire. Feedback from readers suggests that most prefer do-it-yourself effects units that enable them to go beyond the limits of commercial units, with some very extreme effects being produced. This effects unit was produced as a result of a few requests for a tremolo unit that would produce a more violent effect than the normal type, which produces one of the mildest of musical effects.

Rise and fall

The tremolo effect is produced by amplitude modulating the input signal with the output from an lfo (low frequency oscillator). The latter usually operates in the range 0.1 to 10 Hertz. Conventionally, the output waveform of the lfo is one which has a low harmonic content, and gives smooth variations in volume. In practice this generally means a sinewave signal or a triangular type. This gives a mild effect, and a final result which largely retains the characteristics of the original sound. Figure1 helps to explain the modulation process, which really just uses the low frequency oscillator to control the volume of the output signal. The waveform in (a) is the output of the lfo, which in this case is a triangular waveform. Fig.1(b) shows the output signal obtained with an input signal at a constant amplitude. When the modulation signal is at its peak negative level, the amplitude of the output signal is very low. Most tremolo units never actually cut off the output signal completely, and the maximum attenuation would typically be about 20 to 40dB. In other words, the amplitude of the signal would be reduced by a factor of between ten and 100. As the amplitude of the modulation signal falls back towards zero, the amplitude of the output signal steadily increases. The level of the output signal continues to increase as the amplitude of the modulation signal rises in a positive direction. Once the modulation signal reaches its peak positive value, the process is reversed, with the output signal being steadily reduced in level until the modulation waveform reaches its peak negative value once again. This process continues indefinitely, with the volume of the output signal being varied at a rate controlled by the modulation signal from the lfo. This gives quite a mild effect, with a sort or rhythmic "throbbing" sound being introduced to the processed signal. Manually operating a swell pedal at a rate of a few Herz would actually give exactly the same effect (but would not be a very practical way of generating it!). A more intense effect can be obtained

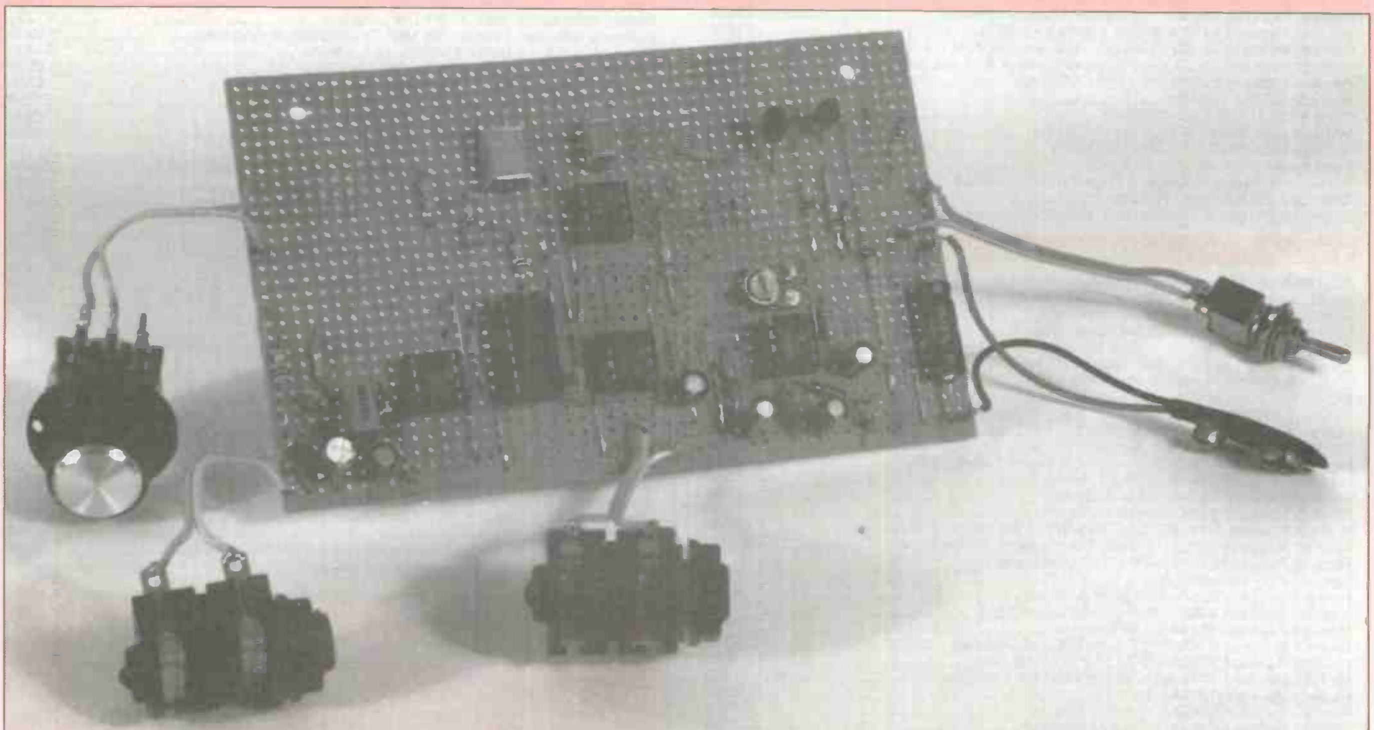
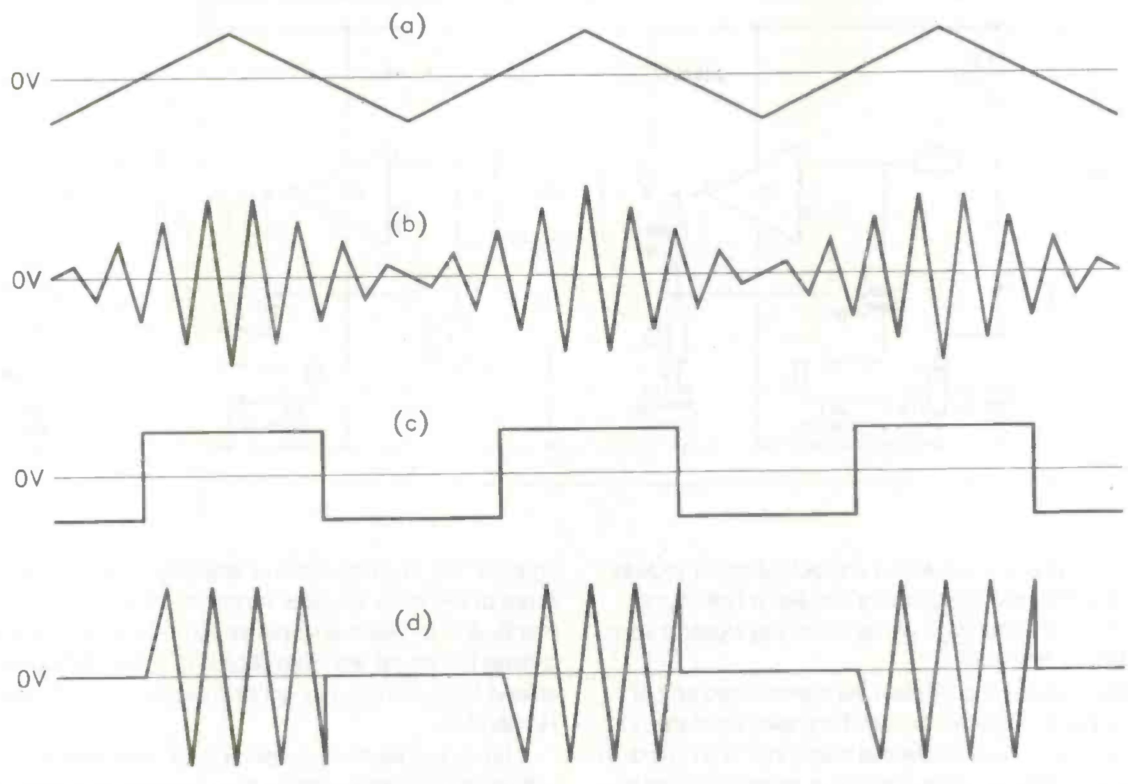


Figure 1: Waveforms for a conventional tremolo unit (a and b), and the chopper effects unit (c and d)



simply by using a modulation waveform that has a high harmonic content, such as a squarewave or pulse signal, and by using greater modulation depth.

This results in the signal being switched on and off, or "chopped" as this type of thing is sometimes termed. The waveforms of Fig.1(a) and (b) show a squarewave modulation signal and the resultant output signal. Although the two output waveforms of figure1 may look similar, the actual sounds produced are very different indeed.

The conventional tremolo effect leaves the original sound largely intact, but the "chopping" effect tends to dominate the sound of the final output. A guitar plus tremolo gives a sound that is still unmistakably that of a guitar, but a guitar plus chopping gives a sound that is more into the realms of the synthesiser. This is either good or bad, depending on your musical tastes and preferences. One problem with chopping a signal is that it tends to produce switching "clicks". In the waveform of figure 1(d) the signal is always switched on at the beginning of a half cycle, which gives glitch-free results. The signal is switched off at its peak negative or positive level, which gives the worst possible glitch. The signal is instantly switched from its peak level to zero volts. In practice the degree of glitching on each transition is purely random, and can be anything from one of these extremes to the other. It is possible to use various means of reducing the glitching, or it can simply be accepted as part of what will always be a rather extreme effect.

System operation

The block diagram of figure 2 helps to explain the way in which the "chopper" effects unit functions. The main signal path is through the amplifier at the input, the electronic switch, and the buffer amplifier.

The input amplifier simply acts as a buffer stage when the unit is used with a high output guitar pickup, or another high level signal source. It can be used to provide voltage

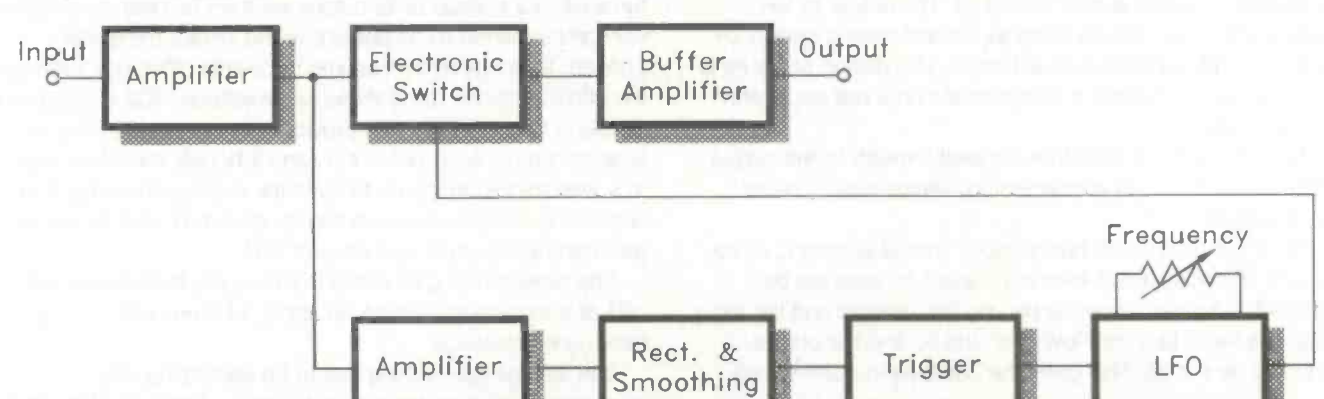
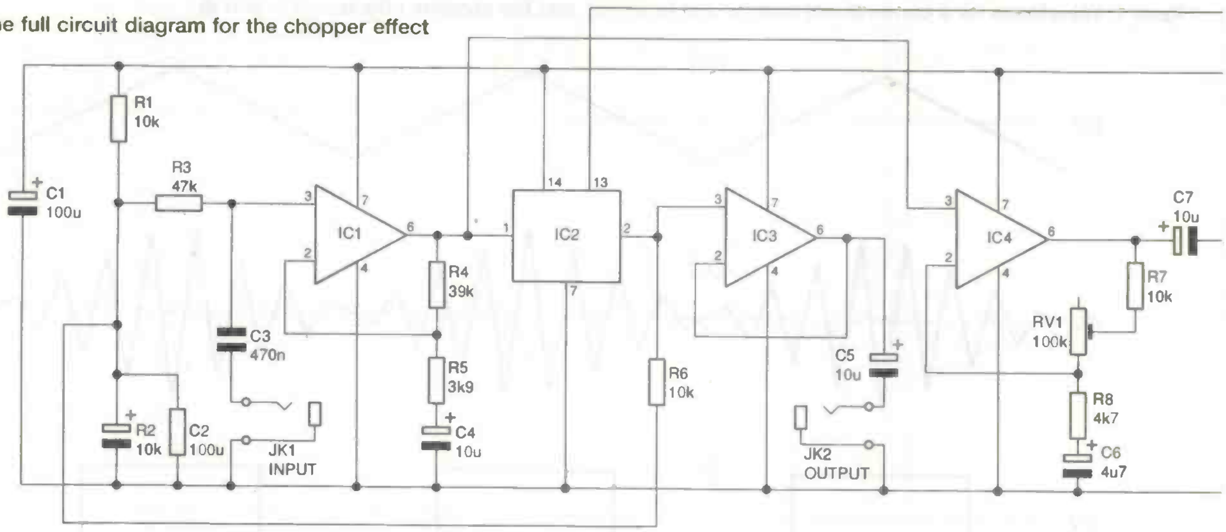


