AUTOMOTIVE • RADIO • AUDIO • TECHNOLOGY

# ELECTRONICS

## The Maplin Magazine

• Britain's Best Selling Electronics Magazine

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FULL SOR

## Discover the Secrets of the Universe!

**How to...**

**Build the Millennium Hi-Fi Valve Amplifier**

**Keep Clear Vision with a Car Rear Wiper Controller**

**Build a Versatile Low Noise RF Preamplifier**

**Plus... Lots, Lots, More!**

**Explained Inside...**

**New Method of Demodulating FM Radio Signals**

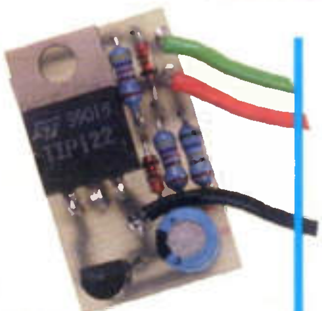
**How to Design and Build Your Own Subwoofer Systems**

**5 PROJECTS FOR YOU TO BUILD**

# 3 INDISPENSABLE WINTER MOTORING PROJECTS FOR YOU TO BUILD!

# ON THE MAKE WITH MAPLIN

## Courtesy Light Extender



- Low component count
- No setting up required
- Optional ignition override
- Requires no external power supply

How many times have you got into your car on a dark night, only to find that the ignition switch appears to have gone for a walk and seems hell-bent on rejecting all attempts to insert the ignition key?

This compact project keeps the interior light on for a time after the car door has been closed, allowing time to find keys, ignition switch, or even your way out of the garage!

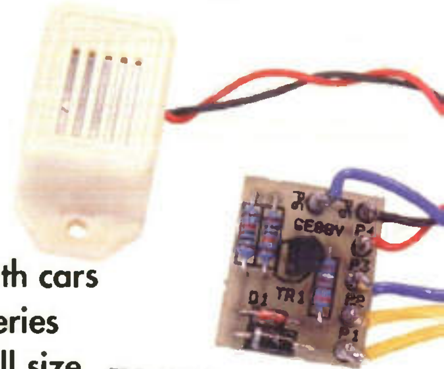
Installation is simple: only two wires to connect: or, an optional third wire can override the unit when the ignition is switched on.

Order as LP66W, Car Courtesy Light Extender. Price £2.95. Details in *Electronics* No. 44 (XA44X)

Available separately:
Courtesy Light PCB: GE81C, £0.98
Box and base type 1: JX56L, £0.68

Optional items (Not in kit):
Hook-up wire 16/0.2 Black, 10m, FA26D, £0.78
Hook-up wire 16/0.2 Red, 10m, FA33L, £0.78

## Lights-on Warning Indicator



- Buzzer sounds when car lights are left on
- Easily fitted to most negative earth cars
- No more flat batteries
- Low cost and small size

**NO MORE FLAT BATTERIES**

Hands up, those drivers who have never left their car lights on and returned to find the battery closely resembling a pancake? If your hand is up, you either have a super-efficient memory, or a chauffeur, or have probably just dropped your copy of *Electronics* and are being stared at by everyone else around you.

For us other, mere fallible mortals, this easily constructed project emits a reminding buzz if the driver's door is opened while the lights are on and the ignition is off, the combination of conditions ensuring that the buzzer only sounds when the driver is genuinely about to leave the car.

Order as LP77J, Lights On Reminder. Price £4.75.
Details in *Electronics* No. 50 (XA50E)
Available separately:
Lights On PCB, GE88V, £1.36

