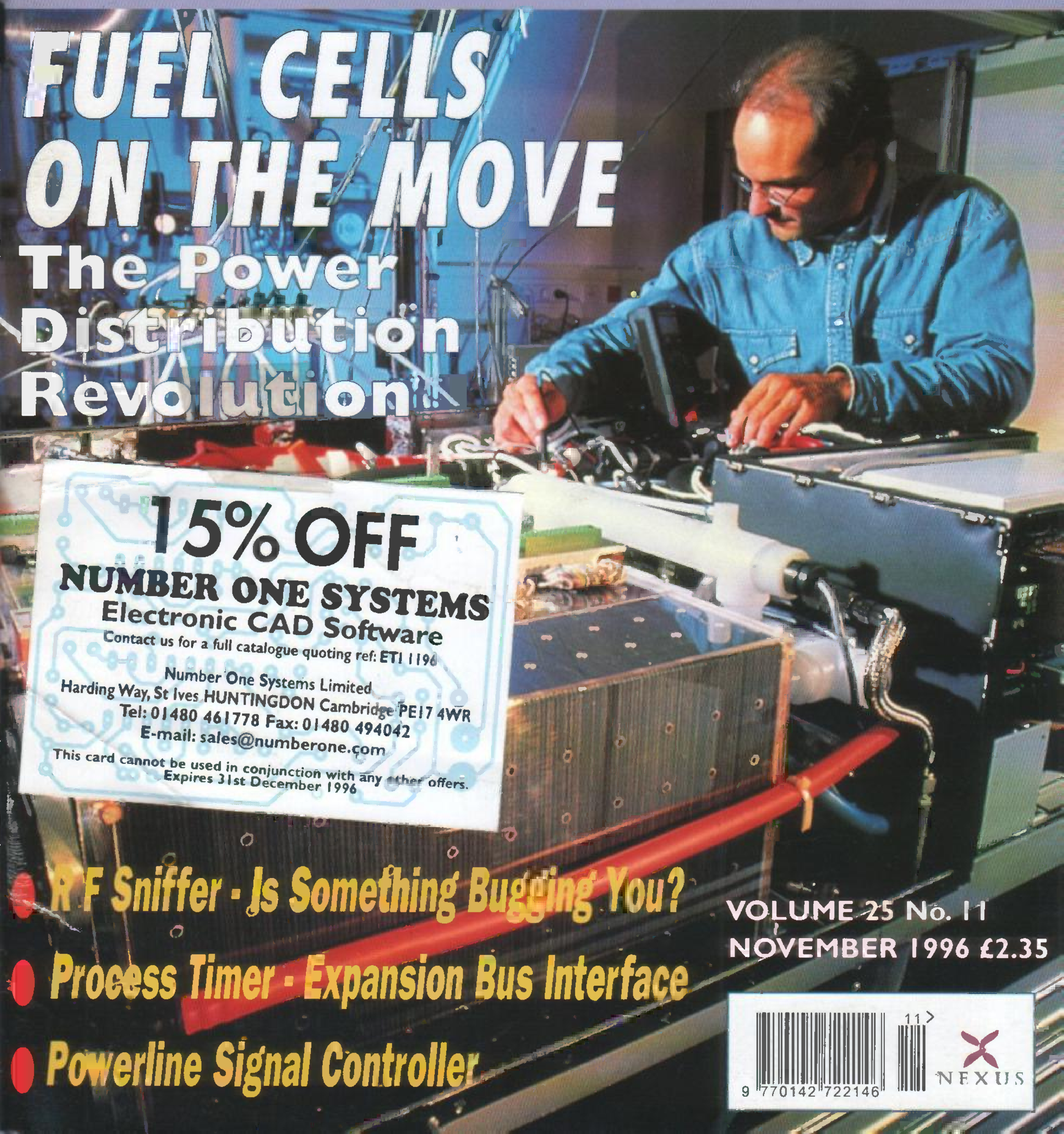
ETI

ELECTRONICS TODAY INTERNATIONAL

MicroAmp – The Professional Microphone Amplifier

Improved Background Noise Generator

"Phoney Phone" - Where is it?



FUEL CELLS ON THE MOVE

The Power Distribution Revolution

- R F Sniffer - Is Something Bugging You?
- Process Timer - Expansion Bus Interface
- Powerline Signal Controller

VOLUME 25 No. 11
NOVEMBER 1996 £2.35

9 770142 722146 11

NEXUS

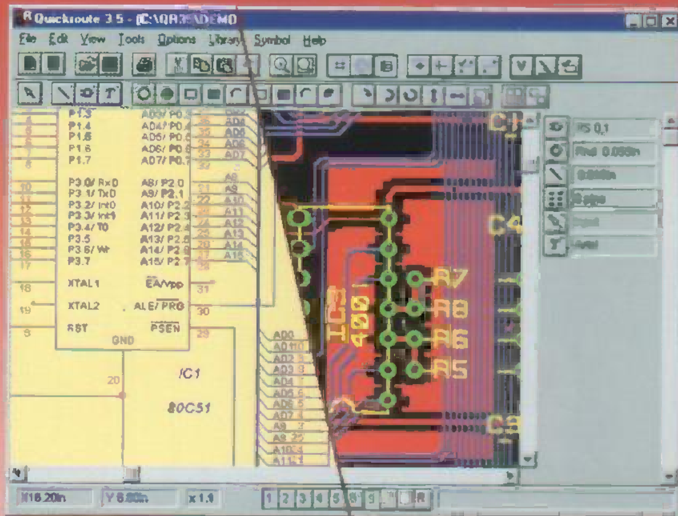
QUICKROUTE

Integrated Schematic & PCB Design System

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

Practical Wireless July 96

CAD CAM RECOMMENDED



	Personal	Designer	PRO	PRO+
PCB & Schematic Design	*	*	*	*
Schematic Capture		*	*	*
Design Rule Checking		*	*	*
Connectivity Checking		1	1	2
RouteASSIST (assisted routing)		*	*	*
Auto router			*	*
Export WMF & Tango			*	*
Export Gerber/NC-Drill			*	*
Extended Libraries			*	*
Tango + Gerber import				*
Update PCB from schematic				*
DXF & SPICE Export				*
Copper Fill				*

1 Simple pass/fail 2 Advanced Check

NEW Library Packs Available!

Quickroute 3.5 is a powerful, affordable and easy to use integrated schematic & PCB design system for windows. With its multiple button bars, ' tool tips' , and ' parts bin' Quickroute helps you to get working quickly and efficiently

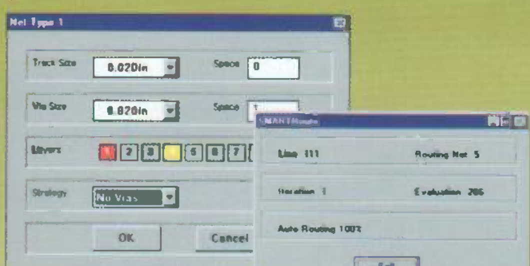
Quickroute is available in 4 different versions (see Table) all of which offer great value for money. Quickroute is available with multi-sheet schematic capture, 1-8 layer auto-routing, copper fill, engineering change, and a range of popular file import/export features allowing connection to simulators and other software packages (details on request). Prices are Personal (£68), Designer (£149), PRO (£249) and PRO+(£399). Please add P&P and V.A.T to total (see below*).

£68

SMART ROUTE

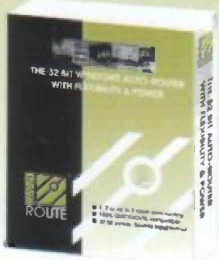
NEW

THE 32 BIT AUTO-ROUTER WITH FLEXIBILITY & POWER



SMARTRoute 1.0 is a new 32 bit auto-router that offers amazing flexibility & power at an affordable price! Compatible with Windows 3.1/95/NT, SMARTRoute gives you total control over routing strategies including layers used, track & via sizes, design rules, etc.

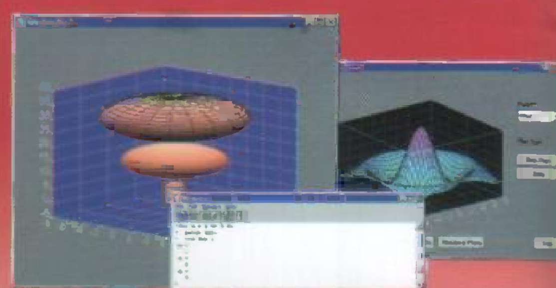
SMARTRoute is completely compatible with Quickroute 3.5 and offers improved completion rates compared with Quickroute' s built in auto-router (ask for details) SMARTRoute is available for £149 plus P&P and V.A.T. Special bundle pricing for Quickroute and SMARTRoute when purchased together.



Just £149

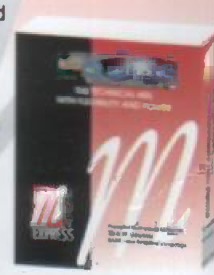
M EXPRESS

VISUALISATION, DATA ANALYSIS & APPLICATION DEVELOPMENT



MExpress is a powerful tool that can be used interactively to load, analyse and display data - or by using its powerful BASIC-like scripting language - you can create technical applications with buttons, menus, 2D & 3D graphics, and powerful numerical methods (ask for details).

MExpress is available in Standard (£99) and Developers Editions (£299). Prices exclude P&P and V.A.T (see below*). The Developers Edition includes tools for turning MExpress script files into C++ code. This can then be compiled by an MExpress compatible C++compiler into a stand alone executable!



£99

QUICKROUTE SYSTEMS

"The Engineering & Scientific Software People"

Quickroute Systems Ltd., 14 Ley Lane, Marple Bridge, Stockport, SK6 5DD, U.K.

Tel/Fax 0161 449 7101

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

*Post & Packing £5 (UK), £8 (Europe), £12 (World). Please add V.A.T to total

Prices and specifications subject to change without notice. All trade marks are acknowledged & respected. All products sold subject to our standard terms & conditions (available on request)

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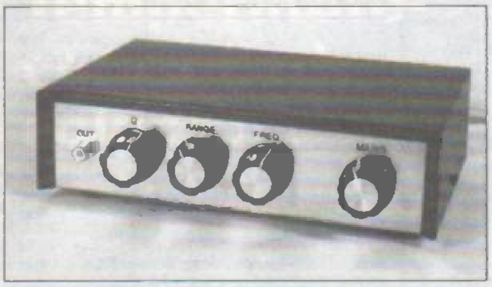
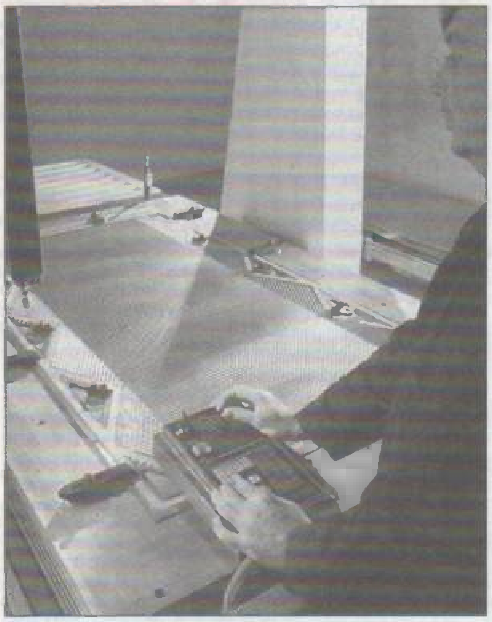
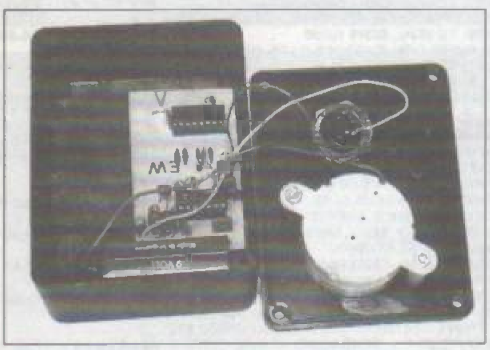
& Features Projects







Fuel Cell Technology on the Move — 9

Storing and drawing energy from fuel cells may one day decentralise energy distribution from large power stations to local ones. It is already gaining ground for motor vehicles, as Douglas Clarkeson reports

Background Noise Generator — 23

Do you have trouble with noisy neighbours? Many people prefer a background noise generator to muffle unrestful sounds. Robert Penfold's new design offers more control over the white noise generated to make it more "natural"

MicroAmp Professional Microphone Amplifier (Part 4) — 29

Barry Porter looks in detail at the principles behind the design of a professional-standard stereo microphone amplifier to make the best of recording quality, wherever microphones are needed

The "Phoney Phone" — 39

Few everyday sounds are more frustrating than the sound of a phone ringing endlessly, especially when you cannot work out where it's coming from. Terry Balbirnie describes how to build a fake phone ringer, and offers some suggestions

Process Timer (Part 4) - the Expansion Bus Interface — 44

From small beginnings, Tim Parker's Process Timer and Controller project has grown into a multi-function controller with multiple uses. This month we add an interface board for the expansion bus

Simple Powerline Signal Controller (Part 2) — 53

In the second and final part of this project to send control signals via domestic wiring, Bart Trepak describes and builds the transmitter unit and assembles the whole thing

Quick RF Sniffer — 59

Planting RF "bugs" in homes and offices has become an undercover industry. But with Raymond Haigh's RF detector you may be able to catch the bugs before they catch you

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Terry Balbirnie investigates heavy-duty wire ratings and fuses

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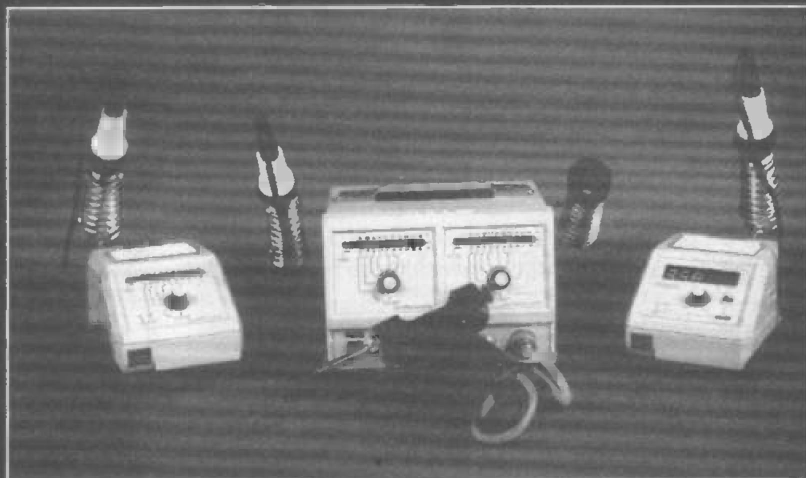
ETI ELECTRONICS TODAY INTERNATIONAL

News...

Temperature-controlled soldering



A new collection of temperature-controlled soldering stations offers two reasonably priced soldering stations, and a more sophisticated soldering and desoldering station for production use.

The SL20 is an electronic temperature-controlled soldering station incorporating a plug-in 48W 24V soldering iron. The temperature is fully adjustable between 150 degrees C and 420 degrees C, and the station has a 12-LED bargraph indicator of actual temperature and heat-on mode. The SL30 is similar to the SL20, but with a higher temperature range of 160 degrees to 480 degrees C, and a digital readout of preset and actual heat.

These models cost £59 and £69 respectively.

The SL916 is a combined soldering and desoldering station with independent temperature control of the soldering iron and desoldering gun so that both can be used simultaneously. The desoldering gun uses a vacuum pump to remove solder from the joint and collects the solder waste in a see-through cartridge that can be easily emptied when full. The station can be used effectively on traditional, plated-through-hole and surface-mount pcbs. It costs £349, beyond the pocket of most amateur constructors, but a time-saver in the long run for anybody running a production line or repair workshop with a steady turnover.

The stations have optional accessories including a wide range of bits for both conventional and surface-mount soldering. Constructors seeking to extend their range of building into smaller or larger boards, greater integration, or surface mount should examine their soldering equipment and consider if they would benefit from an iron, such as the ones described here, with greater temperature-control and tip capabilities. There are now many good models on the market.

Information from Vann Draper Electronics, Unit 5, Premier Works, Canal St., South Wigston, Leicester LS18 2PL. Tel 0116 277 1400 Fax 0116 277 3945.

New Basic compiler for the PIC16C74

Forest Electronic Development have released a compiler for their range of PIC-based microcontrol modules that can be programmed in Basic. The compiler produces hex code which may be used to program a PIC16C74 directly, and which requires no external eeprom or other support circuitry apart from a power supply and oscillator.

The compiler is compatible with the eeprom versions of the Basic modules. Programs can be developed and debugged on a Basic module in the eeprom and, when complete, compiled and used to program 16C74 devices directly. The compiler is hosted under the same Windows development environment as the normal Basic development system, and programs may be edited, debugged, downloaded to a Basic module and compiled all within the same environment. Up to 2600 words of program space is available for the compiled program, allowing up to 2000 lines of Basic to be compiled. The code is optimised to remove unwanted modules. For instance, if code for driving an LCD module is not needed, then it is not included. Code is produced that is between 3 and 100 times faster than the eeprom-based modules. No knowledge of PIC Assembler is required.

For more information about the PIC Basic compiler, and about FED PIC Basic for the 16C74, contact Forest Electronic Developments, 10 Holmhurst Avenue, Christchurch, Dorset. Tel 01425 270191

Free tickets for consumer electronics at Connect 96

Central Presents

CONNECT

The Home Entertainment Experience

NEC Birmingham 18 - 27th October 1996

The organisers of 1996 consumer electronics show Connect are offering 10 pairs of free tickets to the first 10 ETI readers to contact them with the reference number below.

Connect 96 appears at the National Exhibition Centre (NEC) just outside Birmingham from 18th to 26th October. The exhibition is presented by Central Broadcasting, and a major attraction will be a custom-built TV studio, a "sneak preview" of Central's new broadcast headquarters in Birmingham. The organisers are also promising the Connect Sound Stage, "a state-of-the-art 'UFO' structure", with entertainments from chart bands and DJs, light shows and special effects. The show concentrates on consumer electronics, including hi-fi, home cinema theatre and interactive displays. Sennheiser, TDK, Virgin Games, Denon and AJP are among the exhibitors.

The Home PC Show, the Autumn Ideal Home Show and the International Motor Show are running at the NEC at the same time. Tickets to Connect cost £7 (adults) and £5 (children and senior citizens) and include entry to the PC Show and the Ideal Home show. A ticket to all four shows costs £14. Preview Day tickets to Connect (18th August) cost £10.

The NEC is quickly accessible by motorway (M42) and rail. Connect is open 9.30 to 19.00 on most days and 9.30 to 17.30 on the final day.

For advance ticket information and booking, and, if you are one of the 10 quick lucky ones, for your free pair of tickets, phone 0121 767 4114 and quote reference C08.

Quick Look Over: Tip-tinner

Remember the lead free tip tinner from the September news page? It looked interesting so I decided to try it. It seemed to work better than my ordinary one, removing the crust of black scale which won't melt solder and leaving a well tinned tip which did not scale up again too quickly. As lead-free soldering becomes more widespread, with outwork as one driving force, a good lead-free tip tinner will contribute to keeping lead out of the domestic environment.

The two packages are priced at £5.88 and £10.41. Information from Intertronics, Unit 9, Station Field Industrial Estate, Banbury Road, Kidlington, Oxon OX5 1JD Tel 01865 842842 Fax 01865 842172.

Alpha test equipment

Alpha Electronics' new 2-page catalogue of test equipment includes cable detectors and fault locators (including a new LAN section), high voltage and battery testing, chart recorders and data loggers, oscilloscopes and scopemeters, signal sources, time and frequency measurement and other equipment. Alpha also have an instrument hire section and BS 5750/ISO 9002 repair and calibration service. Free from Alpha Electronics (Southern) Ltd. Tel 01622 690187 Fax 01622 678827.

CE-compliance testing comes in-house

BEST 96 from Schaffer is an entire EMC test system in a single unit. It is the first self-contained unit to combine all the functions required for full EU compliance testing of residential, commercial and light-industrial electrical and electronic products. The EMC tester is designed to allow manufacturers who need a CE mark to complete pre-compliance and compliance testing in-house quickly and more cheaply than via an independent testing house.

The core of Best 96 is a compact multi-function generator giving burst, electromagnetic discharge (ESD), surge and power quality pulses for single-phase power-line and data-line compliance tests to the EU electromagnetic immunity standard EN 50082-1 (which applies to the areas of usage mentioned in the previous paragraph. Ground-plane, cables, ground-strap, grounding resistor and coupling clamp for data-line testing are included as part of the standard package, as are instructions for completing tests to compliance standards.

Schaffner say that no specialist EMC skills are needed and that the equipment can be operated by a QA technician or non-specialist engineer. The system offers test management tools including sequencing, customisation, storage options and data analysis, and test certificates, engineering reports and user documentation can be generated and printed within the system.

Equipment covered by the EN 50082-1 standard includes some products designed for use in cinemas, parks, petrol stations, light industrial sites, offices, shops and homes.

Systems like Best 96 offer assistance to manufacturers and designers needing testing facilities to establish the conditions for CE compliance and who may be discouraged by price considerations from using large independent test facilities.

Businesses interested should refer to Schaffner sales offices for pricing information. The UK offices is Schaffner MEC Ltd., Ashville Way, Molly Millar's Lane, Wokingham RG41 2PL Tel 01491 410700 Fax 0118 9792969.

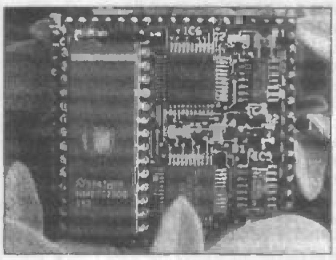
Digital photography storage by PC

NBA Photowallet is a computer-based picture storage system for digital camera users. Makers NBA Quality Systems says that the system can be connected directly to the Kodak DC40, Kodak DC50, Chinon ES-3000 and Casio QV-10 cameras, as well as many other models and others as they become available, and any TWAIN-source scanners and video digitisers. Picture manipulation includes rotate, copy to clipboard, paste-in image from another application, copy, view full size with zoom, print to page size or custom scale, and send pictures via GSM, satellite, telephone or radio using NBA Inter-Comm software.

The software stores digital pictures in named groups called 'Wallets', with unlimited number of pictures to a Wallet and unlimited Wallets (limited, that is, only by the memory size available). It displays Windows bitmap images JPEG images, and can store the Wallets on hard disk, CD-ROM and network drives.

The preferred hardware needed is a 486X or higher PC, 12MB of RAM, 2MB of free hard disk space plus a minimum 10MB for pictures, and a High Colour or True Colour graphics card. 256 colours is workable, although a higher standard is recommended.

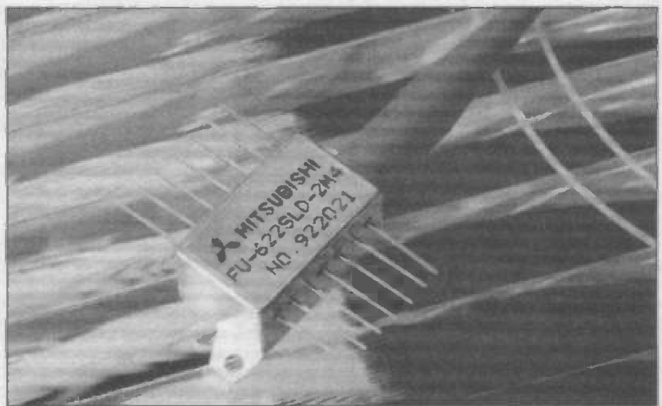
Information from The Digital Camera Company, Guildford, Tel 01483 452100, or NBA Quality Systems, Guildford, Tel 01483 301970 Fax 01483 564746.



Tiny control module

The Devantech EM320 control module is based on the popular high-speed architecture 25-MHz Dallas 80C320 processor, which carries the standard 8051 instruction set, three 16-bit timer/counters, a programmable watchdog timer and an early warning power failure interrupt. The tiny (46mm x 49mm) multilayered PCB is surface mount with a full ground plane. The module provides 32 KB static RAM, 32 or 64 KB of eprom, 30 I/O lines, plus the cull CPU bus access and nearly 32 KB of expansion space. A cross assembler and a fully-optimising C cross compiler are also available for programming the EM320.

For information contact M J Turner Tel/Fax 01945 466672.



High-power self-cooling laser diode module

A laser diode module from Mitsubishi incorporates integral thermal electric cooling circuitry with a capacity of 40 degrees centigrade with a cooling current of 1.5A maximum and a maximum cooling voltage of 3V. Optimised for pump operation, the FU-622SLD-2M4 is designed specifically for the 1.48 micrometre band and has an output of 100 milliwatts of optical power from its fibre end. The optical output is monitored by photodiodes.

The laser diode is rated at 200 milliamps forward voltage and 2V reverse voltage. The photodiode is rated at 2 milliamps forward current and 20V reverse current. The device operates over temperatures from -20 to +65 degrees C, and can be stored at a greater range. Typical operating current of the laser diode is 590mA, operating voltage 1.4V and threshold current 30mA. The spectral width is typically 10 nanometres, and the very accurate diode has a tracking error of typically only 0.3dB. The device is in a butterfly package with an optical pigtail of mode field diameter 10 micrometres and cladding diameter of 125 micrometres.

Information from Mitsubishi marketing. Tel 01707 276 100.

Overseas Readers

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

Exclusive to ETI Readers

15% off all Number One Systems' Electronic CAD Software!

Number One Systems are the European market leaders in affordable CAD software for electronic design. Since 1983 their PCB layout and simulation programs have become an indispensable tool for thousands of design engineers and are used by leading companies like GEC, Hewlett-Packard, IBM and Motorola.

Low cost easy-to-use entry-level programs include the award-winning PCB Drafting program EASY-PC, with over 20,000 licences sold in 90 countries through the world, the powerful analogue and digital circuit simulators ANALYSER 111 and PULSAR, and the time-saving FILTECH filter designer that can produce a complete active or passive filter circuit from a simple graphical description of the required frequency response.

For advanced users, the Professional range extends the capabilities of the entry-level programs with a high-speed autorouter, MultiRouter, typically capable of 100% routing a 200mm by 150mm double-sided board with 140 components including a large PGA device in under 10 minutes, and LAYAN a revolutionary electromagnetic simulator based on original research at Philips Research Laboratories, Redhill, Surrey. With LAYAN, it is possible to simulate the behaviour of an analogue circuit taking full account of the effects of the physical PCB layout. This means that designers can see the effects of unwanted couplings across the layout and can also make use of printed couplers, filters and inductors in their designs.

List prices range from £75.00 for EASY-PC up to £495.00 for LAYAN with free lifetime telephone support for all customers. ETI readers quoting the reference number on the Discount Card can claim 15% off the list price of all Number One Systems' software until the end of December 1996. A full catalogue and price list is available from Number One Systems, Harding Way, St. Ives, HUNTINGDON, Cambridgeshire, PE17 4WR. Telephone: 01480 461778, e-mail: sales@ numberone.com. Please quote the reference number on the card with all enquiries and orders.

MOONSHINE BIBLE 270 page book covering the production of alchohol from potatoes, rice, grains etc Drawings of simple home made stills right through to commercial systems. £15 ref MS1

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

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

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

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

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

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

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

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

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

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

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

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

9 WATT CHIEFTAN TANK LASERS

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

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

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

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

THOUSANDS AVAILABLE RING/FAX FOR DETAILS!

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

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

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

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

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

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

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

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

LIQUID CRYSTAL DISPLAYS Bargain prices,
16 character 2 line, 99x24mm £2.99 ref SM1623A
20 character 2 line, 83x19mm £3.99 ref SM2020A
16 character 4 line, 62x25mm £5.99 ref SMC1640A

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

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

CENTRAL POINT PC TOOLS Award winning software, 1,300 virus checker, memory optimiser, disc optimiser, file compression, low level formatting, backup scheduler, disk defragmenter, undelete, 4 calculators, Dbase, disc editor, over 40 viewers, remote computing, password protection, encryption, comprehensive manual supplied etc £25 ref lot 97 3.5" disks.

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

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

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

COMPUTER DISC CLEAROUT We are left with a lot of software packs that need clearing so we are selling all 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

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

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

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

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

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

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

RED EYE SECURITY PROTECTOR 1,000 watt outdoor PIR switch SALE PRICE £6.99 ref EP57

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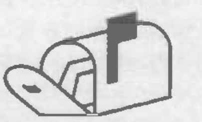

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FUEL CELL TECHNOLOGY on the move

Electrical storage cells represent the ultimate flexibility in the provision of energy, in large or small amounts, industrial, residential or mobile. They are catching up, especially in the automative industries, as Douglas Clarkeson describes

In many ways, the path to greener energy requires progress with technology but also a shift in thinking. The field of fuel cell technology represents just such a challenge of development, and also mental level shifting. The significance of the fuel cell technology is that it has the ability to alter the source of electrical power to a house, to a car or a bus, to a block of flats, or to a city requiring 100 MW of power.

Power stations utilising fuels such as coal, oil and natural gas tend to be economical in relatively large units. Nuclear power stations are even more concentrated units of investment and typically cost several billions of pounds to construct. The long term significance for the power industry may be the ability of fuel cells to decentralise it, with power generation systems being sited even in residential neighbourhoods.

The process of deregulation of the power industry is seen in the USA as a means to reduce utility power costs as a potential attraction for industry. This process has already gone some way, especially in California where by 1998 companies can be in a position to buy power from the utility of their choice.

This choice is being opened up to residential customers by 2003. The development of fuel cell technology is coming at a time where increasing decentralisation will take place in power supply systems and there will be a gap in the market for more flexible, more efficient and less polluting forms of power generation. This move for deregulation would allow the cost of grid distribution to be reduced as less power is required to be transmitted across it.

There could even be some 'wild card' scenarios within the fuel cell field. With millions of homes connected to natural gas in the UK, what is to prevent the development of a flexible 'multi-boiler' system that provides both heat and electricity derived from the fuel cell function? A lot of the energy from my gas boiler seems just to heat the gas exit flue. (And you have probably noticed the same thing in yours.)

Developers, on your marks ....

Fuel cell technology also has the potential to interact - hopefully not to interfere - with alternative sources of power such as wind, solar and biomass. Linked together in a supportive way, fuel cells could provide a means of efficiently using hydrogen produced by electrolysis from wind and solar sources, or producer gas or methanol from biomass sources.

In terms of global warming, fuel cells can help reduce carbon dioxide emissions by using fuels such as natural gas much more efficiently. When hydrogen is used directly, no carbon dioxide is released as a direct result of the fuel cell process.

Discovery of the fuel cell

One of the surprising aspects of fuel cell technology is that it was discovered by Sir William Robert Grove in 1839. Sir William Grove was also the first to demonstrate the dissociation of steam into hydrogen and oxygen by a heated catalyst such as Platinum. In today's parlance, this would be described as 'reformer' technology. He also developed a battery with one cell consisting of zinc in dilute sulphuric acid and another of a platinum cathode in nitric acid, with the cells being separated by a porous container.

Sir William Grove initially made his career in law, but ill health made him turn to science, becoming professor of Physics at the London Institution between 1840 and 1847. He was later to combine both careers by being involved in patent law. His background identifies him as being indeed most suited for the modern day world of fuel cell development - a mind filled with science and the finer points of patent law.

General developments

While the concept has been understood for nearly 160 years, it has only been relatively recently that progress in materials technology has advanced the cause of the fuel cell. Pratt and Whitney successfully developed fuel cells for the Gemini IV mission. These subsequently provided an invaluable source of power for the Apollo moon landing missions. Currently a 12 kW alkaline fuel cell provides power for NASA's space shuttle. This cell can only be run on pure hydrogen and oxygen and is seen as having limited potential for future application.

In the USA, the Department of Energy developed fuel cell systems through the 1970s and 80s with principal effort going into Phosphoric Acid Fuel Cells (PAFC) technology. The commercialisation of this technology is now visible as systems are being supplied to customers. One key research centre in the USA is the Department of Energy's Morgantown Energy Technology Centre (METC). More recently, over the last five years, there has been increasing interest in advanced high temperature fuel cells which operate at higher efficiencies and also require lower capital costs and which in particular can utilise coal gas as a fuel.

With Europe a framework of collaborative projects sponsored by national governments, EC funding and commercial sources are active in developing a range of fuel cell technologies with a bias towards high temperature processes with internal conversion of natural gas to hydrogen.

Similarly within Japan, a diverse mix of organisations and companies are actively involved in development of fuel cell technology.

General types of fuel cell

Table 1 summarises the main types of fuel cell currently being developed or in commercial production.

TYPE DESCRIPTION	*SPFC Solid Polymer*	*PAFC Phosphoric Acid*	*MCFC Molten Carbonate*	*SOFC Solid Oxide*
Operating Temp C	80-200	200	650	1000
Predicted % Efficiency	60	up to 40	65	55
Internal Reforming	No	No	Yes	Yes
Pressure atm	1-8	1-10	1-10	1

Table 1: Summary of main types of fuel cells.

The SPFC is also frequently referred to as the PEM (Proton Exchange Membrane) fuel cell. The SPFC cell typically has sulphuric acid in polymer as its electrode and the PAFC unit phosphoric acid in a silicon carbide matrix. The MCFC cell typically has a mixture of lithium/potassium carbonate sintered on lithium aluminium oxide tile surface.

The use of thin polymer membranes in the SPFC cell provides for a high power density factor which is especially an advantage in general transport situations such as cars and buses.

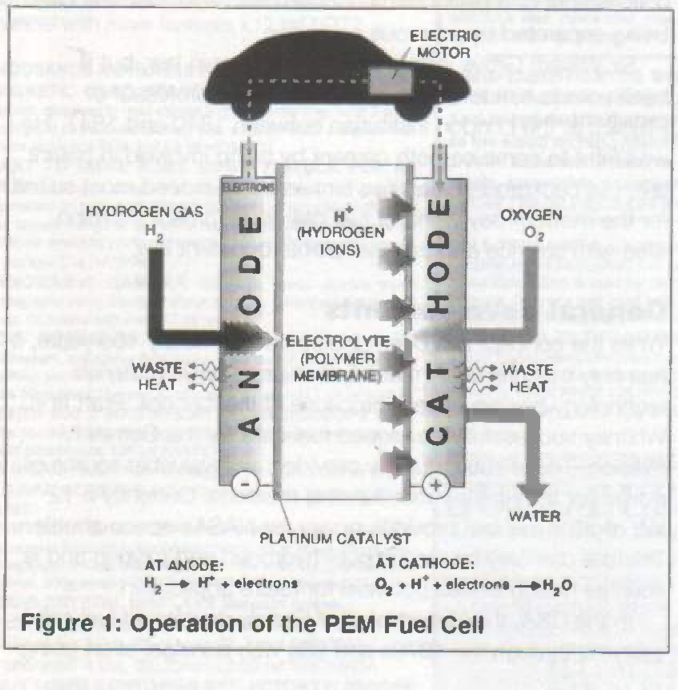

Figure 1: Operation of the PEM Fuel Cell

SPFC or PEM (Proton Exchange Membrane) cells

Figure 1 indicates the essential structure of a section through a SPFC or Proton Exchange Membrane (PEM) fuel cell. Hydrogen is supplied to a gas porous hydrogen anode. Hydrogen migrates across a layer of catalyst (usually platinum) as hydrogen ions after having given up an electron. The protons are small enough to migrate through the membrane across the catalyst and into the oxygen cathode which is a porous structure supplied with oxygen. Electrons left behind at the hydrogen anode travel in a connected circuit to the cathode where the hydrogen ions (protons) are neutralised and water is formed.

The hydrogen ions therefore develops a negative voltage and the oxygen electrode a positive voltage. Under open circuit conditions with no current flowing, the cell potential is around 1V. Under conditions of load the cell potential falls to around 0.6 V. A key feature of the fuel cell technology, however, is its relatively high efficiency. For the SPFC cell, values of around 45% can be achieved. This compares favourably with the typical value of 25% of the internal combustion engine. This is one of the key parameters stacked in favour of fuel cells.

Sulphur and carbon monoxide must be removed from the fuel gases to avoid poisoning the platinum catalyst present in the anode and cathode structures. One of the anxieties about using this cell in vehicle transport is the risk of contamination from vehicle exhausts from vehicles with internal combustion engines.

Within Europe, SPFC technology is being developed in Holland by ECN, in Italy by Sere De Nora and In Germany by Siemens and Dornier with a wider range of companies including Rolls Royce and VESL showing interest in associated technology and applications.

A key developer of SPFC technology is Ballard Power Systems Inc in Vancouver, Canada. Energy Partners Inc of Florida, founded in 1990, is also another developer of proton exchange membrane fuel cells and has developed 20 kW PEM facility using compressed hydrogen. For low to medium sized PEM fuel cell installations, Ballard Power is in many ways already demonstrating the future.

Ballard Power Systems

While there is a wide range of fuel cell technologies available, it is widely considered that the appropriate technology for vehicles is that of PEM or proton exchange membrane. The key characteristics of high power density and quick start up time and the tolerance of variable power demands, map exceedingly well to the driver waiting for the red light to change.

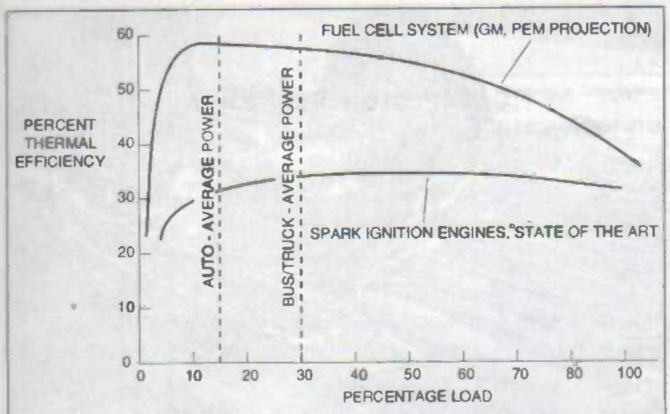

Figure 2: Comparison of efficiencies of PEM fuel cell with state of the art spark ignition internal combustion engine.