Figure 2: The chopper effects unit block diagram

Figure 3: The full circuit diagram for the chopper effect



amplification if the unit is used with a low output guitar pickup. This ensures that the electronic switch handles a high signal level, and that any breakthrough of the switching signal is kept down to a relatively low level.

The electronic switch is controlled via a side-chain of four stages. One of these stages is the low frequency oscillator. On the face of it, this is the only additional stage that is required. In practice there is a slight problem if the lfo is simply allowed to run freely. When the initial note of a piece is played, the signal might be cut off, and it could remain cut off for what, in musical terms, is a long period of time.

With this extreme form of tremolo it is best to avoid very low modulation frequencies, but even with a middling modulation frequency of 2Hz it is possible for a delay of up to 250 milliseconds to occur before the music would start! The additional stages are used to ensure that the signal is always switched on when the first note of a piece is played.

The first stage in the side-chain is an amplifier, and this is followed by a rectifier and smoothing circuit. The output from the smoothing circuit is a positive dc signal that is roughly proportional to the strength of the input signal.

This drives a simple trigger circuit, which produces a high output level if the signal from the smoothing circuit is much more than about 0.8 volts or so. It will be below this figure under standby conditions, but it will be above this voltage while the guitar is being played.

Under standby conditions the output of the trigger stage is low, and the lfo is turned off. The output of the lfo is low, and the electronic switch is also turned off. The output of the trigger stage goes high as soon as the first note is played on the guitar, and the lfo is then activated. The design of the lfo is such that once activated it always starts on a half cycle with the output high.

The input signal is therefore coupled through to the output initially, and there is no embarrassing silence when the first note is played!

The smoothing circuit has a decay time of a second or so, and only a modest input level is sufficient to keep the lfo activated. However, once the playing has ceased and the input signal has fallen to a very low level, the lfo and the output signal will be cut off. This gives the unit built-in noise gating.

The circuit

The full circuit diagram for the "chopper" effects unit appears in figure 3. IC3 is an operational amplifier which is used as the basis of the input amplifier. It operates in the non-inverting mode, and provides an input impedance of 47k. This provides a good match for any normal type of guitar pickup. IC1 has its closed-loop voltage gain set at 11 times by feedback resistors R4 and R5.

The output levels of guitar pickups vary enormously. A voltage gain of about eleven times should give good results with low output pickups, although with the lowest output types it might be better to raise the value of R4 slightly in order to obtain higher gain. With high output pickups it is likely that no amplification will be required. R5 and C4 can then be omitted, and R4 should be replaced with a link-wire.

IC2 is a CMOS 4016BE quad spst analogue switch. In this case only one of the switches is actually utilised, and no connections are made to the other three.

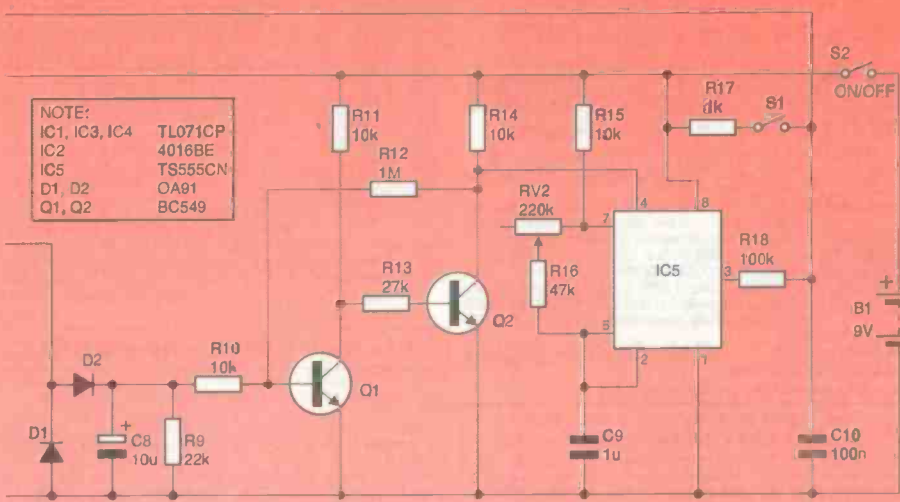
The 4066BE analogue switch is pin-for-pin compatible with the 4016BE, and in some respects has a superior specification. However, the 4066BE is not recommended for use in audio circuits, where it can produce switching "clicks". Therefore, only a 4016BE should be used in this circuit.

R1 and R2 provide a centre-tap on the supply lines which is used to bias the input amplifier. It is also used to hold the output of the electronic switch at half the supply voltage when the switch is in the "off" state.

The coupling to the bias circuit is provided by R6. If preferred, a sample and hold action can be obtained by using a 10n capacitor in place of R6. When the electronic switch turns off, the voltage at its output will then be held at whatever voltage happened to be present at the instant the switch opened. In practice there seems to be little difference between the effect obtained using these two methods. IC3 is used as a simple voltage follower that provides the output buffering. IC4 is driven from the output of IC1, and it boosts the input signal to a level that is adequate to drive the rectifier and smoothing circuit. It is another non-inverting mode circuit, and its voltage gain can be adjusted by means of VR1.

The closed loop gain varies from roughly three times with VR1 at minimum resistance, to about 24 times with VR1 at maximum resistance.

The voltage gain setting has to be something of a compromise. It must not be set too low, which would result in the output being cut off while the input signal was still at a fairly high level. On the other hand, it must not be made so high that



any background noise is sufficient to hold the circuit with the oscillator switched on. The rectifier and smoothing circuit is a simple half-wave type based on D1, D2, and C8. The output impedance of IC4 circuit is quite low, which gives the smoothing circuit a suitably fast attack time.

TR1 and TR2 form a simple trigger circuit which is driven from the output of the smoothing circuit. R12 provides a certain amount of hysteresis, and this helps to avoid problems with "jittery" operation of the oscillator when the trigger is operating close to the switch-over points.

IC5 is used in a standard 555 astable (oscillator) circuit. It is advisable to use a low power version of the 555 as this gives the circuit greatly reduced current consumption.

Also, the standard 555 has a tendency to "crowbar" the supply lines, which would almost certainly introduce strong switching "glitches" onto the output signal.

The reset input of IC5 (pin 4) is driven from the output of the trigger circuit, and is held low under standby conditions.

This results in the oscillator being held in the off state, with C9 discharged, and the output of IC5 (pin 3) held low.

This results in the electronic switch being turned off, and the output signal being suppressed under standby conditions.

When the output of the trigger circuit takes pin 4 high, C9 starts to charge and the output at pin 3 goes high.

This results in the electronic switch closing immediately when the first note is played.

When the input signal has largely decayed and the output of the trigger returns to the low state, IC5 is taken back to the reset condition, with C9 being held discharged and the output set low.

This turns off the electronic switch and provides a noise gate action. R18 and C10 provide some lowpass filtering at the output of IC5.

This slightly slows up the transitions of the electronic switch, and gives more click-free operation.

C10 can be omitted if a faster switching action and a slightly harsher effect are preferred.

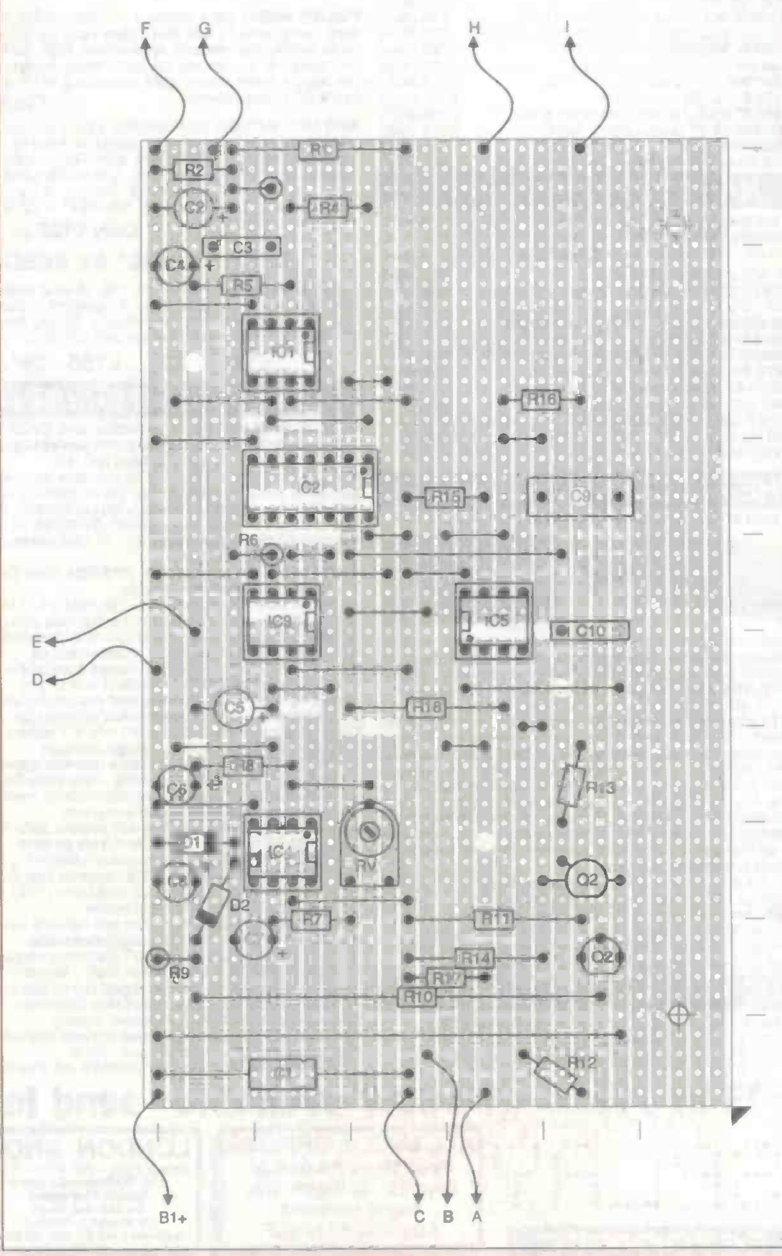
VR2 enables the frequency of the lfo to be varied from about 14Hz with VR2 at minimum resistance, down to about 2Hz or so when it is set at maximum resistance.