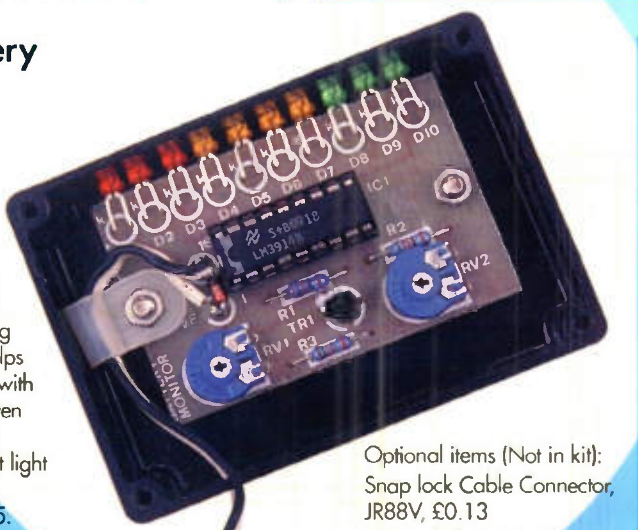
## Car Battery Monitor

- Keeps an eye on your battery
- Reveals charging problems
- Low current consumption

Late for work, you jump into the car and turn the ignition key, only to discover that your battery passed away peacefully in its sleep and now powers a harp synthesiser in silicon heaven.

Many things can cause your battery to feel less than perfect: lights left on, faulty alternator, slipping alternator drive belt, etc. This clever monitor kit helps you keep an eye on your battery's state of health with a row of ten LEDs that show its state of charge. Even "invisible" problems, like a slipping drive belt that prevents the battery charging properly, yet doesn't light the dashboard warning light, can be detected.

Order as LK42V, Car Batt Monitor. Price £9.25.
Details in *Electronics* No. 37 (XA37S)
Available separately: Battery Monitor PCB, GA19V, £1.65



Optional items (Not in kit):
Snap lock Cable Connector, JR88V, £0.13
Terminal Block 5A, HF01B, £0.75

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All items subject to availability, all prices include VAT (subject to change).

Maplin ELECTRONICS

**THE POSITIVE FORCE IN ELECTRONICS!**

FEBRUARY 1994
VOL 13. No. 74

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## REGULARS NOT TO BE MISSED!



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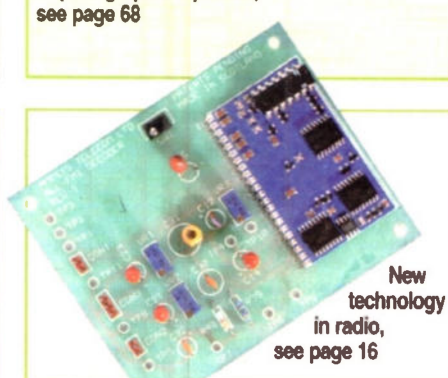
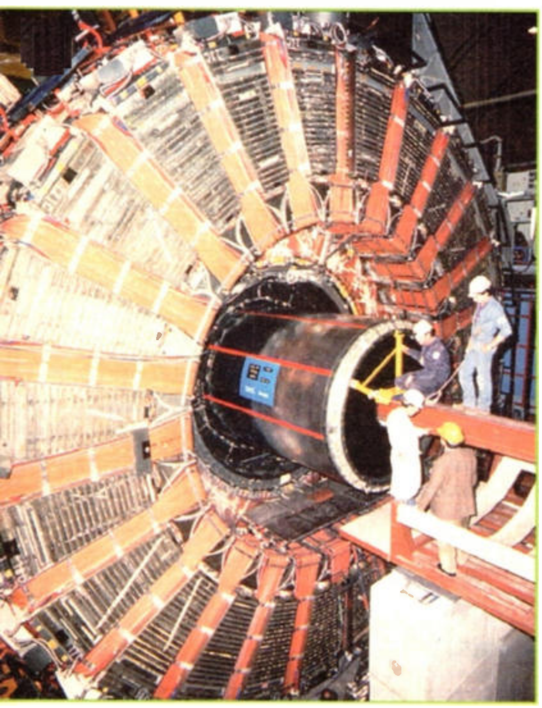


New technology in radio, see page 16

They're huge!

Find out more on page 53



In Search of Creation, read the full story on page 12

Control your car's rear wiper automatically... ...Find out how on page 4!

Return to the sound that time forgot!

Super sound... Super price... See page 36

# TECHNOLOGY WATCH!

## with Keith Brindley

Nowadays Teletext is almost a standard feature on modern television receivers. Most TVs manufactured over the last few years had the feature built-in, and those which hadn't, are very often simple downgraded versions of standard products because boards were removed, or links cut. In other words and in most cases, it costs less to make a television with Teletext than it does to make it without.