Initial reception of the second generation bus has been equally enthusiastic. Powered by a 205 kW (275 HP) fuel cell system, the bus has a range of 250 miles. In a significant commercial development, the City of Chicago has signed a US$5.8 million two year deal to put three buses into service. If this is successful then the Chicago Transit Authority will consider converting its entire 2000 bus fleet to Ballard Fuel Cell engines as the buses become due for replacement.

Figure 3 shows the general construction of a fuel cell unit. The fuel cell module is very much a sandwich with the membrane electrode assembly (3) held between the flow field plate (1). Thus air (4) and hydrogen (2) is distributed on opposite sides of the flow field plate. The air flow channels (4) guide flow over the active membrane and remove water produced by the combination of hydrogen and oxygen.

One of the surprising features of the developments at Ballard Power Systems has been the speed with which the power density of the PEM cells has been increased. Figure 4 indicates the rapid rate at which power units have been made more compact. This feature will be a key factor in vehicle design in the future. During 1995, the power density of the Ballard Fuel cell was increased to 28 kW per cubic foot.

Figure 5 indicates what only six years of development can bring. On the left the 'state of the art' cell of 1989 and on the right the cell of 1995 with a power density of 28 kW/square foot - some ten times greater

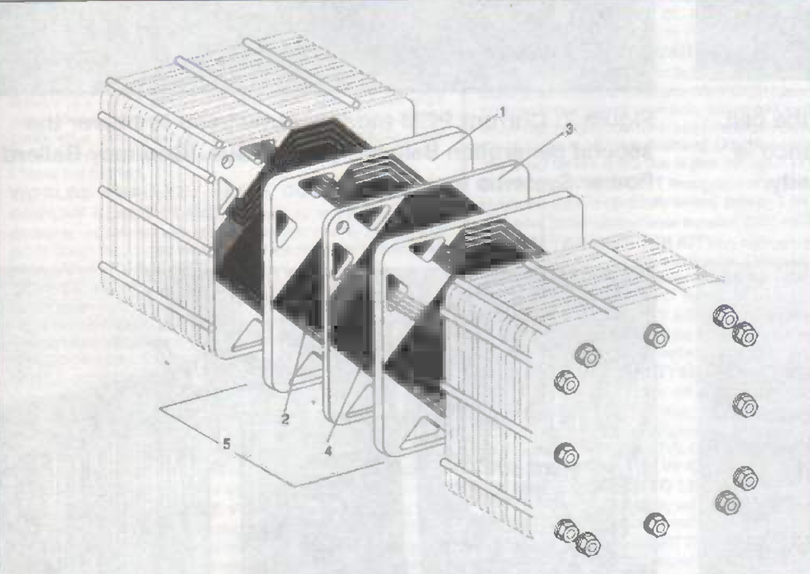

Figure 3: General construction of Ballard fuel cell unit.

(1) flow field plate

(2) hydrogen flowing in flow channels of field plate

(3) membrane assembly

(4) oxygen flowing in flow channels of field plate

(5) a single fuel cell unit

(Courtesy Ballard Power Systems Inc)

In Ballard's PEM technology, the protons migrate through the fluorocarbon polymer membrane electrode which is typically between 0.05 to 0.18 mm thick. It is always tricky to estimate how much of a lead Ballard have on the rest of the field. Some observers estimate as much a 10 years.

Figure 2 indicates a general but relevant comparison between PEM fuel cell technology and the state of the art spark ignition engine. The data at 15% of full load is appropriate for typical urban motoring - not pulling a caravan up through the mountain passes of Switzerland. Thus the fuel cell maintains its significant advantage over a large range of percentage of full vehicle load.

The team at Ballard have developed a typical production PEM fuel cell of a 5 kW stack at 240 A at 20 V when supplied by hydrogen at 30 psi (approximately two atmospheres pressure). In the PEM Ballard fuel cell, the temperature is maintained at 70 degrees C and 100% relative humidity. The corresponding size is only 25 x 25 x 46 cms and weighs 45 kg. Using 24 of these modules to power the initial Ballard Bus, a top speed of 70 km/hr was achieved - supplying power to a 120 kW (160 HP) engine.

It was the demonstration of this bus that led to worldwide interest in the Ballard fuel cell technology. The current phase of development includes the development of a bus with 10 kW stacks.

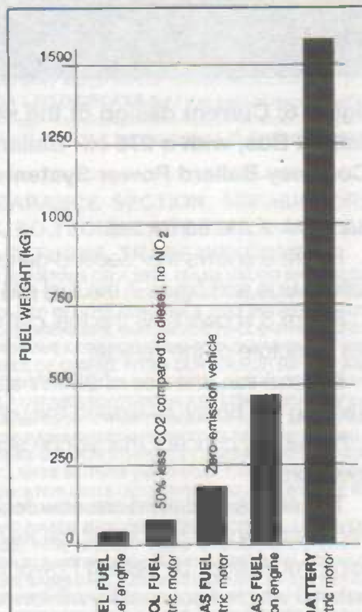

Figure 4: Indication of rapid rate of improvement in power density in kW/cubic foot for Ballard PEM cells. (Courtesy Ballard Power Systems Inc)

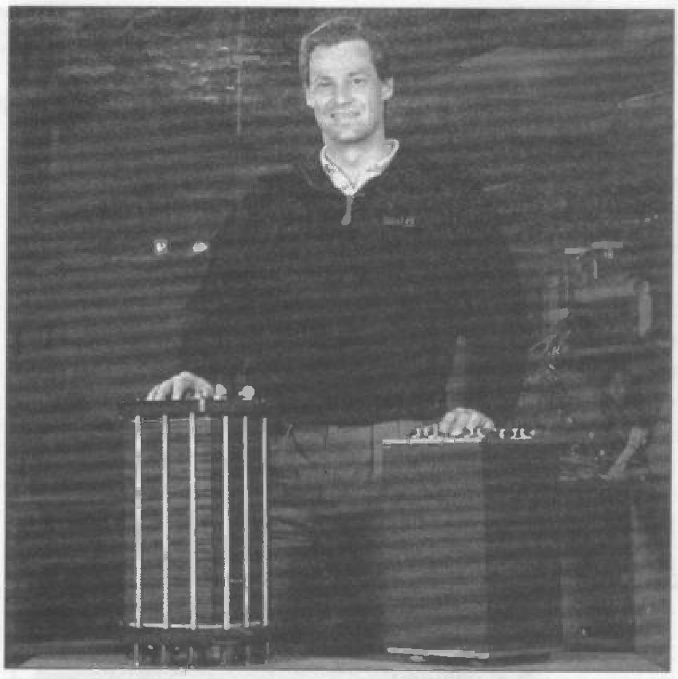

Figure 5: Milestone in development: On the left the cell of 1989 and on the right that of 1995. The difference is an improvement by a factor of ten in power density. (Courtesy Ballard Power Systems Inc)

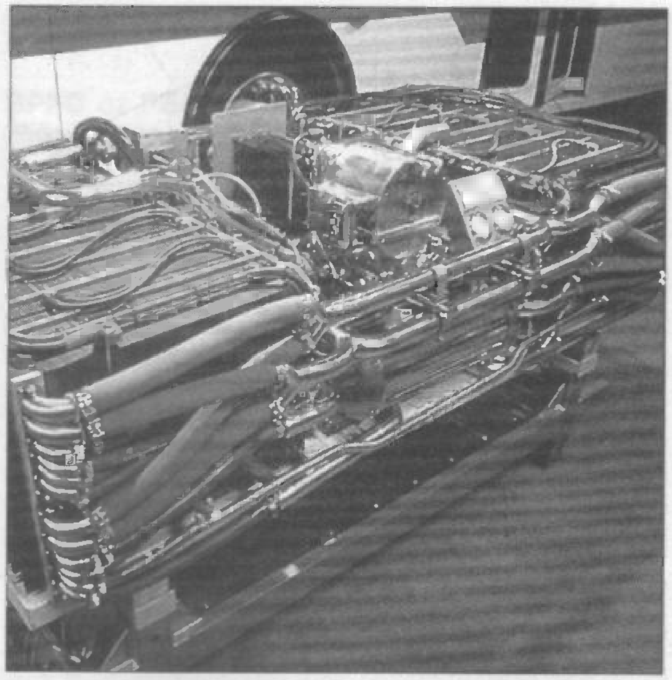

Figure 7: Current PEM module array used to power the second generation Ballard Fuel Cell Bus. (Courtesy Ballard Power Systems Inc)

Figure 6: Current design of the second generation Ballard Bus, with a 275 HP Ballard Fuel Cell engine. (Courtesy Ballard Power Systems Inc)

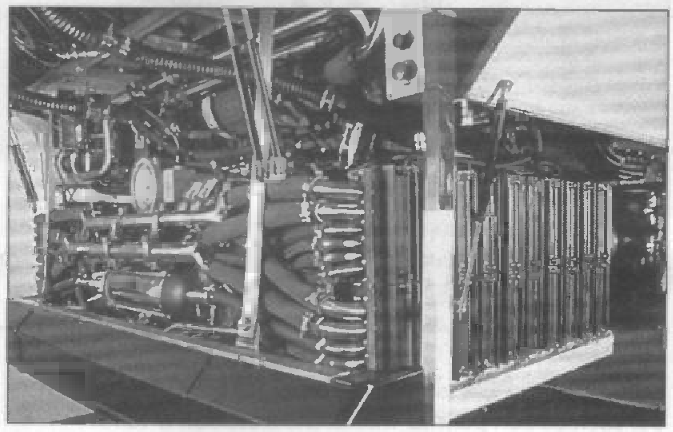

Figure 8: Location of the fuel cell modules at the rear of the Ballard bus. (Courtesy Ballard Power Systems Inc)

than that of the earlier cell.

Figure 6 shows the 'second generation' version of the Ballard Bus and figure 7 the fuel cell module used to power it.

Figure 8 shows how the fuel cell module integrates into the rear structure of the vehicle.

Beyond this, the use of 25 kW stacks and regenerative breaking will hopefully extend the vehicle range to 560 km. This is the vehicle concept that will be scrutinised by transit operators.

The efforts at Ballard are now focused into reducing manufacturing costs. One of the key developments currently being undertaken by Ballard Power is that of a new membrane material which if successful will lower membrane costs by as much as 90%. In addition, alternative lighter and less expensive materials are being investigated to further reduce manufacturing costs for the flow field plate. It is anticipated that volume manufacturing will begin in pilot scale towards the end of 1996. A key player in the technology developments at Ballard Power has been Johnson Matthey plc of the UK. This company has made a significant contribution to reducing the amount of Platinum catalyst in some cell by 75% with no deterioration in performance but with significantly reduced cost and weight.

The future cost projections of the Ballard Fuel cell is indicated in figure 9. This is based both on lower cost of materials and increased volume of production.

Ballard Power System is also working on a 250 kW module powered by Natural Gas. This project was initially one in which Dow Chemical was involved but which Ballard now seeks to complete with a new series of partners. The timescale to complete this stage is now set at the first quarter of 1997.

In a parallel development, Ballard Power has won a $5.9 million contract to develop a methanol fuel cell engine delivering 100 kW (135 HP) in association with Georgetown University, Washington D.C.. This development would be appropriate for smaller sized buses such as airport shuttles and the technology will be generally appropriate for powering cars.

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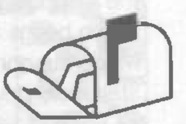

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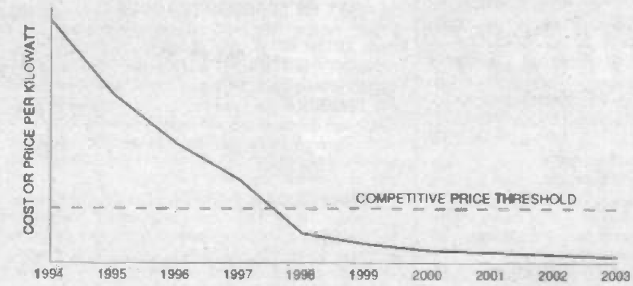

Figure 9: Projected costs of manufacture for Ballard Power units. (Courtesy Ballard Power Systems Inc)

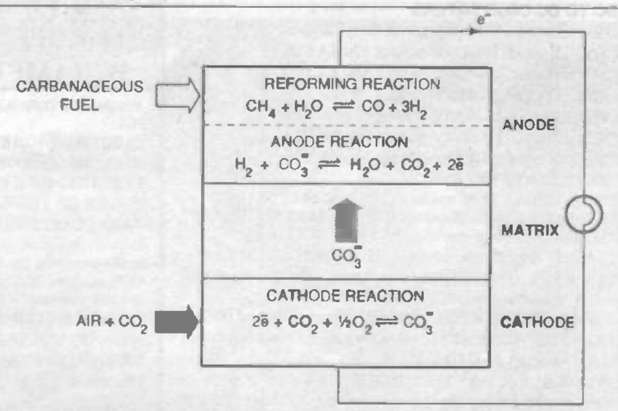

Figure 11: Basic features of the Molten Carbonate Fuel Cell

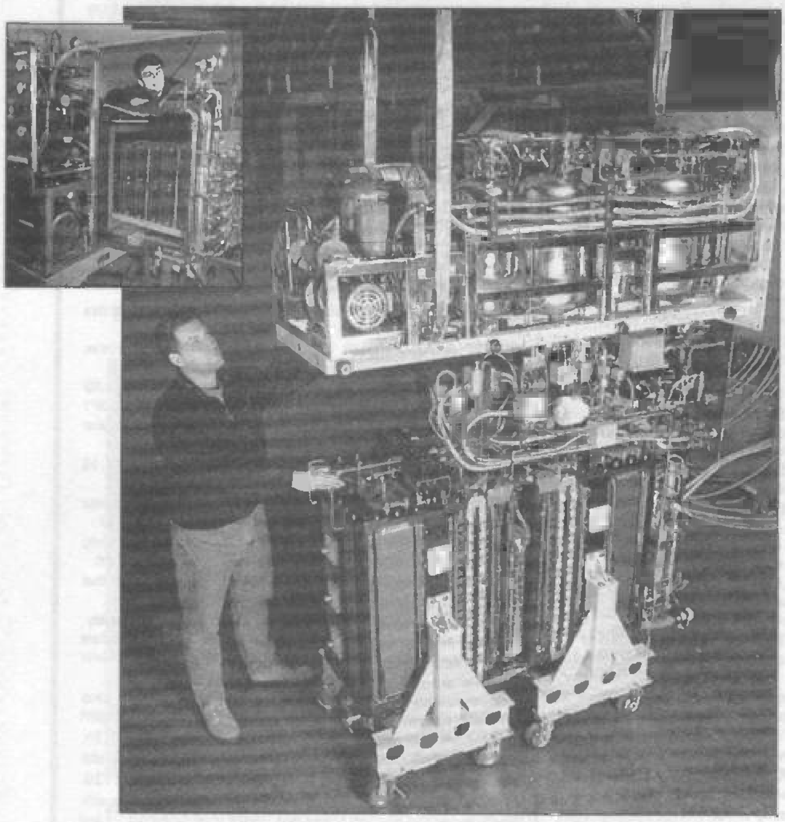

Figure 10: Top Left: Methanol powered PEM unit for Canadian Defence Department Centre: Prototype hydrogen powered fuel cell system developed for German shipbuilder HDW. (Courtesy Ballard Power Systems Inc)

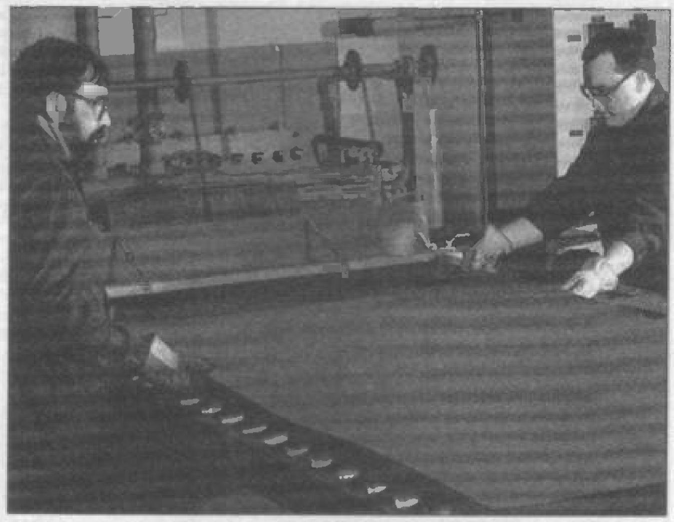

Figure 12: Full size electrode tapes being passed for processing in a high temperature furnace prior to assembly. (Courtesy M-C Power)

It is considered that methanol will be the fuel of choice for automotive requirements and this tends to be the technology that Ballard is negotiating with various manufacturers. In particular Honda have placed an order for $2 million worth of Ballard Fuel Cells.

There has been interest in the use of Ballard fuel cells to power submarines. Fuel cells do run significantly quieter than diesel engines. Deals with Ballard in this area have been made with the Canadian Defence Department and the German ship builders Howaldtswerke-Deutsche Werft AG (HDW). In the case of the Canadian interest, this was for the building of a 40 kW demonstration power unit running on methanol. This project which is nearing completion could be followed by a contract to construct a full sized 400 kW power plant. The contract for HDW is a prototype hydrogen fuelled power plant. Two units have been already delivered. These units are shown in figure 10. These contracts are especially valuable to Ballard to secure revenue at a time when there is a significant requirement for funds for research and development.

Ballard is also investigating the use of its fuel cell technology for a wide range of applications even including those for powering of the ubiquitous PC. In a demonstration desk top unit Ballard demonstrated the ability of a compact unit to work 20 hours on a single charge of fuel.

The molten carbonate fuel cell

A number of groups around the world are seeking to develop the technology of the Molten Carbonate Fuel Cell (MCFC) which brings advantages of high efficiency coupled with moderate construction costs. The prime market here is that of stationery power supplies.

Figure 11 indicates the basic principle of the molten carbonate fuel cell. The electrolyte of the cell is heated to 650 degrees C at which temperature the salt melts and becomes electrically conductive, allowing carbonate ions, to migrate to the anode through which reformed fuel is passed. The carbonate ions and the hydrogen at the anode react to form water and carbon dioxide. Meanwhile at the cathode, oxygen reacts with carbon dioxide (recycled from anode products) to replace carbonate ions that have migrated to the anode. In this set of chemistry, carbon dioxide is used as a link in the chain of ionic interactions but with in theory no net carbon dioxide

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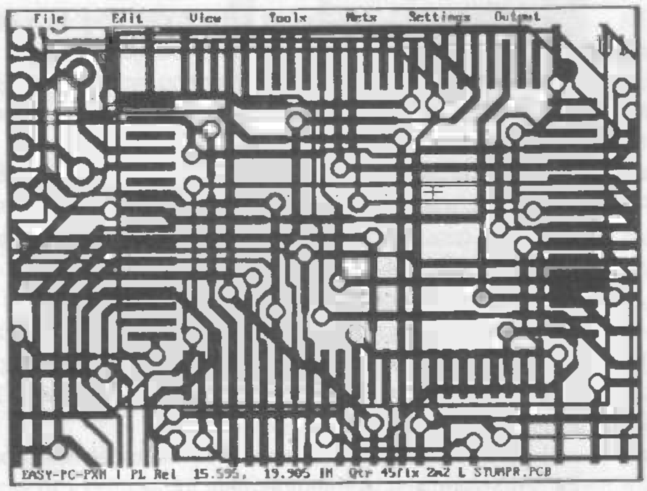

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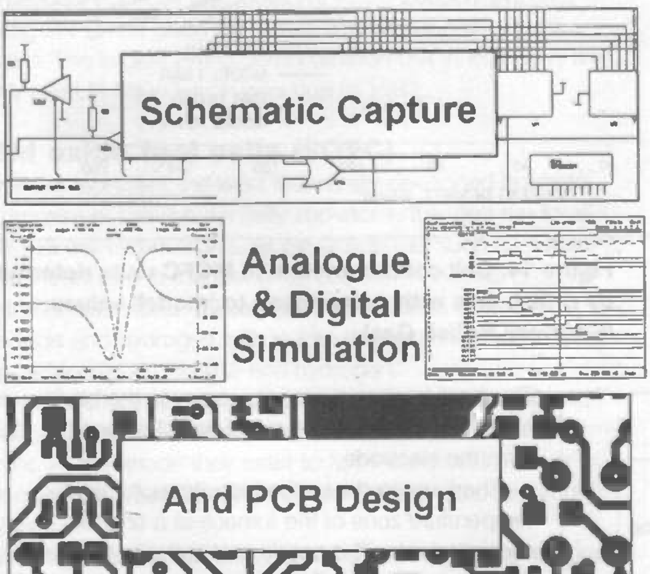

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being produced for pure hydrogen input.

One problem with the cell which is being receiving attention is the rate of degeneration of the nickel oxide cathode where it contacts the molten alkali electrolyte. Various initiatives are taking place within Europe to use more stable materials such as lithium cobaltate. Most development work on MCFC technology in Europe is taking place in centres in the Netherlands and in Germany although British Gas are playing a key role in evaluation of such systems. In Japan, a range of companies including IHI, Mitsubishi, Hitachi and Toshiba are also pursuing MCFC technology, thus indicating that the technology is widely regarded as holding considerable promise. The emphasis on developments is in developing systems that are internally reforming - ie reforming of fuel takes place within the main MC stack.

Steady progress is being made in developing the molten carbonate fuel cell (MCFC) in the USA. The M-C Power Corporation at Burr Ridge, Illinois, is essentially a consortium of companies and organisations with M-C Power as the team leader. With M-C Power, the Institute of Gas Technology (IGT) has been developing the stack technology of molten carbonate fuel cells. The IMHEX concept for MCFC was invented by IGT in the 1980's and this technology was subsequently transferred to M-C Power in 1989. The research and development mode continues at IGT and with M-C Power focusing on manufacture of electrode materials and assembly of cell stacks.

The consortium was recently awarded a $104 million contract by the US Department of Energy to develop MCFC technology. The main market sector for this technology is localised power generation. Already demonstration systems of 250 kW have been successfully implemented. A feature of M-C Power's technology is still the use of an external reformer module to process natural gas to hydrogen prior to supply to the fuel cell complex. Such a facility would also provide co-generation of steam for a district heating system. The IHI natural gas reformer was shipped from Japan after extensive field trials there.

While the fuel cell stack operates principally with hydrogen as the fuel, a so called reformer unit conditions other fuels such as natural gas, propane, methanol or ethanol into a hydrogen rich fuel stream. M-C Power are currently developing a 1 MW MCFC facility. One of the challenges of fuel cell development is to utilise gaseous fuels from as wide a range of sources as possible. It is considered possible, for example, that 50 MW size systems utilising coal gas may be possible by 2010.

Figure 12 shows the full size electrode tapes being passed for processing in a high temperature furnace prior to assembly.

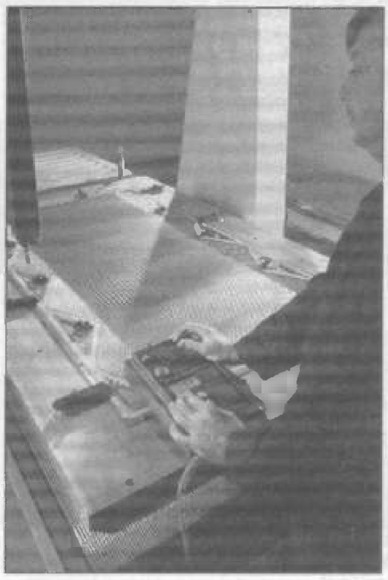

Figure 13: Machine used to manufacture separator plates for MCFC systems (Courtesy M-C Power Inc)

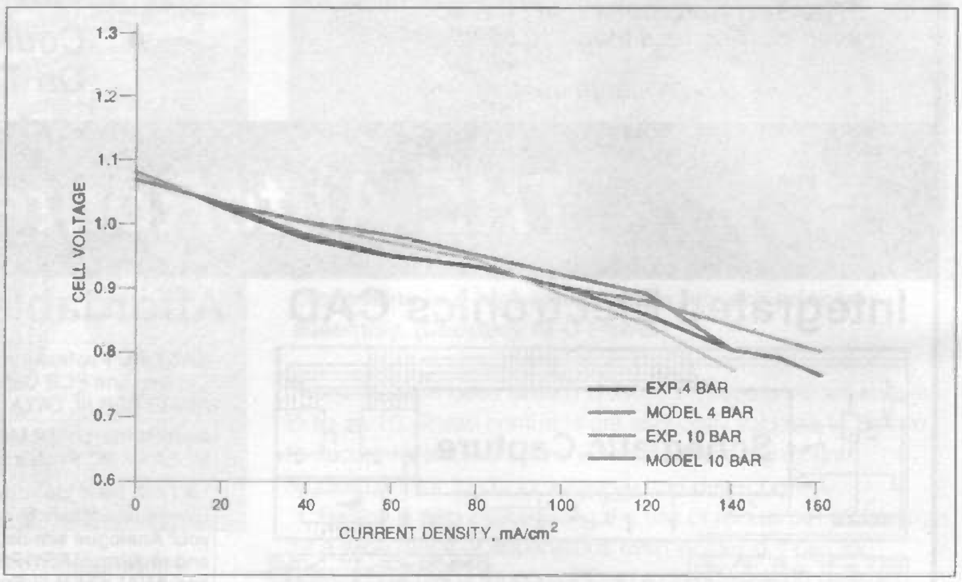

Figure 14: Cell characteristics of MCFC units determined by British Gas with comparison to 'model' values. (Courtesy British Gas)

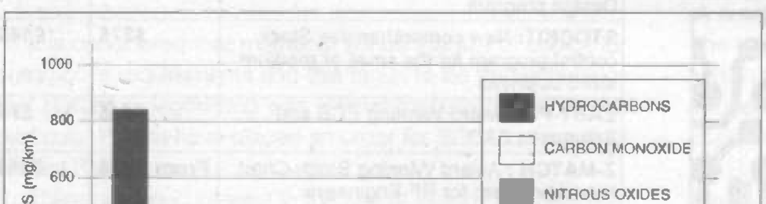

Figure 15: Summary of pollution emissions form petrol (gasoline), electric battery and methanol fuel cell.

This heat treatment process removes the binder material and sinters the metal particles together to form the electrode.

The furnace draws the tape through the high temperature zone of the furnace at a critically controlled rate. The anode and cathode tapes are manufactured using separate processes. With the MCFC the electrode material used can be nickel which is considerably cheaper than the Platinum used with other designs.

A key component of the fuel cell is the separator plate which has an active area of one square metre. Figure 13 shows the machine used to process the separator plate to specific customer requirements. Such a plate forms the structural backbone of the cell and is used also as a means to establish electrical

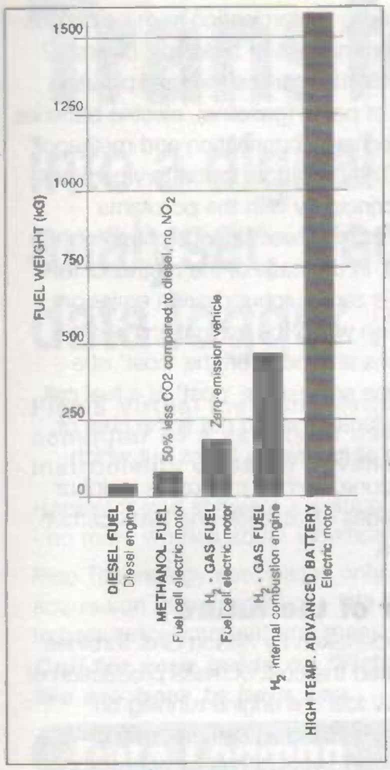

Figure 16: Comparison of weight of fuel required to complete a 750 km range for various power systems. (Courtesy Ballard Power Systems Inc)

connection between cells. M-C Power utilises reformers made by Ishika Wajima-Harima Heavy Industries for reformer technology.

Phosphoric acid fuel cells

Like the SPFC with a platinum catalyst, the sulphur and carbon monoxide must be removed from the fuel input otherwise the efficiency of the unit will decline. The current density achieved by such a unit is around 240 mA per square centimetre - with the cell voltage being around 0.66 V. Stacks consist of several hundred such individual cells linked in series. Hydrogen gas, however, requires to be produced in an external reformer system.

The development of the PAFC was principally undertaken by Pratt and Whitney in the USA who formed a strategic marketing/manufacturing alliance with Toshiba to from International Fuel Cells (IFC). The respectable level of sales of International Fuel Cell Corporation's PC25 200 kW systems utilising PAFC has given the whole field of fuel cells a push forward. The largest PAFC demonstration unit in Europe is the 1 MW plant in Milan which was built in 1993.

Solid oxide fuel cells (SOFC)

These cell represent the least technically developed but hold the promise of being potentially superior in the long run to all other fuel cell technologies. At the anode fuel such as natural gas is introduced in the presence of steam. An initial process of internal reformation takes places to produce carbon monoxide and hydrogen with in turn the carbon dioxide being changed to carbon dioxide and hydrogen.

At sufficiently high temperatures the oxygen ions begin to conduct across the electrolyte and constitute the fuel cell current. At the anode they react to form water and give up their electrons which in turn flow back to the cathode through the load.

Westinghouse in the USA has developed a tubular designed 100 kW system using air electrode supported cells. There is also a broad group of companies in Japan pursuing the technology and also within Europe research is being undertaken by a relatively wide range of companies. Much of the research is in the field of materials science and in the efficiency of gas reforming and susceptibility to carbon deposition.

The UK perspective: British Gas

Based at its research site at Loughborough, British Gas has established a wide range of academic and commercial links within the fuel cell community - both in the UK and abroad. Modest projections for fuel cell uptake indicate a global revenue of £1.2 billion from fuel cell sales. With the UK market, the potential additional gas sales for fuel cell power generation are considered to be significant.

British Gas at their Gas Research Centre in Loughborough have constructed an experimental 'Balance of Plant' (BOP) test rig to test the performance of a range of types of fuel cell. This unique test facility is critical for the evaluation of a range of fuel cell technologies where cells are tested under realistic operating conditions.

Work has been undertaken, for example, to investigate removal of carbon monoxide from reformer units used with SPFC cell stacks by means of specialised ceramic membranes. The successful development of this technology could allow the reformer to be incorporated into the SPFC stack directly. In a separate project, studies have been undertaken of a compact steam reformer for the SPFC in order to provide improved performance and flexibility in operation.

Assessment of MCFC stacks include determination of performance of a 10 kW stack system with direct internal reforming. This work is being undertaken in association with the Dutch company ECN and with EC support from the JOULE programme. Studies of this technology include vital factors such as stability of catalyst, methods of preventing deactivation

Figure 17: The Daimler-Benz NEWCAR-II with a maximum speed of 110 km/hr, a range of around 250 km and using two compact fuel cell stacks from Ballard Power.

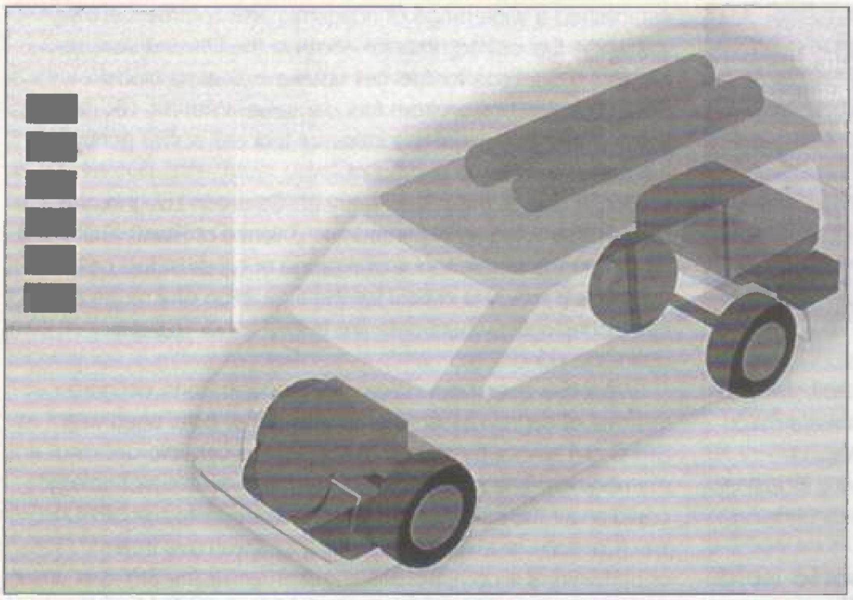

Figure 18: Schematic diagram of the NEWCAR-II design showing hydrogen storage in roof space, fuel cell and compressor in the vehicle rear and motor, transmission and control electronics between the front wheels.

and methods of regenerating the catalyst. A separate study involves general improvement of heat management in MCFC systems.

A key part of the work at British Gas has been the development of a model to simulate the cell characteristics of MCFC units at elevated temperatures and over ranges of pressures. Figure 14 indicates data from cells at 4 bar and 10 bar. Over low/medium loads, higher pressure systems generate more power.

A range of studies also include work with SOFC systems. One EC funded project led by British Gas involves a consortium of collaborative partners and relates to the investigation of low cost SOFC stacks. A separate project relates to investigation of internal reforming on SOFC stack anodes. Work is also in progress in developing a test facility for SOFC systems in order to evaluate new SOFC designs as they become available for assessment.

British Gas is therefore quite active in fuel cell technology. The emphasis appears to be on high temperature systems with direct internal reforming facility.

The Norway connection

Norway is very mindful of the significant reserves of untapped natural gas reserves under its continental shelf. Current estimates indicate a resource in the region of 3,000 billion cubic metres. In particular, there is increasing attention within Norway of the possibility of generating electric power directly from this resource using high temperature fuel cell technology.

The former Norwegian NorCell project appears to have run its course and is now actively seeking foreign capital. Most effort now seems to be focused on the Mjolner Project which seeks to develop solid oxide cells. The apparent lack of investment for such new developments does seem to be a recurrent theme within Norway.

How green is my fuel cell?

The problem of technology links also to environmental issues. Is it more green to use solar and wind power to split water to hydrogen and oxygen than to grow biomass to produce methanol with the process of cultivation giving rise to problems of soil erosion, contamination from herbicides and fertiliser and loss of biological diversity?

Figure 15 summarises the total pollution emissions of petrol (gasoline), electric batteries with grid recharge connection and methanol fuel cells. The pollutants for battery cars are identified principally with the pollutants originating from power stations supplying the power grid. In the case of the methanol fuel cell, there is zero sulphur dioxide emission.

Even then when the evaluations and comparisons are made on the 'cost' of a petrol engine against the 'cost' of a fuel cell one, a key factor missed out is the cost of pollution in all its diverse forms but which includes ozone, carbon monoxide, sulphur dioxide, oxides of nitrogen and hydrocarbon particulates.

The car of the future

Studies undertaken by Allison Gas Turbines has evaluated the cost of mass production of PEM 60 kW fuel cell engine running on methanol and including fuel processing equipment. This was estimated to be $46 per kW.or $3000 per engine. This would indicate that the mass production fuel cell car could rapidly steal a march on its tried and tested but inefficient and polluting internal combustion engine. This new sense of urgency among US vehicle manufacturers broke around March 1994 and has done much to alter the complacency of the US auto industry which had not really committed itself to the battery car.

The fuel cell power unit will have almost no moving parts. There will be no fuel injection, no pistons, no valves, no crank shaft, no distributor, no timing belt, no starter motor, no alternator. Coming up to the beginning of a new millennium, however, the public are more likely to accept a more radical change. Somehow, the conventional advertising slant showing a petrol car as the car of the new millennium with an outbreak of whales over the North American desert no longer seems credible.

Also is there an employment angle? Will fuel cell cars employ less people to make and service? No studies have apparently been published.

The Californian Air Resources board is widely known for its stand on zero emission vehicles (ZEVs). There has recently been developments in the USA relating to this topic. While there is still a commitment to retaining the 2003 mandate for 10% of vehicles to be ZEVs, between 1998 and 2003 it is considered that the mandate should be voluntary.

One of the more significant changes is the formation of an action group of twelve Northeastern states including Massachusetts and - yes - New York to adopt the Californian standards in their region. This has done marvels to focus the mind of the US automobile industry on the new types of car they may have to design and build and at the same time given companies like Ballard a tremendous boost.

Even in the wake of good marketing stunts by the major car maker General Motors in 1990 with the launch of its innovative Impact car, there are doubts that battery technology will be sufficiently popular. The increasing interest in fuel cell technology, however, is seen by many analysts as the way forward to meeting ZEV targets. General Motors, for example, is now working on a methanol powered PEM unit supplied by

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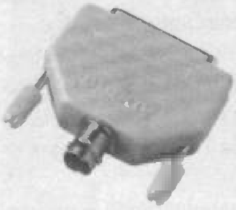

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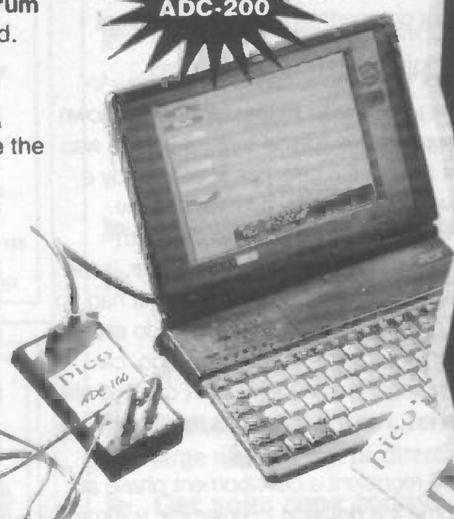

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Ballard Power Systems Inc with battery supplementation by 1996.

It is strange, however, that in the continent of Europe - incidentally where the car was invented, our major cities are increasingly polluted by vehicles, there is no comparable ZEV mandate - even on the horizon. In Paris, the solution at present is to restrict the number of cars entering the city on days of high air pollution. In Athens, there is an acute problem of respiratory disease - especially among children caused by air pollution caused by vehicles. For all the advertisements on the TV for cars there are none that show an x-ray image of the lungs of an inner city child whose lung volume has been reduced by exposure to ozone and clogged by fine hydrocarbon particulates.