Conventional tremolo units are often used with very low modulation frequencies, but with this more extreme version of the effect it is not really practical to use a modulation frequency of much less than about 2Hz. The periods during which the signal was switched off would simply be too long.

Closing S1 "pulls" the control input of the electronic switch high, and provides a simple but effective means of switching the out the effect.

Continued on p. 51

Figure 4: The component layout for the stripboard, which has 50 holes by 30 strips.



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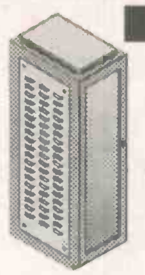

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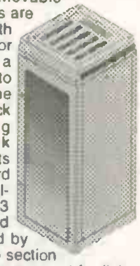

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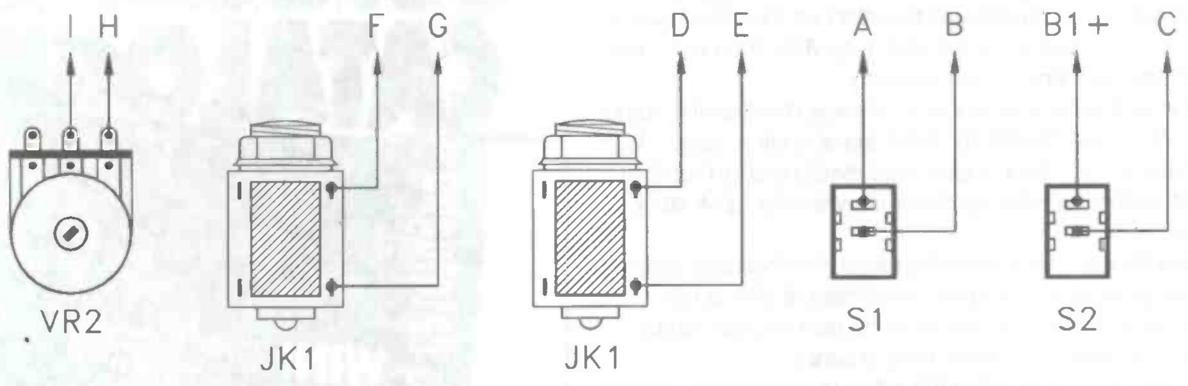
Figure 6: Details of the hard-wiring



Continued from p. 49

The current consumption of the circuit is about eight milliamps, and a PP3 battery is just about adequate to provide this. However, if the unit is likely to receive a lot of use it would be more economic to opt for a higher capacity battery, such as six HP7 size cells in a plastic holder.

Construction

Details of the stripboard panel are provided in figure 4 (component side) and figure 5 (copper side). The board has 50 holes by 30 strips, and it is cut from one of the standard sizes in which the board is sold using a hacksaw. The two mounting holes are drilled next, and these should be 3.2 or 3.3 millimetres in diameter. They will accept either 6BA or metric M3 mounting bolts.

The numerous breaks in the copper strips are then made, taking due care to get each one in exactly the right place. A special tool is available, but a hand held twist drill bit of about 5 millimetres in diameter does the job quite well.

Make sure that each copper strip is cut across its full width, but avoid cutting so deeply into the board that it becomes seriously weakened.

The board is then ready for the link-wires and components to be added. It is probably best to start with the link-wires, solder-pins, and integrated circuit holders, and then add the components. In both cases work methodically across the board as this reduces the risk of omissions and placement errors. The link wires are made from pieces of 24 swg tinned copper wire.

Although some of the wires are quite long it is not essential to use sleeving over any of them.

However, they must be quite taut so that there is no danger of them coming into contact with any of the component leads or solder pins.

Fitting the components is largely straightforward, but bear in mind that the 4016BE used for IC2 is a CMOS device, and that it therefore requires the standard anti-static handling precautions. Note that IC5 has the opposite orientation to the other integrated circuits, and that it will probably be destroyed if it is fitted the wrong way round.

D1 and D2 are germanium diodes, and are more vulnerable to heat damage than normal silicon semiconductors.

Take extra care when fitting these components, and make sure that each soldered joint is completed reasonably swiftly. C9 can be an electrolytic capacitor (with the positive lead connected to pins 2 and 6 of IC5), but the tolerances and leakage levels of electrolytic capacitors are both relatively high. This could give an lfo frequency range which is substantially displaced from the correct range.

Although a polyester capacitor having the appropriate value is relatively expensive, the additional cost is probably justified in this case.

A diecast aluminium case is a popular choice for guitar effects units. Cases of this type have good screening properties, and are extremely tough. Unfortunately, diecast aluminium boxes are relatively expensive.

Plastic cases are not really suitable as they provide no screening against mains "hum" and other electrical noise. Also, many plastic cases are quite brittle and are not suitable for a project that is likely to (literally) be kicked around.

Probably the best budget choice is a folded aluminium case. These are reasonably tough and have good screening properties. The general layout of the unit is not critical, but S1 must be mounted on the top panel of the case so that it can be operated by foot.

The usual choice for this type of thing is a heavy-duty pushbutton switch of the successive operation variety. In other words, a switch that is pressed once to switch in the effect, pressed again to switch it out, and so on.

There is a slight problem with switches of this type in that they are often quite noisy in operation (acoustically noisy that is, rather than electrically noisy).

They can be slightly awkward to operate, which makes it difficult to rapidly and accurately switch the effect in and out. You may prefer to use a large pushbutton switch of the press-to-break type.

With a switch of this type the effect is normally switched off, but is activated while the pushbutton switch is operated. Details of the hard wiring are provided in Figure 6.

This diagram should be used in conjunction with Fig.4 (e.g. point "A" in figure 4 is connected to point "A" in figure 6).

The wiring is very straightforward and should present no difficulties. There is no need to use screened leads to make the connections from the board to the jack sockets.

The latter are shown as insulated (plastic bodied) sockets in figure 6, but open style sockets are equally suitable. Insulated jack sockets normally have a couple of extra tags which connect to switch contacts.

These are of no consequence in the present application, and they are simply ignored.

In use

The guitar connects to JK1 using standard screened jack lead. JK2 is connected to the input of the guitar amplifier, and a screened lead should also be used here. Start with VR1 at a roughly central setting. This is definitely not a subtle effect, and with S1 set to activate the unit the effect on the output signal should be very obvious at any setting of VR2. The best setting for VR1 can be found by trial and error.

If it is set too far in a counter-clockwise direction the output signal will be cut off while the input signal is still at quite a high level. Setting it too far in a clockwise direction could result in the unit having a reluctance to cut off when the input signal has fully decayed.

There should be a reasonable range of in-between settings that give good results, and the adjustment of VR1 is not critical. Bear in mind that some of the best sounds can be obtained by using two effects units in series.

It is well worthwhile trying this effect in conjunction with any form of distortion effects unit.

PARTS LIST

Resistors

Carbon film 0.25W 5% carbon film

R1,R2,R6,R7,R10,	
R11,R14,R15	10k
R3,R16	47k
R4	39k
R5	3k9
R8	4k7
R9	22k
R12	1M
R13	27k
R17	1k
R18	100k

Potentiometers

VR1	100k min hor prest
VR2	220k lin carbon

Capacitors

C1	100u 10V axial elect
C2	100u 10V radial elect
C3	470n polyester
C4,C5,C7,C8	10u 25V radial elect
C6	4u7 50V radial elect
C9	1u polyester
C10	100n polyester

Semiconductors

IC1,IC3,IC4	TLO71CP
IC2	4016BE
IC5	TLC555CN
D1,D2	OA91
TR1,TR2	BC549

Miscellaneous

S1	s.p.s.t. heavy-duty push-button switch
S2	s.p.s.t. min toggle switch
B1	9 volt (PP3 size)
JK1,JK2	Standard jack socket

Case, 0.1 inch pitch stripboard having 50 koles by 30 copper strips, battery connector, control knob, solder pins, multi-strand connecting wire, solder, etc.

PROCESS TIMER and CONTROLLER

WITH EXTERNAL I/O INTERFACE

A PIC16C54 Microcontroller Application by Tim Parker

PART 2 *Power Supply Interface*

In part 1 of this project in last month's ETI, we presented the main controller board for the Process Timer which, as explained in the article, is designed to perform the task of a darkroom timer. Here, in the second part of the project, we present the accompanying power supply as outlined previously. This not only allows the main Process Timer board to be powered via its expansion bus connector, but also provides a single channel input and single channel output interface. The programmed PIC16C54 for the main controller includes software routines to make use of both the input and output channels in ways that will be explained shortly.

Simplicity of connection between the various boards for this project was high on the list of priorities during the design stage. To this end, all the interface boards are self-contained (as far as they can be), all have the same size of expansion bus connector with standardised terminations, and they can all be connected together using a single 34-way ribbon cable fitted

Figure 1. The circuit of the power supply and single-channel I/O interface.

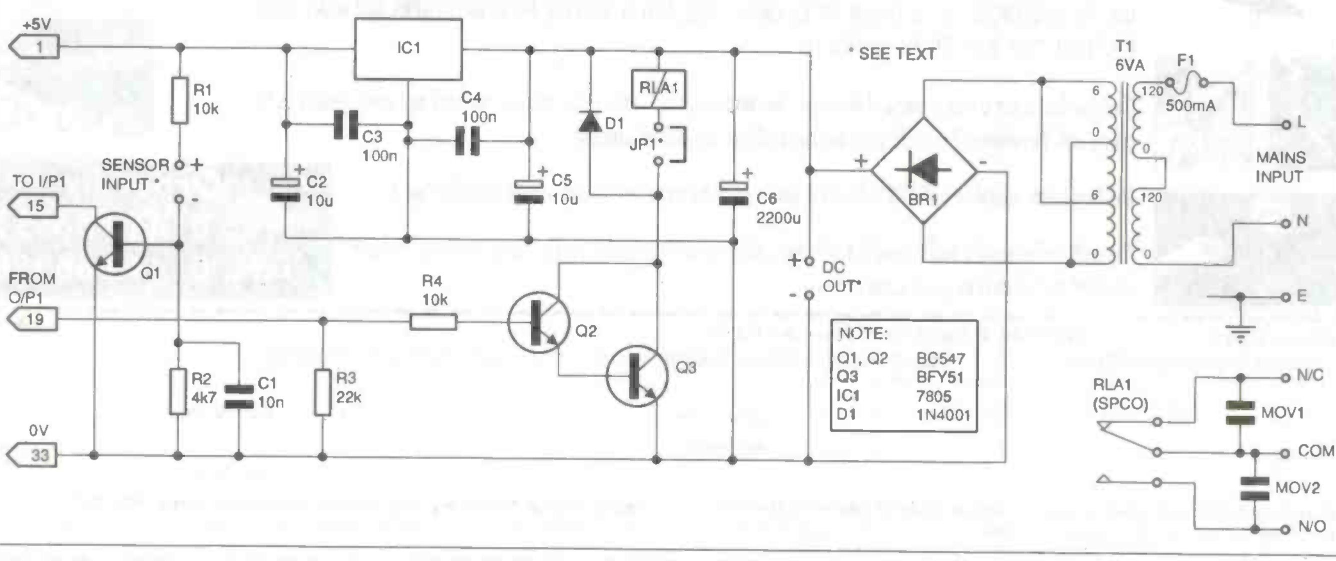
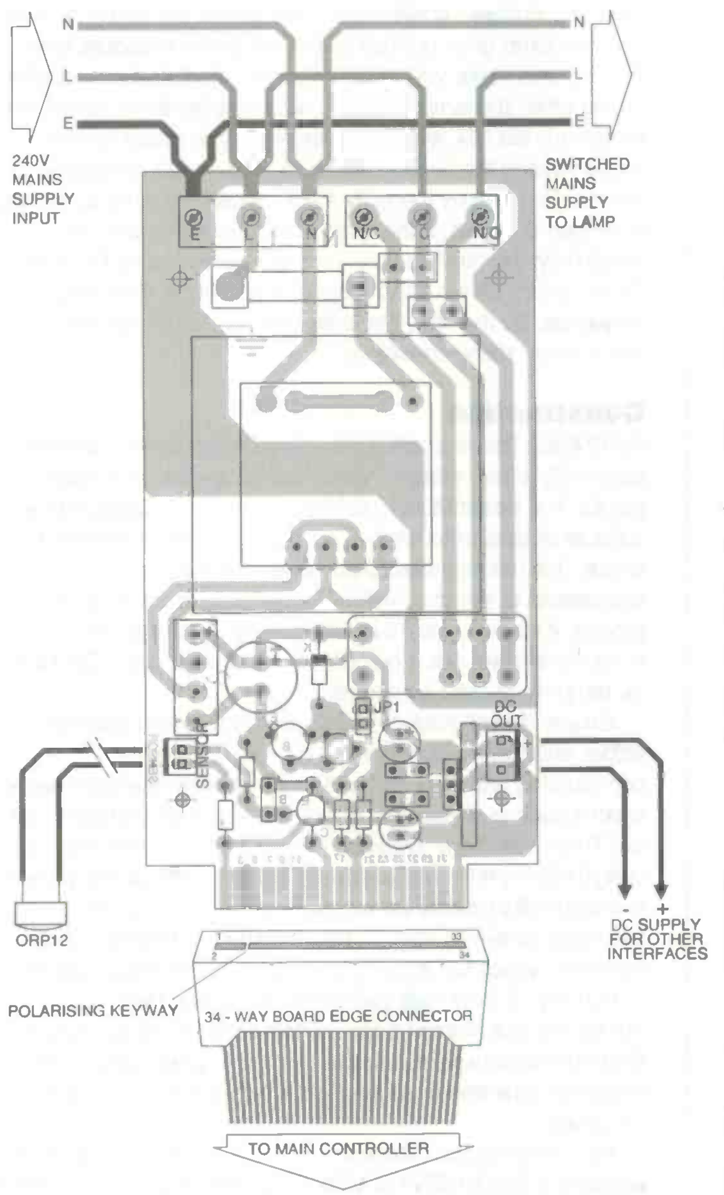