However, the days of standard Teletext are numbered. Already a possible successor – *Megatext* – is on the cards. *Megatext* offers considerably better graphics capabilities than Teletext, using variable pixel-programmed graphics of 384 by 322 pixels in size (compared with current fixed block graphics of Teletext). What's even better however, is that *Megatext*'s speed of display as you change pages is almost instantaneous because all pages (2,048 of them) can be stored in memory.

This is all made possible with a 24-bit RISC-based (reduced instruction set computer) microprocessor, running at 12MIPS (million instructions per second). Given that nothing better has yet appeared on the scene, *Megatext* will be with us in just a couple of years.

### On the Air

As the country's second largest telephone network operator, Mercury has a significant stumbling block to further growth – its local line loops from residential customers to its digital network are based on British Telecom's already existing local loops. For this, Mercury pays BT a usage fee. Ideally Mercury would obviously want its own local loops, but the cost of laying land lines is somewhat prohibitive.

An alternative is to use radio links. A partner of Mercury's in its new *one2one* mobile 'phone network, USWest, is already undertaking trials in the USA of a radio system which could do this in the UK.

### All in the Mind?

I have seen the future. Last night! After a particularly pleasant home-made curry and a 'find-the-murderer' party with close friends – I had a dream. I had a dream about a brave new world in which consumer electronics appliances are used only to the benefit of mankind.

In this dream I see a place where do-it-all wristwatches which allow mobile communications, perform calculations, play stereosound music at digital quality, change your TV channel, and sometimes even tell you the time, are banned from the face of the earth. Somewhere that has no personal digital assistants, notebook computers, or Psion organisers. A place where personal stereos have never been invented, and where surgeons instead, operate with Sony-invented electronic medical instruments costing £9.99 at local discount stores. Where personal computers are used only to run an efficient Welfare State without waiting lists, in which any medication, examination, practice or service is totally free. People view employment as an unfortunate but necessary evil – not the prerequisite of a wealthy lifestyle. Where politicians are no longer needed, and where the term power with reference to one human's control over others is simply an archaic word no longer in the dictionary.

Trouble is, along with the curry last night I drank rather too much. So my dream was the drink talking.