The most contentious issue at present relates to the type of fuel used - hydrogen or methanol. Hydrogen can be stored in a variety of forms including, a compressed gas, a metal hydride, a cryogenic liquid, a liquid hydride, a cryoadsorbed gas or a cooled and compressed gas.

In the use of methanol, the cost of storage is minimal - the same as that of petrol/diesel. Where methanol is used, however, a reformer stage to process the fuel to hydrogen is required.

An analysis of this problem of fuel cell fuel is shown in figure 16 where the various weights of fuel to complete a 750 km range are indicated. There appears to be a consensus that methanol will be the fuel of choice for fuel cell vehicles of the future.

There should always, however, be an element of caution when trying to forecast vehicle technology. It could be that a cocktail of technologies make a contribution. Watch out for the Ultra Capacitor as an energy storage device which is being considered by Ford.

Enter Daimler-Benz

During 1996 Daimler-Benz announced their NECAR-II a vehicle, shown in figure 17, with a maximum speed of 110 km/hr, a range of around 250 km and using two compact fuel cell stacks of 150 individual elements from Ballard Power. Hydrogen is stored in carbon fibre high pressure tanks in the vehicle roof space. The 50 kW fuel cell with air compressor is sited in the rear of the vehicle while the motor, transmission and control electronics are located in a more conventional front compartment between the front wheels.

The schematic design of the vehicle, based on the new V-class vehicle and which can hold up to six passengers is shown in figure 18. In the two years since the initial fuel cell vehicle was demonstrated, the weight ratio of the cells has increased by a factor of five and the power generation by a factor of three.

Work is already in hand in developing a fuel cell system utilising methanol as the fuel. What is surprising, however, is the tremendous pace in development from the initial van that had no space for any load to the present NEWCAR II. Things do seem, at last, to be moving remarkably rapidly. Only a year ago, car industry experts would have considered the fuel cell car was still 25 years away. Within a short time this figure has fallen to between 10 to 15 years.

The next three years will represent a development phase at the end of which could come the decision to enter into volume production of fuel cell powered vehicles. Daimler-Benz is also aware of the significant additional markets that its developments could bring in non-vehicular products and also aware of the key economic importance to Germany's industrial base to maintain momentum in this field. The impression gained from the deliberations of Daimler-Benz is that this initiative has come from the very highest levels in the company.

Free at last?

The news from Ballard is encouraging. There is a danger, however, in leaving such developments to the 'free' market. At the least, the cross over to greener technologies is considerably delayed and what is possibly more alarming, the technologies used initially by the developing world tend to be the worst of those of the industrialised nations. In particular, the full industrialisation of China to current levels of fossil fuel based technology could have dire environmental consequences for us all.

In the rush to privatise utilities in the UK there has not been made available the investment cash available to structure the migration to less polluting technologies. In this, however, the UK is no more guilty than the other main industrialised countries of the world. With the Non Fossil Fuel Obligation charged, essentially, to pay for decommissioning nuclear power stations (and, incidentally, building new ones), why has not even a modest levy been introduced to develop the technology to ensure clearer skies and healthier lungs of tomorrow?

Summary

As a late developer, fuel cell technology seems now able to carry itself across to commercialisation where the dawn of a new market beckons. The significance of fuel cells, however, is in how they can act as potential power sources in almost every industrial and commercial activity.

As ever with a technology that is set to challenge conventional but more polluting systems of power generation, the dramatic fall in cost that comes with the gearing up of mass production as demand increases will be the real indication that the technology has arrived.

Perhaps it is time to astonish your local car dealers. Ask when they expect delivery of the first fuel cell car.

Points of Contact

Ballard Power Systems Inc.,
9000 Glenlyon Parkway, Burnaby, BC,
Canada V5J 5J9.
Tel 001 604 454 0900
Fax 001 604 412 4700

M-C Power Corporation, Inc, 8040 S. Madison Street, Burr Ridge,
Illnois, 60521-5808
Tel 001 708 986 8040
Fax 001 708 986 8153

British Gas Research Centre, Ashby Road,
Loughborough,
LE11 3QU.
Tel 01509 282818
Fax 01509 283144

Daimler-Benz AG,
Corporate Communications (KOM), Eppelstrasse 225,
D-70546 Stuttgart-Mohringen, Germany.
Tel 01049 711 17 93271
Fax 01049 711 17 94365

Internet: Search under 'fuel cell' with a search engine and you will get hundreds of relevant references. Most of these will be of a strong 'marketing' nature.
Drive a Daimler-Benz vehicle at
http:/www1.dbresearchberlin.de:8001

Improved Noise Masker

If noise from outside rouses you to fury, maybe Robert Penfold's natural sound generator will bring some peace into your environment

Noise pollution seems to be a problem that is here to stay, and it is one that seems to get steadily worse. There are methods of electronically combating noise, and the most simple of these is to use a masking technique. This is basically just a matter of using an electronically generated noise at a somewhat higher volume than the noise pollution. The human hearing mechanism is very sensitive and sophisticated, but it has a shortcoming in that it is not good at detecting weak sounds if slightly louder sounds are present. This flaw is exploited in noise masking, and in audio noise reduction systems such as Dolby B.

It is actually a slight oversimplification to say that loud sounds mask quieter ones. The masking of weaker sounds is dependent on the louder sound having a similar frequency content. For example, a low frequency sound will mask another low frequency sound quite effectively, but it will be inefficient at masking middle frequency sounds, and probably totally ineffective against high frequency sounds.

A noise masker was featured in the December 1995 issue of ETI, and this was basically just a "pink" noise generator for use with a hi-fi system (or any audio amplifier and loudspeaker capable of providing reasonable volume levels). You can simply use a television set, radio, etc. to generate masking sounds, but this is not a particularly satisfactory method. The frequency content of the signal from your sound source may not be a good match for the signal you are trying to mask. Also, you may wish to relax without any distractions.

A "pink" noise signal is basically just the standard and familiar background "hiss" sound of audio systems, but with a small amount of lowpass filtering used to give a slightly deeper and less ferocious sound. "Pink" noise is often likened to the sound of gentle rain falling. This type of noise signal contains significant output levels at all audio frequencies, and it will therefore mask any type of sound quite effectively without having to resort to very high volume levels. Of course, sound masking is a technique that is only usable on low to medium soundwaves, as an excessive volume level would be needed in order to mask high sound levels.

Getting the wind up

The original noise masker is quite effective, but it does have a drawback, which is simply the unchanging nature of the sound it produces. Although "pink" noise is a fairly relaxing kind of sound, after several hours it can become a bit monotonous. There is a risk that the masking sound will eventually become a source of irritation!

There is a way around this, which is to make the masking sound vary in some way. This is not as straightforward as it might seem, as the variation could easily make the sound more irksome rather than less. The obvious way of varying the sound is simply to rhythmically vary the volume or pitch. This gives a repetitive and predictable sound, which can rapidly become irritating. One of the most annoying types of noise pollution is the "thump-thump-thump" of a mega-bass stereo system. It is important that the masking sound does not have any of the characteristics that make this "thump-thump-thump" sound so vexatious.

Natural sounds, such as rain and the wind in the tress, are easily ignored by most people. Even when quite loud, natural sounds generally cause no loss of sleep, and one reason for this is the random nature of these sounds. With the "thump-thump- thump" sound of a neighbour's stereo system, you tend to anticipate and wait for each "thump" sound. This makes it difficult to ignore the sound, even if it is actually quite quiet. Sounds of this type seem to cause a level of annoyance that is totally out of proportion to their volume level.

This "improved" sound masker uses "hiss" type noise as the masking signal, but the pitch of the noise is varied in a pseudo-random fashion. This gives wind in the trees type sounds which are good at masking a wide range of sounds, and do not become tiring even after many hours.

System operation

The block diagram of figure 1 shows the general make-up of the improved noise masker. The noise generator produces a standard white noise "hiss" sound, but only provides a low output level. An amplifier is therefore used to boost the signal before it is applied to the v.c.f. (voltage controlled filter). The filter is a simple form of state-variable filter, which can provide both bandpass a lowpass filtering. To my ears at any rate, the lowpass filtering provides the best effect, with the bandpass filtering giving rather too much high frequency output. However, the higher pitched output might be better at masking some types of noise, and bandpass filtering can be used if preferred. A buffer amplifier at the output of the v.c.f. provides a low output impedance signal to the output socket.

The v.c.f. must be swept up and down in frequency at a slow, and ever changing rate, to give a truly random or pseudo- random change in the pitch of the noise. There are several possible approaches, such as using a v.c.o. (voltage controlled oscillator) with a low frequency noise generator to provide the control voltage. The genuinely random approach is certainly possible, but it seems to be difficult to get this type of circuit to work really well in practice. One problem seems to be that true 'randomness' is a little too random, giving relatively little change for much of the time, with excessive changes occurring

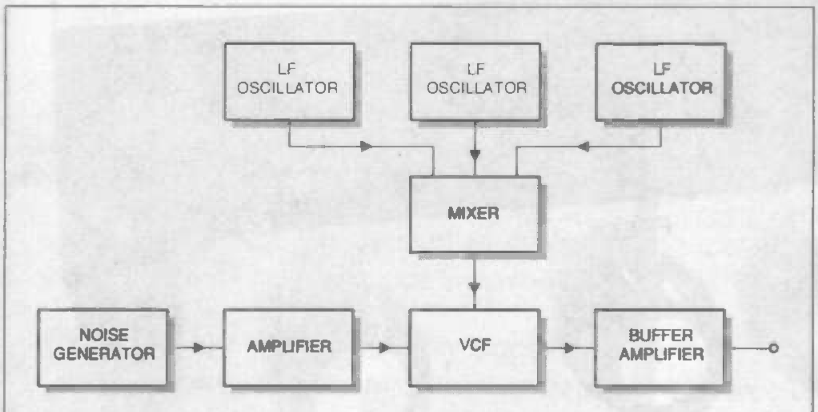


Figure 1: the improved noise masker block diagram

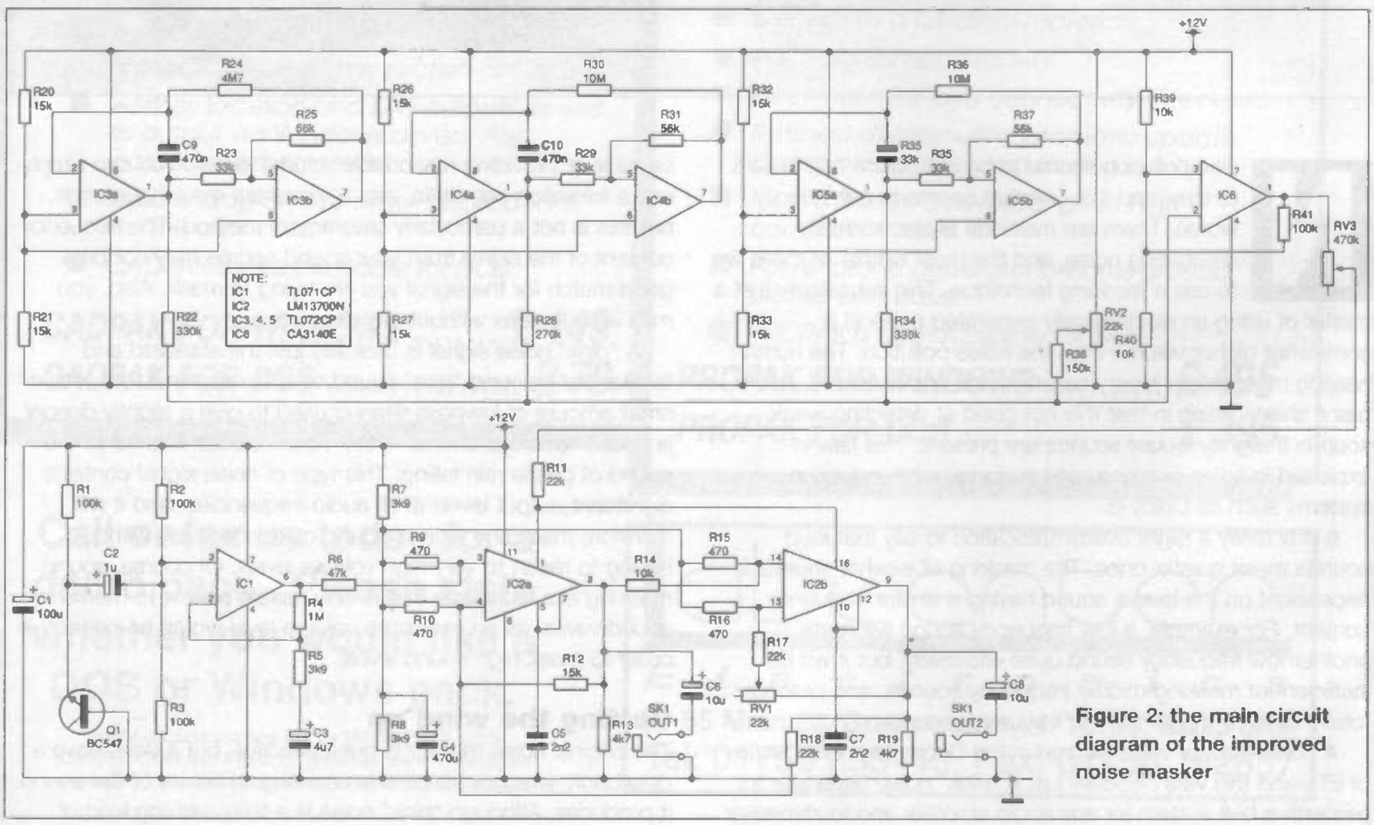
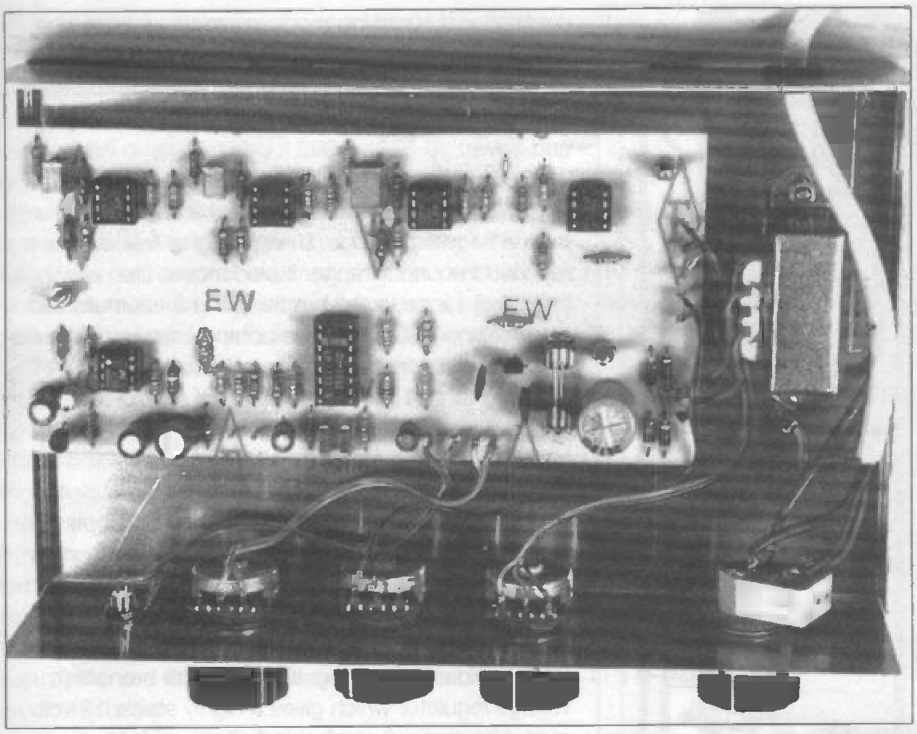


Figure 2: the main circuit diagram of the improved noise masker



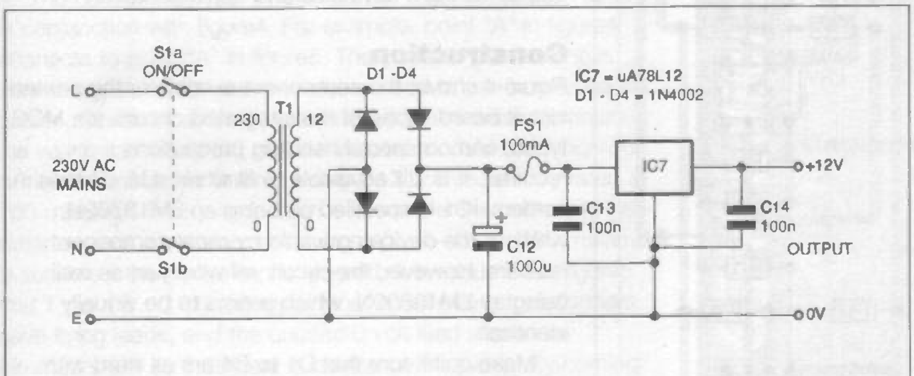


Figure 3: the circuit diagram of the 12 volt mains power supply unit

periodically. A pseudo-random control voltage gives good results, and by its nature is more reliable.

Several methods of pseudo-random modulation were tried, and the simplest that worked well was to simply mix the output from three low frequency oscillators operating on different frequencies. This gives a complex output waveform that will eventually repeat itself, but over such a long period of time that the repetition is not apparent to the listener. The changes produced are faster at some times than at others, but the modulation never ceases for long periods, or goes slightly berserk.

Circuit operation

The main circuit diagram for the improved noise masker appears in figure2, with the mains power supply circuit shown separately in figure3. TR1 acts as the noise generator, or to be more precise, its reverse biased base-emitter junction acts as the noise generator. No connection is made to the collector terminal of TR1. The 12 volt supply voltage is significantly higher than the reverse breakdown potential of TR1, which results in it "avalanching", rather like a zener diode. Also like a zener diode, it produces a substantial amount of noise. A reverse biased base-emitter junction is preferable to a zener diode in this application because it produces a much higher noise level over the audio range.

The amplifier stage uses IC1 as a standard non- inverting mode amplifier. R4 and R5 are the negative feedback resistors, and these set the closed-loop voltage gain of IC1 at just over 250 times. The output of IC1 is direct coupled to the input of the v.c.f., which is based on dual transconductance amplifier IC2. A transconductance amplifier is substantially different to an ordinary operational amplifier. The primary difference is that it is current operated, whereas a standard operational amplifier voltage operated. In practical circuits, including this one, transconductance amplifiers usually have input series resistors and output load resistors that effectively convert them to voltage operated devices.

Another important difference between ordinary operational amplifiers and transconductance amplifiers is that the latter have an additional input. The output current is a factor of the differential input current and the bias current fed to this additional input. The gain of the amplifier can therefore be controlled via the bias current, and is proportional to it. This makes transconductance amplifiers a good basis for voltage controlled amplifiers and filters.

R7, R8, and C4 provide a central supply bias voltage for both sections of IC2. The inputs of the two amplifiers are biased via R9, R10, R15, and R16. R6 couples the output from IC1 to the non-inverting input of IC2a, and R14 provides coupling between the two sections of IC2. The amplifier bias inputs of IC2 are driven via a common series resistor (R11). C5 and C7 are the filter capacitors at the outputs of the transconductance amplifiers. Each section of IC2 has a built-in emitter follower output stage which provides a low output impedance. R13 and R19 are the discrete load resistors for the output amplifiers.

There are feedback paths through R12, R18, and R12 - VR1 which produce bandpass filtering at the output of IC2a, and lowpass filtering at the output of IC2b. With VR1 set at minimum resistance the filter has a low Q value, which gives a broad response at the bandpass output. Setting VR1 higher in value gives a higher Q value, which produces a narrower response from the bandpass filter. It also produces a peak in the response of the lowpass filter, just below the cutoff frequency. In terms of wind sounds, a low Q produces a relatively gentle "wind through the trees" sound, whereas a higher Q provides something closer to a "howling gale" sound. VR1 is effectively a wind speed control!

The oscillators are based on IC3 to IC5, and are identical apart from the values of the timing components. They operate at approximate output frequencies of one cycle per five seconds, 10 seconds, and 20 seconds respectively. The circuit configuration used is the conventional triangular/squarewave type, but in this application it is only the triangular output signals that are of interest. These are combined in a conventional summing mode mixer circuit based on IC6. The oscillator signals are also mixed with the variable output voltage from VR2, which can be used to shift the general frequency range of the filter up and down.

IC6 drives the control input of the v.c.f. via VR3. If VR3 is set at a low value the filter will be swept over a wide frequency range. Using a higher value gives a reduced frequency range. It also moves the frequency range lower, but this can be counteracted by adjusting VR2. The three potentiometers give quite good control over the final sound, enabling it to be adjusted to give effective masking of the noise, hopefully also giving a sound that the user is quite happy to live with for long periods of time if necessary.

A conventional stabilised mains power supply circuit is used to power the circuit, which consumes about 20 milliamps or so. T1 provides a voltage step-down and also provides isolation from the mains supply. D1 to D4 form a full-wave bridge rectifier, and C12 provides smoothing. IC7 is a small monolithic voltage regulator which gives a highly stable 12 volt output having a low noise and ripple content.

Construction

Figure 4 shows the component overlay for the printed circuit board. None of the integrated circuits are MOS types, and no special handling precautions are required. It is still advisable to fit all six d.i.l. devices in holders. IC1 is specified as being an LM13700N, which is the device now sold by most component retailers. However, the circuit will work just as well using an LM13600N, which seems to be virtually identical.

Make quite sure that D1 to D4 are all fitted with the right polarity, since there could be dire consequences if errors are made here. Fuse FS1 is mounted on the board via a pair of fuse-clips, and the board is designed to take Maplin "type 1" fuse-clips, or an exact equivalent. Use plenty of solder when connecting the fuse-clips, so that they are securely fixed to the board. The polyester capacitors should be types which have a lead spacing of 7.5 millimetres, apart from C11 which should have 10 millimetre lead spacing. At this stage only fit single-sided solder pins to the board at the points where connections to T1, the controls, and output sockets will eventually be made.

As this project is mains powered it must be

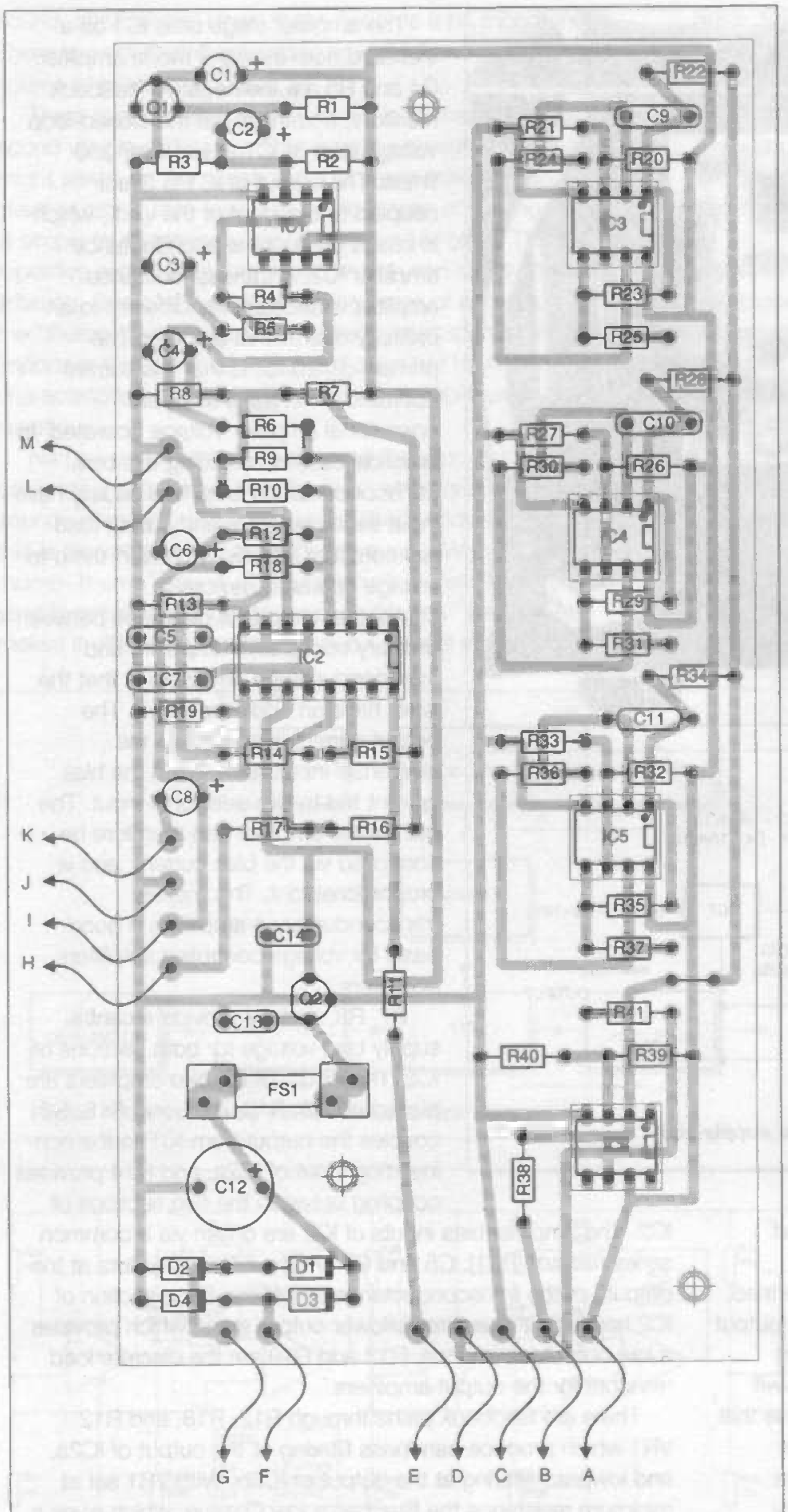


Figure 4: the component overlay for the PCB

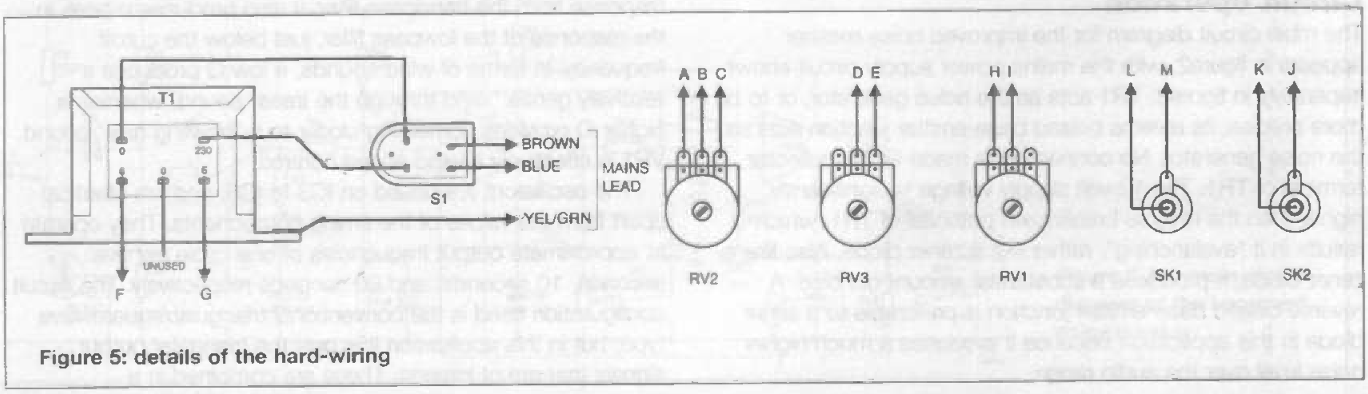


Figure 5: details of the hard-wiring

housed in a metal case which must be reliably earthed to the mains earth lead. The case must be a type which has a screw fitting lid, and not a clip-on, clip-off type which gives easy access to the dangerous mains supply. A metal instrument case which measures about 203 by 127 by 52 millimetres is a good choice. The three potentiometers and output socket(s) are mounted on the left hand section of the front panel, and S1 is mounted well towards the right hand end of the panel. If the bandpass output is not required, omit SK1 and C6. It is only worthwhile including this output if the unit will be used to mask noise that contains a substantial high frequency content.

The printed circuit board is mounted on the base panel of the case, as far to the left as possible. This should leave ample space for T1 on the right hand section of the base panel. The circuit board must be mounted using plastic stand-offs, or mounting bolts and spacers, that hold the board about 12 millimetres or so clear of the case. This ensures that the board is held clear of the left hand fixing screw for the outer casing. Be careful to position T1 where it will not be damaged by the other fixing screw for the outer casing. A solder tag must be fitted to the case to provide a connection point for the mains earth lead, and this can conveniently be fitted on one of T1's mounting bolts.

The hard wiring is shown in figure5, which should be used in conjunction with figure4. For example, point "A" in figure4 connects to point "A" in figure5. The point-to-point wiring is very straightforward, and there is no need to use any screened cables. Obviously extra care should be taken when completing the wiring to T1 and S1, as mistakes here could be dangerous. A mains transformer having a single 12 volt secondary rated at 100 milliamps is required. Such a component is unlikely to be available, but a transformer having a 6 - 0 - 6 volt 100 milliamp is suitable if the centre-tap is ignored. It is assumed in figure5 that T1 is a 6 - 0 - 6 volt type. Most small mains transformers have flying leads, and the unused 0 volt lead should be trimmed short so that there is no risk of it accidentally coming into electrical contact with circuit board or case.

In use

The unit connects to the amplifier via an ordinary screened audio lead. If you wish to drive both channels of a stereo amplifier, the outputs of the noise masker should have no difficulty in driving both channels. Finding the best settings for VR1 to VR3 is just a matter of resorting to some experimentation. In most cases there will be a wide range of settings that give good masking of the noise, and it is a matter of using the effect that you find most pleasing. The unit can produce quite realistic wind sounds for what is quite a simple analogue design, but remember that its purpose is to produce naturalistic sounds to mask noise, rather than to produce the ultimate in natural wind sounds.

The minimum volume needed to mask a sound is to a significant degree dependent on how well you match the masking signal to the noise. If the noise is predominantly at low frequencies (as it often is), then it makes sense to set the masker to produce low pitched sounds. Avoid having the filter swept very low in frequency, as this will result in the output signal virtually ceasing from time to time. This would obviously give no noise masking during these quiet periods. For higher pitched sounds such as alarms, a predominantly high pitched output signal will give the most effective masking. Remember that any tone controls on the amplifier can be used to "shape" the sound to give good masking without having to resort to high volume levels.

PARTS LIST FOR THE IMPROVED NOISE MASKER

Resistors (all 0.25 watt 5% carbon film)

R1,2,3,41	100k (4 off)
R4	1M
R5,7,8	3k9 (3 off)
R6	47k
R9,10,15,16	470R (4 off)
R11,17	22k (2 off)
R12	15k
R13,19	4k7 (2 off)
R14,39,40	10k (3 off)
R18	18k
R20,21,26,27,32,33	15k (6 off)
R22,34	330k (2 off)
R23,29,35	33k (3 off)
R24	4M7
R25,31,37	56k (3 off)
R28	270k
R30,36	10M (2 off)
R38	150k

Potentiometers

VR1	220k lin rotary carbon
VR2	22k lin rotary carbon
VR3	470k lin rotary carbon

Capacitors

C1	100u 16V radial elect
C2	1u 50V radial elect
C3	4u7 50V radial elect
C4	470u 10V radial elect
C5,7	2n2 polyester (2 off)
C6,8	10u 25V radial elect (2 off)
C9,10	470n polyester (2 off)
C11	1u polyester
C12	1000u 25V radial elect
C13,14	100n ceramic (2 off)

Semiconductors

IC1	TL071CP
IC2	LM13700N or LM13600N
IC3,4,5	TLO72CP (3 off)
IC6	CA3140E
IC7	uA78L12 12V 100mA
positive reg.	
TR1	BC549
D1,2,3,4	1N4002 100V 1A rect (4 off)

Miscellaneous

SK1,2	Chassis mounting phono socket (2 off)
S1	Rotary mains switch
T1	Standard mains primary, 12 volt 100mA secondary (or 6 - 0 - 6 volt 100mA secondary)
FS1	20mm 100mA quick-blow

Metal instrument case about 203 x 127 x 52mm, printed circuit board, control knob (4 off), 8-pin d.i.l. holder (5 off), 16-pin d.i.l. holder, 20mm fuse-clips (pair), mains lead and plug, wire, solder, etc.

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Tektronix 454 - 150MHz - 2 Channel .... £4??
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Tektronix 2215 60MHz dual trace £450
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Tektronix 2445 150 MHz - 4 Channel £1250
Tektronix 2445A - 150MHz - 4 Channel £165
Tektronix 2225 – 50MHz dual ch £450
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Datalab DL 1080 Programmable Transient Recorder £350
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The ETI Micro Amp Part 1

Barry Porter designs a professional-standard stereo microphone amplifier that can feed the line inputs of a mixing console or suitable recorder for improved recording quality

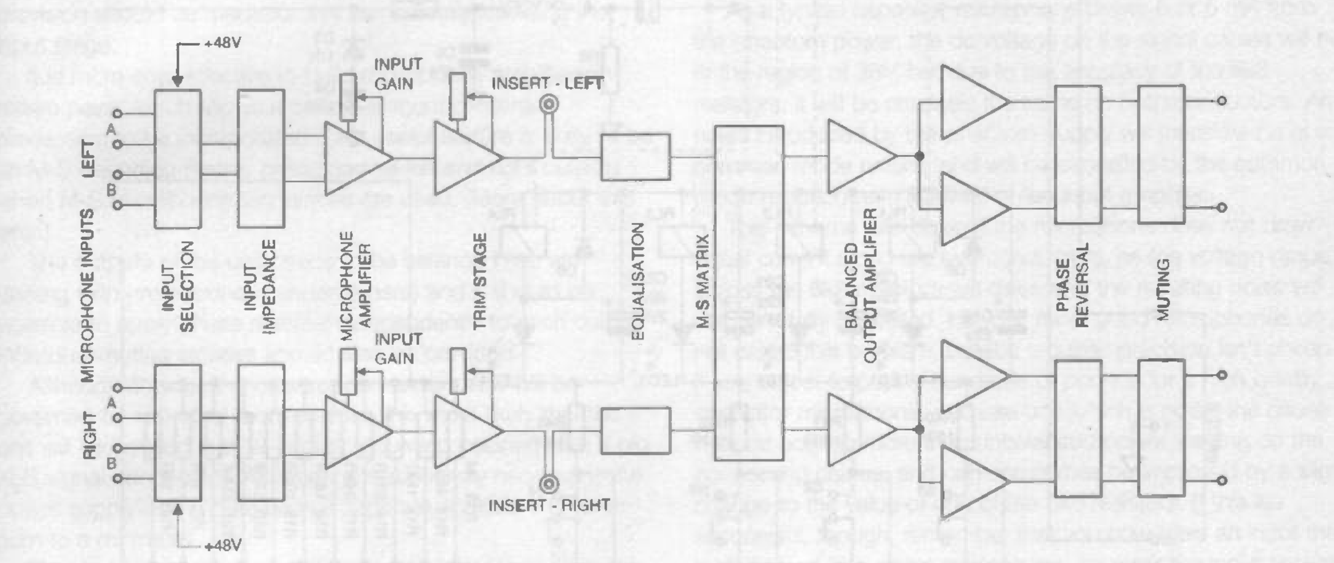

Figure 1: The block diagram of the Microamp.

Over the years, I have wondered why manufacturers of tape recorders - reel-to-reel, cassette or DAT - waste their time and their customers' money by providing microphone input amplifiers that often consist of a couple of transistors or an op-amp of questionable performance. They are normally unbalanced, with no provision for gain adjustment, filtering or input loading. The universal omission of phantom power ensures that high quality capacitor microphones cannot be used, so it becomes impossible to obtain adequate recording quality without resorting to external equipment.

If you have a mixing console, in theory your problems are solved - but are they? Very few consoles, including some of those tennis-court-sized ones beloved by some studios, have microphone input stages that don't leave a great deal to be desired. Cost is the usual constraint. One well known console manufacturer with an advertising and marketing budget that would keep me in Ferraris for life allows its designer around £1 for a microphone amplifier - including the gain potentiometer!)

So, even if you have a mixer, there is every chance that your recording quality can be improved by bypassing the inbuilt microphone amplifiers and using separate, dedicated units. Preferably, these should be placed close to the microphones to keep low level cable runs as short as possible, returning high level signals to the line inputs of the console.

The MicroAmp is designed to provide this kind of unit, and will be described in three parts: the general principles and first two stages in this part, the next three stages with the PCB layout for the twin channels and construction and test details for the whole unit in the second part, and the power supply section (alternative all-singing and budget designs) with its own PCB layouts and parts list, in the third part. But first, let us consider what we are looking for.

Ideal features

What features should a remote microphone amplifier possess? The input stage must be extremely quiet, with sufficient gain adjustment to allow any type of microphone to be used. Traditionally, a transformer has been used to give a balanced input with total ground isolation, but good quality microphone transformers are very expensive unless you buy them in large quantities (up to £80 each.), while lesser ones tend to suffer from shortcomings such as phase shift, distortion, low frequency overload, uneven frequency response, poor screening from external fields etc.

An electronically balanced low noise input stage is the obvious alternative, although its design is not quite as straightforward as it may initially appear. In order to operate with professional capacitor microphones, the input socket must be supplied with +48V phantom power through matched 6k8 resistors, which makes capacitive coupling necessary, although when a dynamic (moving coil.) microphone is in use, the +48V may be switched off and the inputs directly coupled.

Steps must be taken to eliminate any radio frequencies from the input amplifier, and it may be advantageous with some types of microphone to be able to change the amplifier input impedance.