Figure 2. Connection details to the PCB



with multiple board edge connectors. If you wish to add a further board to the expansion bus, it's simply a matter of adding another board edge connector to the ribbon cable. This gives us the ability to 'plug and play' with the Process Timer at will. The power supply is no exception to this, apart from the fact that only one power supply can be connected to the expansion bus at any time.

Only the regulated +5V supply is brought out to the expansion bus connector, which is adequate for most interface purposes. Should you require a higher voltage to that available on the expansion bus, then there is a connector made available on the Power Supply board to 'tap off' the input to the regulator, which provides a smoothed, but unregulated off-load output voltage of about 10 - 12V DC.

The circuit

The basics of the power supply are pretty straightforward. The 6V AC from the transformer T1 is passed through a full wave bridge rectifier BR1 and smoothed by C6, which results in a DC voltage across C6 of around 12V with no load connected. This is applied to the input of regulator IC1, which in turn produces a stable, regulated +5V DC on its output. This provides the main +5V supply output on the expansion bus connector (terminal 1) to power the main Process Timer and any interface boards that are connected to it. Capacitors C2 to C5 are placed close to IC1 so as to reduce high frequency noise on the supply lines, and stabilise IC1 against the possibility of oscillation.

Input and output channel

The I/O interface of the power supply makes use of the O/P1 and I/P1 port lines of the Process Timer expansion bus. O/P1 - on terminal 19 - is the output signal for TR2 and TR3, which themselves form a Darlington transistor and are used to switch the output relay RLA1. The jumper link JP1 allows the relay to be disabled if not required, for instance, when a different interface is connected to the expansion bus during software development for other purposes, where the operation of RLA1 might become a nuisance. Resistor R3 ensures that the relay remains in the off (de-energised) state when the power supply is disconnected from any form of interface - including the Process Timer. Darlington drivers have a terrific amount of gain compared to a single bipolar transistor, and leaving the base floating will result in the relay 'chattering' due to stray noise pickup.

The contacts of the relay have a single pole changeover (SPCO) configuration, and are rated to carry the mains load of the exposure lamp which is connected to them. The two metal oxide varistors MOV1 and MOV2 provide a degree of contact suppression in order to reduce the amount of arcing when the relay contacts are opened with a live load connected. These are not essential in a lot of cases, but should prolong the life of the contacts if an inductive load is used. Obviously, if only an ON/OFF action is required then a single pole normally open (SPNO) relay can be substituted, and MOV1 omitted from the board.

For the input to the Process Timer, I/P1 - on terminal 15 - is used as a light sensor input. Connected to this is the open collector of transistor TR1, which forms part of the sensor input circuit based around R1, R2, C1 and TR1 itself on the power supply board. The component values shown for R1 and R2 allow an ORP12 or other light dependent resistor (LDR) with similar characteristics to be connected directly to the power supply board via a 2-pin connector. The value of R1 can be altered if needed, to suit varying light level outputs produced by different types of exposure lamps. If anything, the value of R1 might need increasing (up) to 100KW to compensate for ambient light.

It should go without saying that the LDR must be positioned such that a definite change of light level occurs between the lamp's on and off state, otherwise the Process Timer will continue timing even when the lamp is off, because sufficient ambient light will be hitting the LDR. If the light sensing feature is not required then a jumper link can be fitted to the board where the LDR would normally connect. This will keep TR1 permanently turned on, and so produce the necessary (low) 'light on' signal required.

In order to produce accurate exposure times, it is necessary to time the exposure only when the lamp is actually lit. This is not usually a problem with normal incandescent (filament) lamps, since they light as soon as power is applied (assuming the bulb hasn't blown, of course). But this darkroom timer application was designed with another purpose in mind as well: that of

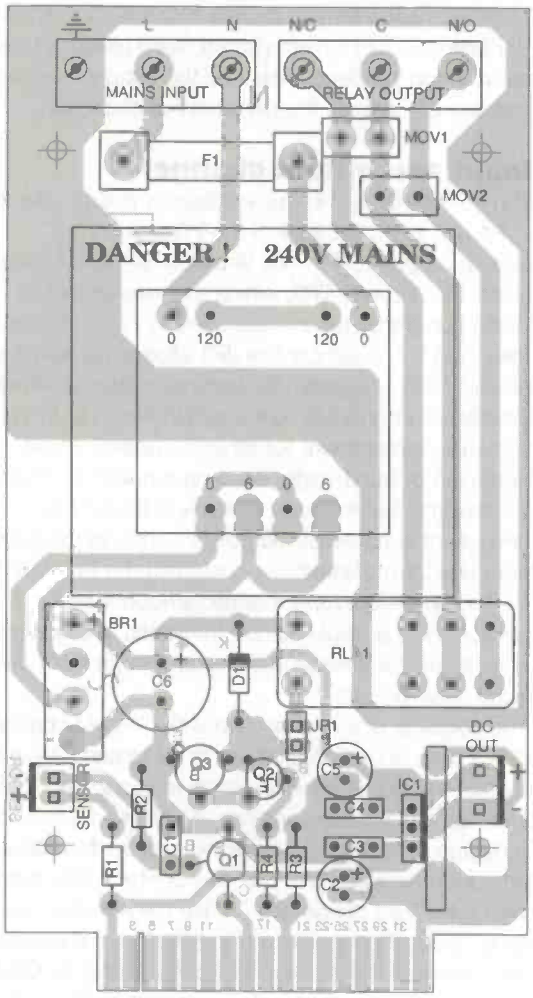


Figure 3. The component layout for the power supply

timing the exposure of photosensitive copper-clad laminate, used by constructors to produce their own PCBs. The exposure units used for these purposes are almost invariably fitted with ultraviolet (UV) fluorescent tubes, and an integral igniter circuit, which needs time to 'strike' before the tubes will light. Anyone who has used these units - particularly the small, low volume production versions - will know that when the tubes and starters begin to age a little, it takes more and more time from the moment the switch is 'thrown' to when the lamps actually come on. So, starting the time period from the moment the unit is turned on results in ever-reducing exposure times, and consequently produces under-exposed boards. Unfortunately, this will not be discovered until the laminate gets to the development stage, when you realise that the photo resist is not going to come off properly. At this point you are left with three options. The first is to give up and scrap the board for use at a later date. The second is to start again with a new board, and the third is to attempt to realign the transparency over the sections of pattern that are visible, and expose the board once more. But again, people who have done this know that under these conditions the exposure time becomes very critical, and generally this option is not very successful either. Nevertheless, we still try. Don't we?

This is where the light sensor comes in. Drilling a suitable hole in (say) the end of the exposure unit and fitting the ORP12 in it provides feedback to the Process Timer, which won't begin or continue timing until the exposure unit is lit. Furthermore, this input is monitored continuously throughout the timing process, so if the lamp goes out half way through the exposure time, the Process Timer will pause what it's doing, and only continue timing when the lamp re-lights. Note that the lamp output will remain turned ON, even if the lamp itself goes out for any reason during the timing sequence, and for safety reasons no attempt is made by the software to restart the lamp by turning it off then on again. If the failed lamp condition remains indefinitely, the reset button can be pressed on the Process Timer to turn off the lamp output bit and abort the timing sequence. By the way, this is the only button which has any affect under these conditions.

Construction

WARNING! This is a mains powered project board carrying potentially lethal voltages, which are accessible at various points. The board MUST be fitted safely and securely into a suitable enclosure to remove any possible risk of electrical shock. It is not intended to be constructed by novice enthusiasts or persons with no experience of this type of project. If you are unsure about any aspect of the construction whatsoever then ask a competent person for help - DO NOT be tempted to build it yourself.

Ensure that all soldered joints are good, clean and free from solder bridges. It's important to exercise care when constructing any PCB, but even more so with mains powered boards such as these, where nothing less than perfection will do. There aren't any awkward components on the board, and everything is pretty well spaced. The most difficult component to solder will probably be the transformer T1, since PCB mounting versions usually have varnished or enamel coated terminals, which will either require scraping off before soldering, or burning off extremely well during soldering. Personally, I'd opt for the first method because this reduces the amount of time the molten solder is applied to the copper pads, where excessive time spent soldering may 'unglue' the copper from the board.

For safety reasons the transformer T1, relay RLA1 and the varistors (if fitted) MOV1 & MOV2 must be soldered as close to the board as you can possibly get them, with no excess bare lead showing, and the fuse F1 and fuse-holder MUST be fitted with a protective insulating cover. By doing this there should be no easily accessible point on the topside of the board which has mains voltages on it that could be touched with the fingers. But this by no means implies that it is still safe to do so.

When fitting the board into a suitable enclosure, the safety aspect which must be observed will dictate how the board is to be mounted. It should be bolted to the enclosure using all four mounting points, and nylon stand-offs used to raise the board to a suitable height to enable the attachment of a 34-way board edge connector. There are two possibilities for the positioning of the board within the case. It can either be totally enclosed inside the case, with the board edge connector touching the inside of one end, and then a rectangular hole cut out of the case to accept the whole board edge connector. Or, the case could have a slot cut into one end to allow just the edge connector part of the board to be made accessibly externally.