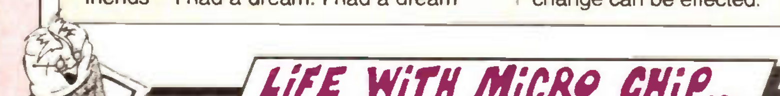
### Plug it in

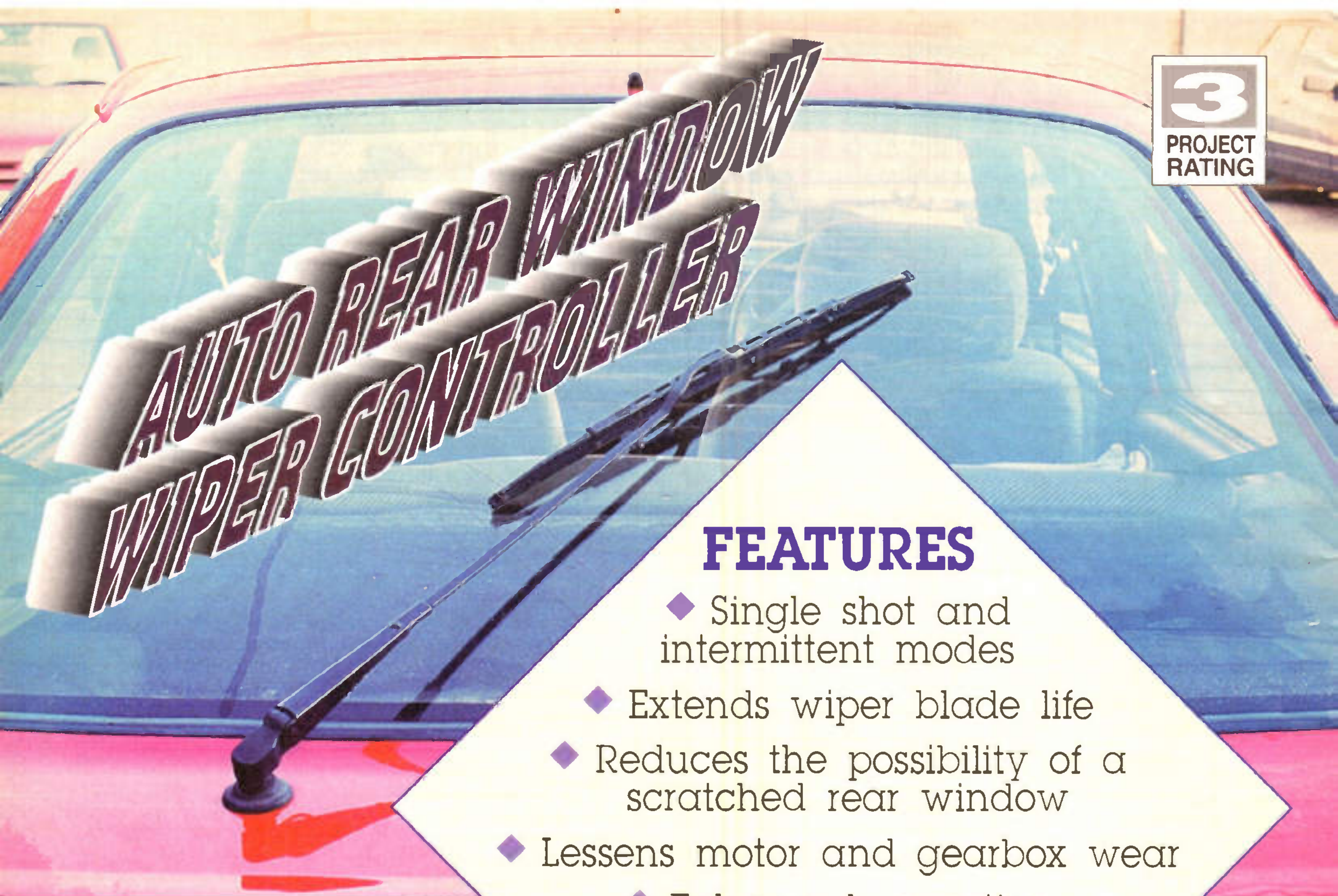
Following on from earlier reports in this column regarding the possibility of losing the UK's 110V outdoor portable industrial mains configuration together with our 13A plug and socket arrangement in a European-wide move towards harmonisation in electrical installations, reader JWCD of Gillingham wrote to tell me of communications on the topic with his MP, James Couchman. He wrote to his MP in October shortly after my first foray into the discussion, with the result that James Couchman passed on his letter to Tim Sainsbury the Minister for Industry at the DTI. Tim Sainsbury wrote back to say that obviously the implications for the UK of any change to a European-wide harmonised electrical system would have to be carefully considered before any change can be effected.

Without wishing to publish ministerial communications *per se*, it's worth pointing out a couple of things of note in Tim Sainsbury's reply. First, the current CENELEC proposals include both sleeved pins and shuttered sockets (just as our existing 13A plug and socket arrangement does). This ensures a safety level not inconsistent with the current UK system. So while any change to a different system to our own may be inconvenient, it will be at least as safe as it currently is.

Secondly, and far more serious however, while the Health and Safety Executive prefers a 110V supply for portable industrial applications, they are prepared to accept a higher voltage if it can be shown to be as safe. The problem is, of course, how do we measure safety where human lives are concerned. With a transformed 110V supply in which the maximum voltage-to-earth is 55V, there is no danger at all. Anyone could touch a 'hot' wire in such an installation with no serious consequence, but what would be the consequence of a voltage-to-earth of 100V? Or 115V? Do we need to find this out by practical measurement of human lives on the building site? How many bricklayers need to die before a voltage is considered dangerous? How many injuries have to occur? So why can't we find out in a more humane way, such as testing out voltages on non-humans? A straightforward test would be to connect a large number of guinea pigs up to auto-transformers and wind up the voltage until they start popping their clogs – at which point a good average unsafe voltage would be apparent as the result. Of course, I'm not advocating that real guinea pigs are used in such an inhumane experiment. No, I've got a far better idea which would in no way harm defenceless animals, yet in the same test would also rid the world of a few dumb creatures. You see, what I have in mind involves using Ministers for Industry or EC Commissioners as trial samples. They probably form the closest link to humans we can ever get to, without ever endangering real people. I am, of course, only joking. Aren't I? This topic – I hope – is now closed.