The gain of the overall unit needs to be variable from

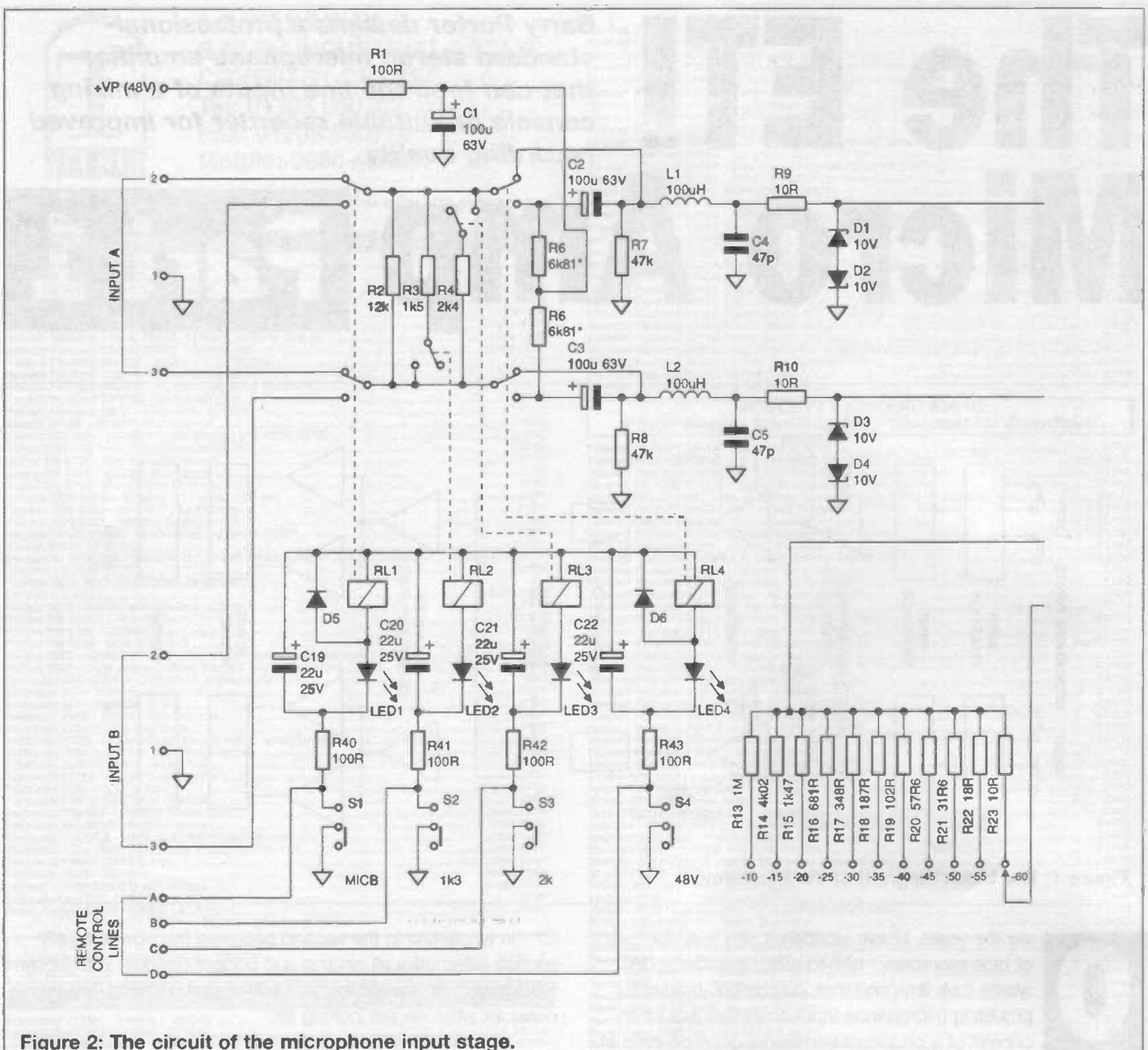

Figure 2: The circuit of the microphone input stage.

approximately 10dB to 60dB, and ideally this should be selected by a multi-position switch in discrete steps, with a rotary trim control to allow any gain to be chosen. Although a single rotary control can be used to cover the complete gain range, its calibration can only be approximate, which makes it virtually impossible to set two inputs to the same gain, as would normally be required for crossed pair recording. The additional cost of a rotary switch and its associated resistor network is therefore felt to be justified.

Microphones are not perfect, especially with regard to frequency response, so some form of filtering or equalisation is beneficial. This need not be too elaborate as, if extreme correction is required, the console equaliser can be used, or a separate unit can be inserted into the signal path - therefore provision should be made for this immediately following the input stage.

It is more cost-effective to build microphone amplifiers in stereo pairs, which allows a certain amount of stereo processing to be incorporated. One useful feature is likely to be an M-S decoding matrix, giving normal left and right outputs when M-S microphone techniques are used. (More about this later.)

The outputs of the unit needs to be balanced (we are dealing with professional standards here) and it should be possible to apply phase reversal independently to each output. Individual muting facilities should also be provided.

Although choice of enclosure, connectors etc. will be governed by individual requirements, it is most likely that the unit will be housed in a 19-in rack mounting cabinet, with 3 pin XLR signal connectors. Although not absolutely necessary, the power supply unit should be in a separate enclosure to keep hum to a minimum.

That just about sums up the basic requirements, which are illustrated by the system block diagram (figure 1).

The input stage

One input stage is shown in figure 2. Essentially, the circuit is an elaboration of a standard instrumentation amplifier which uses two buffer stages in front of a differential amplifier.

Two separate input connectors are used for each channel. This can be useful for location recording, where duplicate microphones can be set up in case of a failure. It also allows rapid comparison between two microphones, as switching can be controlled remotely by grounding the respective control pin of the remote connector.

From the selected input socket, the signal is buffered by low noise transistors, Q1 and Q2. The input impedance is adjustable by switching resistors R3 and R4 in parallel with R2. Allowing for R7 and R8, the impedance will be 10k6 when switches S2 and S3 are open, 1k31 with S2 closed, 1k96 with S3 closed and 849R when both are closed. This range should be adequate for most high quality microphones, most of which are designed to operate when loaded by approximately 1k3. Some modern capacitor microphones, particularly those with electronically balanced output stages, will be happy with virtually any loading, but any transfer loss will be reduced by using a higher than normal input impedance.

Moving coil and some older capacitor types are more critical of loading, and if the manufacturers information is not specific on this point, a degree of experimenting is called for. If in doubt, use 1k3 as a starting point, and listen for changes in the high frequency response when making any changes. Again, the switch functions may be remotely operated, making comparisons easy.

Capacitor microphones require power to operate their internal electronics. Some electret types have a built-in battery, but high quality professional models rely on "phantom power". This is a positive voltage, fed to the microphone along the signal cables. Obviously, any noise introduced by the phantom power is liable to be amplified by the microphone amplifier unless steps are taken to avoid this.

Conventional phantom power is +48V which is fed equally to the balanced microphone cable by two 6k8 resistors. The actual value of these resistors is not critical - what is important is that they must be equal in value, and must remain so over a wide temperature range. The resistance matching should be to at least 0.1%, with a temperature coefficient of better than 25ppm/degrees C over a range of 0 degrees to +50 degrees.

As a typical capacitor microphone draws 5 or 6 mA from the phantom power, the dc voltage on the signal cables will be in the region of 36V, but due to the accuracy of the 6k8 resistors, it will be precisely the same on both conductors. Any noise introduced by the phantom supply will therefore be of a common mode nature, and will be cancelled by the common mode rejection ratio (CMRR) of the input amplifier.

This scheme falls down if the microphone does not draw equal current along the two conductors, as the voltage drops across the 6k8 resistors will differ, and the resulting noise will not be totally cancelled. Happily, most good microphones do not cause this problem, but the required precision isn't cheap. If you object to paying hundreds of pounds for a high quality capacitor microphone, and use one which is noisy, the cause may be nothing more than unbalanced power loading on the connecting cables, and can sometimes be improved by a slight change to the value of one of the 6k8 resistors. If this is successful, though, remember that you now have an input that is dedicated to a single microphone, so mark the input socket accordingly!

The phantom power voltage must be kept away from the amplifier inputs, hence electrolytic capacitors C2 and C3. These could be left in circuit at all times, and the incoming 48V switched on or off, but I felt it preferable to remove them when phantom power is not required. The reason is not, as audiophiles may think, that electrolytics mess up the sound, but that it allows the capacitors to have a permanent polarising voltage applied to them, which experience has shown will help extend their lives. In the past I have found that electrolytics used where no polarising voltage is present can become extremely leaky, in some cases appearing as a short circuit within a year or two.

Needless to say, the phantom power voltage must be extremely smooth and free from spurious noise. Primarily, this is a function of the power supply unit, but to ensure that the injection point - the junction of R5 and R6 - is as quiet as possible, the incoming 48V is locally decoupled by R1 and C1. As the phantom power switching takes place at the most sensitive part of the circuit, sealed relay contacts are used, as these are less likely to introduce noise and distortion than a normal switch. The use of relays for the switching functions also allows control from a remote position, as already discussed, so the additional cost was felt to be justified.

Before the signal reaches the input amplifier, it passes through an RF filter comprising inductors L1 and L2 and capacitors C4 and C5. This network is 3dB down at approximately 2.3MHz, and should remove any danger of incoming RF causing problems, but if a lower turnover frequency is required, C4 and C5 may be increased to 100pF. Note that these capacitors must be close tolerance types in

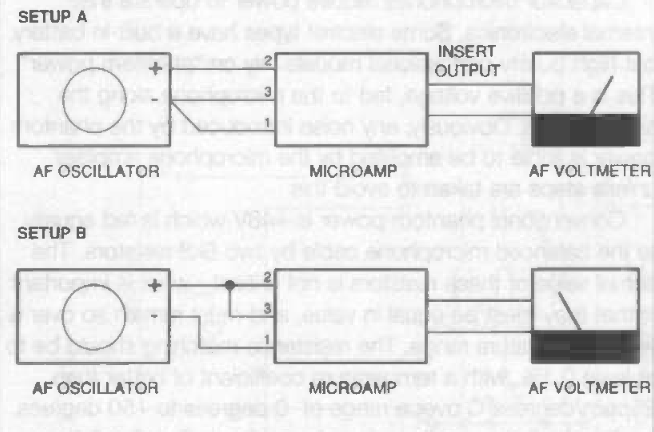

Figure 3: Input common mode adjustment: see text.

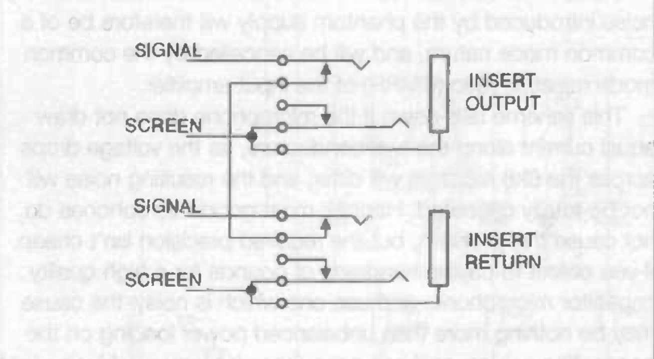

Figure 4: The insertion point jack wiring.

order that their effect on the high frequency common mode rejection is kept to a minimum.

Although the SSM2220 input devices have internal base-emitter diodes, it has been found worthwhile to add additional protection in the form of resistors R9 and R10 and zener diodes D1-4.

Noise

The choice of input transistors was relatively simple. After comparing various circuit configurations using the usual recipe for low noise inputs - loads of transistors connected in parallel - with similar circuits using LM394 dual NPN devices, the LM394 or equivalent SSM2210 was not only marginally quieter, but the noise that was present sounded smoother and less objectionable. I would have used this device, had not a number of SSM2220 PNP dual matched transistors come my way as free sample. Free transistors always sound better than ones that have been paid for, I find, so I built an upside-down circuit and had a listen. Although the effect was subtle, the PNP device certainly sounded better than the NPN version, and as a consequence was chosen for the final design.

The SSM2220 has a specified noise voltage density of 0.7nV/√Hz, which has been reduced by √2 (3dB) by using both transistors in each package in parallel. The relatively high collector current (2mA) reduces Schottky noise, the associated increase in current noise being relatively unimportant when the source impedance is low.

The original aim was to achieve an input amplifier noise figure of 1dB or less when operated with a 200R source impedance. To explain further, the Johnson noise of a resistive component is given by:

$$E_n = \sqrt{4kTBR}$$

Where k = Boltzmanns Constant = 1.381×10^{-23}

T = Temperature in Degrees Kelvin = degreesC+273

B = Bandwidth in Hz

R = Resistance in ohms

A 200R resistor therefore will contribute 0.2566uV just by being there. Translating this into a more familiar term, dBu, this becomes

$$20 \log(0.775E_n) = -129.6\text{dBu}$$

If we now put a well screened 200R resistor across the input terminals of a perfectly noiseless amplifier with 50dB gain, the noise of the resistor at the amplifier output will measure -129.6+50 = -79.6dBu. If instead of this, we measure -78.6dBu, the amplifier is adding 1dB of noise, and is said to have a noise figure of 1dB.

Take it from me, there are not many microphone amplifiers around that consistently achieve a 1dB noise figure, even though it's quoted by most manufacturers. If the circuit of Figure 2 is carefully constructed, using the recommended components, it will have a noise figure of 1dB, or even slightly less.

Gain

Some things fall naturally into pairs - bacon & eggs, Astaire & Rogers, input stage gain & overload margin.

In an ideal world, all input stages would take whatever signal level was thrown at them, but as they don't, we have to accept that there is always the danger of the signal being clipped by overdriven circuitry.

When run from +/-15V rails, most op-amps will have an output swing of about 8V or +20dBu, but it is now usual for professional equipment to have overload margins of between 20 and 30dB. As the microphone amplifier is more likely to be overloaded than later stages in the signal path, (quickly pulling down a fader won't save your day) I have aimed at a 30dB margin. This can easily be increased, but at the expense of a rise in output noise; however, for certain types of unrepeatable live recording, it may be safer to accept the noise, and increase the overload margin to 36dB or even more.

It should be clear that with a maximum output of +20dBu, a 30dB overload margin requires that the nominal signal level must be -10dBu, so for example, when the input level control indicates -50, the input amplifier will have a gain of 40dB. Most microphones have output voltages in the range of 1mV to 250mV, so an input sensitivity -60 to -10dBu would appear to be about right.

This is a convenient range, as it allows a standard 11 position switch to be calibrated in 5dB steps. If the following trim control has +/-6dB adjustment, the input sensitivity may be set anywhere between -4dBu and -66dBu.

The stage gain is set by feedback resistors R28 and R30 (Rf) in conjunction with switched shunt resistors R13 to R23 (Rs), the gain being given by: 20log((2Rf÷Rs)+1)

It is essential that gain changes can be made without introducing switching clicks, as it may be necessary to make an adjustment during a "take". The emitters of Q1 and Q2 will be at +0.6V, and will be virtually identical, but any difference

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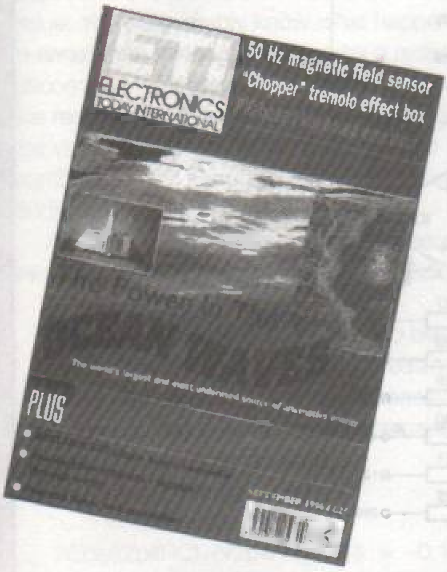

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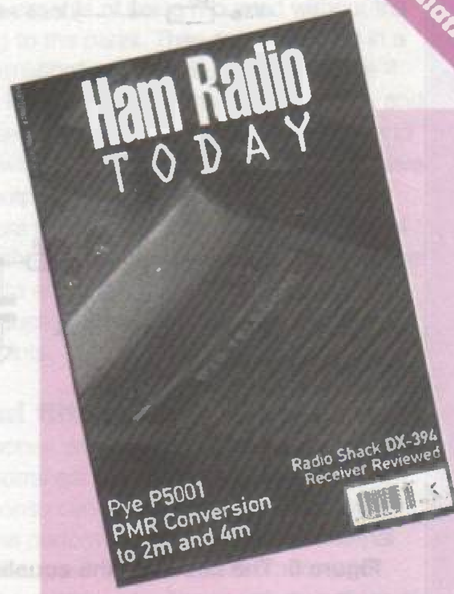

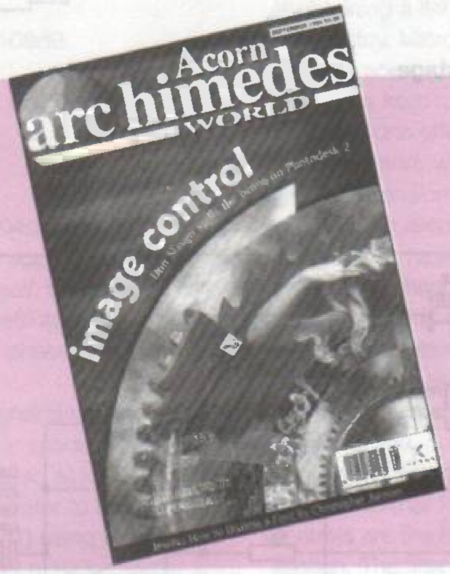

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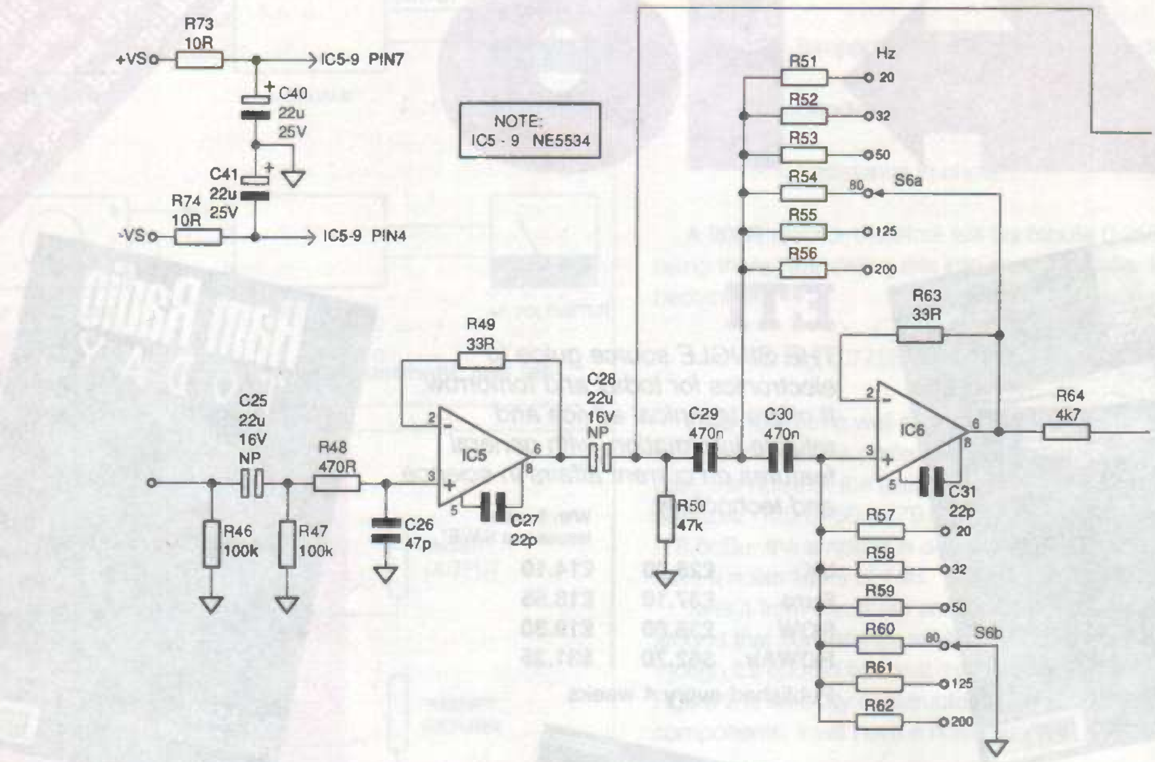
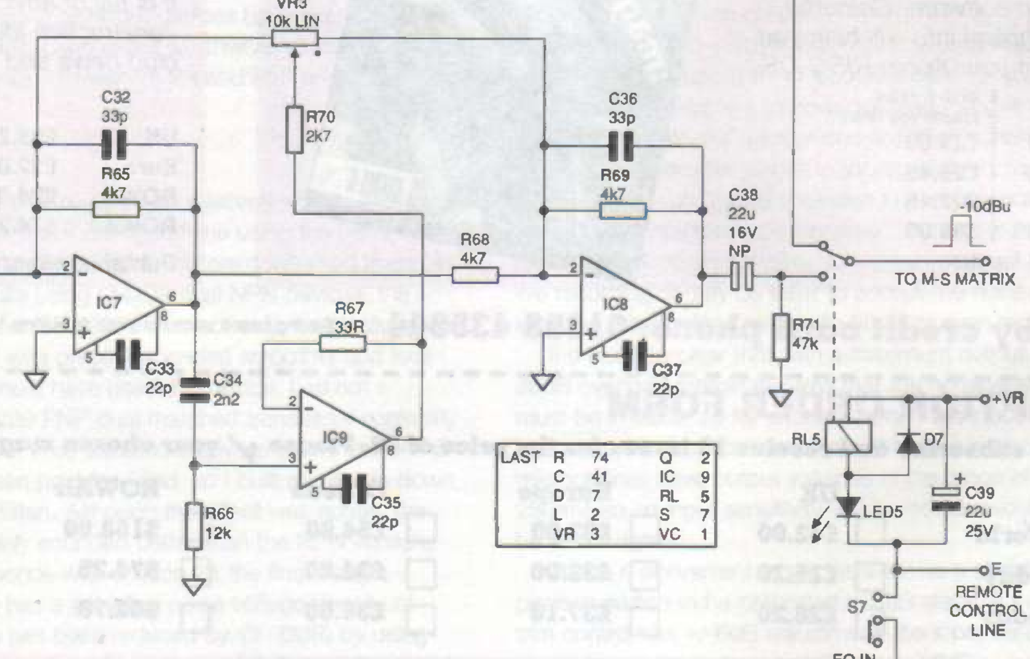


Figure 5: The circuit of the equaliser stage.



that does exist will certainly rule out noise-free switching unless the switch is isolated from the emitters by capacitors. Unfortunately, these need to be somewhat on the large side; so large in fact, that if you are prepared only to change the input gain during breaks in recording when the monitors can be turned down, you could consider replacing C6 and C7 with pieces of wire.

"Why do they need to be so large?" you ask. It's all to do with frequency response at the lower end of the audio spectrum. In effect, C6 and C7 are in series, which halves their value. You presumably know what happens when a capacitor in series with a signal is loaded by a resistor to ground? Yes, it becomes a high pass filter, and for a given capacitor, the lower the resistance the more it rolls off low frequencies. Now, look at the value of R23 - 10R, which is the load for the series combination of C6 and C7 when the input gain is set to -60dBu.

As a starting point, to maintain a reasonable LF response, let us see what capacitors will give a -3dB point of 1Hz.

C = 1(2pifR) = 16000uF

therefore C6 and C7 each need to be 32000uF!

To increase R23 would entail increasing the value of R28 and R30, and would incur a noise penalty. So now let's try a compromise. If C6 and C7 are each made 10000uF, the response at 20Hz will be given by:

$$20\log((2\pi fRC)\div(\sqrt{2\pi fRC})^2+1)) = -0.108\text{dB}$$

$$\text{Where } f = 20,\ R = 10,\ C = 5000\mu F$$

The resulting phase shift will be:

$$90-\tan^{-1}(2\pi fRC) = +9.04\text{degrees}$$

Considering that these figures will only apply at the most sensitive setting, and will improve as the gain is reduced, they are just about acceptable. (At the 55dB setting, the 20Hz response has improved to -0.033dB with phase shift at +5.05 degrees.)

Following the input gain stages, the signal is unbalanced by differential amplifier IC3. The input common mode rejection is controlled by this stage, and may be adjusted at low and high frequencies by VR1 and VC1 respectively (refer to figure 3).

The method of doing this is as follows: 1) using Setup A, with the MicroAmp gain set to -50dB apply a 100Hz signal at about -20dBu and adjust for an output level of +20dBu (7.75V). 2) Change to Setup B and adjust VR1 for minimum output (less than -40dBu). 3) Set oscillator frequency to 10kHz and adjust VC1 for minimum output (less than -30dBu). 4) Repeat steps 2 and 3 until lowest reading is arrived at. 5) Apply locking compound to VR1 and VC1.

Trim stage

The final part of the input amplifier is the gain trim stage, IC4, an inverting amplifier with variable feedback. Ideally, the trim control should be a high quality wirewound potentiometer, or as a minimum one with a conductive plastic track and multi-finger wiper, as contact problems between the wiper and track will introduce noise of a particularly nasty variety.

The output of IC4 feeds the insertion jack, and is therefore ac-coupled by capacitor C18. Ideally this should be a non-polarised electrolytic, as the only dc voltage present is a few millivolts caused by the output offset of IC4, and a normal, polarised capacitor used under these conditions will soon suffer from increased leakage, and may do its best to imitate a piece of wire - without gain!

Series resistor R39 has been added as a precaution, as IC4 may show a tendency to oscillate if the insertion output becomes shorted to ground for any reason.

Insertion point

Each channel insertion point consists of two stereo jack sockets - one termed "Send" and one "Return". The sockets used should be fitted with switches on their tip and ring contacts, and must be capable of being mounted without the sleeve contact shorting to the panel. They are connected in a manner known as "normalling", which is illustrated in figure 4.

Although the signal is unbalanced at the insertion point, and mono jacks may be used, it is advisable to use stereo ones to maintain compatibility with external equipment which may have balanced inputs and outputs.

These connectors are intended to allow the introduction of external equipment such as equalisers or limiters into the signal path, but if you intend to adopt the purist approach, you will have very little use for such devices and may decide not to include the insertion points.

Equalisation and filters

Even the best microphones do not have a perfectly flat frequency response. Some are better than others, and to aim at obtaining a flat response can be the first step towards bankruptcy. Microphone performance is affected by external factors - source distance, room acoustics, absorption and reflections from room boundaries etc. The sensitivity pattern of a microphone affects its response, particularly at the low frequency end, where omni-directional types generally have greater extension.

The main recording tool for correcting microphones is the equaliser - a type of glorified tone control - which is part of every input channel of a mixing console. A typical channel equaliser (EQ) is a complicated affair, consisting of three or four separate frequency bands, controlling over amplitude, frequency, "Q" and curve shape. Variable high and low pass filters are usually incorporated.

In practice, only small amounts of equalisation are usually applied it is being used for a particular effect, and experience has shown that for microphone correction, the most used controls are the high pass filter and the high frequency shelving section. The filter is usually used to counteract the "proximity effect" which increases the microphone's low frequency output when placed close to the sound source. This is most evident on vocals, and LF (low frequency) roll-off in the 50-100Hz region is often required. In the high frequency zone, it is sometimes necessary to apply a gentle up or down shelving response to correct for absorption or reflection in the recording venue.

An equaliser section with both high and low frequency capability has been incorporated - more drastic effects being better applied by a separate unit plugged into the insertion points, or by using the channel equalisers of a mixing console.

The high pass filter

The equaliser section is shown in figure 5. The return signal from the insertion point is buffered by unity gain stage IC5 then passes to the high pass filter operating around IC6. The filter has six switch selected frequencies covering 20Hz to 200Hz in approximately equal logarithmic steps. It would be possible to have a continuously variable frequency control, but the cost of suitably ratioed potentiometers would be a great deal more than the cost of the recommended switches, and the repeatability from one channel to another would not be accurate enough without selecting the potentiometer sections, as these would need to be reverse logarithmic, and therefore very difficult to manufacture with the required degree of accuracy.

There is a further advantage to using a switch for frequency selection - namely that the operating frequency and filter characteristics can be determined by the choice of a few resistors.

Table 1 gives values for both Butterworth (maximally flat) and Bessel (minimum phase shift) characteristics, together with the formula for calculating other operating frequencies. The filter slope was set at 12dB per octave, as experience has shown this to be audibly the best compromise between ultimate slope and excessive phase shift.

Table 1 High pass filter variations.

Resistor	*Bessel*	*Frequency*	*Butterworth*
R51	25k5	20Hz	12k
R52	15k8	32Hz	7k5
R53	10k2	50Hz	4k75
R54	6k34	80Hz	3k
R55	4k02	125Hz	1k91
R56	2k55	200Hz	1k2
R57	34k	20Hz	24k
R58	21k	32Hz	15k
R59	13k7	50Hz	9k53
R60	8k45	80Hz	6k04
R61	5k36	125Hz	3k83
R63	200Hz	2k4	3k4

Butterworth characteristic: R51 - R56 = (÷2)$^{-1}$÷(2pifC)

R57 - R62 = (÷2)÷(2pifC)

Bessel characteristic: R51 - R56 = 1.498÷(2pifC)

R57 - R62 = 1.998÷(2pifC)

The high frequency equaliser

The shelving response is obtained by feeding the output of a single pole high pass filter, IC9, via the amplitude control, VR3, to the inverting input of either IC7 or IC8.

When directed to IC7, the signal acts as additional negative feedback, reducing the high frequency gain of IC7, thereby causing the overall response to shelve downwards to an amount decided by series resistor R70. In the Lift setting of VR3, the output of IC9 is fed forward around R68 to the inverting input of IC8, giving high frequency lift.

The maximum amount of lift and cut has been set at approximately 6dB which has proved in practice to be more than enough to cope with virtually any circumstance. If greater degrees of correction are thought necessary, R70 may be reduced in value to a minimum of 680R.

When not required, the equaliser section may be totally bypassed by relay RL5, operated by switch S7.

In the next part, we will finish describing the circuit and describe construction of the main part of the MicroAmp.

PARTS LIST FOR THE MICRO AMP

Resistors:

[All available from Electromail unless otherwise stated]
The following resistors are for one channel only. For a stereo unit, two of each are required:

R1,R40 to R43,R72,R93,R94	100R	148-269
R2,R66	12k	148-758
R3	1k5	148-540
R4	2k4	148-590
R5,R6	6k81	166-560
R7,R8,R38,R50,R71,R91,R92	47k	148-893
R9,R10,R23,R44,R45,R73,R74,R87, R88,R95,R97 to R99	10R	148-017
R11 to R13,R29,R31	1M	149-228
R14	4k02	166-346
R15	1k47	165-927
R16	681R	165-602
R17	348R	165-321
R18	187R	165-062
R19	102R	164-817
R20	56R	148-196
R21	30R	148-124
R22	18R	148-073
R24,R25	3k6	148-635
R26,R27,R36,R37,R85,R96 10k	148-736	
R28,R30	1k58	165-955
R32,R33,R35	3k3	148-629
R51-R62- See Table in Part 1		
R64,R65,R68,R69	4k7	148-663
R70	2k7	148-607
R77	13k	148-764
R79 to R84,R86,R89,R90	5k1	148-
R46,R47,R75,R76	100k	148-972
R48	470R	148-427
253		
R100	22R	148-095
The following resistors are for the M-S decoder, and only one of each is required for a stereo unit		
R102,R103	100k	148-972
R39,R49,R63,R67	33R	148-130
R104,R105	220k	149-060
R106,R107	33R	148-130
R108,R10,R121,R122	47k	148-893
R110 to 113,R115 to R120	3k3	148-629
R114	3k0	148-613
R123,R125	560R	148-449
R34,R78	3k0	148-613
R124,R126	330k	149-105
R127 AOT		
R128	100R	148-269
R129	1M	149-228
R130,R131	10R	148-017

PARTS FOR THE MICRO AMP

Capacitors:

Note: Where the R-S part number is starred (*) an alternative and preferable part is available from Audio Solutions Ltd.

The following capacitors are for one channel only. For a stereo unit, two of each are required:

C1 to C3	100uF 63V	395-055
C4, C5	47pF 1%	115-483
C6,C7	10000uF 16V	106-164
C8a,C9,C11,C12,C15,C17, C27,C31,C33,C35,C37, C43 to C49	22pF 2%	113-229
C8b, C19 to C24, C39 to C41, C52 to C55	22uF 25V	493-749*
C10,C13,	10pF 2%	113-207
C14,C16,C32,C36	33pF 2%	113-235
C18,C25,C28,C38,C42	22uF 16V N.P	768-920*
C26	47pF 1%	115-483
C29,C30	0.47uF	169-1528
C34	2200pF 1%	115-398
C50,C51	100uF N.P	768-891*
C56 to C59	0.1uF	114-840

The following capacitors are for the M-S decoder, and only one of each is required for a stereo unit.

C60,C61,C76,C77	1.0uF	169-1411
C62,C63,C67,C69,C71,C73	22pF 2%	113-229
C64,C65,C74,C75	22uF N.P	768-920*
C66,C68,C70,C72	33pF 2%	113-235
C78,C80,C81	22uF 25V	493-749*
C79	100uF Tant	102-730

Semiconductors and miscellaneous

(Those without an R-S part number are not available from Electromail, but may be ordered from Audio Solutions Ltd) The following components are for one channel only. For a stereo unit, two of each are required:

Q1,Q2	SSM2220	ASL
IC1-IC13	NE5534	428-212*
L1,L2	100uH	228-286
VR1	500R	375-893
VR2,VR3	10k lin	410-508
VR4	10k	375-938
VR5	500R	375-893
VC1, VC2	6-50pF	127-307
D1-4	10V zener	283-722
D5-10	1N4148	271-606
RL2, RL3	1p N/O	817-066*
RL1, RL4 to RL7	2p C/O	396-696*
S1 toS4, S7 to S9	4p C/O	333-748*
S5	1p 11pos	ASL
S6	2p 6pos	ASL

The following semiconductors are for the M-S decoder, and only one of each is required for a stereo unit.

5	BD135	299-323
Q6	BC182 (BC546)	296-071
IC14 to IC19	NE5534	428-212*
VR6	500R	375-893
VC3	6-50pF	127-307
D11	2.7V zener	283-586
D12, D13	1N4148	271-606
RL8	2p C/O	396-696*
S10	4p C/O	333-748*
P1	Piezo sounder	245-001

Other parts, such as connectors, knobs, enclosures etc. may be chosen at will, and a browse through the Electromail catalogue is recommended.