The second method is better from a safety point of view, because if the first method is used then an insulating barrier - made from strips of plastic or nylon - must be firmly fitted

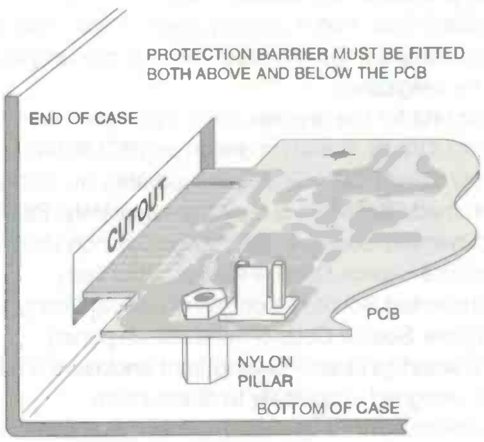
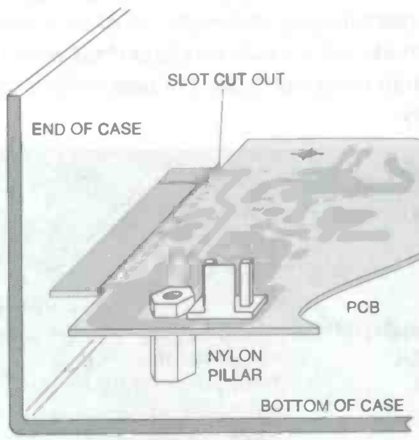


Figure 4. Two methods of mounting the PCB



internally above and below (so as to be in contact with the full width of) the board to stop anyone from dropping screwdrivers, knives, forks, spoons, bits of wire or ANY metal object which could cause a short circuit to the mains section of the board. We are not trying to make light of any aspect of this project, it is a very serious matter that must have your full attention paid to safety.

Don't forget this bit ...

In part 1 of this project you may remember that you were required to bridge together pins 9 & 10 of IC4 on the main controller board, so that the Process Timer would function correctly without the power supply/interface connected. This solder bridge should now be removed before connecting the two projects together. As mentioned earlier, if you don't want to use the light sensing facility of the power supply, simply fit a jumper link across the two sensor input pins on the power supply PCB. A point to bear in mind with this, is that if you are experimenting with your own software on the main controller and a further interface is connected to the expansion bus, this jumper link will need removing if you are to use I/P1 as an input signal from elsewhere. Leaving the jumper link in place will pull I/P1 low at all times. While on the subject of jumper links, don't forget to fit one of these to JP1, so as to enable the operation of the relay. If you are developing your own software for the main controller that makes use of the input and output ports of the expansion bus, and you do not require the use of RLA1, but still need the power supply connected via the expansion bus, then remove this jumper link to disable the relay.

In use

If you are currently using a different power supply, and powering the main controller via the +Vin and 0V terminals, then remove it before connecting this power supply to the expansion bus. Failure to do so could result in damage to the regulator circuits on one or other of the power supply units, not to mention the main controller itself.

The Power Supply connects to the Process Timer via a 34-way ribbon cable fitted with board edge connectors at various points along its length. If you are making up your own ribbon cable make sure that all of the connectors are fitted in the same orientation, that is, pin 1 on all of them connected to the same ribbon cable strand; be careful not to get any of them back-to-front - it's very easily done.

Programming

The following software examples demonstrate how to turn the relay on and off, and also how to read the state of all 7 inputs. The documented program listing available for this project has labels defined for all constants and variables used, and is also more structured, but here the software takes a more direct approach. The PIC16C54 does not have port C available, but its address in memory is available as a general purpose file register (in RAM), so this address is used to store the current value on the expansion bus input port.

```
;@pr:*********************************
; SOFTWARE FOR USE ON THE DTE PROCESS
TIMER/CONTROLLER BOARD.
; (c) 1996 TIM PARKER / DTE MICRO SYSTEMS.

; SUBROUTINE TO TURN THE RELAY ON

RLYON
MOVLW B'00000000'
TRIS                        06   ; SET PORT B AS ALL
OUTPUTS
MOVLW 01                         ; SET BIT 1 HIGH
MOVWF 06                         ; PUT IT ON PORT B
MOVLW 05                         ; GET IC3 STROBE LINE
MOVWF 05                         ; AND PULL IT LOW
MOVLW 07                         ; GET 'ALL OFF' CODE
MOVWF 05                         ; SET ALL STROBE LINES
HIGH
RETLW 00                         ; AND RETURN FROM
SUBROUTINE

; SUBROUTINE TO TURN THE RELAY OFF

RLYOFF
MOVLW B'00000000'
TRIS                        06   ; SET PORT B AS ALL
OUTPUTS
MOVLW 00                         ; SET BIT 1 LOW
MOVWF 06                         ; PUT IT ON PORT B
MOVLW 05                         ; GET IC3 STROBE LINE
MOVWF 05                         ; AND PULL IT LOW
MOVLW 07                         ; GET 'ALL OFF' CODE
MOVWF 05                         ; SET ALL STROBE LINES
HIGH
RETLW 00                         ; AND RETURN FROM
SUBROUTINE

; SUBROUTINE TO READ THE EXPANSION BUS INPUT PORT.
; ON EXIT, FILE REGISTER f7 CONTAINS THE 8-BIT
RESULT

READBUS
MOVLW B'11111111'
TRIS                        06   ; SET PORT B AS ALL
INPUTS
MOVLW 04                         ; GET IC4 STROBE LINE
MOVWF 05                         ; AND PULL IT LOW
MOVF                        06,00        ; GET DATA ON
PORT B IN 'W'
```

```
MOVWF 07                        ; AND STORE IT IN f7
MOVLW 07                        ; GET 'ALL OFF' CODE
MOVWF 05                        ; SET ALL STROBE LINES
HIGH
MOVLW B'00000001'
TRIS                            06  ; AND RESTORE RB0
FOR INPUT
RETLW 00                        ; RETURN FROM SUBROUTINE
;*********************************
```

Other uses

The standard operation of the Process Timer as a darkroom timer only uses I/P1 for light sensing. However, by changing the software it is possible to make the program respond in an entirely different way. For example, you could connect a footswitch across the sensor input pins on the power supply, and alter the software so that this acts as a second focus button during the 'Command' mode, and as a 'pause' input during the 'Run' mode.

The flexibility provided by software - as opposed to hardware - modifications gives you far more control over these types of projects than ever before. You may, for instance, want the lamp to remain on during the 'pause' time, or you might prefer the lamp to go off but leave the timer running as normal. You might even want to pause the entire process. The use of microcontrollers makes these modifications very easy to implement.

Another use for the input - based on PCB production - could be to detect whether or not the lid of the UV exposure unit is closed before actually turning on the light and starting the timing sequence.

This could be achieved by the operation of a microswitch fitted to the outside of the unit, and activated via a simple actuator arrangement. In both these examples it doesn't matter whether the switch you use is normally open (N.O.) or normally closed (N.C.), since this can be detected in software and responded to accordingly.

Whatever your preference, this, and more, can all be accommodated by re-programming the PIC. And don't forget that you are not limited to just one input.

The power supply only makes use of I/P1, so there are another 6 available for you to play with, or all 7 if you leave the sensor terminals on the power supply unconnected (open circuit). Next month we will present a further board to complement this project. This will be a software development board for programmers wishing to use the main controller for their own interface purposes, and allows software to be tested out without connecting the Process Timer to any proposed target interface.

KITS and BITS available

A complete kit of components for the Process Timer PSU/Interface, which includes everything in the parts list except items marked *, is available from the author by mail order only at the following address:

DTE MICRO SYSTEMS
112 SHOBNALL ROAD
BURTON ON TRENT
STAFFORDSHIRE
DE14 2BB

Component kit for the Process Timer PSU/Interface: £21.50
(Kit includes the PCB and all other necessary items)
The PCB can be purchased separately if required for:£7.80
A suitable (undrilled) ABS plastic enclosure: £3.90
Parts available from Part 1 of this project. Please note although we printed samples, the complete listing is too long to print out in full in the magazine:
Component Kit for the process timer main controller: £29.50
(Kit includes D/S PCB and programmed PIC16C54)
The double sided PCB is available separately at: £9.00
A programmed PIC16C54 is available separately: £8.50
Fully documented Source Code text on 3.5 inch disk: £8.50
(The complete Source Code + various other files)
Fully documented Source Code listing - printed copy: £8.50.
(The complete Source Code printed out on paper)
A suitable smart (undrilled) sloping front enclosure: £8.00. (The PCB was designed specifically to fit this case)
1 metre pre-assembled 34-way expansion bus cable: £4.00
(fitted with three 34-way expansion bus connectors)
All prices are inclusive, but please add £2.50 to the total order value to cover carriage and handling charges. If ordering from overseas, payment must be in pounds Sterling (£) and cheques/bank drafts/money orders etc. must be drawn on a British bank. Goods will normally be dispatched within five working days from receipt or order, but please allow up to 28 days for delivery.

PARTS LIST FOR THE POWER SUPPLY INTERFACE

Resistors

R1,4	10KW (2 off)
R2	4K7
R3	22KW

Capacitors

C1,3,4	100nF Ceramic or Polyester (3 off)
C2,5	10mF / 25V Radial Electrolytic (2 off)
C6	2200mF / 25V Radial Electrolytic

Semiconductors

BR1	100V / 1.9A Bridge Rectifier
D1	1N4001
IC1	7805 +5V Voltage Regulator
TR1,2	BC547 NPN Transistor (2 off)
TR3	BFY51 NPN Transistor

Miscellaneous

F1	500mA 20mm Fuse
JP1	0.1" Jumper Link
MOV1,2275V	metal oxide varistor (2 off) *
RLA1	12V SPCO PCB Relay
T1	0-6-0-6 / 6VA PCB transformer
Fuseholder	20mm PCB fuseholder
Fuseholder Cover	Plastic Cover To Suit Above
Heatsink	Shallow Heatsink for IC1
Sensor	ORP12 Light Dependant Resistor (LDR)
Terminals	3-Way 10mm pitch PCB Terminal Block (2 off)
Connector	2-Way PCB Pin Header - 2.54mm pitch (2 off)
Connector	2-Way PCB Pin Header - 5.08mm pitch
Case	Enclosure to suit *
Hardware	General Fixing Hardware *
Cable	3-Core Mains Flex *
PCB	DTE Process Timer PSU / Interface

* These parts not included in the kit

Pre-Hertzian Wireless:

The Needles and Fastnet Lighthouse System

PART 1

As we approach the end of the 1990s, George Pickworth recreates an experiment in cable-free telegraphy created over a century ago for remote communications - with lighthouses.

In Europe in the late 1800s it was usually possible to route telegraph lines inland so as to avoid having to cross wide river estuaries. That meant that there was no need to develop wireless systems like those that were a vital part of the telegraph system in parts of the Empire such as India. Nevertheless, in the UK there was a real need for a reliable wireless telegraph link to reach lighthouses on remote islands, particularly the Needles and Fastnet Rook, where rough seas and the rocky landfall made it impractical to bring submarine cables up onto the shore.

Electromagnetic induction systems were rejected for this use because the small surface area of the Needles and Fastnet Rock could not accommodate the widely spaced electrodes needed by the Preece system that was used experimentally on Flatholme Island in the Severn Estuary. The waves which periodically swept over the islands also precluded the installation of the type of large-diameter inductors used with the Stevenson system (intended for, but never actually installed on, Muckle Flugga in the Shetland Islands).

Water

The chosen solution was to employ the sea water itself as the conductor over the final stretch to the islands, thus avoiding the need to bring a cable ashore. The original plan required a pair of submarine cables extending from shore in the form of a "V" to embrace the island. However, because of what I have called the "360-degrees phenomenon", it was found to be possible to dispense with one of these cables. As a result, a single-cable system evolved. The single cable system was adopted for the Needles and Fastnet, where it proved to be highly successful, and yet this remarkable and seemingly unique "wireless" system is now almost forgotten. So this study looks at the philosophy and evolution of this unusual and ingenious system.

The "V" system

The "V" system was conceived by Willoughby Smith as a means of extending electric telegraphy to wooden lightships anchored offshore, where the use of continuous cables was out of the question. During small scale trials, Willoughby Smith extended a pair of cables insulated with gutta percha from a lakeside in the form of a "V". The cables terminated in a pair of copper electrodes placed on the lake bed so as to embrace a rowing boat. Electrodes were attached to the boat's bow and stern under its waterline, and these were connected to a galvanometer, as in figure 1.