The opinions expressed by the author are not necessarily those of the publisher or the editor.



# AUTO REAR WINDOW WIPER CONTROLLER

3 PROJECT RATING

## FEATURES

- Single shot and intermittent modes
- Extends wiper blade life
- Reduces the possibility of a scratched rear window
- Lessens motor and gearbox wear
- Enhanced operation
- Multi-mode operation
- Auto wipe when in reverse

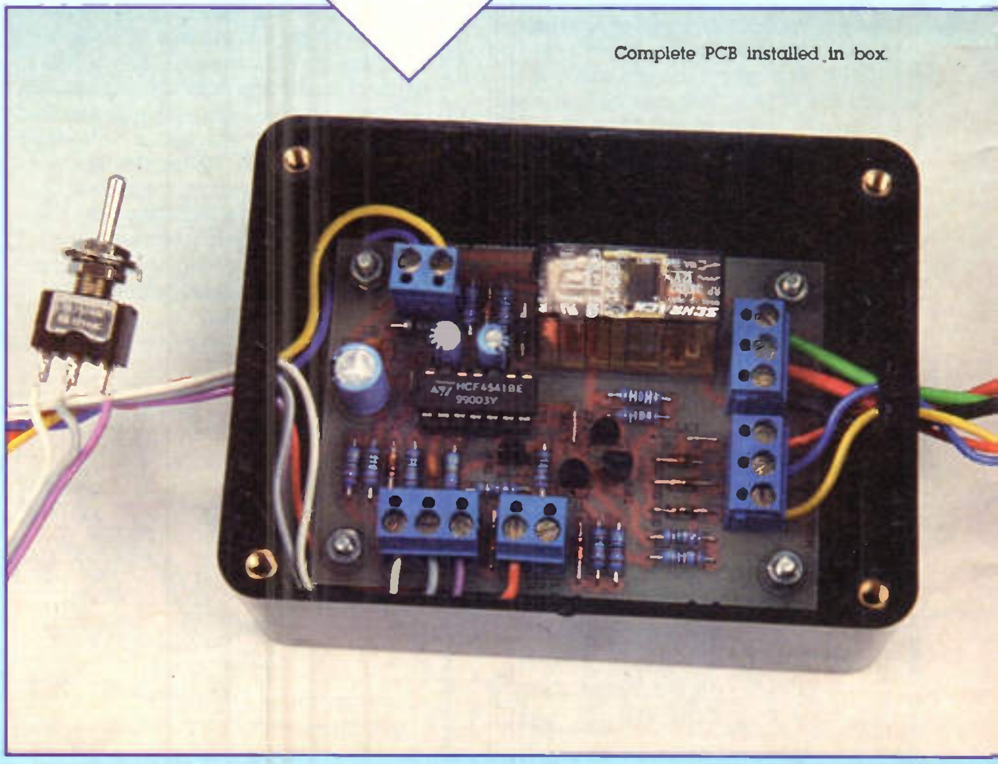
**Design by Alan Williamson**

**Text by Robin Hall and Alan Williamson**

How often have you been driving along in traffic and found that you needed to clear the rear window; either because you cannot see out the back, due to the window being dirty, or covered with heavy grime from travelling. In most cars, whilst the main wiper switch is usually close to hand, the rear wiper switch can often be located in an almost unreachable position, requiring you to divert attention from the road to the switch. After operating the switch, you then find that your attention is again taken up with driving; by now you are aware that the rear wiper is still switched on, but you cannot look down again to switch it off – so it is left on until it is safe to do so. At this point you would probably wish that you had more control over the rear wiper! This is where the Auto Rear Wiper Controller is intended to enhance the function of a basic car rear window wiper.