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AD736JN	£8.75
AD795JN	£5.94
AD797AN	£8.69
AD811N	£6.73
AD812AN	£6.32
AD813AN	£8.81
AD817AN	£3.85
AD820AN	£3.24
AD822AN	£5.20
AD826AN	£5.33
AD829JN	£6.41
AD830AN	£6.14
AD847JN	£5.71
AD9696KN	£7.73
ADEL2020A	£5.06
ADM222AH	£3.55
ADM232AA	£3.55
ADM485JN	£2.97
ADM690AN	£5.13
ADM691AN	£6.48
ADM695AN	£6.48
ADM699AN	£3.58
CA741CE	£0.26
CA747CE	£0.39
CA3046	£0.37
CA3059	£1.16
CA3080E	£0.73
CA3130E	£0.98
CA3140E	£0.51
CA3189E	£1.22
CA3240E	£1.12
DG211CJ	£1.55
DG212CJ	£1.55
DG411DJ	£3.11
EL2030CN	£5.67
ICL7106	£2.80
ICL7611DCP	£1.06
ICL7621	£1.70
ICL8038	£5.25
ICM7555	£0.36
ICM7556	£0.98
L165V	£2.63
L272M	£1.86
L293E	£4.35
L297	£6.37
L298	£6.99
L6219	£4.48
LF347N	£0.46
LF351N	£0.43
LF353N	£0.42
LF356	£0.84
LM301A	£0.25
LM308N	£0.58
LM311N-8	£0.32
LM318	£0.98
LM319N-14	£0.96
LM324	£0.24
LM335Z	£1.52
LM339N	£0.24
LM348N	£0.31
LM358N	£0.27
LM377	£2.57
LM380N-14	£1.12
LM381N	£2.64
LM386	£0.79
LM392N	£0.79
LM393N	£0.21
LM709T	£0.79
LM733	£1.04
LM748CN-8	£0.37
LM759CP	£3.38
LM1458	£0.37
LM1881	£3.92
LM2917N8	£3.10
LM3900N	£0.72
LM3909N	£1.76
LM3911	£2.56
LM3914	£2.30
LM3915	£2.70
LM13600	£1.66
LMC660CN	£2.16
LMC6032IN	£1.55
LP311N	£0.74
LP324N	£0.67
LP339N	£0.73
LT1013CN8	£2.99
LT1014CN	£10.20
MAX202CPE	£2.97
MAX208CN	£6.99
MAX220CPE	£5.06
MAX222CPE	£5.06
MAX232CPE	£2.16
MAX483CP	£3.13
MAX485CP	£2.58
MAX631ACP	£4.99
MAX635ACP	£4.99
MC1488	£0.39
MC1489	£0.39
MC3302	£0.56
MC3340P	£1.60
MC4558P	£0.36
MV601DP	£2.97
NE521N	£6.39
NE531	£1.47
NE555N	£0.25
NE556N	£0.36
NE565	£1.84
NE566N	£0.90
NE567N	£0.39
NE571N	£2.47
NE592	£0.62
NE5532N	£0.80
NE5534N	£0.64
NE5539N	£4.35
NE5560N	£2.31
OP07CN	£1.42
OP27CN	£2.90
OP77GP	£2.36
OP90GP	£3.11
OP97FP	£2.43
OP113GP	£3.44
OP176GP	£2.09
OP177GP	£1.89
OP200GP	£5.60
OP213FP	£5.20
OP275GP	£2.57
OP282GP	£2.27
OP283GP	£5.20
OP290GP	£5.40
OP297GP	£5.74
OP400GP	£11.81
OP495GP	£8.69
RC4136	£1.00
SAA1027	£4.46
SG3524N	£1.08
SG3543	£6.88
SL486	£2.88
SL490	£3.04
SSM2015P	£12.32
SSM2016P	£13.33
SSM2017P	£3.38
SSM2131P	£4.19
SSM2141P	£4.21
SSM2142P	£6.40
SSM2143P	£3.78
TBA120S	£0.90
TBA800	£0.70
TBA810S	£0.64
TBA820M	£0.40
TDA1170S	£2.48
TDA2002	£1.04
TDA2004	£3.11
TDA2030	£1.18
TDA2050V	£3.98
TDA2611A	£1.88
TDA2822A	£1.68
TED3718DP	£5.03
TEA5115	£3.11
TL061CP	£0.35
TL062CP	£0.60
TL064CN	£0.72
TL071CP	£0.48
TL072CP	£0.50
TL074CN	£0.50
TL081	£0.33
TL082CP	£0.54
TL084CN	£0.50
TL494CN	£1.46
TL7705ACP	£1.62
TLC271	£0.54
TLC272	£0.88
TMP01FP	£5.60
ULN2003	£0.52
ULN2004A	£0.48
ULN2803	£0.90
ULN2804A	£1.64
ULN2806	£1.20
XR2206	£5.71
ZN409CE	£1.89
ZN414Z	£1.16
ZN416E	£1.99
ZN1034E	£3.11
EPROM's	
2716	£4.74
2732	£4.84
2764-25	£4.20
27C64-25	£3.44
27C010	£5.74
27128-20	£4.08
27C128-20	£4.08
27256-20	£4.85
27C256-20	£3.68
27C512	£3.42
RAM	
4164-15	£1.78
6116-10	£1.53
6264-10	£3.16
41256-10	£2.80
62256-10	£5.30
511000-8	£8.54
514256-8	£6.80
A/D Converters Data Acquisition	
AD420AN	£25.38
AD557JN	£8.75
AD574AJN	£18.48
AD775JN	£18.48
AD7226KN	£25.69
AD7528JN	£8.63
AD7545AKN	£14.04
AD7828KN	£20.33
ICL7109CPL	£7.75
TLC549IP	£3.51
ZN425E	£5.94
ZN426E	£3.13
ZN427E	£9.25
ZN428E	£5.94
ZN448E	£7.02
Voltage Regulators	
7805	£0.35
7808	£0.50
7812	£0.38
7815	£0.38
7905	£0.40
7912	£0.30
7915	£0.38
7924	£0.38
78L05	£0.23
78L08	£0.23
78L12	£0.23
78L15	£0.24
78L24	£0.39
79L05	£0.23
79L12	£0.23
79L15	£0.28
79L24	£0.30
ADM666AN	£3.44
L200CV	£1.30
L296	£8.13
L387A	£3.24
LM2940CT	£2.30
LM317T	£0.50
LM323K	£2.84
LM334Z	£1.35
LM338K	£5.52
LM723	£0.29
LP2950CZ	£2.97
REF01CP	£3.44
REF02CP	£4.66
REF12Z	£1.28
REF195GP	£4.72
REF25Z	£1.24
REF50Z	£1.22
TL431CP	£0.45
ZN423	£1.55
ZN458B	£1.89
Diodes	
1N914	£0.06
1N916	£0.06
1N4001	£0.06
1N4002	£0.07
1N4003	£0.07
1N4004	£0.07
1N4005	£0.07
1N4006	£0.08
1N4007	£0.08
1N4148	£0.05
1N4149	£0.06
1N5400	£0.09
1N5401	£0.09
1N5402	£0.10
1N5404	£0.11
1N5406	£0.12
1N5407	£0.14
1N5408	£0.15
BA157	£0.10
BA158	£0.10
BA159	£0.10
BY126	£0.13
BY127	£0.18
BY133	£0.10
OA47	£0.28
OA90	£0.07
OA91	£0.10
OA200	£0.56
OA202	£0.29
Zeners 2.7 to 33V	
400mW	£0.08
1.3W	£0.14
Bridge Rectifiers	
1.5A 50V	£0.19
1.5A 200V	£0.20
1.5A 400V	£0.22
1.5A 600V	£0.22
1.5A 800V	£0.27
1.5A 1kV	£0.24
3A 200V	£0.36
3A 400V	£0.40
3A 600V	£0.33
6A 200V	£0.70
6A 800V	£0.59
10A 400V	£1.39
25A 200V	£1.68
25A 600V	£1.80
Thyristors	
C106D	£0.36
PO102AA	£0.30
TIC116D	£0.66
TIC126D	£0.77
Triacs	
ZO105DA	£0.42
TIC206D	£0.65
TIC226D	£0.94
BTA08-600B	£0.99
TIC236D	£0.96
Diac, St. Switch	
DB3, 32V	£0.20
BRY39	£1.30
Transistors	
2N1613	£0.31
2N1711	£0.26
2N1893	£0.29
2N2218A	£0.28
2N2219A	£0.25
2N2222A	£0.18
2N2646	£1.12
2N2904A	£0.25
2N2905A	£0.25
2N2907	£0.20
2N2907A	£0.20
2N2926	£0.16
2N3053	£0.27
2N3054	£0.85
2N3055	£0.58
2N3439	£0.62
2N3440	£0.50
2N3702	£0.09
2N3703	£0.10
2N3704	£0.10
2N3705	£0.10
2N3706	£0.10
2N3771	£1.44
2N3772	£1.51
2N3773	£1.70
2N3819	£0.40
2N3820	£0.66
2N3904	£0.10
2N3905	£0.10
2N3906	£0.10
2N4036	£0.34
2N5245	£0.80
2N5296	£0.57
2N5321	£0.57
2N5322	£0.57
2N5401	£0.11
2N5551	£0.11
2N6107	£0.60
2N6491	£1.58
2SB548	£0.30
2SD1730	£1.44
AC126	£0.44
AC127	£0.50
AC128	£0.40
AC187	£0.48
AC188	£0.48
ACY17	£3.84
AD149	£1.67
AD161	£0.92
AD162	£0.92
BC107	£0.16
BC107B	£0.17
BC108	£0.14
BC108A	£0.14
BC108C	£0.15
BC109	£0.17
BC109C	£0.19
BC114	£0.19
BC115	£0.41
BC116	£0.41
BC118	£0.41
BC132	£0.36
BC134	£0.36
BC135	£0.36
BC140	£0.25
BC141	£0.27
BC142	£0.31
BC143	£0.34
BC149	£0.21
BC154	£0.36
BC157	£0.12
BC159	£0.17
BC160	£0.28
BC170	£0.16
BC170B	£0.16
BC171	£0.11
BC171B	£0.16
BC172	£0.13
BC172B	£0.13
BC177	£0.18
BC178	£0.18
BC179	£0.18
BC179A	£0.17
BC182	£0.11
BC182A	£0.11
BC182B	£0.12
BC182L	£0.08
BC182LB	£0.08
BC183	£0.08
BC183L	£0.08
BC183LB	£0.08
BC184	£0.08
BC184L	£0.08
BC186	£0.33
BC204C	£0.72
BC206B	£0.72
BC207B	£0.74
BC208	£0.72
BC209A	£0.72
BC212	£0.08
BC212L	£0.08
BC212LB	£0.08
BC213	£0.08
BC213B	£0.08
BC213LC	£0.08
BC214	£0.08
BC214L	£0.08
BC225	£0.15
BC237B	£0.09
BC238B	£0.09
BC238C	£0.09
BC239C	£0.10
BC250A	£0.15
BC251	£0.13
BC252	£0.13
BC261B	£0.30
BC262B	£0.24
BC267B	£0.30
BC307	£0.10
BC308	£0.10
BC319C	£0.13
BC327	£0.10
BC327-16	£0.10
BC328	£0.10
BC328-16	£0.10
BC337	£0.10
BC337-25	£0.12
BC338	£0.10
BC338-25	£0.10
BC348B	£0.14
BC357	£0.25
BC393	£0.73
BC414C	£0.13
BC441	£0.40
BC461	£0.40
BC463	£0.29
BC478	£0.32
BC479	£0.32
BC490	£0.24
BC516	£0.22
BC517	£0.17
BC527	£0.20
BC528	£0.20
BC537	£0.20
BC546B	£0.08
BC546C	£0.08
BC547B	£0.09
BC547C	£0.09
BC548C	£0.08
BC549C	£0.10
BC550C	£0.10
BC556A	£0.08
BC557B	£0.08
BC557C	£0.08
BC558C	£0.08
BC559C	£0.08
BC560A	£0.09
BC560B	£0.09
BC637	£0.21
BC638	£0.21
BC639	£0.21
BC640	£0.21
BCY70	£0.22
BCY71	£0.20
BCY72	£0.20
BD124P	£6.86
BD135	£0.21
BD136	£0.21
BD137	£0.23
BD138	£0.22
BD139	£0.26
BD140	£0.25
BD150C	£0.82
BD165	£0.42
BD166	£0.35
BD187	£0.39
BD201	£0.40
BD202	£0.40
BD203	£0.40
BD204	£0.40
BD222	£0.58
BD225	£0.42
BD232	£0.50
BD237	£0.32
BD238	£0.44
BD240C	£0.37
BD243B	£0.50
BD244A	£0.53
BD244C	£0.53
BD245C	£1.18
BD246	£1.18
BD246C	£1.18
BD283	£0.61
BD284	£0.61
BD400	£0.79
BD441	£0.41
BD442	£0.37
BD534	£0.47
BD535	£0.50
BD536	£0.65
BD581	£0.62
BD597	£0.92
BD646	£0.52
BD648	£0.52
BD650	£0.53
BD707	£0.42
BD708	£1.04
BD807	£0.80
BDX32	£1.78
BDX33C	£0.56
BDX34C	£0.50
BDX53C	£0.47
BDX54C	£0.50
BF180	£0.31
BF182	£0.31
BF185	£0.58
BF194	£0.31
BF194B	£0.19
BF195	£0.19
BF244	£0.35
BF244B	£0.40
BF244C	£0.35
BF257	£0.33
BF259	£0.33
BF337	£0.40
BF355	£0.38
BF423	£0.13
BF451	£0.19
BF459	£0.33
BF469	£0.36
BFX29	£0.29
BFX84	£0.31
BFX85	£0.32
BFY50	£0.30
BFY51	£0.25
BFY52	£0.28
BS107	£0.21
BS170	£0.23
BSW66	£1.35
BU126	£1.32
BU205	£1.41
BU208A	£1.24
BU326A	£1.40
BU500	£1.54
BU508A	£0.98
BU508D	£1.44
BU526	£1.74
BU806	£1.06
BUT11A	£1.30
BUT11AF	£1.30
BUX84	£0.78
IRF540	£1.26
IRF740	£1.80
MJ2501	£1.60
MJ3001	£1.80
MJ11015	£2.11
MJ11016	£2.56
MJE340	£0.40
MJE350	£0.48
MPSA05	£0.14
MPSA06	£0.12
MPSA13	£0.12
MPSA42	£0.17
MRF475	£7.28
TIP29C	£0.31
TIP30C	£0.31
TIP31C	£0.41
TIP32C	£0.41
TIP33C	£0.72
TIP41A	£0.48
TIP42C	£0.52
TIP47	£0.48
TIP48	£0.62
TIP50	£0.53
TIP121	£0.48
TIP122	£0.48
TIP125	£0.46
TIP127	£0.40
TIP132	£0.46
TIP137	£0.56
TIP142	£1.30
TIP147	£1.12
TIP2955	£0.97
TIP3055	£0.70
VN10KM	£0.48
ZTX300	£0.16
ZTX500	£0.16

SAMEDAY DESPATCH

No Minimum Order Value

Electrolytic Radial

µF	16v	25v	40v	63v	100v
0.47	—	—	—	£0.05	—
1.0	—	—	—	£0.05	£0.05
2.2	—	—	—	£0.05	—
4.7	—	—	£0.05	£0.05	£0.05
10	£0.05	£0.05	£0.05	£0.05	£0.09
22	£0.05	£0.05	£0.05	£0.07	£0.11
33	£0.05	—	£0.05	—	—
47	£0.05	£0.05	£0.07	£0.10	£0.19
100	£0.06	£0.06	£0.10	£0.13	£0.26
220	£0.08	£0.09	£0.13	£0.25	—
330	£0.09	—	£0.19	—	—
470	£0.12	£0.17	£0.24	£0.33	—
1000	£0.15	£0.33	£0.34	—	—
2200	£0.27	£0.55	£0.70	—	—
3300	—	£0.94	—	—	—
4700	£0.67	£1.05	—	—	—

Electrolytic Axial

µF	16v	25v	40v	63v	100v	250v	450v
0.47	—	—	—	—	—	—	—
1.0	—	—	—	£0.13	—	—	£0.22
2.2	—	—	—	£0.13	—	—	£0.30
4.7	—	—	—	£0.13	—	—	£0.41
10	£0.12	—	£0.12	£0.13	£0.17	£0.40	£0.51
22	£0.12	£0.13	£0.14	£0.15	£0.21	£0.52	£1.06
33	—	—	—	—	—	—	—
47	£0.13	£0.13	£0.15	£0.19	£0.32	£0.57	—
100	£0.14	£0.16	£0.19	£0.26	£0.44	—	—
220	£0.19	£0.20	£0.27	£0.39	£0.48	—	—
330	—	—	—	—	—	—	—
470	£0.24	£0.28	£0.43	£0.53	—	—	—
1000	£0.33	£0.43	£0.59	£1.08	—	—	—
2200	£0.53	£0.66	£1.11	£1.55	—	—	—
3300	—	—	—	—	—	—	—
4700	£0.86	£1.11	—	—	—	—	—

Ceramic Mini Disc

1.0,1.2,1.5,1.8,2.2,2.7,3.3,3.9,4.7,5.7,6.8,8.2

1.0pF to 22nF 100V	£0.06
47nF & 100nF 50V	£0.07

Also in stock - Mylar Film, MKT, Boxed & Dipped Polyester, Tantalum, Sub-miniature, low Leakage & 105°C Radials

Dipped Ceramic Multilayer

10,22,33,47 and multiples.

10pF to 100nF 100V	£0.10
220nF 100V	£0.14
330nF 100V	£0.16
470nF 100V	£0.22
1.0µF 100V	£0.29

Full Technical Specification available

Resistors - Please State Value Required

¼W Carbon Film 5%	E12 Series	1Ω-10M	£0.02 Each, £0.60 per 100
¼W Metal Film 1%	E24 Series	10Ω-1M	£0.04 Each, £1.72 per 100
½W Carbon Film 5%	E12 Series	1Ω-10M	£0.02 Each, £0.95 per 100
1W Carbon Film 5%	E12 Series	1Ω0-10M	£0.07 Each, £3.90 per 100
2W Carbon Film 5%	E12 Series	1Ω0-10M	£0.12 Each, £5.99 per 100
2.5W Wirewound 5%	E12 Series	0Ω1-220Ω	£0.23 Each

per 100 of same value only

Preset Resistors - Please State Value Required

Enclosed, 10mm Square Horz / Vert.	100Ω - 1M0 0.15W	£0.15 Each
Skeleton, 10mm Dia. Horz / Vert.	100Ω - 1M0 0.1W	£0.11 Each
Sub-min, 6mm Dia, Horzontal	E3 100Ω-1M0 0.2W	£0.19 Each
Multiturn, 10mm Square, Top Adjust.	E3 100Ω-1M0 0.5W	£1.00 Each
Multiturn, 19mm Long, End Adjust.	E3 50Ω-2M0 0.5W	£0.64 Each

Potentiometers - Please State Value Required

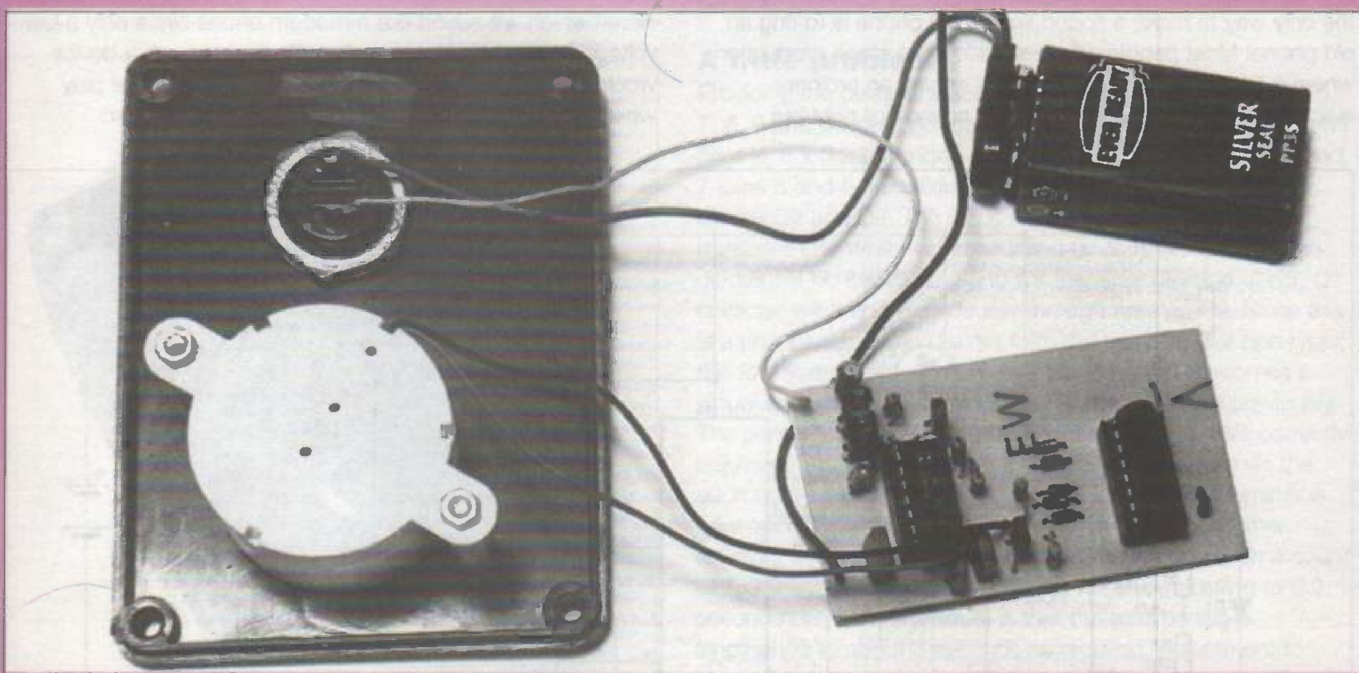
Single Gang - ¼" Shaft, 25mm Dia.	470Ω-2M2 Linear	£0.49 Each
Single Gang - ¼" Shaft, 25mm Dia.	470Ω-2M2 Logarithmic	£0.49 Each
Dual Gang - ¼" Shaft, 20mm Dia.	1K0-2M2 Linear	£1.62 Each
Dual Gang - ¼" Shaft, 20mm Dia.	1K0-2M2 Logarithmic	£1.71 Each
Switched - ¼" Shaft, 20mm Dia.	1K0-2M2 Linear	£1.56 Each
Switched - ¼" Shaft, 20mm Dia.	1K0-2M2 Logarithmic	£1.69 Each
PCB Mount, Splined Shaft, 16mm Dia.	470Ω-1M0 Linear	£0.42 Each
PCB Mount, Splined Shaft, 16mm Dia.	470Ω,4K7,1M0 Log	£0.42 Each
Dual PCB, Splined Shaft, 16mm Dia.	10K,50K100K,500K Linear	£0.85 Each
Dual PCB, Splined Shaft, 16mm Dia.	10K,50K,100K,500K Logarithmic	£0.85 Each

ORDERING INFORMATION - Carriage £1.25+Vat, Prices Exclude Vat (17½%), Add Carriage & Vat to all orders. Payment with Order. PO/Cheques payable to ESR Electronic Components. ALL Credit Card Orders Accepted. NO Credit Card Surcharges. Trade discount for Schools & Colleges.

PHONEY PHONE

By Terry Balbirnie

Sounds like a phone - isn't a phone!



This circuit simulates the ringing of a modern push-button telephone providing the same double beat as used in the UK. Since this ringing pattern is also used in Australia, New Zealand, the Irish Republic and several other countries, the device should be found useful for readers in places other than Britain.

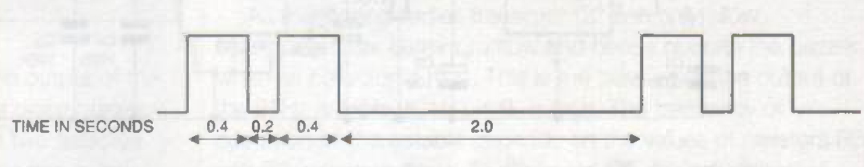


Figure 1: the signal of the UK phone ringing pattern

But why?

The Phoney Phone circuit was originally designed for an amateur stage production and was hidden on-stage next to a real phone. For this purpose, the on-off switch was situated remotely. However, there are a number of other reasons why someone would wish to construct such a circuit. It could be used to give a professional touch to home communications projects. It could be built into a child's toy phone to give extra realism. Another use would be to provide an excuse for ending a lengthy call due to the "other phone" ringing.

However, some readers will construct the circuit simply for practical joking. If it is left hidden in an office, it is entertaining to watch people picking up phones trying to find the one which is ringing. It is also amusing to switch it on at a large railway station and observe people reaching for their mobiles! Although many cellular phones ring in the continental way - in single beats - some may be adjusted to ring with the fixed-line BT pattern.

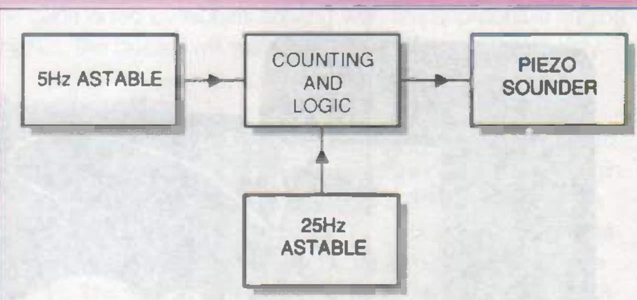


Figure 2: the block diagram

A bit of theory

To ring a phone, the line to which it is connected provides an ac signal at a relatively high voltage. In the UK system, the frequency is 25Hz at some 70 volts. This signal is pulsed on and off in double beats in the manner shown in figure 1. It can be seen that the familiar UK ringing pattern is produced by two

0.4 second bursts separated by a 0.2 second space. There follows a two-second pause then the cycle repeats. The high operating voltage allows a small current to be used and this results in a lower loss of power through the resistance of the wire than would otherwise be the case.

Traditional telephones use a twin electromagnet assembly having a hinged armature with a small hammer on the end. As current flows through the coils, the armature is attracted to each electromagnet in turn - one on the first ac half cycle and the other on the second one. The hammer strikes two small bells in turn. These are tuned to different notes so the sounds blend to give a characteristic chord. This effect is difficult to produce electronically with any degree of realism. In practice, the only way to make a sound like an old phone is to ring an old phone! Most people will have watched a stage production where a telephone was simulated by ringing an ordinary electric bell off-stage. Not only is the sound not right but invariably the ringing pattern is not matched accurately by the person pressing the switch. Commercial bell-ringing circuits are available and these provide an ac signal with the correct frequency, rhythm and voltage to ring a real phone. A similar home-made device would be difficult to construct since a step-up transformer would be needed to increase the voltage to a level sufficient to operate the phone.

The old type of dial telephone, although still to be seen, is becoming something of a rarity. Most phones today use an electronic circuit which operates in conjunction with a small loudspeaker or piezo buzzer to produce the ring. Because these respond to the ac signal sent along the line they give a characteristic warbling tone. It is straightforward to construct a circuit which will sound like a modern phone since only a low-voltage battery supply is needed. Obviously, such a device would be inappropriate to use in, say, a 1950s stage play where traditional methods would still need to be used.

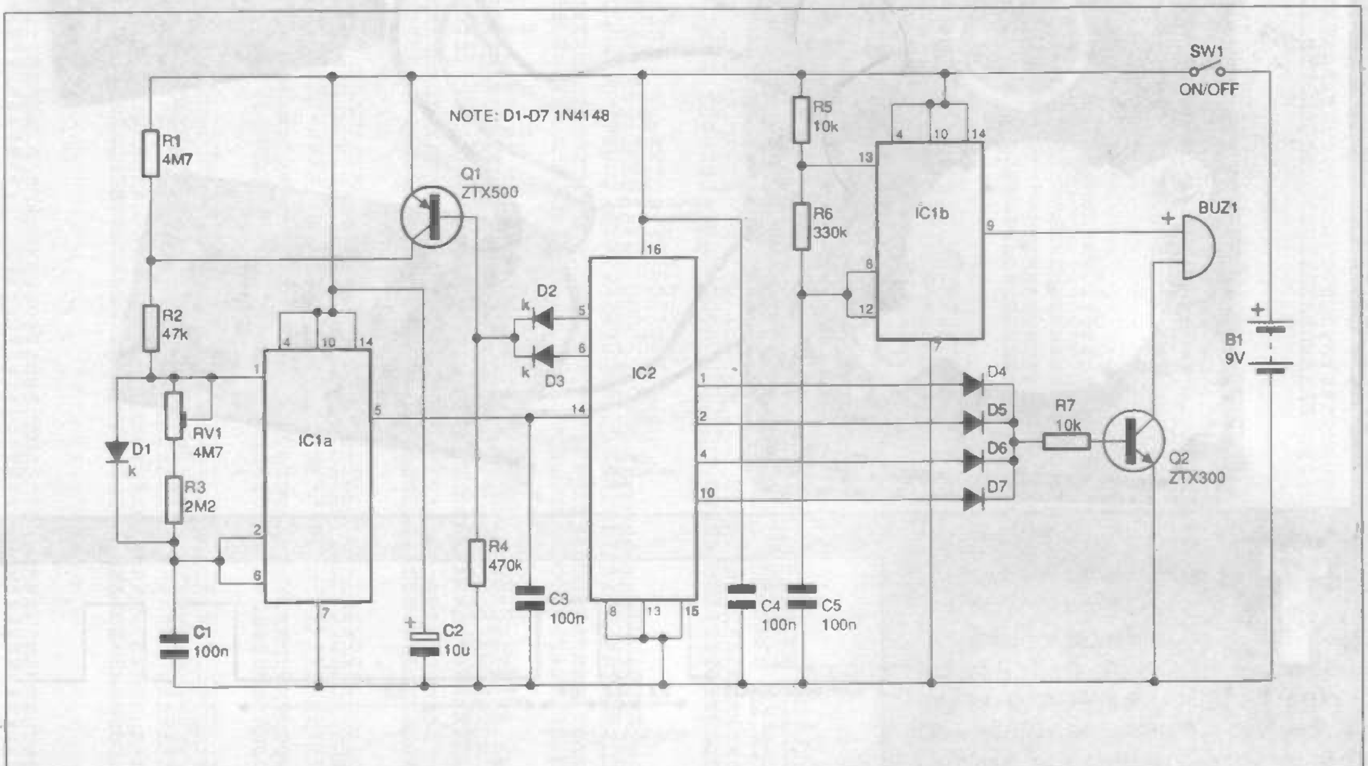
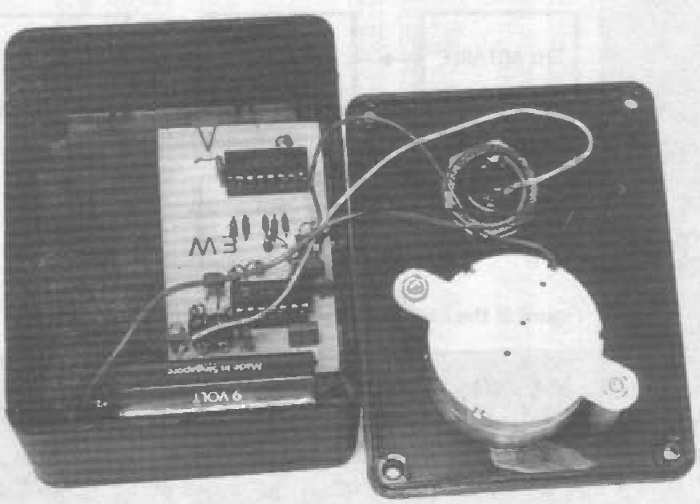


Figure 3: the circuit of the Phoney Phone



Since there are now many different types of sounder used inside phones, any loud device of the type specified will be suitable. Although people are now very tolerant to the sound of the ring itself, any significant deviation from the correct rhythm will sound unrealistic. Also, the warbling effect is crucial in providing a convincing effect.

How it works

The circuit for the Phoney Phone project is illustrated as a block diagram in figure 2. There are two astable circuits, one giving a train of pulses at a frequency of 5Hz (5 pulses per second) and the other.at 25Hz. The counting and logic circuitry allows two of the pulses from the first astable to pass through and blend into a single 0.4 second pulse. There is then a space of one pulse (0.2 second) followed by a further two blended pulses and a 2 second gap. The cycle then repeats. The pulses passing through the

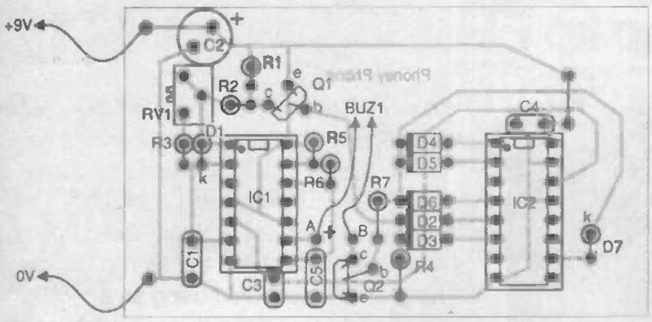
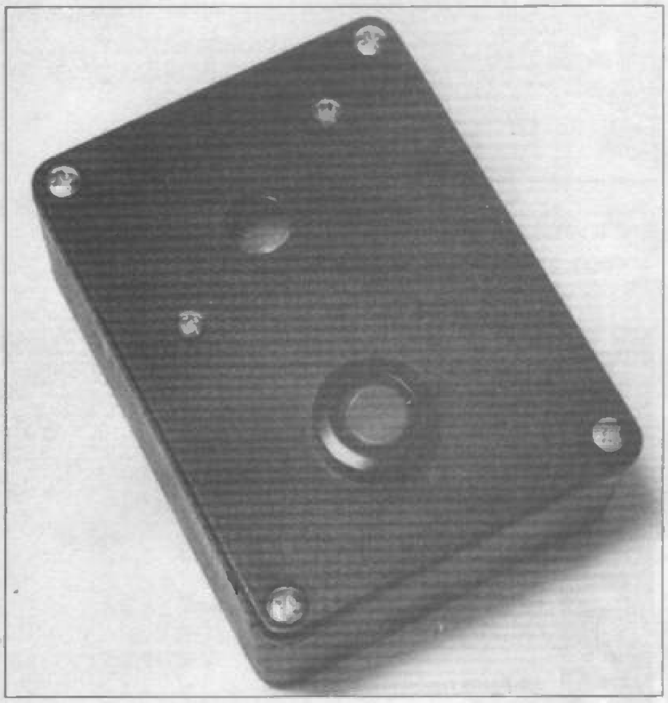


Figure 4: the component layout



counter and logic section are combined with the output of the 25Hz astable to provide a warbling effect in the piezo buzzer.

The circuit is shown in detail in figure 3. The two astables are based on IC1a and IC1b respectively. These are, in fact, both parts of the same timer integrated circuit, IC1. Consider IC1a first. The frequency depends on the values of fixed resistors R1, R2 and R3, preset potentiometer, RV1, and capacitor, C1. However, for most of the time, R1 will be bypassed so the timing depends only on the other components. The purpose of R1 and how this is switched in and out of the circuit will be explained presently.

At the end of construction, RV1 will be adjusted to provide a 5 Hz signal from IC1a output, pin 5. Diode, D1, modifies the waveform to give short on states and long off ones - that is, brief pulses which are most effective at operating the rest of the circuit.

Taking turns

The pulses derived from IC1a are applied to IC2 clock input, pin 14. This device is a decade counter integrated circuit. Thus, as pulses are received, the circuit counts them and outputs 0, 1, 2, 3 etc. up to 9 (pins 3, 2, 4, 7, 10, 1, 5, 6, 9 and 11) go high in turn. Capacitor C3 removes the effect of any random noise picked up on the PCB track between IC1 pin 5 and IC2 pin 14 which could cause false operation. When the last pulse has been received, the device resets and begins again. Each output therefore goes high for 0.2 seconds with the whole cycle lasting for 2 seconds. Outputs 1, 2, 4 and 5 (pins 2, 4, 10 and 1 respectively) are selected and OR gated together using diodes D4 to D7. If any of these outputs are high, base current will flow into transistor, Q2, via current-limiting resistor, R7. However, the transistor will only turn on if the collector is high. The significance of this will be explained presently. With outputs 1 and 2, base current will flow for 0.4s (that is, for two pulses). Following that will be a space of 0.2 seconds (while unconnected output 3 goes high) and a further 0.4 second pulse when outputs 4 and 5 go high. There will then be a long pause while unconnected outputs 6 onwards go high.

A little problem

Providing the delay of 2 seconds is a problem. IC2 outputs 6, 7, 8, 9 and 0 would normally provide a delay of only 1 second (that is, 5 x 0.2 seconds). To solve this difficulty, outputs 6 and 7 (pins 5 and 6 respectively) are OR gated together using diodes D2 and D3. The result is applied to the base of transistor Q1. While IC2 is counting up to 5, neither of these diodes will be conducting and will therefore have no effect. Q1 collector will then be made low through resistor, R4. Since this is a pnp transistor (as distinct from the more familiar npn type), this low state keeps is on. The emitter/collector becomes a virtual short-circuit and bypasses R1 as mentioned previously. The period of IC1a will then be 0.2 seconds with RV1 correctly adjusted. On counts 5 and 6, Q1 base is made high via the appropriate diode and it switches off. The collector/emitter is now open circuit and R1 appears in series with the other resistors in the chain. This extends the time period. On a count of 7 onwards, Q1 turns on again with pulses returning to 0.2 seconds duration. The effect is that the total period is lengthened to about 3 seconds as required. Adjustment to RV1 will provide a compromise whereby the pulse repetition frequency and two-second gap are both reasonably correct.

As mentioned earlier, transistor Q2 can only allow collector/emitter current to flow and hence operate the buzzer when its collector is high. This is the case when the output of the 25Hz astable, IC1b pin 9, is high. The frequency of operation of this astable depends on the values of resistors R5 and R6 in conjunction with capacitor, C5. No adjustment is provided since the exact frequency is not important. As IC1b output, pin 9, pulses high, collector current will flow through the buzzer during the times when the base is also high. Since the base is fed by signals arriving with the appropriate ringing rhythm, the buzzer will warble in the familiar telephone way.

Construction

Construction is based on a single-sided printed circuit board (PCB) and the component overlay is shown in figure 4. Begin by soldering the two ic sockets and the link wire in position. Follow with all resistors (including RV1) and capacitors. Note that there are two types of capacitor having the same value (100nF). The disc ceramic units are soldered in positions C3 and C4 while the metallised polyester ones are used for C1 and C5. Take care over the polarity of electrolytic capacitor C2 - the negative end is connected to the track leading to the 0V line. Solder all seven diodes in place taking care over their orientation. In the case of D1, the cathode is connected to IC1 pin 2. In the case of the groups D4, 5 and 6 and D2 and D3, the cathode ends are those which are connected together at the left-hand side. With D7 it is connected to the upper pad. Solder the two transistors in position by first bending their pins

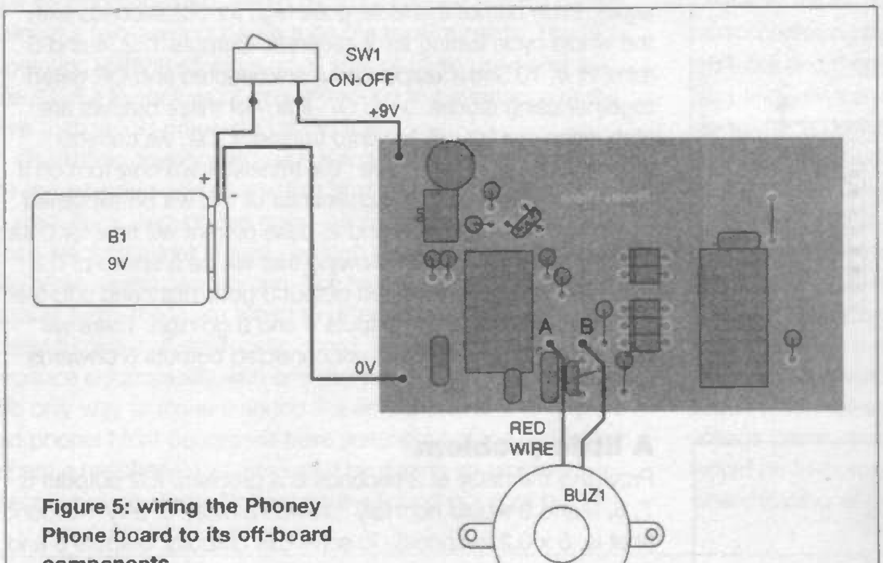


Figure 5: wiring the Phoney Phone board to its off-board components

sufficiently to match the layout of holes in the PCB. Take particular care over the orientation. Note that although the transistors appear identical, they are of different types (as marked on the body). It will be seen that pnp transistor Q1 has its emitter connected direct to the positive line. This will seem strange to those used to working with the npn variety.

Solder the negative (black) PP3 battery connector to the point labelled "0V". Solder a 10cm piece of stranded connecting wire to the point labelled "+9V". Solder the buzzer wires to the points marked "A" and "B". The red (positive) wire must connect to point A. Adjust RV1 to approximately mid-track position.

Complete construction of the circuit panel by inserting the ics into their sockets taking care over the orientation. Since these are CMOS devices, it is possible for them to be damaged by static charge on the body, so touch something which is earthed - such as a water tap - before handling the pins.

Testing

For testing purposes, twist the "+9V" wire from the circuit panel to the red battery snap wire and connect the battery. The buzzer will begin operating. There should be a warbling sound and pulses should be given in a double-beat pattern (although the timing will probably be too fast or too slow to sound realistic).

Adjust RV1 for best operation - clockwise rotation of the sliding contact (as viewed from the edge of the PCB) will increase the timing. The double bleep should be made to last for 1 second followed by a pause of two seconds. Listening to the one-second ticks from a quartz clock will help Make adjustments until both of these timings are as close as possible to their correct values.