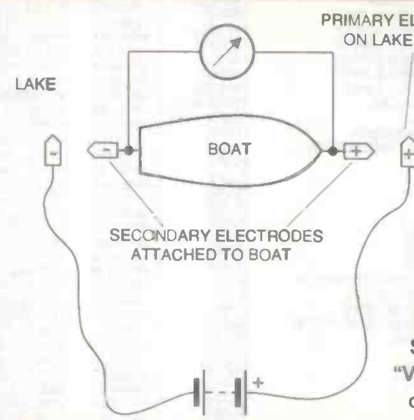


Figure 1: Willoughby Smith's experimental "V" system - the water completes the circuit

The submarine cables and electrodes are referred to in this study as the "primary circuit". The electrodes on the boat or island, together with their connecting wires, are referred to as the "secondary circuit". The same applies to the single wire system.

The philosophy of the "V" system was that when the primary circuit was energised, the secondary circuit would provide a lower resistance path between the two primary electrodes than the intervening water, and the galvanometer would indicate a current. However, because the resistance of the galvanometer was higher than the intervening water it merely indicated a potential difference.

Willoughby Smith found that the galvanometer indicated a current only when the boat was aligned with the primary electrodes. The current fell to zero when the boat was rotated through 90 degrees. This prevented its use with lightships which swing around their anchors.

Nonetheless, the "V" system potentially provided electric telegraphy to lighthouses on rocky islands, so long as the secondary electrodes could be aligned with the primary electrodes. Unfortunately this was not always feasible.

The single cable system

However, as already mentioned, the 360-degree phenomenon made it possible to dispense with one of the two submarine cables of the "V" system. The complementary electrode could be placed in the sea near the shore, as in figure 2. The single

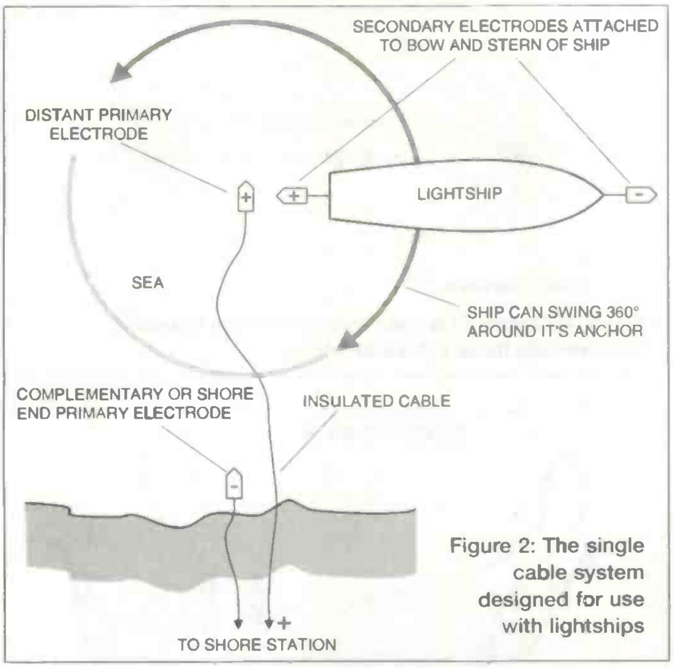


Figure 2: The single cable system designed for use with lightships

cable not only significantly reduced the cost of the system but, far more significantly, the secondary electrodes could be aligned radially at any angle with the distant primary electrode, so avoiding the problems inherent in the "V" system.

If the distant electrode was placed on the sea bed adjacent to a lightship's anchor, signalling could continue as the ship swung around its anchor, as it figure 3. Although the single cable system was proposed for use with lightships, I have no record of it actually being used; presumably this was because wooden lightships were rapidly being replaced with steel ships.

On the other hand, the single cable system seemed inherently suited for communication with lighthouses on rocky islands where problems had been experienced in bringing cables ashore. See figure 4.

360-degree conduction

The 360-degree phenomenon was observed by Trowbridge in the USA around 1880. He found that a potential difference occurred across a pair of fairly closely spaced probes inserted into the soil radially to the earthing rod of the earth return circuit of a telegraph-land-line The potential across the probes remained fairly constant at various radial positions to the earthing rod, as in figure 5, a result which was surprising at the time.

The fact that a potential developed across probes even when they were inserted when on the "far" side of the earthing rods caused Trowbridge to dismiss the concept of current flowing through the earth from one rod to the other; Trowbridge reasoned that if this was the case, a potential would develop across the probes only when they were aligned between the two earthing rods.

Instead, Trowbridge visualised the earth as a massive capacitor, where, during charging or discharging, the current converged or dispersed radially over the earth's surface. Incidentally, the pioneers were puzzled as to how the current found its way from one earthing rod to the other; the capacitor concept offered some explanation.

Steinheil

Remarkably, Steinheil had already shown that current does indeed flow from one earthing rod to the other, but rather than take the short, direct route it spreads out in a pattern similar to the magnetic field lines of a bar magnet. See figure 6. In modern terms, the explanation for this is that the current is proportioned among all the possible paths according to their relative conductivity, i.e. each path may be regarded as a separate resistor, and the current which flows in it can be calculated by Ohm's law.

The electrical characteristics of the earth can be roughly modelled as a vast grid arrangement of resistors.

Theoretically, the current flow lines extend to infinity, and this phenomenon was studied by Steinheil and others as a possible medium for a wireless telegraph system. Indeed, a wireless system based on current flow lines was actually employed for extending the telegraph system in India across rivers too wide to be spanned by overhead cables. Nonetheless, it can be seen in figure 6 that the current flow lines extend from earthing rods over 360 degrees and this created the effect observed by Trowbridge. However, this phenomenon only reaches an easily measurable level when the distance separating the earthing rods is much greater that that of the probes. Also, one of the probes must be close to one of the earthing rods. There is clearly more current flow to be measured in the direct line between the electrodes than in other directions, with the least being measured in a direction directly away from the other electrode. If the measurement electrodes are close together, and the excitation electrodes far apart, the currents are almost the same, while moving the excitation electrodes closer together increases the differences in measured current.

In the bath

To determine whether the 360-degree phenomenon occurred in water, Willoughby Smith conducted small scale trials with electrodes and probes in a wooden trough. I reproduced his experiments in a domestic bath, and the following notes illustrates the principles of Willoughby Smith's single cable system. The bath was partly filled with water and the primary electrodes, consisting of 1p coins (which also have the advantage of being cheap) were spaced along its length as shown in figure 7a. The connecting leads were pressed against the coins by means of plastic clothes pegs.

WARNING: because of the danger of combining electricity with water, experiments of this type should only be attempted using a low-voltage battery, such as a PP3, as a power source and NEVER a mains power source of any kind, as this could be lethal. THINK ELECTRICAL SAFETY AT ALL TIMES.

A pair of probes, representing the secondary electrodes on a wooden ship or rocky island, were made up from bare

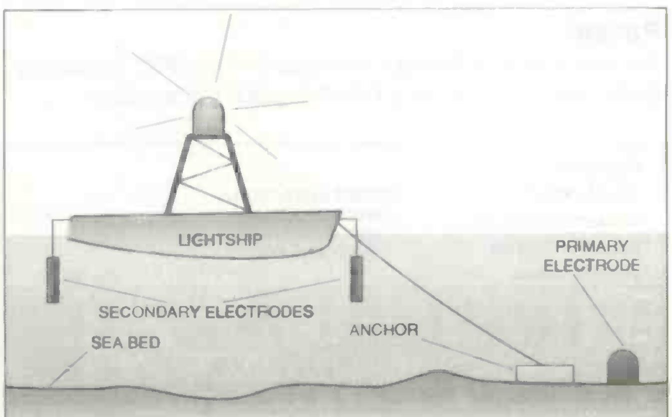


Figure 3: Willoughby Smith's proposed lightship system based on the 360-degree phenomenon

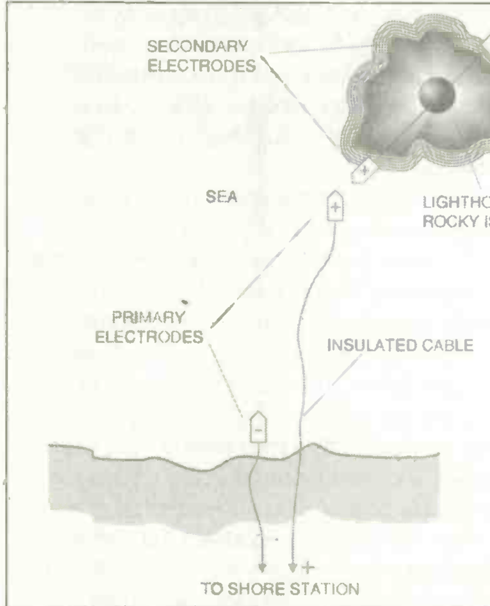


Figure 4: The single cable system applied to a lighthouse

copper wire 1.0mm in diameter and 50mm long, attached to a piece of plastic. See figure 7a.

Once the electrodes were energised with 6 volts, a potential developed across the probes when they were aligned radially at any angle with an electrode, demonstrating the 360-degree phenomenon occurring in water, as in figure 7b.

It is interesting that the probes also allowed me to trace the current flow lines as first visualised by Steinheil (see figure 6).

In the lake.

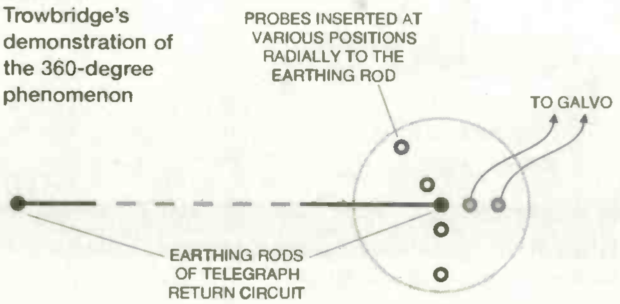
Impressed by the resluts of his wooden trough experiment, Willoughby Smith moved his experiments to a lake. One electrode was placed on the lake bed some distance from the bank, and the complementary electrode was placed in the water close to the bank.

The secondary electrodes were attached to the boat in the same way as for the "V" system. As with the wooden trough experiment, the spacing of the primary electrodes was many times greater than that for the secondary electrodes. At that time, many telegraph signals were read by observing the swing of a galvanometer needle, and the lake trials apparently indicated that in a practical system the potential across the secondary electrodes would be sufficient to give consistent galvanometer readings. Furthermore, the swing of the needle would be large enough to allow reliable signalling when the secondary electrodes were aligned radially at any angle to the primary electrode.

Patent

The outcome from the lake trials was that in 1887, Willoughby Smith and W P Granville (of the Telegraph Construction

Figure 5: Trowbridge's demonstration of the 360-degree phenomenon



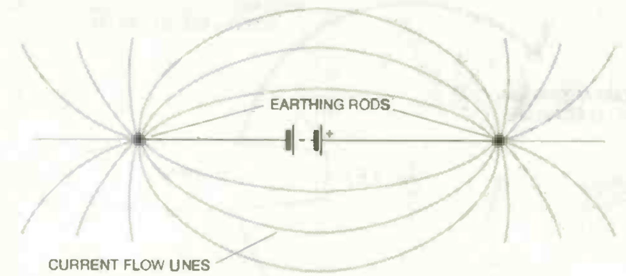


Figure 6: Current flow lines as visualised by Sheinheil. Theoretically these extend to infinity

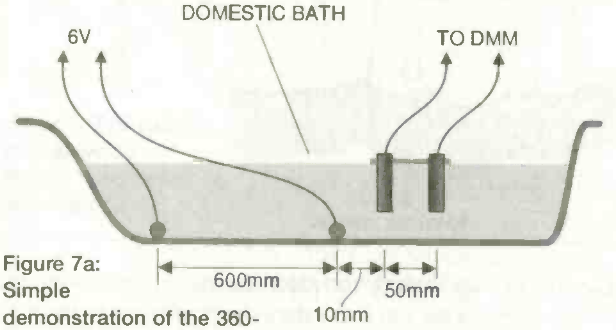


Figure 7a: Simple demonstration of the 360-degree phenomenon

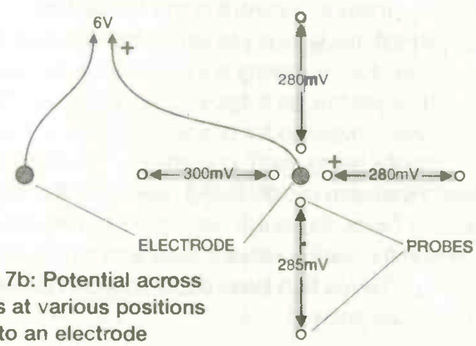


Figure 7b: Potential across probes at various positions radial to an electrode

Company) secured a patent for their system. This was followed in 1982 by the Trinity Board placing the Needles lighthouse at the disposal of the Telegraph Construction Company so that the practicability of the single cable system could be proved.