### Important Safety Warning

Since a car battery is capable of delivering extremely high currents, it is imperative that every possible precaution be taken to prevent accidental short circuits occurring. Remove **all** items of metal jewellery, watches, etc. Before connecting the module to the car electrics, the battery should be disconnected. Helpful hint – remove ground connection first, to prevent accidental shorting of the '+' terminal to the bodywork or engine. It is essential to use a suitably rated fuse in the supply to module. The wire used for the connections should be rated to safely pass the required current.



Complete PCB installed in box.

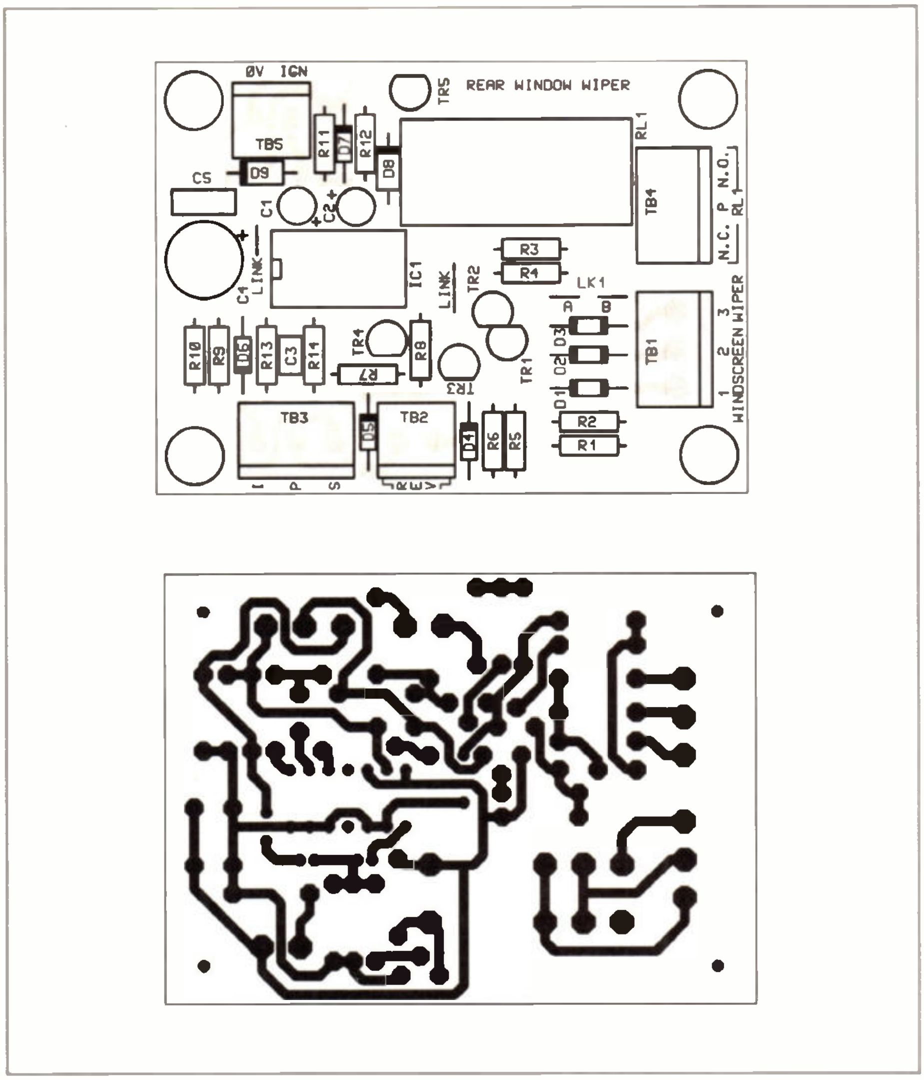



Figure 3. PCB Legend and Track.

| Switching to Supply | Switching to Ground |
|---|---|
| Fit D1 to D3 with Anodes to TB1 and fit LK1 'A' (see Figure 4a) | Fit D1 to D3 with Cathodes to TB1 and fit LK1 'B' (see Figure 4b) |
| Components Marked * <br> *Do not fit* R1,R2,R5,R6, D4, TR1 & TR3 <br> Fit D5 <br> R3 & R7 = 47k | Components Marked * <br> All fitted *except* D5 <br> R3 & R7 = 1k |

Table 1. Component options and values (including link selection).