Boxing up

Any plastic box large enough to accommodate the circuit panel, sounder, PP3 battery and on-off switch may be used. For maximum volume, the buzzer should be mounted so that its top surface is close to the lid where there should be a hole a little larger than that in the sounder for the sound to pass through (see photograph). If a small box is being used, plan the positions of the internal components carefully. If the sounder is mounted on the lid as in the prototype, ensure that there will be sufficient clearance below it for the other circuit components when it is in position. Also, if attaching the sounder in this way, use plastic spacers on the bolt shanks otherwise the mounting lugs on the device will be excessively strained when the nuts are tightened. On no account should the mounting nuts touch any ic pins or uninsulated component end leads. Refer to figure 5 and complete the wiring. The circuit panel may be secured using an adhesive fixing pad or a small hole may be drilled in a free part and a small nut and bolt used. The battery may be attached using an adhesive fixing pad or a small bracket. If the switch needs to be situated remotely, any reasonable length of light-duty twin wire may be used.

Choice of RV1

If the specified value (4M7) is not available, use a value of 2M2 instead. If the timing cannot be made long enough, increase the value of R3 and vice versa.

PARTS LIST FOR THE PHONEY PHONE

Resistors

R1	4M7
R2	47k
R3	2M2
R4	470k
R5, R7	10k
R6	330k

All fixed resistors 0.25W 5%

RV1	4M7 miniature vertical preset (see text).

Capacitors

C1, C5	100n min metallised polyester - 5mm pin spacing
C2	10m 16V electrolytic
C3, C4	100n min disc ceramic

Semiconductors

IC1	7555 dual timer
IC2	4017 decade counter
Q1	ZTX500 pnp
Q2	ZTX300 npn
D1-D7	1N4148

Miscellaneous

BUZ1	Piezo buzzer: 3-24V d.c. operation 103dB output.
SW1	Miniature slide, toggle or rocker switch.

Printed circuit board (PCB), 14-pin d.i.l. socket, 16-pin d.i.l. socket, PP3 battery and connector. Plastic box for project.

PROCESS TIMER and CONTROLLER

Part 4

This latest instalment of Tim Parker's "Process Timer/Controller" project Is a highly versatile multi-function expansion bus interface card to allow access to the outside world

In line with all the previous boards in this project, this one too is self-contained and, though simple in its basic design, it provides a wealth of features which will enable you to make full use of the expansion bus on the main controller for a wide range of 'real world' applications.

Who would have thought that from the humble beginning of this series of articles, it would be possible to exploit the low-end PIC16C54 microcontroller to this degree? The Process Timer/Controller of part 1, together with this Expansion Bus Interface Card, demonstrates that you don't have to 'move up' to a PIC device with more available I/O pins simply because the initial appearance of the PIC16C54 leads you to think that no more than twelve external devices can be connected to it. The Process Controller main board alone proves this wrong (incidentally, because topics have moved on from the original darkroom timer aspect of part 1, we will now refer to the main unit as the Process Controller, rather than the Process Timer, OK?), with four 7-segment LED displays, eight on-board pushbuttons and a piezo transducer. In all, 37 I/O port lines would be required to control each bit individually. By adding this 14-channel Interface card to the expansion bus, the number increases to 51 I/O port lines. It is also a false belief that, without a built-in timer interrupt, the PIC16C54 cannot be used to achieve accurate timing periods, since this too has already been disproved in previous articles.

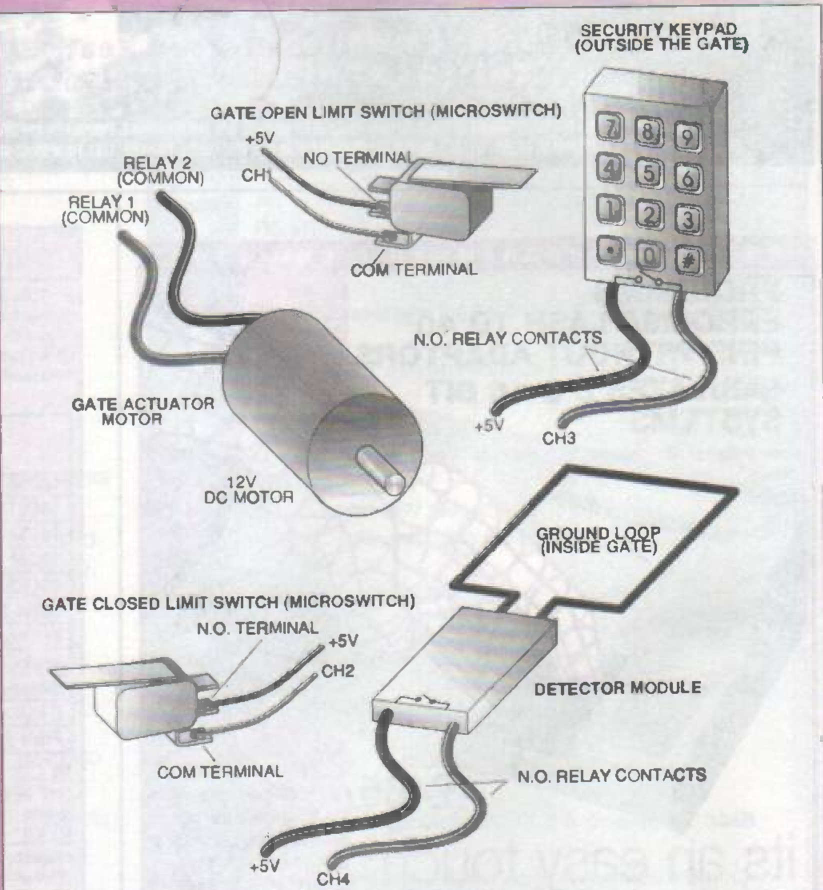


Figure 1: connections for LDRs, switches and thermistors. Note that CHn = any one of the 7 input channels

In part 3 of this series we presented a software development board, and some applications software for an automatic gate controller. Later in this article we will look at implementing the software on this interface card to produce a scaled down model of a working version, together with the connections required (which, by the way, differ slightly from those shown last month). More details later.

Outputs

The expansion bus output port on the Process Controller connects to the inputs of two Darlington driver ics - IC1 and IC2 - on the interface card. The outputs of IC1 are used to drive the seven single pole changeover (SPCO) relays, each of which can be disabled via their respective jumper links JP1 to JP7 if not required. There are reasons why you may want to disable some relays, which will be made apparent shortly.

Each relay has an LED indicator connected across it to show its state. Past experience has proved that these indicators are a necessity when trying to establish which one is switching under software control, because when you have a PCB with numerous relays on board, and your software isn't doing what it should, it's very hard to feel which one is actually switching by placing your finger on each one in turn, since the mechanical vibration through the board means that they all 'feel' the same. At least with the LEDs across them you can see which one is (or should be) energised.

Although the Darlington driver ics have protection diodes fitted internally to each of their outputs, diodes D1 to D7 have been included on the board to protect against the back emf generated if any of the jumper links are removed while that particular relay is energised. In this situation the internal protection diodes of IC1 will have no effect.

The second Darlington driver, IC2, is connected in parallel with IC1, and is used to provide open collector outputs from the interface card. Because both of these ics are connected in parallel, as each relay is energised by the outputs of IC1 going low, so too is each 'O/C' output pulled to ground by IC2, which allows this ic to act as a slave for IC1 without burdening the load already seen by the outputs of IC1.

Here lie the reasons for the jumper links mentioned previously. While the relays provide voltage-free contact outputs, their operation can only be very slow due to their mechanical aspects. If, for your particular application, you require some high speed outputs together with some relay outputs, then the jumper links for the relays connected to your high speed outputs can be removed. This will prevent the irritating and undesirable relay 'buzzing' due to the rapid turn-on and -off time periods.

The use of relay contacts and open collector outputs is not limited to a choice between slow relay outputs or high speed open collector outputs. They can be used simultaneously at the slower relay switching speeds to give operation of one and the other if required, which facilitates the connection of additional devices to each output channel. Or they can be used simply to provide remote indicator lamps for the states of the relays, without having to use the relay contacts themselves. This is very useful if you have two devices to control which operate at different voltages, since one of them can be connected to the relay contacts and the other to the corresponding open collector output.

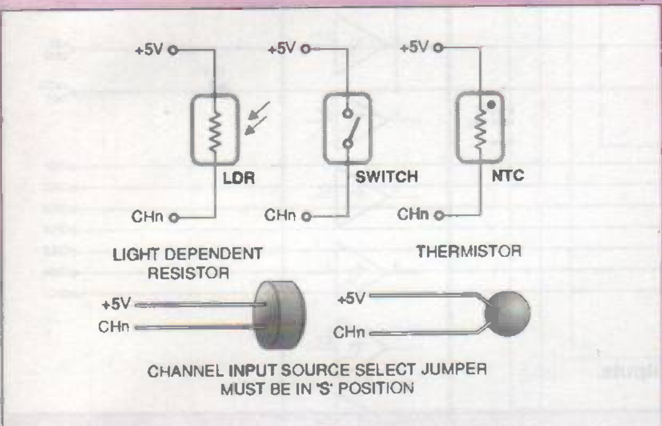
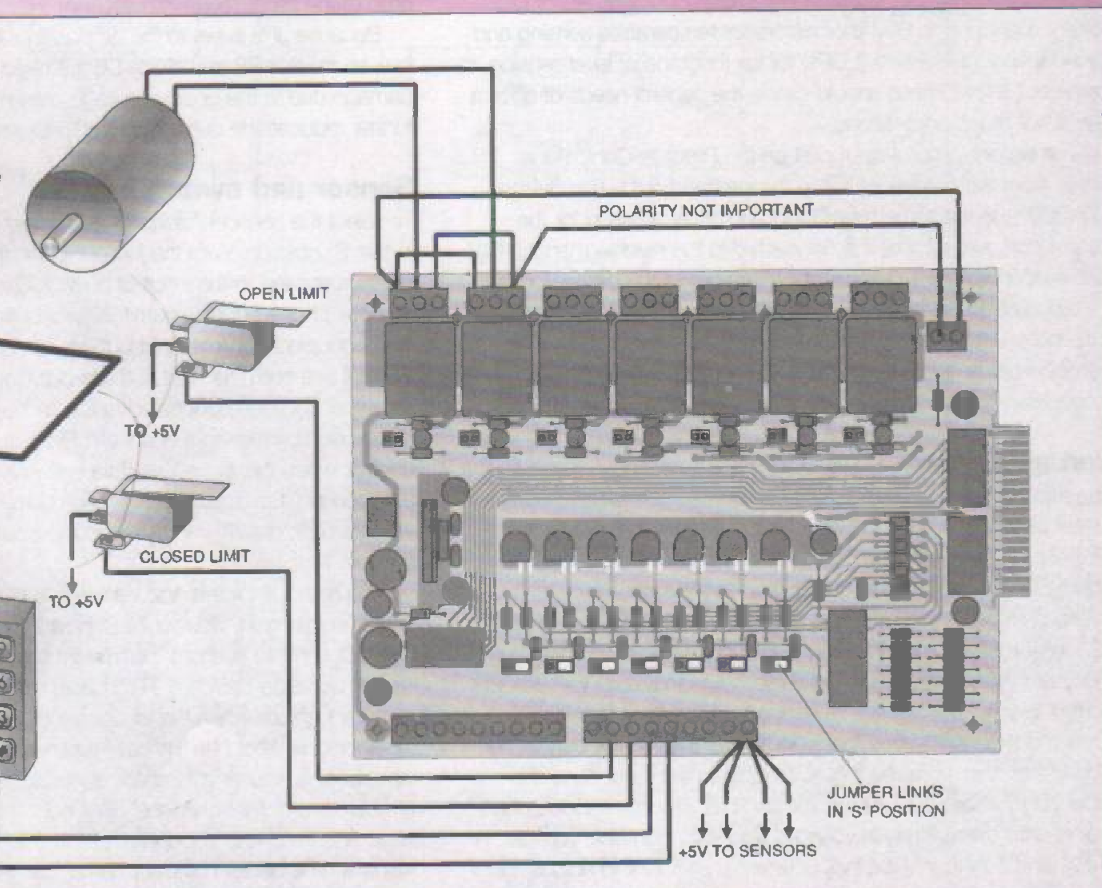


Figure 2: the basic components of the Automatic Gate Controller

Inputs

Rather than restricting the use of the inputs to the more usual (and mundane) digital TTL signal levels, it was decided beneficial to

Figure 3: connections between the interface card and the external devices. (For reasons of clarity, the supply connections and interface cables to the card are not shown here.)



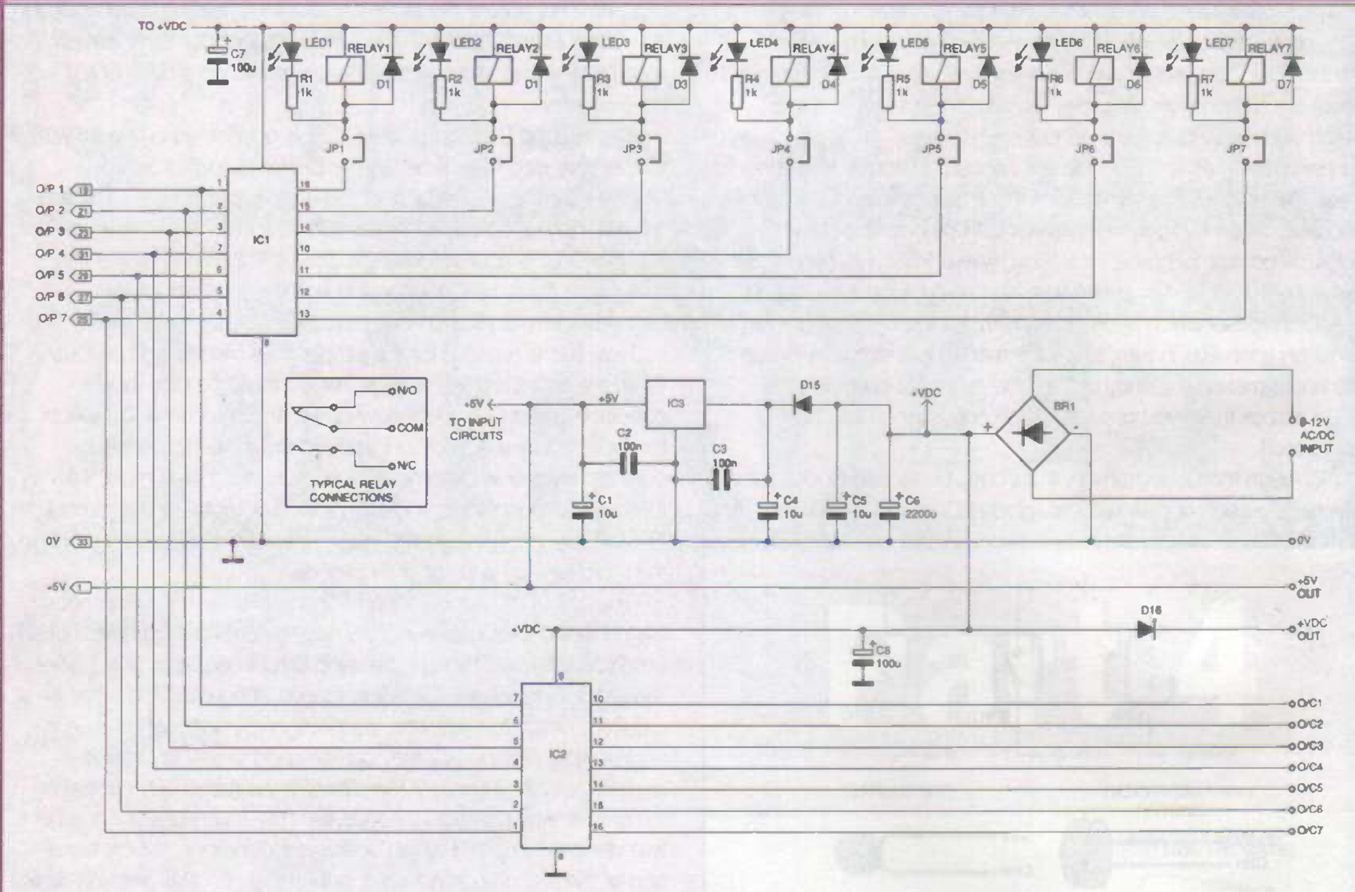


Figure 4: Power supply input, 7 channel relay and open collector outputs.

provide the facilities to accept input signals from a wide range of sources on each of the seven channels. To this end, each channel will directly accept TTL signal levels, switch contacts, AC or DC voltage inputs up to 50V, thermistors for temperature sensing and light dependent resistors (LDRs) for lux (brightness) level sensing, to name but a few. These should satisfy the general needs of quite a few, if not most, applications.

The expansion bus input port on the Process Controller is driven from the outputs of IC4 in the interface card. This device - ULN2003 - is the same type Darlington driver as used for the output port, except that it is connected in the reverse manner, that is, the open collector outputs of IC4 are fed to the expansion bus.

Since all seven input channels are identical, the following explanation of how they work will make reference to the components based around channel 1, but apply equally and respectively to the remaining six channels.

Voltage inputs

The two position jumper link JP8 selects the input signal source; 'S' for switch or sensor inputs, 'V' for voltage signal inputs. With JP8 set to the 'V' position, voltages ranging from TTL levels up to about 50V (AC or DC) may be applied to the input terminal. This voltage is fed, via R15 to the input of IC4. R15 and zener diode ZD1 ensure that if the input voltage is above about 10 volts, only the zener voltage is used to drive the inputs to IC4, since without current limiting, the highest low-impedance voltage these can accept is around 7 volts. That's not to say the voltage cannot be higher than this, because it can, as long as the input current is reduced to a safe level, which it is via R15. The zener diode only comes into operation with voltages above its clamping voltage (10V), and only then if the input current is sufficient to actually get it conducting, which requires about 5mA itself. With a 50V input signal, the maximum current seen by the zener diode will be 50mA once its been through R15, and that's without taking the voltage drop of the zener diode into account.

Because JP8 is set to the 'V' position, the output of IC5a will be low, so resistor R8 and diode D8 are used to protect the IC from damage due to the positive voltage present at the input to IC4. R8 further reduces the current from R15 to a safe level for D8.

Sensor and switch inputs

To select the sensor or switch input source, JP8 should be placed in the 'S' position. With the jumper link in this position the incoming signal is applied to the input of buffer IC5a. This device is actually an octal bi-directional transmit/receive buffer, and contains 16 cross-coupled Schmitt input buffers, but only one half of it is used. You will see from the inset in the circuit diagram that each buffer has a second one connected to the same pins, but in reverse to those used by the input channels. Pin 1 of IC5 is the data direction control, when this pin is low, data is transferred from pin 11 to pin 9. When pin 1 is high, as is the case here, since it is pulled up to +5V via R29, data is transferred in the opposite direction, from pin 9 to pin 11.

The reasons for this apparent waste of device use are two-fold. First and foremost, we require Schmitt triggering in order to connect sensors such as thermistors and LDRs to the signal inputs, because standard TTL buffers will go into oscillation at very high frequencies when the inputs get close to their switching threshold, as would be the case when the sensor connected to the input begins adjusting its characteristics corresponding to the temperature or light changes. Secondly, the pinout of the device is ideal, and it's cheap enough to use in this manner, yet still 'waste' half of it. The device must also be of the 'HC' or 'HCT' variety to allow the use of relatively high (compared to standard 'LS' TTL

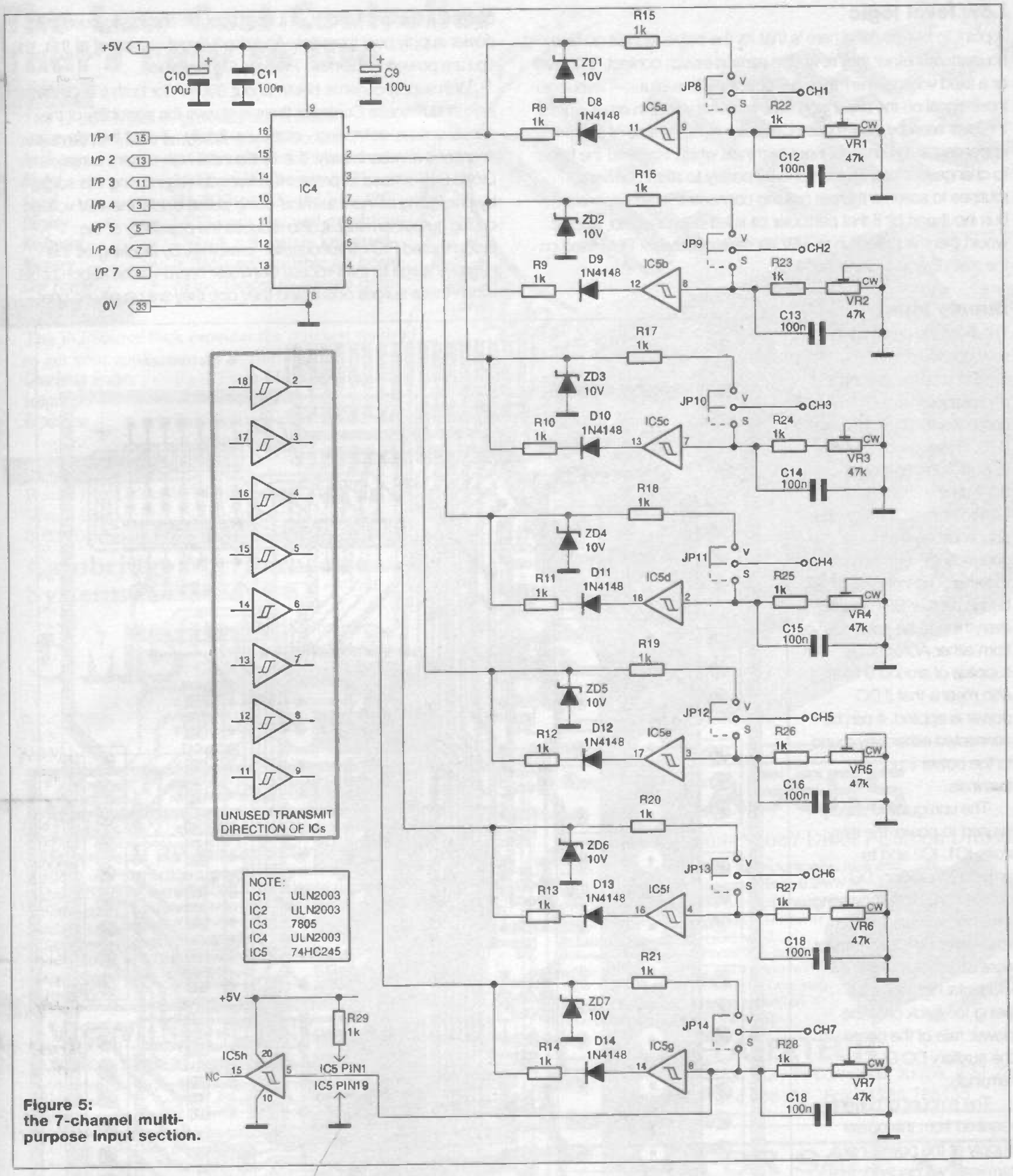


Figure 5: the 7-channel multi-purpose input section.

devices) resistor values on the inputs to the buffers.

With no signal present on the channel input terminal, the input of IC5a is held low by R22 and VR1. This produces a corresponding low output on pin 11, which in turn results in the output of IC4 being turned off or 'floating'. As a matter of interest, it is possible to apply TTL level input signals to the channel input terminal with JP8 set to the 'S' or 'V' position. With an NTC (negative temperature coefficient) thermistor or light dependent resistor connected as shown in the diagrams below, the triggering threshold of either can be adjusted with VR1. In the case of an NTC thermistor, its resistance decreases as the temperature increases. In the case of an LDR, its resistance decreases as the light level increases. So, as the temperature or light level respectively rises, so too will the voltage on pin 9 of IC5a, caused by the potential difference of the sensor, R22 and VR1. It follows then, that VR1 can be used to adjust this voltage, thereby setting the point at which you wish to detect a preset temperature or light level.

The inputs are not restricted to just LDRs and thermistors; these are detailed simply because they are two of the most common devices used. In fact, almost any sensor which exhibits resistance change (including potentiometers) can be connected, just so long as those characteristics are within the adjustment range of presets VR1 to VR7.

Low level logic

A point to bear in mind here is that as the inputs signals go high, no matter whether they're from a sensor, switch contact, TTL level or a fixed voltage, the Process Controller will 'see' a low level logic input signal on the expansion bus, and vice versa. In other words, the level seen by the Process Controller is the inverse of that appearing at the channel input terminals which triggered the buffer to change its state. This is done purposely to allow software routines to assume there is nothing connected to an expansion bus input port bit if that particular bit is left unconnected, since it would then be pulled up to +5V via resistor network RN2 fitted on the main Process Controller.

Supply input

The interface card has its own on-board +5V regulator, based around IC3 and associated components C1 to C6 and D15. This is used not only to power the on-board ics, but also the Process Controller itself, through the ribbon cable which connects the two boards together. The inclusion of bridge rectifier BR1 enables everything to be powered from either AC or DC supplies of around 9 volts. It also means that if DC power is applied, it can be connected either way round to the power input terminals.

The unregulated supply is used to power the relay coils, IC1, IC2 and to provide an auxiliary DC output via D16 for powering external devices. The function of D16 is to protect against accidental or incidental high voltages being fed back onto the power rails of the board via the auxiliary DC OUT terminals.

The amount of current required from the power supply at the power input terminals will depend, to a large extent, on what you intend connecting to the output terminals, which will obviously increase if you are utilising both the relay and open collector outputs simultaneously, and also whether you have the software development board fitted to the ribbon cable, each of which consumes a little more current, maybe not a lot, but it could just be enough to push the power supply over the edge. And don't forget, on top of all this, you are powering the main Process Controller too.

With supply currents below about 300mA for both the interface card and Process Controller there is always the possibility of the supply voltage collapsing - albeit very briefly - if all of the relays are energised simultaneously, due to the initial high current surge. Diode D15 is used to protect IC3 from damage during this surge, by preventing its input terminal being pulled below the +5V voltage on the output terminal. It also reduces the possibility of the programmed PIC microcontroller 'crashing', by blocking off this negative surge to the Process Controller board via the ribbon cable. When these surges occur (and they do), they are usually so brief -

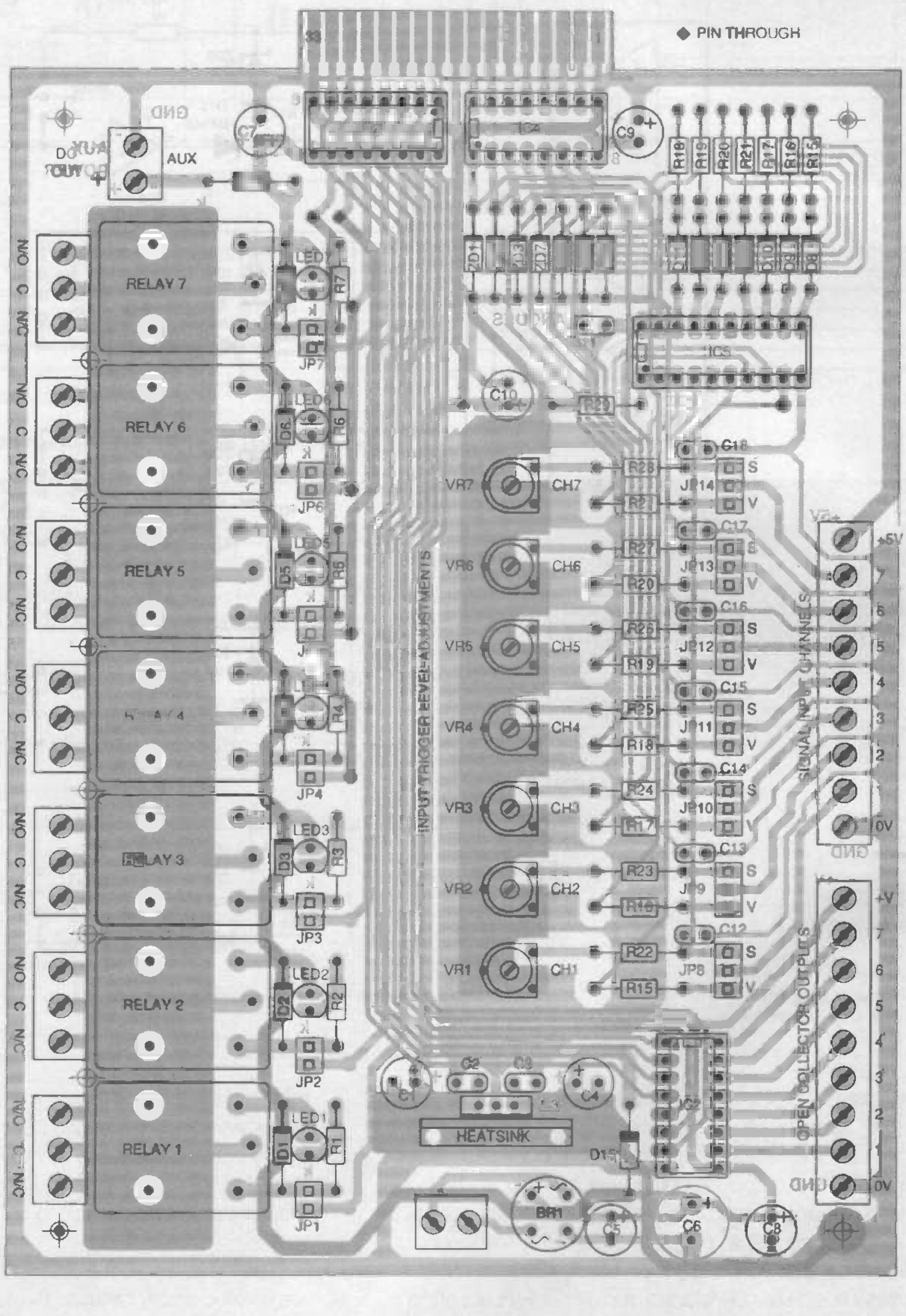


Figure 6 the component layout. The PCB is double-sided. However, as connections between the top and bottom sides are made via component legs, plated-through-holes are not needed

in the order of only a few milliseconds - the capacitance on the Process Controller should be sufficient to uphold its own +5V supply long enough for the main supply to recover.

Construction

The PCB is a fairly large conventional (non PTH) double-sided board. As with all PCB construction, begin with the lowest profile components first - resistors and diodes etc., building up to the highest one, which in this case is IC3 with its heatsink.

There are 8 via or 'feed thru' holes on the board, each of which must have a short length of wire inserted, and soldered to the top and bottom sides of the board. These points are marked on the topside copper track pattern with a heavy 'dot' symbol.

The construction process is pretty straight-forward. Basically, where a component has a pad on both sides of the board, then it must be soldered both sides of the board. Ensure all diodes (including BR1), electrolytic capacitors and ics are fitted in the correct orientation, as once they are soldered top and bottom, they can be very difficult to remove without lifting the copper pads and tracks on the topside of the board.

Three of the dil ics - 1, 2 and 4 - cannot be fitted in sockets, and must be soldered directly to the board, since they all have certain pads which must be soldered both top and bottom. IC5 has been purposely allowed to fit into an ic socket, and you are strongly recommended to do so. Why? Because this is the most likely chip to be destroyed if you accidentally apply a high voltage to one of the input channel terminals when that channel's input source select jumper link is fitted in the 'S' position. Fitting a socket allows IC5 to be replaced easily and repeatedly. This is the voice of experience!

Purchasing relays in this quantity can be a little expensive, particularly if you don't initially have a use for all of them. If you wish to reduce the cost, you can fit only the number of relays required for your application, but remember, ALL of the components which have top and bottom pads MUST be soldered to the board, even the relay protection diodes in the positions where you do not have a relay fitted. This is because these components are used to transfer tracks from the top to the bottom of the board, and leaving them out will result in incomplete continuity.

Don't worry about soldering the presets VR1 to VR7 to the topside ground plane, it is not necessary. Neither are the topside connections to the heatsink mounting pins, although it would be better if you could get a good amount of solder to them, because this will increase the rigidity of the heatsink tremendously.

As always, make a thorough check of the completed board for possible incorrect component orientation. With a repetitive board such as this, it's easy to insert a diode the wrong way round. Fortunately, they're also very easy to spot too. Check also that there are no dry joints or solder bridges, especially in between the ic pins which are soldered to the topside of the board.

In use

Connect the interface card to one of the expansion bus ribbon cable connectors as normal. The interface card is intended to provide power not only for itself, but also the main Process Controller, so disconnect any supply lines you may already have connected to the Process Controller. If sufficient current is available, these may now be connected to the interface card instead.

For the time being, set the input source select links to the right hand 'S' position. Insert the "Darkroom Timer" programmed PIC into the Process Controller and connect a suitable 9V - 12V AC or DC power supply either way round to the power input terminals. There may be a very brief click from each of the relays as the PIC microcontroller initialises itself, but they should all be in the de-energised (off) state once it's running and 00:00 shows in the displays. If not, turn off immediately and check for faults on the interface card, then try again.

If you like, the software development board can be plugged into the ribbon cable together with the interface card, but make sure that all DIP switches on it are open.

The built-in test routine of the darkroom timer program (mentioned last month) can be used to test the correct operation of the interface, only this time the input signals can be simulated by linking the +5V terminal to any of the channel inputs, and the relays will activate in response to them. Note that the /OE control signal is permanently asserted by the interface card, so it makes no difference in which position the link is fitted on the Process Controller.

Using the software

We will now look at implementing the Automatic Gate Controller program described last month on the interface card (the software can be obtained from the author. Also, if there is sufficient demand, ETI will print it next month). The drawing below shows the basic components and the connections required by an automatic gate controller. You will notice from the drawing that the connections are slightly different from those given last month, in that the common connection to the input devices (limit switches, loop detector etc.) is taken to the +5V supply rail, rather than the 0V line. This is because the demonstration had to be performed with the software development board fitted, not the interface card.

No changes are required to the software for this application, as it can be applied directly to the interface card. For those who do not have a ground loop detector and security keypad to hand (which accounts for most of us), these input signals can be simulated either on the software development board (if fitted), or by substituting these units with further normally open (N/O) switches on the interface card, just like the limit switches.

The full explanation of how the Automatic Gate Controller works was given last month, so it will not be repeated here. Suffice it to say that the same procedure is required here as was described previously. The main difference is that you can now connect a small (cassette player type), non speed regulated DC motor to the relay outputs, which was not possible before. The motor's rotational direction will depend on which way round it is connected, and the polarity of the connections to the auxiliary power terminals on the interface card, either of which can be reversed if required.

After the successful testing of the board, power down, remove the "Darkroom Timer" program from the Process Controller, install the "Automatic Gate Controller" program, connect all of the external devices as shown in the diagram, and power back up.

During normal operation, the normally-open contacts of two right hand relays (6 and 7) will reflect the status - open or closed - of the gate open and gate closed limit switches, which could be used for remote signalling. If these are not required, or if they simply get annoying, they can be disabled by removing their respective relay enable jumper links JP6 and/or JP7. If you require some slave outputs, remember that the open collector outputs are being pulled low in sympathy with the relay outputs, even if some relays have been disabled, so these are still available for use in this way.

Because in this application the +5V supply is returned to the input channels, the jumper links are set to the 'S' position. If, in other applications, you intend returning a higher voltage, maybe because it's being generated by some other external device, and cannot be overridden, then set the respective jumper links to the 'V' position, otherwise you will almost certainly destroy IC5 on the interface card, so be ready with another.

The versatility of the PIC microcontroller, coupled with the main Process Controller, removes the ties normally associated with dedicated control systems, and the interface card will serve you well for numerous tasks. All you need to do is write your own software to control it. When you come upon another task, there is no need to purchase an entirely different system, simply change the program and off you go again.

PARTS LIST FOR THE INTERFACE CARD

Parts List

Resistors

R1 - 29	1K (29 off)
VR1 - 7	47K horizontal preset (7 off)

Capacitors

C1, 4, 5	10uF/25V radial electrolytic (3 off)
C2, 3, 11 - 18	100nF polyester or ceramic (10 off)
C6	2200uF/25V radial electrolytic
C7, 8, 9, 10	100uF/25V radial electrolytic (4 off)

Semiconductors

BR1	WO2 - 1.5A/200V bridge rectifier
D1 - 7, 15, 16	1N4001 rectifier diode (9 off)
D8 - 14	1N4148 signal diode (7 off)
IC1, 2, 4	ULN2003 Darlington driver (3 off)
IC3	7805 +5V regulator
IC5	74HC245 octal bi-directional buffer
LED1 - 7	3mm red LED (7 off)

Miscellaneous

RELAY1 - 7	12V/400R 5A SPDT PCB relay (7 off)
Terminals	2-Way PCB terminal block (2 off)
	3-Way PCB terminal block (13 off)
	2-Way PCB pin header (7 off)
	3-Way PCB pin header (7 off)
JP1 - 14	0.1-in jumper links (14 off)
Heatsink	PCB mounting heatsink for IC3
	M3 nut, screw and washers
Supports	PCB support pillars (5 off)
PCB	DTE Process Controller D/S Interface Card

All items listed are supplied in the component kit

Caution

Our apologies for ending on a serious note, but it is well justified. Although only low voltages have been used in the examples, undoubtedly some of the more adventurous constructors among you are going to want to control some form of mains powered device - lighting being possibly the most common example. While there is no reason this cannot be done, it must be stressed that extreme care must be exercised when doing so, and only attempted by persons fully competent in this area.

For these purposes, the interface card MUST be fitted securely inside a suitable enclosure, and all metal parts of that enclosure must be earthed for safety. Do not take any risks with mains voltage electricity, it is lethal, and can be fatal.