As the decision to go ahead with the Needles system was based on the lake trials, I decided to reproduce these trials to gain a greater insight into the operation of the system.

The Needles and Fastnet system, together with some notes on the reproduction of the Willoughby Smith lake trials, will be described in the second part of this article.

Practical applications

The author has carried out an experiment to show the 360-degree phenomenon in bathwater. The phenomenon is of particular interest because the flow of current in a uniform resistive medium exhibits the same patterns as magnetic fields in free space. Indeed, working with magnetism has often been likened to working with electricity in a weak salt solution with no Insulating materials available. Few people understand magnetism well enough to design equipment in which fields in air are of importance, and this experiment is one way to gain some understanding of the subject. This principle could be used to build a ground current communicator - perhaps to be used as an intercom between outbuildings with (say) a metal fence wire as the single wire.

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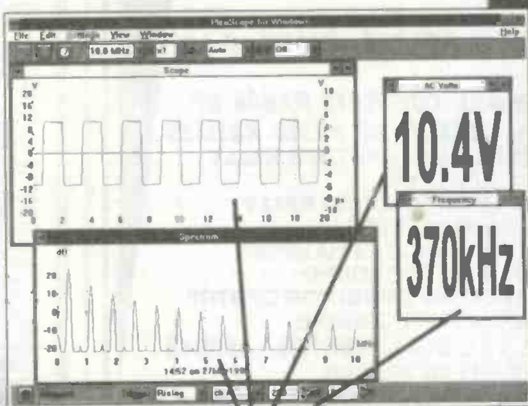

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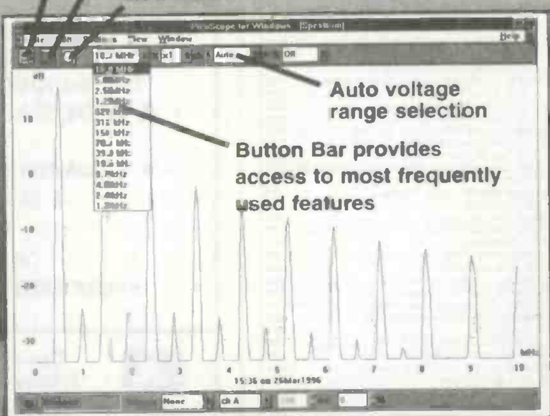

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Practically Speaking

BY TERRY BALBIRNIE

Over the next few months, we shall look at the topic of choosing the right connecting wire for the job in more detail. It is assumed that this is of the copper-core type. Resistance wire (using materials other than copper) will be looked at later. Also, the confusing subject of standard wire gauge will be discussed at a later time. A length of copper wire has a certain resistance even though this is likely to be low. For example, a 100 cm length of wire with a diameter of 0.5 mm will have a resistance of some 0.09 ohm. A longer piece of similar wire will have a proportionally greater resistance so 200 cm would have a resistance of about 0.18 ohm and so on.

A bit thick

For a given length, a thicker wire has a lower resistance than a thinner one. This may be pictured as water finding it easier to flow through a wide hose pipe than a narrow one. Mathematicians will tell you that doubling the diameter of a circle will give four times the area. In simple situations, current is carried throughout the whole cross-section area of the copper. Since wire usually has a circular cross-section, it may be expected that a certain length of wire having a diameter 0.5 mm will have four times the resistance of one having a diameter of 1 mm. There is also a temperature effect - the resistance of a given piece of wire increases with temperature. Between zero and 100 degrees C it rises by about 40%. For this reason, figures are often quoted for 20 degrees C which is about room temperature. When current flows through the resistance of a wire, heat is produced and the temperature will rise. The heat is given off (dissipated) from the surface and passed to the air. Although a long wire of given diameter will have a higher resistance than a short one, the greater length provides a proportionally greater surface area over which the heat can be dissipated. This will usually present a smaller problem than wire which is too thin for the purpose. This will overheat, burn the insulation and possibly cause a fire (see photograph).

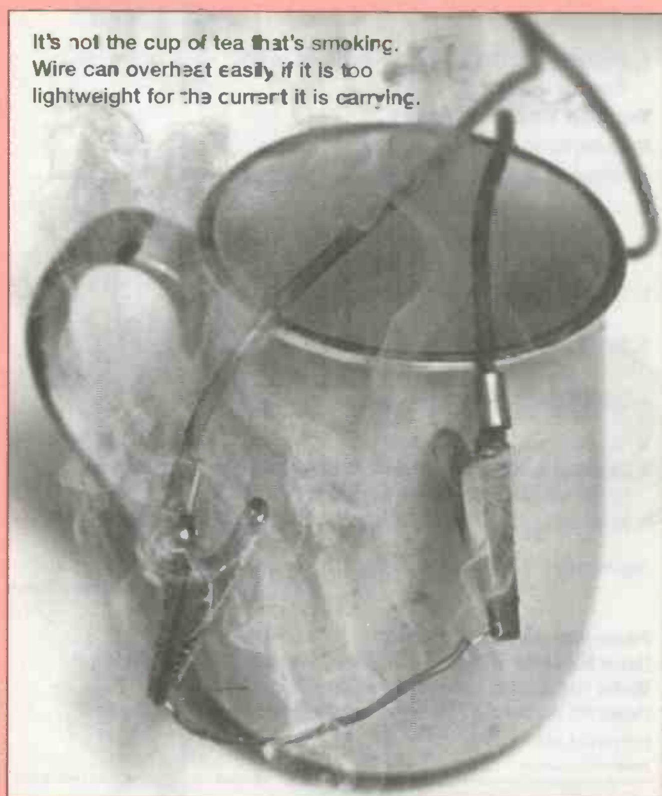
Check it out

Although 100 cm of wire having a diameter of 1 mm will have one-quarter the resistance of the same length of some having a diameter of 0.5 mm, this is not to say that it can carry four times the current. This is because, although the cross-section area is four times greater, the surface area from which the heat escapes is only double. Readers with mathematical ability could check this point by regarding the wire as a cylinder. The maximum current which may be carried by a piece of wire will therefore depend on its diameter in a non-linear way. For example, a wire of diameter 0.5 mm would need a current of more than 2A, to raise it to a temperature of 100 degrees C in free air. A wire of 1 mm diameter would need only 5A for the same temperature rise - not 8A as might have been expected. An important point to note is that the current rating of a wire will need to be reduced if it is routed in a confined space, or where it is grouped with other wires. A bundle of wires will have a smaller effective surface area than the wires taken individually. The heat will therefore find it more difficult to escape. The rating will also be less for connecting wire where the heat must pass through plastic insulation which is a poor conductor of heat. It is usually unwise to work to the limit of a wire's current carrying capacity.

Keeping cool

To give some practical examples. The popular type of insulated single-strand connecting wire described as "1/0.6" has a single 0.6 mm diameter core. The cross section area is 0.28 mm and the current carrying capacity is quoted as 1.6A. This is the current at which it will still remain cool. If it was used in a restricted space, or bundled with other wires, it would be wise to re-rate it to, say, 0.8A.

The insulated wire described as "7/0.2" - i.e. seven strands each having a diameter of 0.2 mm has a slightly smaller cross section area than "1/0.6" at 0.22 mm and is rated 1.4A. In certain pieces of equipment such as battery chargers, a large current is often encountered. Suppose the maximum current is 3A. The type of wire known as "32/0.2" (i.e. 32 strands each of 0.2 mm diameter) and having a cross section area of 1 mm would be a good choice. This is rated at 6A.



It's not the cup of tea that's smoking. Wire can overheat easily if it is too lightweight for the current it is carrying.

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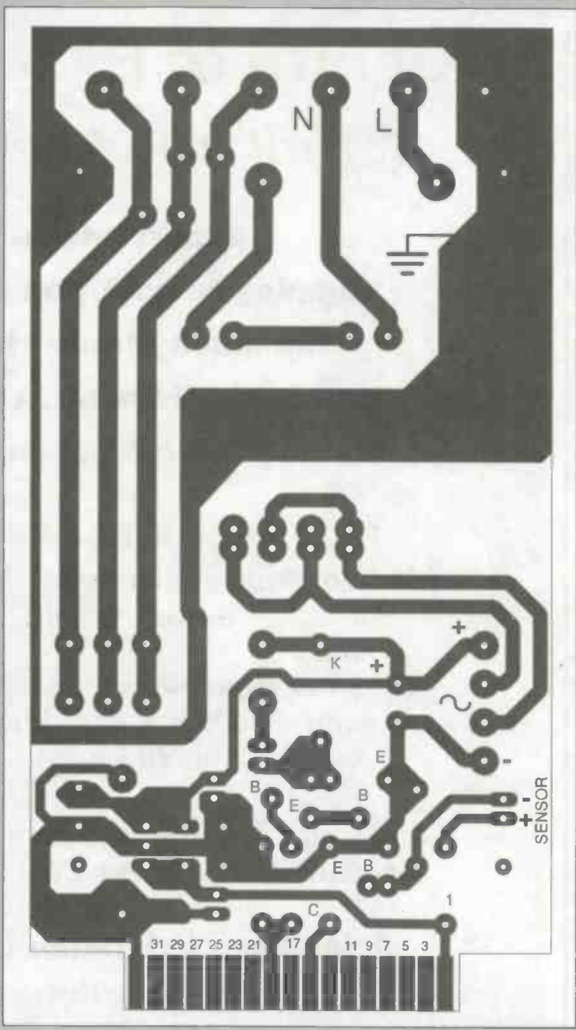

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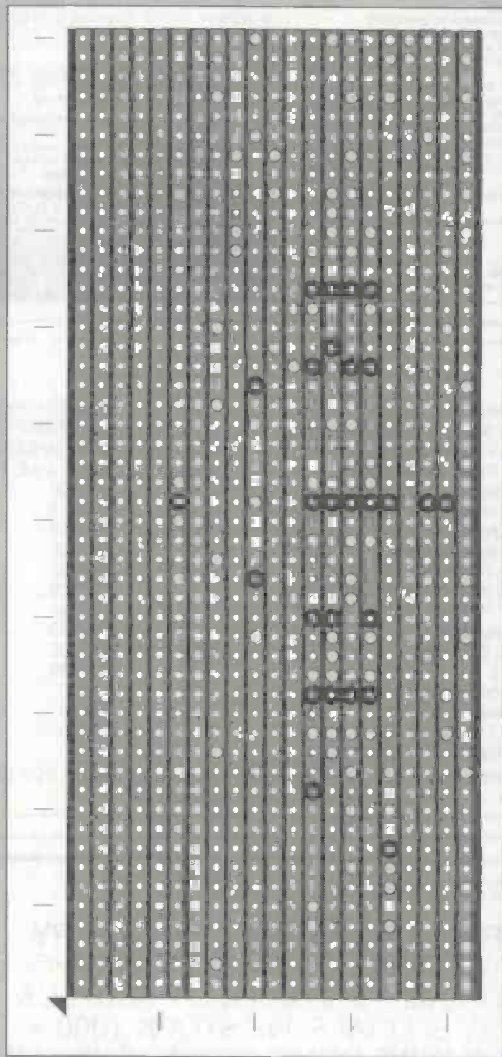

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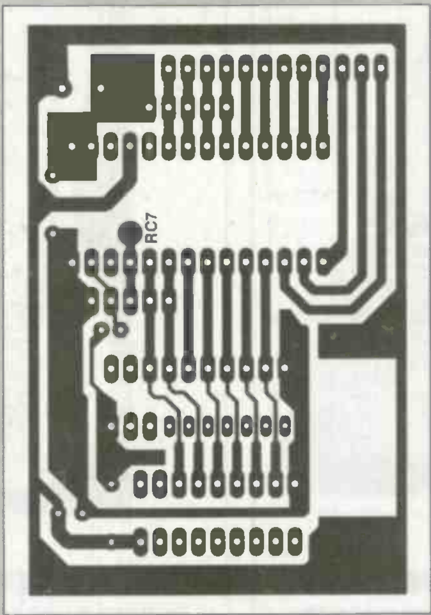

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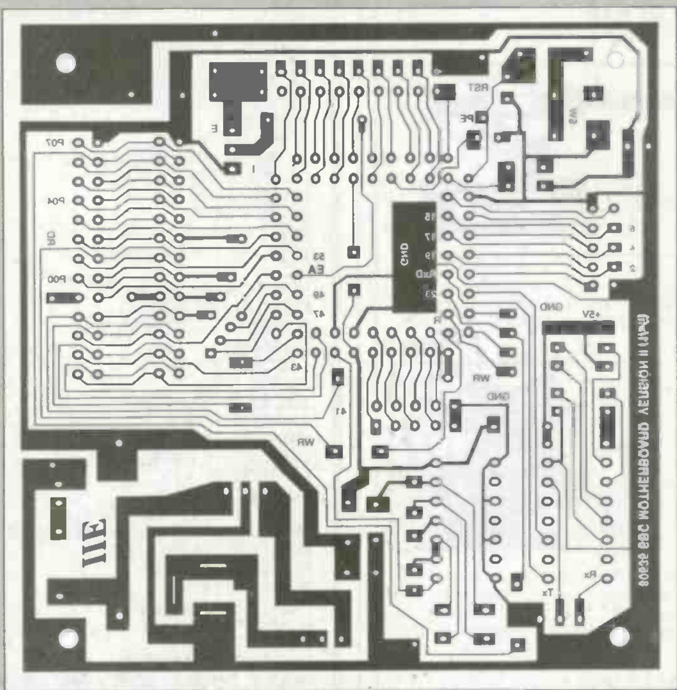

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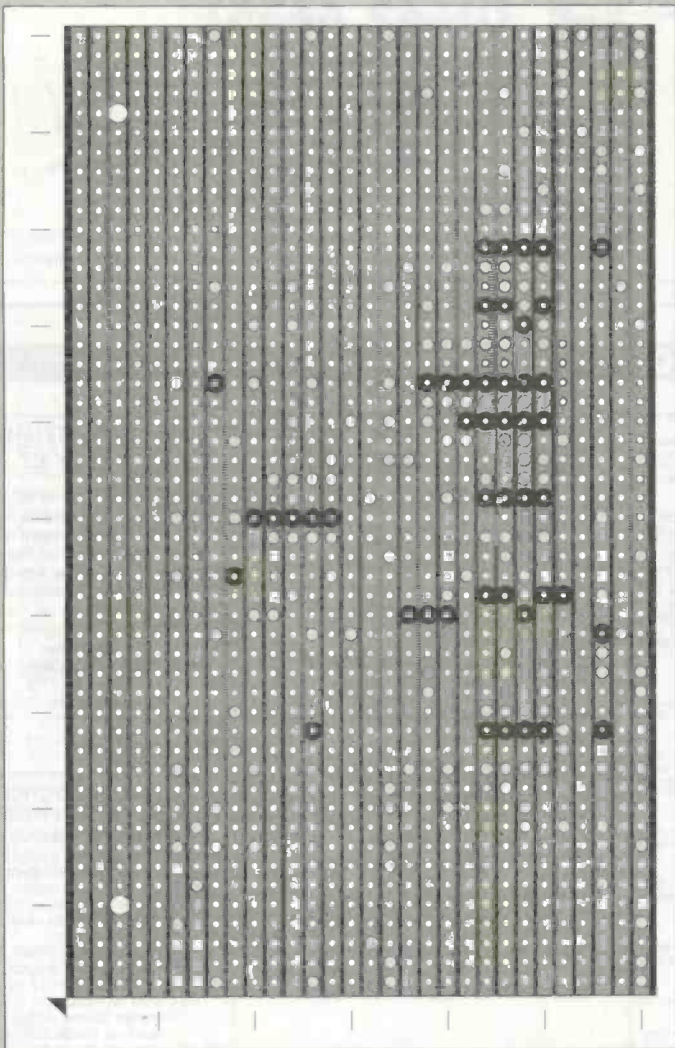

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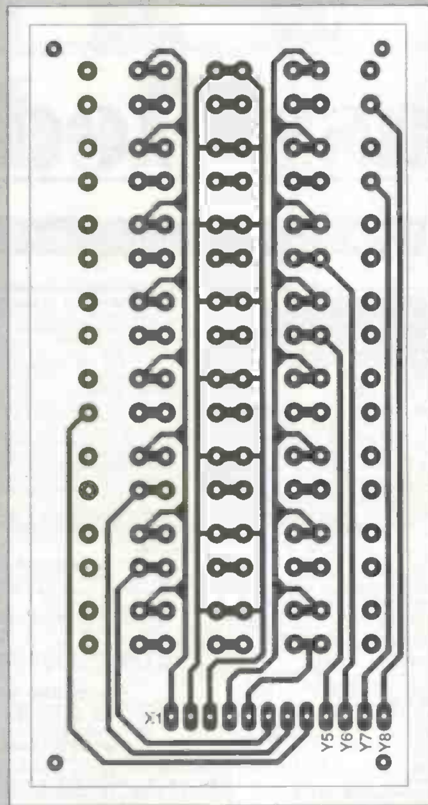

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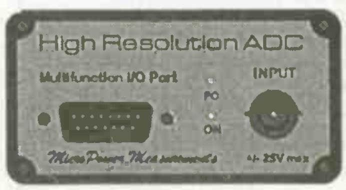

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Around the Corner

What were we talking about before the break? Hobbies ... and how the hobby of electronics is going to grow in the future. As well as "how", perhaps we should get back to basics and ask "why?" or, more exactly, "what for?" Most people who voluntarily spend their spare time and money on electronics do it because they enjoy it. I hope so, anyway, because electronics is a demanding pastime, which gives back much more in return for greater commitment. And there is a lot to enjoy, which is often overlooked by people who are not doing it. Not may years ago, a boffin in the Humanities undertook a careful analysis of the nature of happiness, partly based upon his experiences of Scottish country dancing. Happiness, he concluded, had a great deal to do with participating in something serious, which is also a game - something to do for pleasure, but that also needs a certain level of personal effort and commitment. He also thought that the most rewarding "serious games" seemed to involve music, exercise, and meeting people. You can see how the Scottish country dancing might fit in, although strangely, it does not seem to be everyone's idea of greatest happiness.

But where does electronics come into this equation? The popular idea of an "electronics hobbyist" is an earnest, probably bearded individual, crouched over a workbench littered with unidentifiable odds and ends, burning things with a soldering iron; or over a computer in the depth of the night, typing messages to unknown people on the other side of the world; or the old stereotype of the radio amateur forever tuning around his shortwave receiver just in case there is a ship in trouble in the Channel and he is needed to call out the Coastguard.

Oddly, my earliest experience of electronics hobbyists is not quite like this. Admittedly, they were serious (mostly planning careers in the field) and they did spend hours patiently soldering things together, or persuading one of the earlier microprocessors to accept a simple program in primitive assembler. But they were also the only department with its own bar, and they usually seemed to be making something that flashed on and off and could be used at parties. Or helping to fix some ailing piece of hi-fi, or generally bossing their friends into letting them make their radios or guitar amplifiers work a bit better. The engineering bar also attracted psychology students. Now, if this was some sort of case study, it's been a very long one, because they still phone up and say "my fax won't work..." and "my computer doesn't..." and then suggest a dinner or a barbecue. I think that then, as now, they were looking for company, beer, and a bit of help with their experiments. Because somebody has to know how the machinery works.

Most of those erstwhile hobbyists are still in the business, working on projects that travel all over the world. They still meet people while making themselves useful and sharing a beer, and they still run up and down flights of stairs carrying heavy pieces of test equipment. And they all began in electronics for the love of it, and are still motivated by its diversity. There were two kinds of engineering students even in those days: the ones who were absorbed by maths, and the ones who were absorbed by making things work. Both lots went either straight into practical electronics or straight into management, bringing their electronics knowledge to the organisation of high-tech businesses like BT and the erstwhile British Rail. The best thing about making electronics into a career is that you spend more time working with electronics. The worst thing is that you get less time to experiment with areas outside your speciality. But however much you know, there is always more to find out (often the hard way) and always more to get out of it - astronomy, communications, microcontrollers, interfacing, analogue signal sensing, position-finding, hi-fi, battery and power supply technology, timers, doorbells, a better car alarm... It all starts with the tinkering, persistence and insatiable curiosity of electronics hobbyists. Things change and the cutting edge seems ever harder to keep up with, but wasn't that what it was all about? I don't think that electronics hobbyists will die out, someone, somewhere, has to know how things work.

The Challenge - things that electronics hasn't fixed yet

A vital typing-finger has been damaged, removing a slice of skin with a sharp knife, leaving a raw area that is slow to heal and painful to use. How can electronics help to repair the finger, or compensate for it? Send your suggestions to the Editor at the address on the right.

Next Month

In the October 1996 issue of Electronics Today International we continue with the third part of Tim Parker's Process Timer and Controller, in which he adds a test board to allow programmers writing their own software to test their code, with sample control software. John Linsley Hood has designed a Squarer circuit to add a good quality squarewave to his Low Distortion Oscillator to show amplifier faults quickly and graphically. From Terry Balbirnie is the "off you go" push-to-go timed shutdown switch from anything from computer monitors to reading lights. Tim Parker uses the PIC16C55 to control a Databus Monitor that displays the state of an 8-bit output port in decimal or hexadecimal, an unusual and informative application. Bart Trepak has devised a Powerline Signal Remote Control for sending signals around the mains so that you don't have to run new cables. Douglas Clarkeson is looking at the future uses of fuel cells as a substitute for fossil fuels in the future.

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ABC CONSUMER PRESS

ISSN 0142-7229

Subscription rates-UK £25.80 Europe £34.70 Sterling Overseas £36.20 US Dollars Overseas $54.00

Published by Nexus Special Interests, Nexus House, Boundary Way, Hemel Hempstead HP2 7ST. Telephone (01442) 66551. UK newstrade distribution by Comag Magazine Marketing, Tavistock Road, West Drayton, Middlesex, UB77QE. Overseas and non-newstrade sales by Magazine Sales Department, Nexus House, Boundary Way, Hemel Hempstead, HP2 7ST. Telephone (01442) 66551. Facsimile (01442) 66998. Subscriptions by Nexus Subscription Dept, Tower House, Sovergn Park, Lathkill Street, Market Harborough, Leicestershire, LE 16 9EF .
US subscriptions by Wise Owl Worldwide Publications, 4314 West 238th Street, Torrance, CA90505 USA. For Visa/Mastercard orders in USA - Telephone (310) 375 6258 Fax (310) 375 0548. Pacific Time: 9am-9pm Weekdays. 10am-6pm Weekends.
Typesetting and origination by Ebony, Liskeard, Cornwall. Printed by Wiltshire Ltd. Bristol.

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