Kits and bits

A complete kit of parts for the Interface Card, which includes the PCB and all of the components in the parts list, 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

KIT:	Expansion Bus Interface Card (PCB included)	£39.00
PCB:	Expansion Bus Interface Card (PCB only)	£15.00

PARTS FROM EARLIER ISSUES

Part 3

KIT:	Software Development Board (PCB included)	£11.00
PCB:	Software Development Board (PCB only)	£ 5.50
PIC:	16C54 Programmed for Automatic Gate Controller	£ 9.00

Part 2

KIT:	Process Timer PSU / Interface (PCB included)	£21.50
PCB:	Process Timer PSU / Interface (PCB only)	£ 7.80
CASE:	Suitable (undrilled) ABS plastic enclosure for PSU	£ 3.75

Part 1

KIT:	Process Timer / Controller Main Controller (kit includes D/S PCB and Programmed PIC16C54)	£29.50
PCB:	Process Timer / Controller (D/S PCB only)	£ 9.00
PIC:	16C54 Programmed for Darkroom Timer Project	£ 8.50
CASE:	A smart (undrilled) sloping front enclosure (The PCB was designed to fit this case)	£ 8.00
CABLE:	1-metre pre-assembled 34-way expansion bus cable fitted with three 34-way bus connectors:	£4.00

Software

PIC source code listings for the Process/Darkroom Timer Expansion Bus test routine and Automatic Gate Controller.

Fully documented source code listings on 3.5 inch disk £ 8.50

Fully documented source code listings - printed copy £ 8.50

All prices are inclusive, but please add £2.50 (UK) or £4.00 (elsewhere) to the total order value to cover carriage and handling charges. If ordering from overseas, payment must be in pounds Sterling (£). Cheques, bank drafts or money orders etc. must be drawn on a British bank.

Goods will normally be dispatched within five working days from receipt or order, subject to availability and cheque clearance, but please allow up to 28 days for delivery.

SIMPLE POWERLINE SIGNAL CONTROLLER

Part 2

In last month's article Bart Trepak described the construction of a simple receiver for a mains carrier remote control system for switching one or two appliances on or off independently. In this concluding article the companion transmitter is described

In keeping with the philosophy of keeping this design simple, the circuit of the transmitter consists basically of two oscillators and power supply. The full circuit diagram is shown in figure 5, and closely follows the block diagram shown last month. The circuit again uses a capacitor to drop the mains voltage down to 15 volts for the rest of the circuit. This is cheaper than using a transformer as the supply current requirements for the circuit are quite small and isolation from the mains is not required; indeed it is undesirable in this case, provided, of course the user is suitably and properly isolated from the circuit, which can easily be achieved by mounting the finished unit in a plastic box. C1 provides this mains dropping function with R1 serving to discharge this capacitor when power is removed, and R2 preventing the injected carrier signal from being "shorted out" by the zener diode D2. D2 clamps the voltage to 15 volts and this is rectified to provide a -15V dc supply by D1 and C3. There is no particular reason for having a negative supply, it just made the PCB layout slightly easier.

The transmitter

The heart of the circuit is TR1 which is connected as a Hartley oscillator. The frequency of oscillation is determined by the inductance of the transformer (a similar unit to that used in the receiver) and capacitor C5, and will be approximately 100kHz with the components specified. This can be adjusted over a small range as can the corresponding coil in the receiver to enable both circuits to be tuned to the same frequency. The signal is coupled to the mains via the secondary of the transformer and C2. (A word of warning, incidentally, about C1 and C2. These capacitors should be rated for 250V ac operation and preferably be self healing types, as failure of these components could cause severe damage to the rest of the circuit. This also applies to the capacitors C1 and C7 in the receiver).

R5 (or R6)	1kHz	10f kHz	15f kHz
15k	2.27	22.7	34.1
18k	1.89	18.9	28.4
22k	1.56	15.6	23.4
27k	1.23k	12.8	19.2
33k	1.04	10.4	15.6
39k	0.86	8.6	12.9
47k	0.76	7.6	11.4
56k	0.66	6.6	9.9
68k	0.53	5.3	7.9
82k	0.45	4.5	6.8
100k	0.37	3.7	5.6

Table 1

Transistor TR1 only receives base current via R4 when the outputs of IC1d or IC2d are low (ie at -15V) and since these outputs are normally high (ie at 0V), it is therefore normally off and not oscillating. The coding for each channel is performed by a single CMOS 4001 (quad NOR gate) IC. The first two gates are connected as a monostable, which produces a pulse of about 0.4 seconds each time the push button is pressed and enables the oscillator based on the other two gates in the package. To generate two tones to control two appliances, two such circuits are required and both ICs operate in the same

R4	F_{osc} kHz
2M7	4.9
2M2	6.0
1M8	7.2
1M5	9.0
1M2	10.8
1M0	13.0
820k	15.5
680k	18.3
560k	22.3
470k	28.3
390k	30.6
330k	37.6

Table 2

way except that the two oscillator frequencies set by R5 and R6 are different. The oscillator outputs are used to gate the 100kHz oscillator built around TR1 via the OR gate formed by diodes D3 and D4, so that this transistor produces a burst of 100kHz oscillation each time the output of the tone oscillator goes low to -15V.

If more than two receivers are to be controlled, further circuits similar to that constructed around IC1 should be built but with different values of R5 and each connected to R4 via a diode. If the resulting frequency is such that more than 512 cycles are produced each time the push button is pressed, then R9 which controls the monostable time constant will also need to be modified.

A single monostable/oscillator circuit using one IC could have been built and the frequency selected by means of a single pole multi-way rotary switch which would switch in different values of R5. A double pole switch would be required if R9 also needed to be varied. Since a 4001 and the associated components cost much less than a rotary switch two individual circuits were used but for more channels, the economics may be different.

Construction

The transmitter circuit is best constructed on a printed circuit board and a suitable layout is shown in figure 6. As usual, pay particular attention to diode and electrolytic capacitors to ensure that these are inserted into the circuit the correct way around. The ICs are CMOS devices and should be handled carefully to minimise the risk of damage due to static. Sockets for these devices are therefore recommended.

Note that capacitors C1 and C3 are mounted flat on the pcb. This is done to allow clearance for the two push button switches S1 and S2 which would otherwise not protrude through the holes in the box. Note also the orientation of the switches. If different style push switches are used which are taller, it may not be necessary to lay the capacitors down. Alternatively, panel-mounted push switches could be used and wired to the circuit board. Different switches may have different connections and it should be remembered that the ones specified have four terminals. In the case of the switch adjacent to the terminal block, two of the connections are used as a jumper link across the tracks and this connection should be made by a wire link if the switch used does not make this connection.

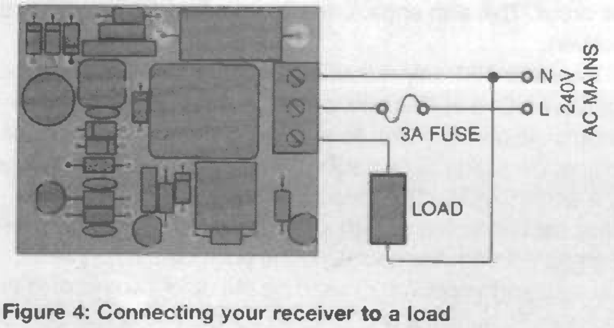


Figure 4: Connecting your receiver to a load

REMEMBER THAT BOTH THESE CIRCUITS OPERATE DIRECTLY FROM THE MAINS AND HIGH VOLTAGES ARE PRESENT. DISCONNECT THE CIRCUIT FROM THE SUPPLY BEFORE ATTEMPTING ANY SOLDERING. DO NOT TOUCH OR EARTH ANY PART OF THE CIRCUIT. MAKE ANY ADJUSTMENTS ONLY WITH A PLASTIC TRIMMING TOOL. USING A METAL SCREWDRIVER OR TOUCHING LIVE PARTS COULD RESULT IN "FRIED CHIPS" OR WORSE - FATAL DAMAGE TO YOU.

Testing

Testing the units must of necessity be carried out when the circuits are out of their boxes so that great care must be exercised. It is perhaps best to secure the circuit board to a board so that there is no tendency for the circuit to fall off the bench when leads are connected. Note that the circuit must not be earthed at any point as damage will occur and for this reason an oscilloscope or any other earthed test equipment should not be used unless you are sure that the inputs to such equipment are floating and not at earth potential. A 60W light bulb temporarily connected in series with the live terminal will prevent any disconcerting bangs and blown fuses and pcb tracks in the event of a mistake in connecting the units to the mains but may not prevent damage to low voltage components.

When assembly of the transmitter is complete, connect a piece of two core mains flex to the terminal block on the transmitter board and connect the unit to the mains via a plug fitted with a 2A fuse. Note that the earth pin of the plug is not used. Switch on and with a multimeter set to 20V dc check that a voltage of about 15V dc is present between pins 7 and 14 of both IC holders (pin 7 negative). The same test should be carried out on the receiver(s), with the same precautions, except that here the voltage across C8 should be around 12 volts and that at pins 7 and 8 of the IC about 4.5 volts (pin 7 negative). If this is the case, switch off, disconnect the units from the mains supply and plug in IC1 in the receiver(s) and ICs 1 and 2 into the transmitter.

Next solder a piece of insulated wire between pins 6 and 14 of either IC1 or IC2 on the transmitter and switch on the supply. This will enable the oscillator TR1 and cause it to generate a 100kHz signal continuously. The voltage across TR2 in each receiver should be monitored on a dc voltmeter and set to a minimum value by adjusting the tuning of the transformer T1 in each receiver. This again should be done with a plastic tool as a metal screwdriver, as well as being potentially dangerous, could alter the tuning or break the fragile ferrite material. When this has been done, the transmitter should be removed to a distant location (electrically) such as a mains outlet in another room which is not on the same circuit as the one where the receivers are plugged in and the test repeated to ensure that all transmitters and the receiver are adjusted to the same carrier frequency.

When this has been done, the link on the transmitter should be removed and the transmitter returned to the bench. The voltage across TR2 should be monitored and should read about 4 or 5 volts falling to a lower value when a push button is pressed. While keeping the button depressed, note that the voltage returns to its original value after a short time which

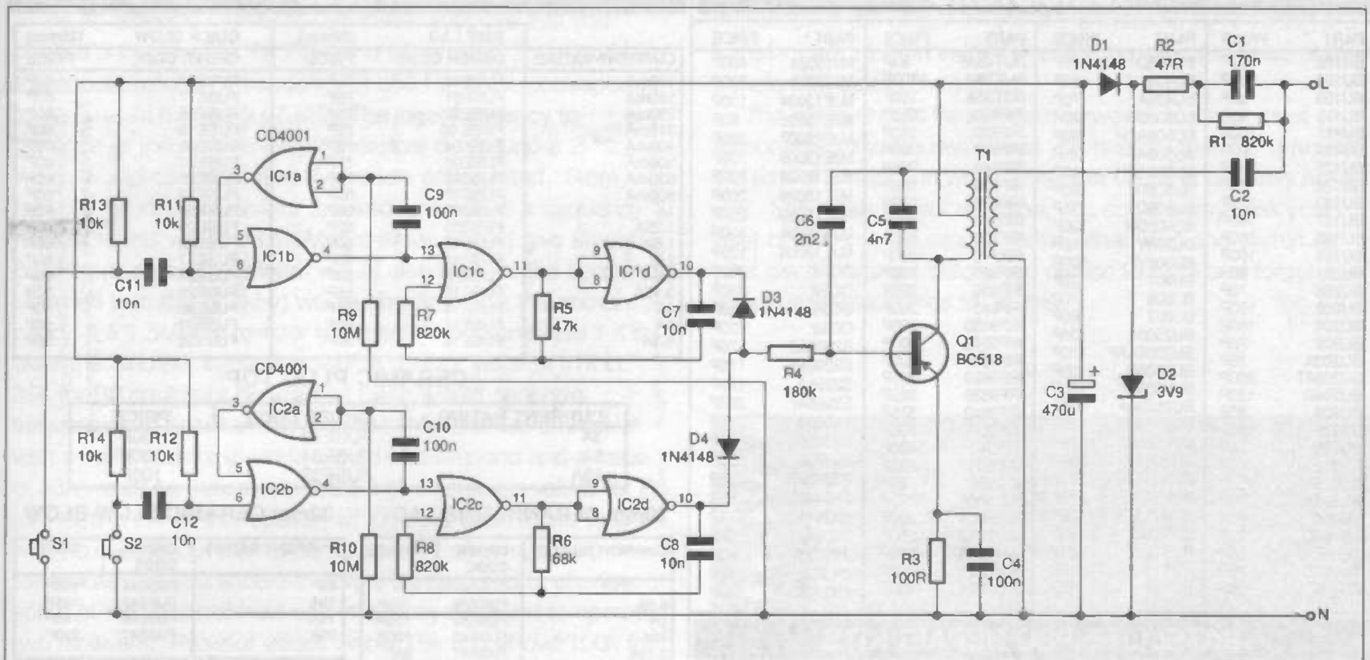


Figure 5: The power line signal transmitter

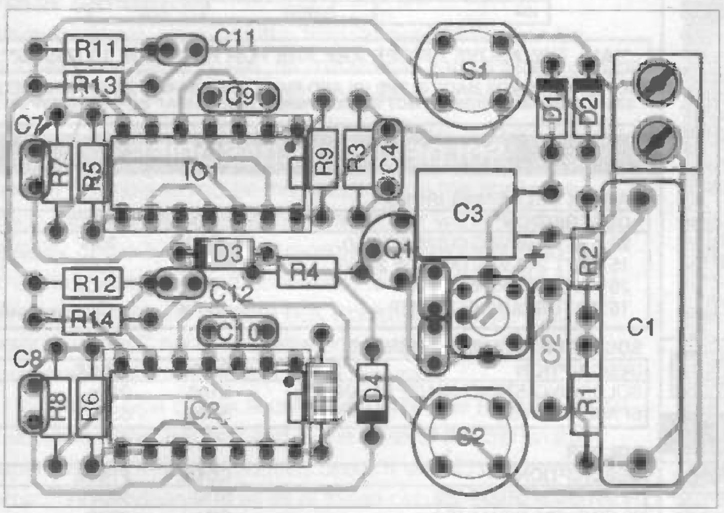


Figure 6: The PCB layout and component overlay for the transmitter

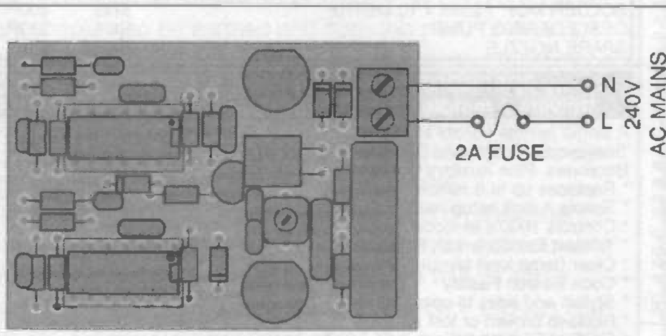


Figure 7: Connecting your transmitter to the mains

shows that the monostable part of the transmitter circuit is also working. The relay in the corresponding receiver should also switch on and then off on a subsequent operation of the push button.

Because the value of R4 is not very critical, the values suggested in the parts list should work without modification. If other channels are also required, the proposed value of R5 (or R6) in the transmitter should first be tested to ensure that no other receivers are activated with this value. A preset may then be connected in place of R4 in the receiver and its value adjusted until the relay in the receiver responds. The preset setting should be varied in both directions (up and down in value) until the relay stops responding before being adjusted to the mid point between these settings. The value of resistance may then be measured and the preset replaced by the nearest preferred value of fixed resistor.

R5 (or R6)	R4
100k	2M7
68k	2M2
47k	1M5
27k	820k
15k	390k

Table 3

The relatively large tolerance in the frequency to which the receiver will respond will limit the number of different channels which can be implemented, but it should be possible to make at least six using the above method. To make the resistor selection easier, table 1 gives measured values of the tone frequency "f" obtained from the transmitter prototype with various values of R5 together with calculated values of 10f and 15f which are the limits within which the frequency of the oscillator in the receiver will need to be set. Table 2 shows the frequency "Fosc" obtained at pin 2 of IC1 in the receiver for various values of R4. Note that these are measured values and make no allowances for component tolerances but they give a rough idea of the values required to obtain correct operation.

TRANSISTORS

PART	PRICE	PART	PRICE	PART	PRICE	PART	PRICE
BU105	80P	BU408D	75P	BUT18AF	80P	MJ15024	400P
BU108	100P	BU409	85P	BUT30V	1700P	MJ15025	700P
BU109	80P	BU426A	70P	BUT56A	100P	MJE13004	100P
BU110	90P	BU506DF	120P	IRF450	650P	MJE13005	60P
BU111	100P	BU508APH	80P	IRF520	150P	MJE13007	100P
BU124	60P	BU508AF	95P	IRF530	300P	MJE13009	100P
BU125	100P	BU508APH	80P	IRF540	300P	MJE15028	200P
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
BU407D	75P	BUT18	80P	MJ15022	250P		
BU408	60P			MJ15023	400P		

SATELLITE PSU REPAIR KITS

Experience shows that 50% of all receiver power supplies 'bounce' unless the correct precautionary measures are taken when being serviced. A kit of all the recommended parts is supplied for the most popular models, which when fitted should overcome this.

MAKE & MODELS	ORDER CODE	PRICE
PACE PRD800, PRD900	SATPSU1	650P
PACE SS900, 9200, 9010,9210, 9020, 9220	SATPSU2	650P
AMSTRAD SRD510, SRD520	SATPSU3	650P
AMSTRAD SRD500	SATPSU4	650P
AMSTRAD SRX340, SRX345, SRX350	SATPSU5	650P
PACE D100/150	SATPSU6	650P
CHURCHILL D2MAC	SATPSU7	650P
PACE MSS100	SATPSU8	730P
PACE MSS200/300 APPOLLO	SATSPU9	650P
PACE MSS500/1000	SATPSU10	1230P
FERGUSON SRD4	SATPSU11	835P
ECHOSTAR SR5500	SATPSU12	1735P
ECHOSTAR 6500/7700/8700	SARPSU13	3125P
AMSTRAD SRD600	SATPSU14	3125P
MIMTEC (Surensen)	SATPSU15	775P
AMSTRAD SRD700/SR950/SRX100/302 SRX501/502/1002/2001/SRD2000 SAT250	SATPSU16	730P

PACE 9000 SWITCH MODE TRANSFORMER
ORDER CODE; PACE9000 PRICE 800p

SERVICE AIDS

DESCRIPTION	VOLUME	CODE	PRICE
VIDEO HEAD CLEANER	75 ML	SP01	160P
VIDEO HEAD CLEANER	200 ML	SP27	250P
SWITCH CLEANER	176 ML	SP02	170P
SUPER 40	400 ML	SP15	250P
SILICONE GEASE	200 ML	SP03	210P
FREEZE IT	170 ML	SP04	300P
FREEZE IT	400 ML	SP16	600P
FOAM CLEANER	400 ML	SP05	180P
ANTI STATIC	150 ML	SP06	190P
AEROKLEANE	200 ML	SP07	220P
AERO DUSTER	150 ML	SP08	310P
AERO DUSTER	400 ML	SP17	550P
PLASTIC SEAL	200 ML	SP09	250P
GLASS CLEANER	250 ML	SP10	160P
COLDKLENE	250 ML	SP13	230P
EXCEL POLISH 80	250 ML	SP18	150P
ADHESIVE 120	400 ML	SP19	190P
LABEL REMOVER 130	200 ML	SP20	240P
REFURB 140	400ML	SP21	240P
TUBE SILICON GREASE	50 GRAMMES	SP11	220P
TUBE SILICON SEALANT WHITE	75ML	SP22	280P
TUBE SILICON SEALANT CLEAR	75 ML	SP23	280P
TUBE HEAT SINK COMPOUND	25 GRAMMES	SP12	150p
DRIVE CLEANER	200ML	SP24	150p
SCREEN CLEANER	200 ML	SP25	150P
COMPUTER CARE KIT		SP26	2100P
ANTI STATIC FOAM CLEANER	400 ML	SP28	175p
AIR DUSTER	400 ML	SP29	450P

ALL THE ABOVE ITEMS ARE MANUFACTURED BY SERVISOL

IF YOU PURCHASE MORE THAN ONE SERVISOL PRODUCT POSTAGE & PACKAGE WILL BE CHARGED AS FOLLOWS: 300p FOR 5 CANS 450p FOR MORE THAN 5 CANS

FUSES

	TIME LAG (20mm)		QUICK BLOW (20mm)	
CURRENT RATING	ORDER CODE	PRICE	ORDER CODE	PRICE
100mA	FUSE36	75P	FUSE37	60P
160mA	FUSE01	75P	FUSE17	60P
250mA	FUSE02	75P	FUSE18	60P
315mA	FUSE 03	75P	FUSE19	60P
400mA	FUSE04	75P	FUSE20	60P
500mA	FUSE05	75P	FUSE21	60P
630mA	FUSE06	75P	FUSE22	60P
800mA	FUSE07	60P	FUSE23	60P
1A	FUSE08	60P	FUSE24	60P
1.25A	FUSE09	60P	FUSE25	60P
1.6A	FUSE10	60P	FUSE26	60P
2A	FUSE11	50P	FUSE27	60P
2.5A	FUSE12	50P	FUSE28	60P
3.15A	FUSE13	55P	FUSE29	50P
4A	FUSE14	55P	FUSE30	50P
5A	FUSE15	60P	FUSE31	50P
6.3A	FUSE16	60P	FUSE32	50P

CERAMIC PLUG TOP

CURRENT RATING	ORDER CODE	PRICE
3A	FUSE33	100P
5A	FUSE34	100P
13A	FUSE35	100P

20mm CERAMIC TIME LAG

CURRENT RATING	ORDER CODE	PRICE
6.3A	FUSE38	100P
8A	FUSE39	100P
10A	FUSE40	100P
3.15A	FUSE41	85P
4A	FUSE42	85P
5A	FUSE43	85P

32mm CERAMIC SLOW BLOW

CURRENT RATING	ORDER CODE	PRICE
8A	FUSE44	185P
10A	FUSE45	185P
15A	FUSE46	185P
20A	FUSE47	210P

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22 SWG 500 GRAMMES	SI12	700P

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DESCRIPTION	CODE	PRICE
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As an example of how to use these, suppose that you choose a value of 56k for R5 in the transmitter. From table 1 this should result in a frequency of 658 Hz which corresponds to an Fosc of 6.58 to 9.87 kHz. The ideal frequency to generate at the receiver would therefore be around 8.2kHz which would correspond to the middle of this band. From table 2, the value of resistor required to produce a frequency nearest to this would be 1.5Mohm which should give around 8.9kHz. A value of 1.8Mohm would also work as the frequency obtained with this (7.2kHz) would also fall within the above band. If a 1.5Mohm resistor is chosen, then from table 1 it is clear that another transmitter with a resistor value of 47k or 39k for R5 could not be used as these would generate frequencies of between 7.5 and 12.3kHz to which a receiver with a 1.5M resistor (8.9kHz) would also respond and a value of 33k would be indicated. Table 3 gives suitable values for R5 (or R6) and R4 (in the receiver) which have been found to work with no overlap but this takes no account of component tolerances and you should therefore be prepared to change some of the values should one frequency be found to operate two receivers. Resistor values below 15k and above 100k for R5 could also be used provided corresponding values are used for R4 in the receivers although this has not been tried.

Final assembly

When testing is complete, the finished assemblies can be mounted in suitable boxes. As mentioned, the receivers can be built into either a "plug" type box or a more conventional plastic box fitted with a socket into which the appliance to be controlled can be plugged in. Alternatively, if space allows, it may be possible to mount the circuit inside the appliance which it is intended to switch although this will limit the flexibility of the system. The transmitter is best mounted in a small hand held box and connected to the mains via a two core mains cable. A suitable box would be the type sold for "remote control" hand-sets although in this case, the battery compartment (if any) would not be required.

Whatever type of box is used will determine how the circuit is secured within the box and in the case of the transmitter depending on the push buttons used. It should be remembered however, that all of these circuits operate at mains potential so plastic boxes are preferred and care should be taken to ensure that fingers or screwdrivers cannot be pushed into the box to touch any of the live parts. All exposed metal parts such as screws supporting or securing any circuit board should also be earthed and from this point of view, it is probably best to avoid these and use self adhesive plastic pcb supports if possible. Remember also to ensure that the mains cable enters the box through a suitable grommet and is well secured within the box so that it cannot be pulled out. Do not rely on the terminal blocks on the board for this.

The range of the finished units will depend on a number of factors such as the wiring layout of the house and the number and types of appliance which are connected to it. In some circumstances, appliances plugged into adjacent sockets can attenuate the signal considerably and if this is the case, some repositioning may be required. It is also possible for some appliances which generate a large amount of interference to swamp the available signal and make the system fail to operate correctly. The range beyond the confines of the house has also not been tested but should not be a problem. If you find that your neighbours system is switching on your morning coffee at bed time or your electric blanket on in the morning just after you have got up, it is an easy matter to change the frequency of the carrier in one of the systems by re-tuning the transformers T1 or in extreme cases changing the value of the transformer tuning capacitors.

The range should be sufficient however, to cover most reasonable sized houses unless you happen to live in a house the size of a palace in which case this circuit is probably not for you. Still, if this is your situation, you could always ask your valet or butler to nip around to the other wing and switch on your electric blanket before you decide to retire and forget about using electronics to do this!

PARTS LIST FOR THE POWERLINE SIGNAL

Parts List

R1,R7,R8	820k
R2	47R
R3	100R
R4	180k
R5	47k (see text)
R6	68k (see text)
R9,R10 10M	
R11 to R14	10k
C1	470nF/400V
C2	10n/250V ac
C3	470uF/16V
C4	100n
C5	4n7
C6	2n2
C7,C8,C11,C12	10n
C9-C10	100n
T1*	RD7 Transformer
D1,D3,D4	1N4148 diode
D2	3V9/400mW zener
TR1	BC548 NPN transistor
IC1-IC2	CD4001 quad NOR gate (CMOS)

S1-S2 push switches, PCB, 2-way terminal block, 2x14 pin IC socket, box.

* These items are available from the author at the following prices:

RD7 Transformer £0.50
UM3763 IC £4.50

Pack containing 2x UM3763 plus 3x RD7 transformers £10.00
Prices include UK postage. Please add £2 for overseas orders. Send postal order or cheque to:
B Trepack, 20 The Avenue, London W143 8PH
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£1 BARGAIN PACKS - List 5

If you would like to receive the other four £1 lists and a lot of other lists, request these when you order or send SAE.

TEST PRODS FOR MULTIMETERS with 4mm sockets. Good length very flexible lead. Ref: D86.
8 OHM PM SPEAKER, size 8" x 4", pack of two. These may be lightly rusty and that is why they are so cheap but are electrically OK. Ref: D102.
PAXOLIN PANELS, size 6" x 6", approximately 1/16" thick, pack of two. Ref: D103.
13A SOCKET, virtually unbreakable, ideal for trailing lead. Ref: D95.
PIEZO BUZZER with electronic sounder circuit, 3V to 9V D.C. operated, Ref: D76.
DITTO but without internal electronics, pack of two, Ref: D75.
LUMINOUS ROCKER SWITCH, approximately 30mm sq: pack of two, Ref: D64.
ROTARY SWITCH, 9-pole 6-way, small size and 1/4" spindle, pack of two, Ref: D54.
FERRITE RODS, 7" with coils for long and medium waves, pack of two, Ref: D52.
DITTO but without the coils, pack of three, Ref: D52.
SLIDE SWITCHES, **SPDT**, pack of 20, Ref: D50.
MAINS DP ROTARY SWITCH with 1/4" control spindle, pack of five, Ref: D49.
ELECTROLYTIC CAP, 800µF at 6.4V, pack of 20, Ref: D48.
ELECTROLYTIC CAP, 100µF + 100µF 12V, pack of 10, ref: D47.
MINI RELAY with 5V coil, size only 26mm x 19mm x 1mm, has two sets of changeover contacts, Ref: D42.
MAINS SUPPRESSOR CAPS 0.1µF 250V A.C., pack of 10, Ref: 1050.
TELESCOPIC AERIAL, chrome plated, extendable and folds over for improved F.M. reception, Ref: 1051.
MES LAMP HOLDERS, slide on to 1/4" tag, pack of 10, Ref: 1054.
PAXOLIN TUBING, 1/4" internal diameter, pack of two, 12" lengths, Ref: 1056.
ULTRA THIN DRILLS, 0.4mm pack of 10, Ref: 1042.
20A TOGGLE SWITCHES, centre off, part spring controlled, will stay on when pushed up but will spring back when pushed down, pack of two, Ref: 1043.
HALL EFFECT DEVICES, mounted on small heatsink, pack of two, Ref: 1022.
12V POLARISED RELAY, two chageover contacts, Ref: 1032.
PAXOLIN PANEL, 12" x 12" 1/16" thick, Ref: 1033.
MINI POTTED TRANSFORMER, **ONLY 1.5VA 15V-0V-15V OR 30V**. Ref: 964.
PRE-SET POTS, one megohm, pack of five. Ref: 998.
WHITE PROJECT BOX with rocker switch in top left-hand side, size 78mm x 115mm x 35mm, unprinted. Ref: 1006.
6V SOLENOID, good strong pull but quite small, pack of two, Ref: 1012.
FIGURE-8 MAINS FLEX, also makes good speaker lead, 15m, Ref: 1014.
HIGH CURRENT RELAY, 12V A.C. or 12V D.C.., three changeover contacts, Ref: 1016.
LOUDSPEAKER, 8 Ohm 5W, 3.7" round, Ref: 962.
NEON PILOT LIGHTS, oblong for front panel mounting, with internal resistor for normal mains operation, pack of four, Ref: 970.
3.5MM JACK PLUGS, pack of 10, Ref: 975.
WANDER PLUGS, pack of 10, Ref: 986.
PSU, mains operated, two outputs, one 9.5V at 550mA and the other 15V at 150mA.. Ref: 988.
ANOTHER PSU, mains operated, output 15V A.C. at 320mA, Ref: 989.
PHOTOCELLS, silicon chip type, pack of four, Ref: 939.
LOUDSPEAKER, 5" 4 Ohm 5W rating, Ref: 946.
230V ROD ELEMENTS.750w terminal-ended, 10" long, pack of two, Ref: 943.
LOUDSPEAKER, 7" x 5" 4 Ohm 5W, Ref: 949.
LOUDSPEAKER, 4" circular 6 Ohm 3W, pack of 2. Ref: 951.
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PAXOLIN PANEL, 8 1/2" x 3 1/2" with electrolytics 250µF and 100mF, Ref: 905.
CAR SOCKET PLUG with P.C.B. compartment, Ref: 917.
FOUR-CORE FLEX suitable for telephone extensions, 10m, Ref: 918.
VERO OFF-CUTS, approximately 30 square inches of useful sizes, Ref: 927.
PROJECT CASE, 95mm x 66mm x 23mm with removable lid, held by four screws, pack of two, Ref: 876.
SOLENOIDS, 12V to 24V, will push or pull, pack of two, Ref: 877.
2M MAINS LEAD, 3-core with instrument plug moulded on. Ref: 879.
TELESCOPIC AERIAL, chrome plated, extendable, pack of two. Ref: 884.
MICROPHONE, dynamic with normal body for hand holding, Ref: 885.
CROCODILE CLIPS, superior quality flex, can be attached without soldering, five each red and black, RefF 886.
BATTERY CONNECTOR FOR PP3, superior quality, pack of four,. Ref: 887.
LIGHTWEIGHT STEREO HEADPHONES, Ref: 898.
PRESETS, 470 Ohm and 220 kilohm, mounted on single panel, pack of 10, Ref: 849.
THERMOSTAT for ovens with 1/4" spindle to take control knob, Ref: 857.
12V-0V-12V 10W MAINS TRANSFORMER, Ref: 811.
18V-0V-18V 10W MAINS TRANSFORMER, Ref: 813.
AIR-SPACED TRIMMER CAPS, 2pF to20pF, pack of two, Ref: 818.
AMPLIFIER, 9V or 12V operated Mullard 1153, ref: 823.
2 CIRCUIT MICROSWITCHES, licon, pack of 4, ref: 825.
LARGE SIZE MICROSWITCHES (20mm x 6mm x 10mm) changeover contacts, pack of two, Ref: 826.
MAINS VOLTAGE PUSHSWITCH with white dolly, through panel mounting by hexagonal nut, Ref: 829.
POINTER KNOB for spindle which is just under 1/4", like most thermostats, pack of four, Ref: 833.

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CAT. No.	DESCRIPTION	PRICE £
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I010	5-input Stereo Mixer, with monitor output	I9.3I
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I039	Stereo VU Meter	4.60
I040	I0W HiFi Power Amplifier	2.76
I041	25W HiFi Power Amplifier	4.60
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I048	Electronic Thermostat	3.68
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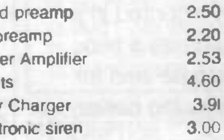

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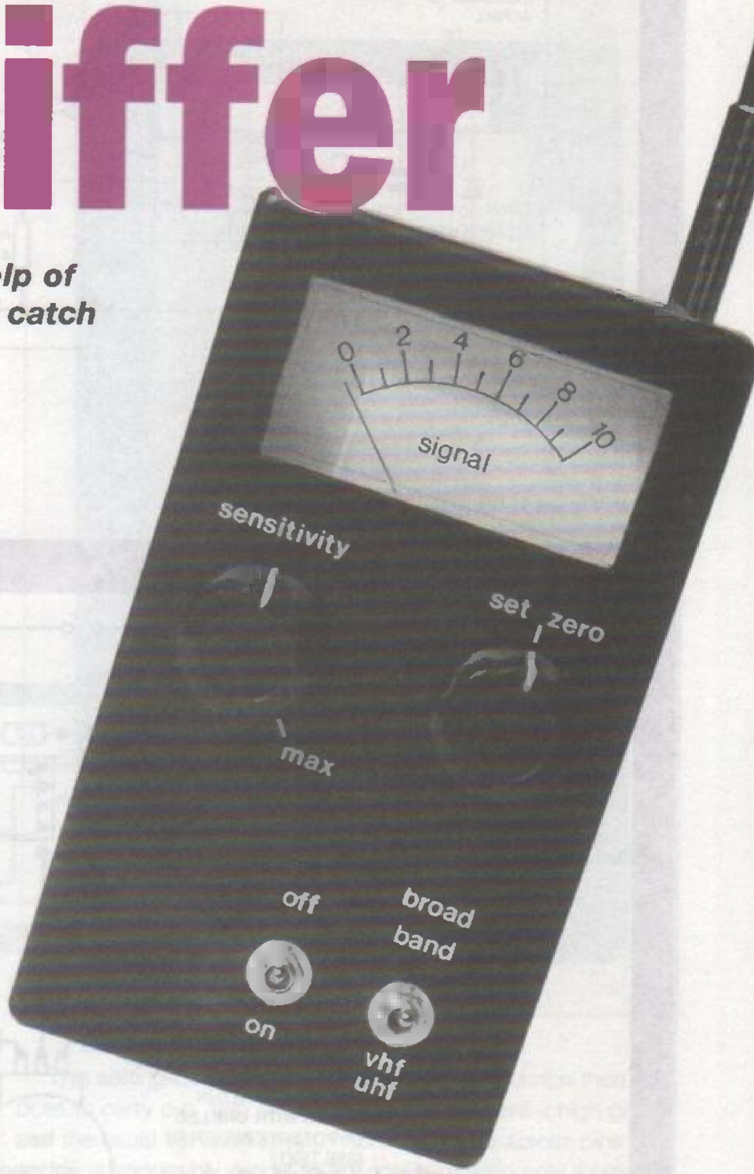
RF Sniffer

Is somebody listening to you? With the help of Raymond Haigh's bug-detector, you could catch them out first

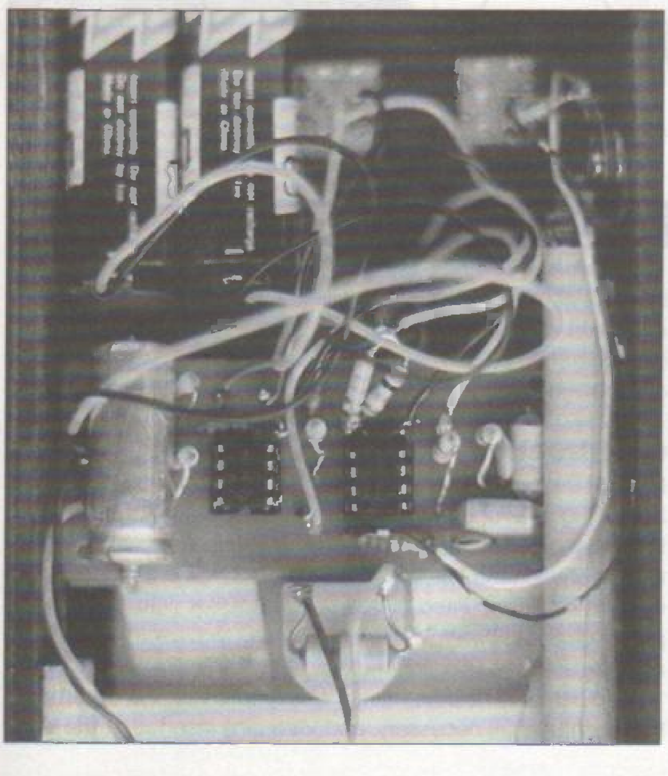


Competition is fierce and pressures to succeed have never been more intense. Espionage is becoming a very real threat in businesses or professions which depend on information and ideas. And the threat is not confined to the workplace: marriage partners concerned that they might have an erring spouse are making increasing use of micro-transmitter style bugs to confirm or ease their suspicions.

These bugging devices are inexpensive and readily available. They can easily be concealed in telephone power outlets, and a thousand and one other places around the home or office.

The 'Sniffer' unit described here is sensitive to RF radiation over a wide spectrum, from around 100 kHz through VHF to 450 or 500 MHz, and it will help detect and locate low-power spy transmitters. Most constructors will have the parts in their spares box (and if they have to be purchased, they are not expensive) and the unit can be assembled in an evening.

So, why not check out your office or home and dispel those nagging fears?



The circuit

The circuit diagram of the unit is given in figure 1.

RE signals picked up by a short telescopic aerial are rectified in a voltage-doubling circuit formed by diodes, DI and D2, and CI The resulting dc is applied to the non-inverting input of operational amplifier, CI. RF choke, L2, and the low value capacitor, C1, act as a simple high-pass filter to prevent the unit responding to low-frequency ac fields. A lower nductance RF choke, L1 can be switched into circuit to bypass low, medium, and some of the higher radio frequencies, and further restrict the response of the unit. C2 shunts residual RF to ground,'and R1 acts as a load for the voltage doubler. The gain of the amplifier is fixed by R4 and R5, which determine the level of feedback to the inverting input of the device.

Resistor combination R2 and R3 null out off-set currents so that the meter pointer can be set at zero under no-signal conditions.

Output from the first op-amp is connected to the non-inverting input of 1C2. Potentiometer R7 varies the level of feedback across this second amplifier, and enables the sensitivity of the unit to be adjusted. R9 sets the meter to read around 3V FSD, and also prevents damage to the movement

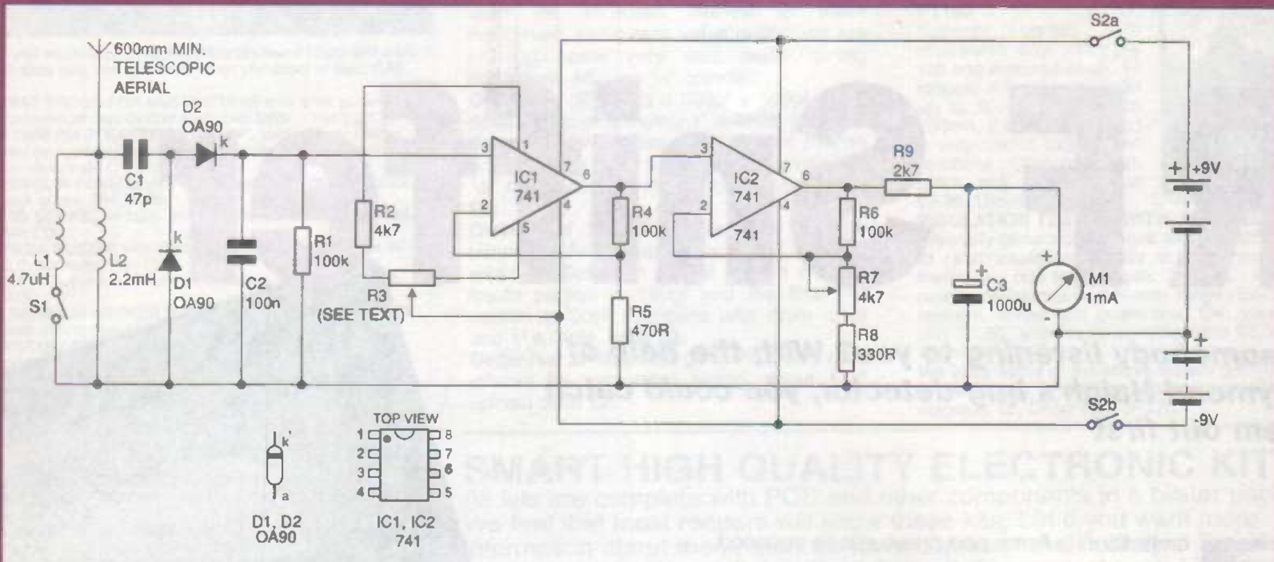


Figure 1: the circuit of the RF Sniffer

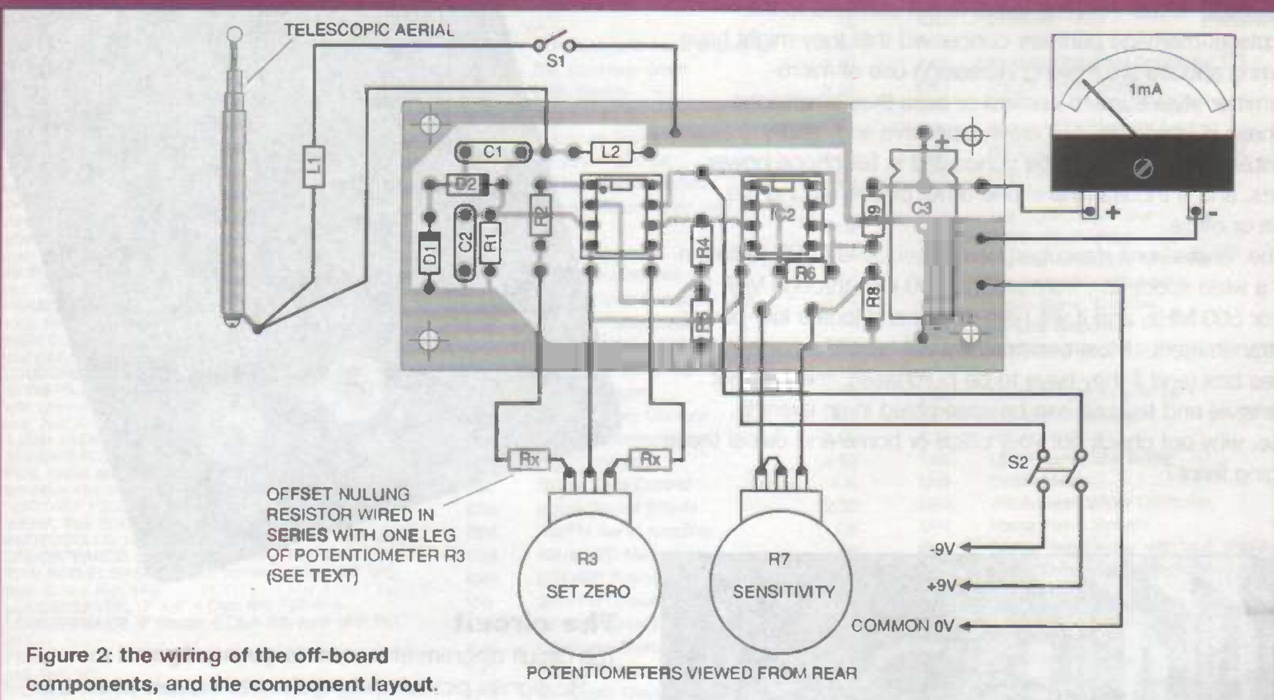


Figure 2: the wiring of the off-board components, and the component layout.

in the event of the second IC being driven into saturation. C3 smooths out any random fluctuations in the output. The dual 9V-0-9V battery supply is switched into circuit by S2A and S2B.

Components

Point-contact germanium diodes should be used for DI and D2 in order to maximise the frequency response and sensitivity of the unit (they conduct at lower forward voltages than silicon diodes). Suitable miniature RF chokes are listed in the Cirkit catalogue, but L1 can be formed by winding 30 tums of 34 or 36 SWG enamelled copper wire on the body of a 0.25-watt 1 megohm resistor. An inexpensive signal strength or 'VU' meter will be suitable as an indicator. These instruments usually have a sensitivity of around 200 uA, and will require shunting, or an increase in the value of R9, to give the required 3-4V full scale deflection. Meter sensitivity is not critical, and a l or 2 mA instrument will be satisfactory for this application with the value of R9 as shown.

Construction

Most of the components are mounted on a small printed circuit board. Figure 2 shows the component side of the board and figure 3 the copper track side. The low inductance choke L1 is wired between the telescopic aerial and S1; and the additional resistor, RX, is mounted on the tags of the set-zero potentiometer, R3. Provision is made on the board for either an axial or radial lead version of electrolytic capacitor C3.

The use of ic holders makes it easy to check the op-amps by substitution, if necessary, and Vero pins inserted at the lead-out points aid off-board wiring. The meter, telescopic aerial, PCB, potentiometers, etc., can be wired up on the bench for testing and setting up before being mounted in a small plastic case.

Setting-up and testing

If clear glass components have been used for DI and D2, they must be shielded from light before undertaking the setting-up procedure. (The photovoltaic effect of the diode junctions is sufficient to swing the meter pointer hard over when the unit is set to high sensitivity).

Make the usual checks for bridged copper tracks and bad soldered joints on the PCB, and check the orientation of the diodes, op-amps and C3. Temporarily connect the 4K7 pre-set in the R3 position (ie to R2 and pin 5 of ICI, with the slider to pin 4 of the IC) and set it to mid-travel. Then, with the meter disconnected, switch on the power supply. Current drain from each battery should be around 2.5mA.

Connect a test meter in place of the 1 mA meter movement, and switch it to read 5 or 10 mA FSD. Adjust the 4K7 pre-set to bring the pointer to zero. It is likely that the slider of the pre-set will be well off-centre. Note whether the higher resistance leg of the potentiometer goes to R2 or pin 5 of the ic.

Connect the 1 K potentiometer (which is to be the actual set-zero control) in the R3 position, and wire the pre-set in series with what needs to be its high resistance leg. Set the 1 K potentiometer to mid-travel, then adjust the pre-set to bring the meter pointer to zero again. Remove the test meter and connect up the 1 mA movement to be used in the Sniffer. Check that its pointer can be brought to zero with the sensitivity control set at maximum and the slider of the I K set-zero control at centre travel, making any necessary adjustments to the pre-set.

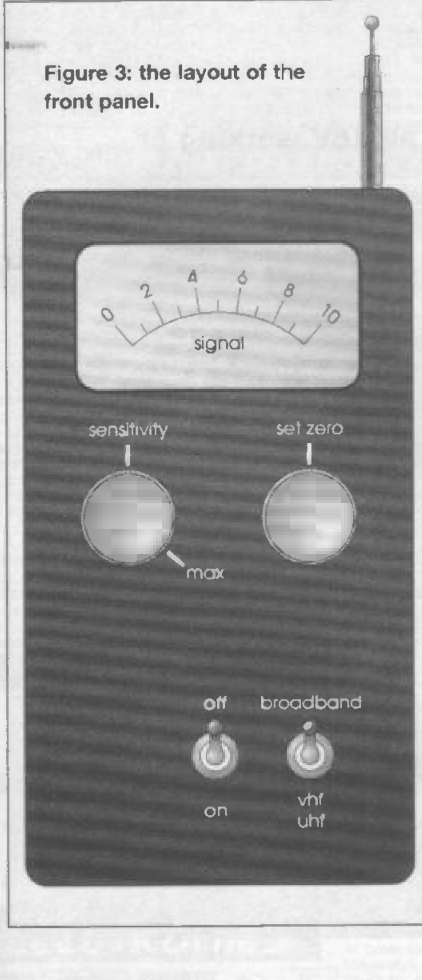
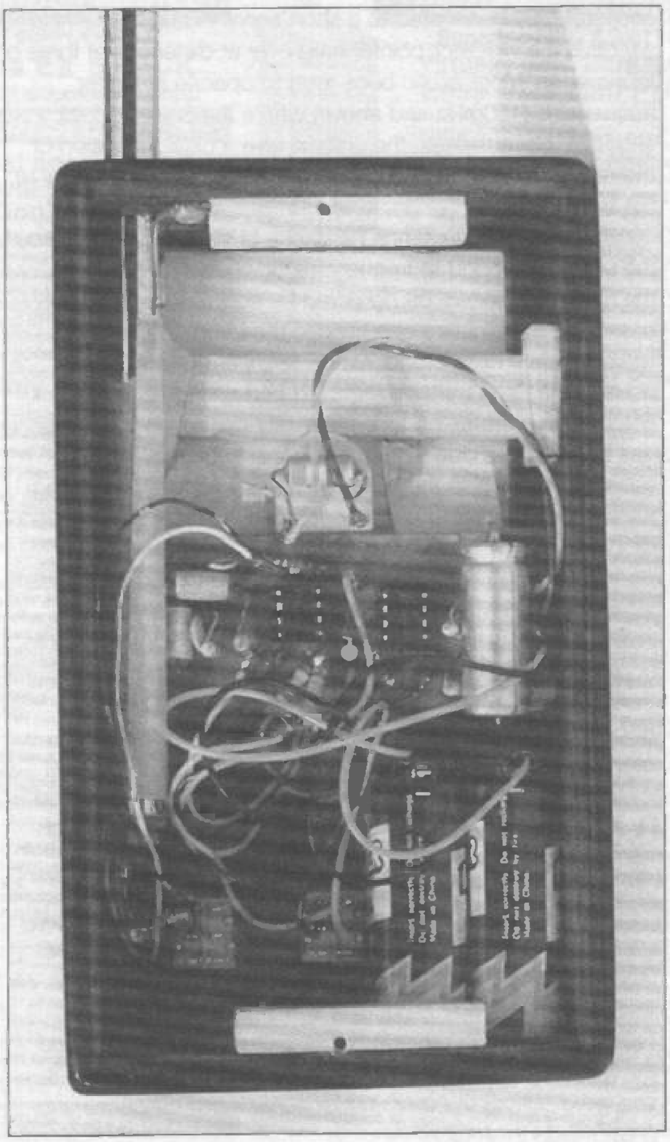


Figure 3: the layout of the front panel.

Measure the resistance of the pre-set and substitute a fixed resistor, RX, of the closest standard value.

A number of 741 op-amps were tried in the ICI position, and offset nulling was always obtained with the 4K7 resistor, R2, connected to pin 1 of the ic. In the remote eventuality of the meter refusing to zero, connect the 4K7 pre-set directly to pin 1 of the ic (ie, short out R2). If a null is obtained with this arrangement, R2 should be connected between the potentiometer and pin 5.



This setting-up procedure takes longer to describe than it does to carry out. Two amplifiers in cascade have a high gain, and the usual 10K nulling potentiometer, wired across pins 1 and 5, is impossibly critical to adjust. By making only a small portion of the potentiometer variable, the action of the nulling or set-zero control is made much more gentle.

A high-quality instrumentation type op-amp with a very low input offset current could have been used for IC1, but these devices are comparatively expensive (and less likely to be found in spares boxes), and the arrangement described above works well when the setting-up procedure has been carried out.

Switch out LI and test the Sniffer by bringing it close to a source of RF radiation. (A computer VDU or a TV receiver should drive the pointer hard over.)

Using the Sniffer

A measure of skill and experience is needed to use the instrument and interpret the comparative scale readings, and it is a good idea to try out the unit at home before embarking on a 'search-and-destroy' mission.

This is not the place to describe the circuitry of eavesdropping bugs. Sufficient to say that simple versions of these micro-transmitters operate within, or close to, the VHF FM broadcast band and radiate about as much RF power as a single bipolar transistor, eg a BCI08, wired as an LC tuned oscillator, and connected to a short aerial. A bug of this kind will drive the indicator pointer hard over at distances of three or four metres. More exotic bugs tend to operate at higher frequencies (450mHz and above) where the Sniffer is less sensitive. Nevertheless, the unit will give a clear indication of the radiation when its aerial is in reasonably close proximity to the transmitter.

With the low inductance RF choke LI switched out of circuit, the unit will respond to frequencies down to 100kHz or so, and the meter pointer will be deflected by signals radiated from broadcast transmitters operating in the Long and Medium wave bands. These broadcast RF fields are intensified by house wiring and metal objects (eg bed springs and the silvering on mirrors), and the sensitivity control on the Sniffer has to be turned down so that any low frequency transmissions within the building can be identified. Adjusting the set zero control to cancel out steady background radiation can also be of assistance.

Micro-transmitters used for eavesdropping invariably radiate at VHF and above, and the Sniffer should normally be operated with LI switched into circuit to make it insensitive to troublesome lower frequencies. Notwithstanding this, personal computers, VDUs and TV receivers are best disconnected from the mains supply while carrying out a search.

Some bugs are designed to be activated for a set period by a telephone call to the room or office. Put a call through from a neighbouring room, or otherwise arrange for the phone to ring, before commencing the search. Similarly, bugs can be installed to transmit only when a telephone call is being received, and a connection should be made to the 'speaking clock' during the course of the survey.

Sweep the Sniffer aerial over light fittings, suspended ceilings, desks and other furniture, pictures, wall clocks and the like. Try and imagine where you would conceal a bug if you were putting the room under surveillance. Chances are, great minds think alike.

Here's hoping you were being paranoid after all!

How it works

The RF voltage developed across one or both of the input inductors is converted to dc and doubled by the action of CI, DI and D2. The charge developed across C1 when the RF voltage swings negative is added to the positive voltage swing.

Operational amplifiers IC1 and 1C2, are both connected in the non-inverting, closed-loop mode, with feedback applied to their inverting inputs. The negative feedback is derived from a potential divider across the output of each device. With this arrangement, the gain of IC1 is given by R4+ R5 / R5, and is approximately 214.

Inserting potentiometer R7 into the lower leg of IC2's feedback network enables the gain of this stage to be varied between 21 and 304. The overall gain of the unit ranges, therefore, between approximately 4500 and 65000 times.

Op-amps are not perfect, and there is inevitably a slight imbalance within the differential input circuitry under quiescent (no signal) conditions. When this small offset current is amplified to the extent possible with this circuit, it will drive the output stage into saturation, and provision has to be made for cancelling it out. Potentiometer R3 connected to the nulling circuitry within ICI, performs this function. With the gain available, the adjustment of the offset nulling or set-zero control is extremely critical. Resistors are accordingly placed in series with the potentiometer to reduce the control voltage across its track. By this means its action is limited to the critical nulling region, and the meter pointer can be brought to zero without difficulty.

Offset nulling is not required for 1C2. The nulling provisions centred on ICI balance the entire circuit by placing the necessary compensating voltage on the input pin of 1C2.

Series resistor R9 sets the meter to read around 3V FSD. The output impedance of the 741 is very low in this circuit, and the ic can accordingly supply sufficient current to damage a sensitive meter movement. Increase R9 or fit a shunt if a meter with a lower ESD than 1 mA is used).

Inexpensive meters are not likely to have much electro-magnetic damping, and high-value capacitor C3 is wired across the meter to prevent sudden output changes causing wild pointer swings.

PARTS LIST FOR THE RF SNIFFER

Resistors 0.25 watt, 5% tolerance or better

RI	100k
R2	4k7
R3	4k7 setting-up pre-set and 1k linear potentiometer for the actual set-zero control (see text).
R4	100k
R5	470
R6	100k
R7	4k7 linear potentiometer
R8	330
R9	2k7
RX	See text.

Capacitors: all 16V working or greater

C1	47pF ceramic
C2	100nF (0.1uF) ceramic
C3	1000uF electrolytic, axial lead

Inductors

LI	4.7uH (see text)
L2	2.2mH

Semiconductors

DI	OA 90
D2	OA90
IC1	741
IC2	741

Switches and meter

SI	single pole toggle switch
S2	double pole toggle switch
M1	moving coil panel meter with a 1 mA full scale deflection

Miscellaneous

PCB making materials, ic holders, Vero pins, hook-up wire, control knobs, battery connectors, PP3 batteries, telescopic aerial and small plastic case.

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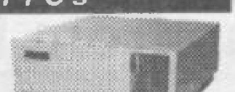

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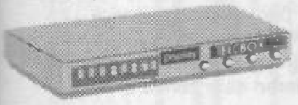

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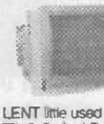

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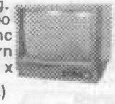

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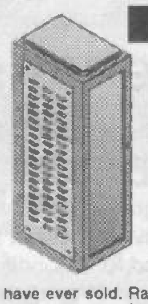

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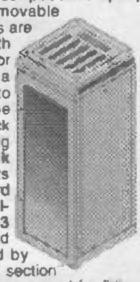

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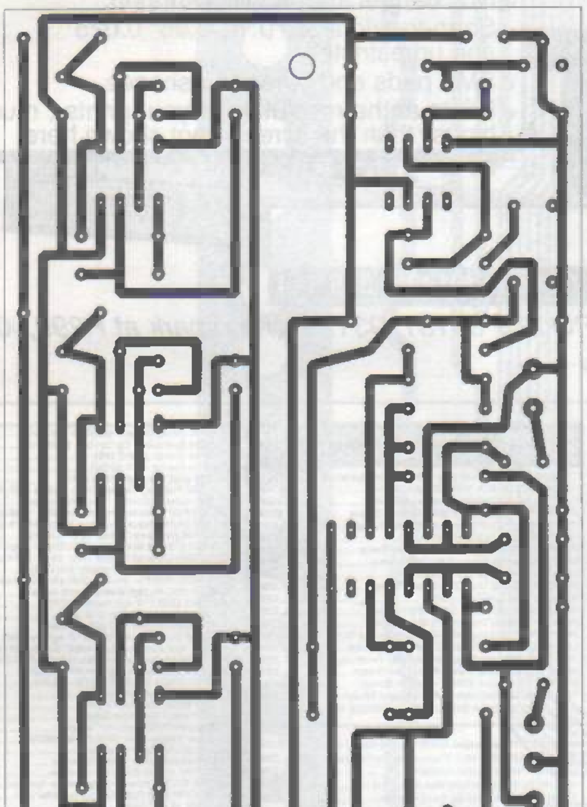
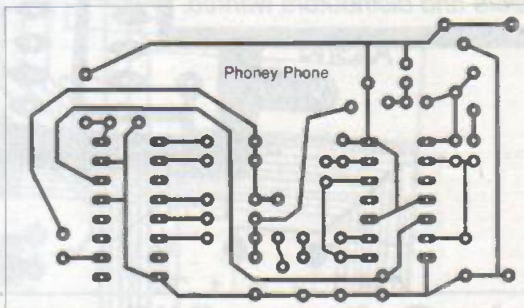


BACKGROUND NOISE GENERATOR



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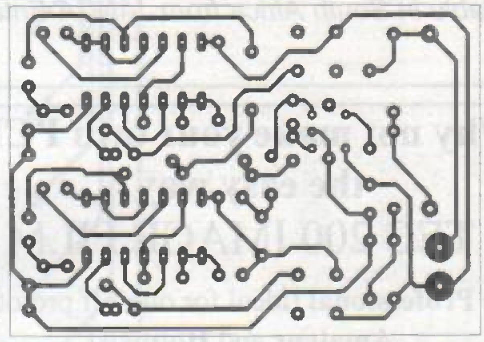

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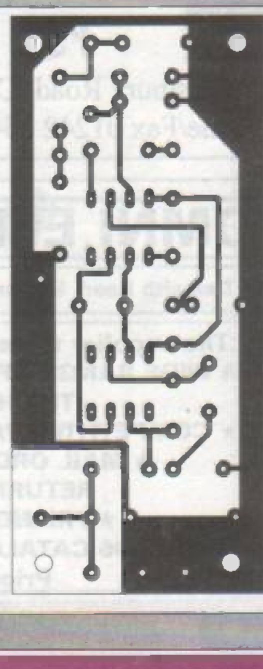
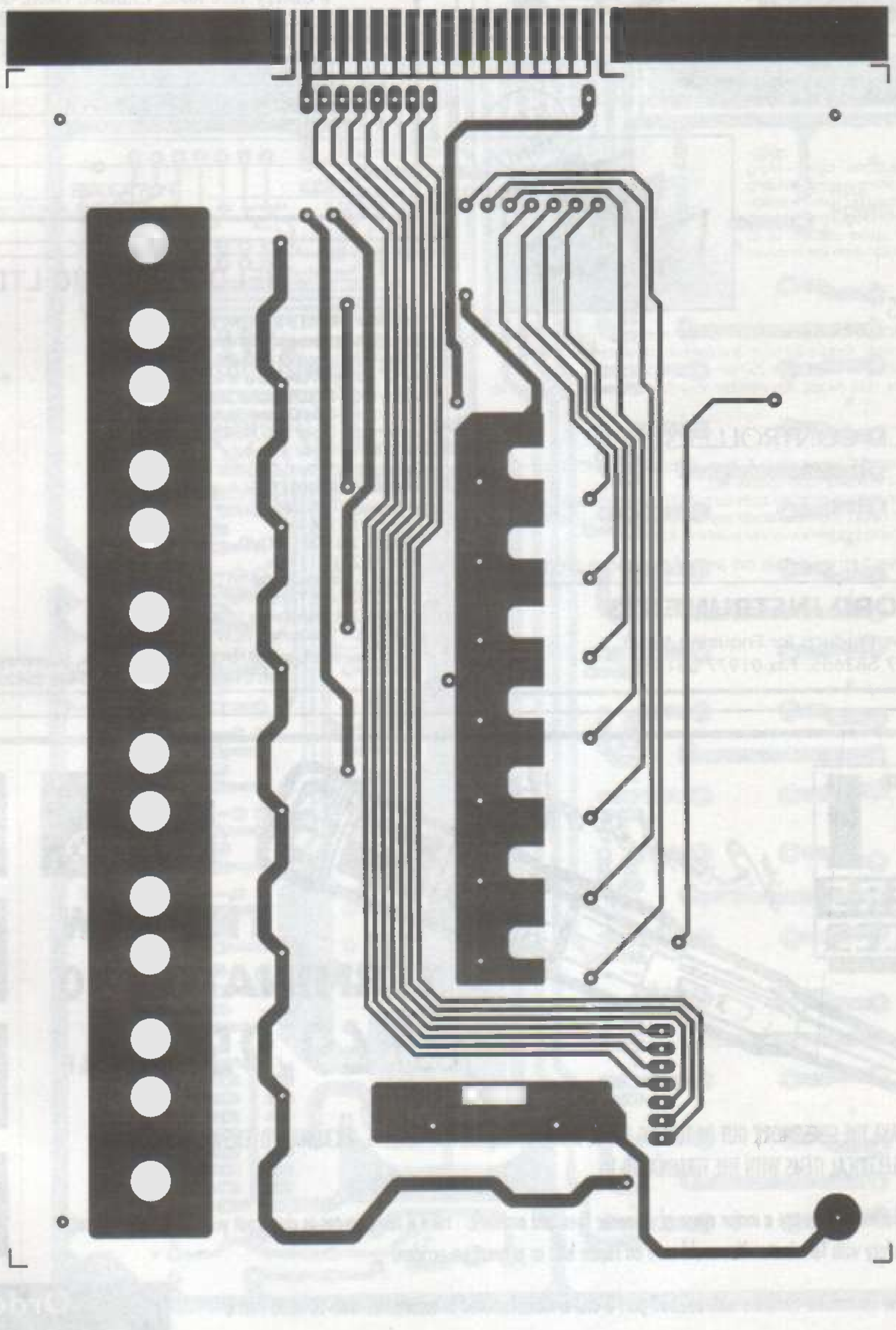
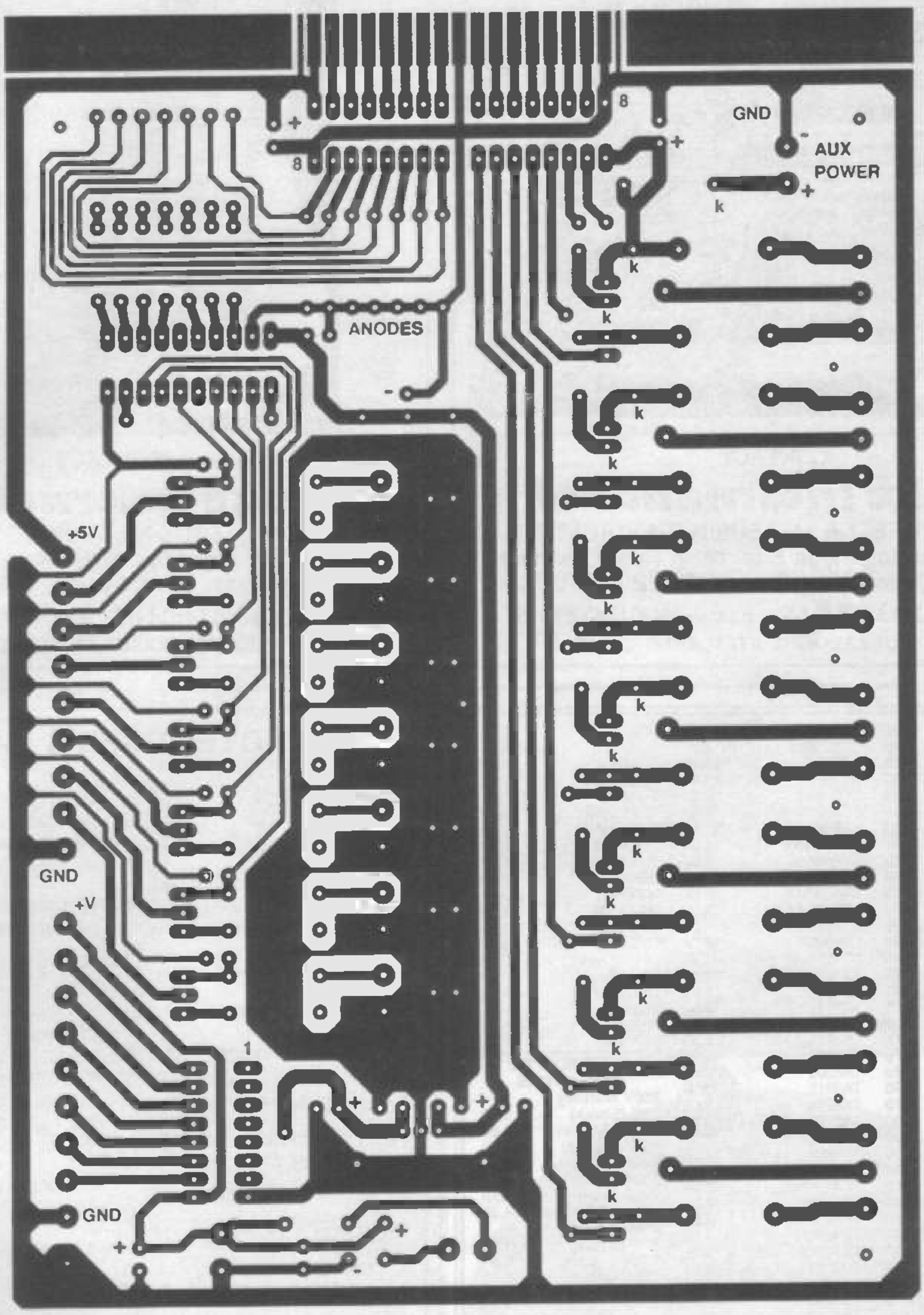




PTCF PROCESS TIMER PART 2



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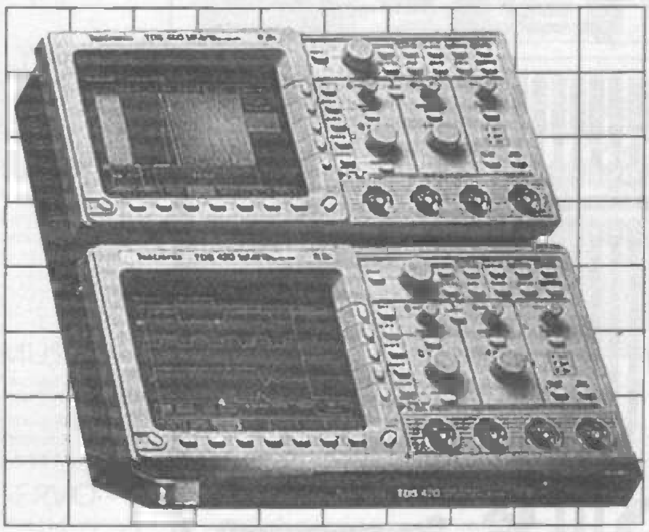

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Practically Speaking

BY TERRY BALBIRNIE

Last month we looked at the choice of connecting wire from the point of view of current rating. It is essential to use wire of sufficient thickness to prevent overheating, melting insulation and possible fire

It is important to realize that a wire which is just able to carry a given current in free air will overheat if it is coiled up. This is because the heat produced deep in the mass of the material finds it difficult reaching the surface to escape. A familiar example is a mains extension lead of the type wound on a plastic reel. Commercial leads are given two ratings - one for the wire completely unwound and another (lower) one for when it is wound on its reel. These ratings will be clearly marked on it (see photograph). Typically, a 13A extension lead can only carry 6A if wound up. To find the maximum power (wattage) of the appliance which may be connected, multiply the maximum current by the voltage of the supply. In a fuse, the overheating of a piece of wire due to a current flowing through it is put to good use. A fuse consists of a short piece of wire, thinner than that used anywhere else in the circuit. This provides protection against possible fire damage by cutting off the supply if an excessive current flows. It works because a current exceeding the rating of the wire will cause it to overheat and melt. Gone are the days when fuses were simply pieces of unprotected wire. The fuse wire is generally run inside an insulating tube so that red hot pieces of molten material cannot cause burns or fire.

Blow it

Fuses are marked with the current rating in amps or milliamps. This may range from 50mA to perhaps 16A in commercial fuses. Industrial ones can go much higher. As well as the current rating, fuses are also classified as "FF" (very quick acting used for protecting semiconductors), "F" (standard fast blow) and "T" which is a time lag variety (often called slow-blow or anti-surge). The latter type is useful in circuits containing motors, transformers, large-value capacitors filament lamps and other devices. When the power supply is connected, these allow a higher current than normal to flow for a short time. It quickly settles down but could blow a fast acting fuse.

A time delay fuse will typically withstand ten times the rated current for 20ms and this will usually be sufficient. It is essential to replace a blown fuse not only with one of the same current rating but also of the same type.

One practical point which is not generally understood is that fuses used in mains wiring should be of a special type - not enclosed in a glass tube. When a short-circuit occurs in mains wiring, an enormous can flow (possibly several thousand amps) and this will continue for the time taken for the fuse wire to melt.

The violence of this process would cause the tube to shatter and this could cause problems in its own right. Mains fuses are contained in sand-filled ceramic tubes and are known as HBC (high breaking capacity) types. The disadvantage of these is that they are opaque and it is impossible to tell whether the fuse has blown of not by visual inspection. Fuses used in UK plugs are of this type and are able to withstand breaking a current of some 6000A. By contrast, a glass fuse will only withstand ten times its nominal current rating without the possibility of it shattering violently. HRC fuses are available in the popular 20 mm size but not from all suppliers. Sometimes amateurs use ordinary glass fuses instead with potentially dangerous consequences.

Temperature rising

Do not confuse the standard type of fuse with a thermal fuse. This device is also connected in series with a piece of equipment and will also melt and break the circuit if it overheats. The difference is that the overheating is caused by some external means and not due to the current flowing through it. Thermal fuses are often used in such appliances as electric irons.

If the iron overheats due to some fault, the material inside the fuse will melt and break the circuit. These fuses are not a substitute for a standard fuse, one of these must be fitted as well. Thermal fuses are bought, not by the current rating (they will typically carry 10A), but by the temperature they will withstand before melting. Typical temperature ratings range from 72°C to 248°C. One practical point is that, when a thermal fuse blows, the new one must not be soldered in place. The heat from the soldering iron would possibly blow it! A secure mechanical fixing, such as screw terminals or a crimped connector, should be used.

Coil-up mains extension wires should have their mains ratings extended and wound clearly marked, as in this example.

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Around the Corner

Continuing from last month's Round the Corner, a topic which has made many people ponder: whither electronics hobbyists from here? On the face of it, business has the lion's share of electronics development. A product on the market can represent many man-years of design and development, and even sometimes of basic research. Levels of complexity beyond most people's ability to keep track of are handled relatively easily by computer-aided design (CAD) tools, some of which will automatically take a design change from schematic through layout to purchasing lists with little human intervention.

Where hobbyists score is with projects which industry finds hard to produce at a reasonably low price, or which are too specialised for the large electronics manufacturers to be interested - where we want a device for a specific task that does not lend itself to mass-production, for example. And there arise from time to time areas which are too new for the mass market, and then the hobbyist can push forward the uses of the new technology. Then there are all the projects that are built for the sake of curiosity, interest, and the satisfaction of knowing exactly how the gadget works and of being able to repair or modify it at short notice.

In the days when all cars used a contact breaker in the distributor for spark generation, if you added an electronic ignition and it failed you could very often repair it on the spot. At worst you could link round it and use the standard, if less efficient, ignition system. Nowadays, if your automobile engine control computer fails, your sole option is to have a new one fitted, often after a tow to the garage and a further delay while the part is ordered and delivered.

Personally, given the choice I prefer to be able to fix anything that goes wrong.

Electronics in its early days was largely advanced by enthusiasts, and there were few professionals. There are still areas which are underexploited or undervalued by industry, and amateurs can design and build novel gadgets.

Finally, where do tomorrow's designers come from? It seems as if more of today's graduates have not been electronics hobbyists before studying electronics. They learn the academic approach - and, of course, mathematical modelling and simulation can spell the difference between a reliable design which works well and one which works on a good day if all the components are in the centre of their tolerances.

On simulators, the story runs that the help desk of a major American semiconductor manufacturer received a phone call complaining that their unity gain stable amplifier oscillated in an effectively unity gain circuit in which it should have worked. Eventually the question "How did the breadboard model perform?" was asked. "No, this is not the breadboard, this is a simulation", came the reply. "The breadboard model worked OK". The semiconductor company demurred that it was responsible for the semiconductor device, not the simulator, and the user had to agree.

On the other hand, a "feel" for what electronics can do when you push it can spell the difference between a "by the book" design which will do the job, and an innovative one which does something that competitors in the industry said could not be done at all.

Then you begin to learn about patents ...

The Challenge - things that electronics hasn't fixed yet

PIR-controlled security floodlights that switch on at inopportune times. A major cause is that a sensitivity setting that will just trigger on a large human in summer, when the background is warm, will also trigger on a small feline in winter when the background is cold. How do you compensate for background temperature with a minimal component cost? See if the PIR controlled garden light planned for next year has an answer, or if your suggested answer is incorporated in it.

Send your suggestions to the Editor at the address on the right.

Next Month

In the December 1996 issue of Electronics Today International we look to valve enthusiasts with a bench PSU designed by Peter Kenyon specially for use with valve equipment. For the playful we have a model train controller from Robert Penfold and the game of Digital Dice from Bart Trepak. Barry Porter continues his MicroAmp with part 2, and Richard Grodzik presents a PIC16C54-controlled Remote Data Logger ... and more. And Nick Hampshire reports on MIT's work on ultra-small robotics.

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Nexus House, Boundary Way,
Hemel Hempstead HP2 7ST
Telephone (01442) 66551
Fax (01442) 66998