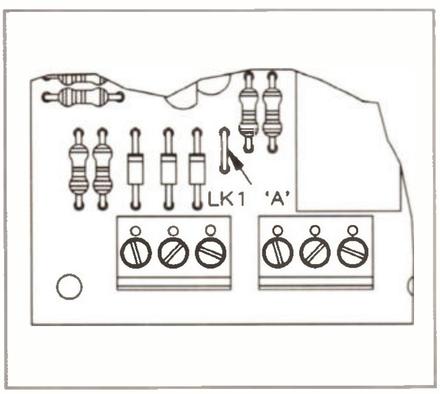



Figure 4a. Orientation of D1 to D3 and link selection (switching to supply).

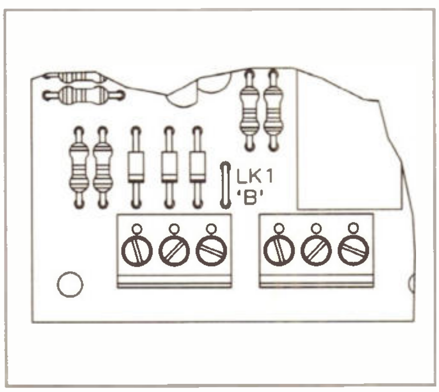



Figure 4b. Orientation of D1 to D3 and link selection (switching to ground).

components provide detection of the 'on/off' condition of the front windscreen wipers. Since cars of different makes and models may use either positive supply or ground switching, both 'senses' are catered for. TR3, TR4 and associated components provide the same function for the reversing lights. In these parts of the circuit, certain components will need to be fitted or omitted, depending on whether positive or negative switching is used. These components are marked with an asterisk on the circuit diagram.

TR2 combined with TR4 form a two input NAND gate; TR2 must be on to allow TR4 to pull pin 6 of IC1 low.

S1 controls the mode of the controller, and has three positions: the centre position is 'Off', the other two positions are 'Intermittent' and 'Single Shot'.

IC1 is a programmable timer, configured as an astable oscillator; IC1 is only required for the Intermittent mode of operation. The time out period (delay between sweeps) is determined by the value of R13.

TR5 and associated components switch RL1, which in turn operates the rear wiper motor.

## Circuit Operation

The circuit operates in the following manner: turning the ignition key on, supplies power to the circuit. Turning on the front windscreen wipers will cause TR2 to conduct. With the switch S1 in the Single Shot position, TR2 will pull the negative end of capacitor C1 low causing a pulse to be fed into the base of TR5, which in turn will briefly operate the relay.

With the switch S1 in the Intermittent position, whilst TR5 and the relay operate as before, pin 6 of IC1 is also pulled low via TR2, which will begin to time out and produce subsequent pulses (at the end of each time out period) via capacitor C2 for the Intermittent mode of operation.

In the reverse mode of operation, when the front windscreen wipers are switched on as before, TR2 will conduct, and when the reverse gear is selected this switches on TR4 which pulls D6 and R9 low, pin 6 of IC1 is also pulled low. The rear wiper is then forced into the Intermittent mode of operation, regardless of the mode selected by S1.

## Construction

Refer to PCB legend shown in Figure 3 and the component options shown in Table 1. Figure 4a and 4b show the position of LK1 and the orientation of D1, D2, D3. Which figure is followed will be dictated by the polarity of the wiper supply switching.

If the supply to the wiper is positive supply switched (assuming negative earth), refer to Figure 4a, the following components must *not* be fitted: R1, R2, R5, R6, D4, TR1 & TR3. Note R3 & R7 should both be 47k in this circuit configuration. Diodes D1 to D3 should have anodes connected to TB1 and link LK1 should then be in position 'A', and D5 must be fitted. If the wiper is switched to ground, all the components

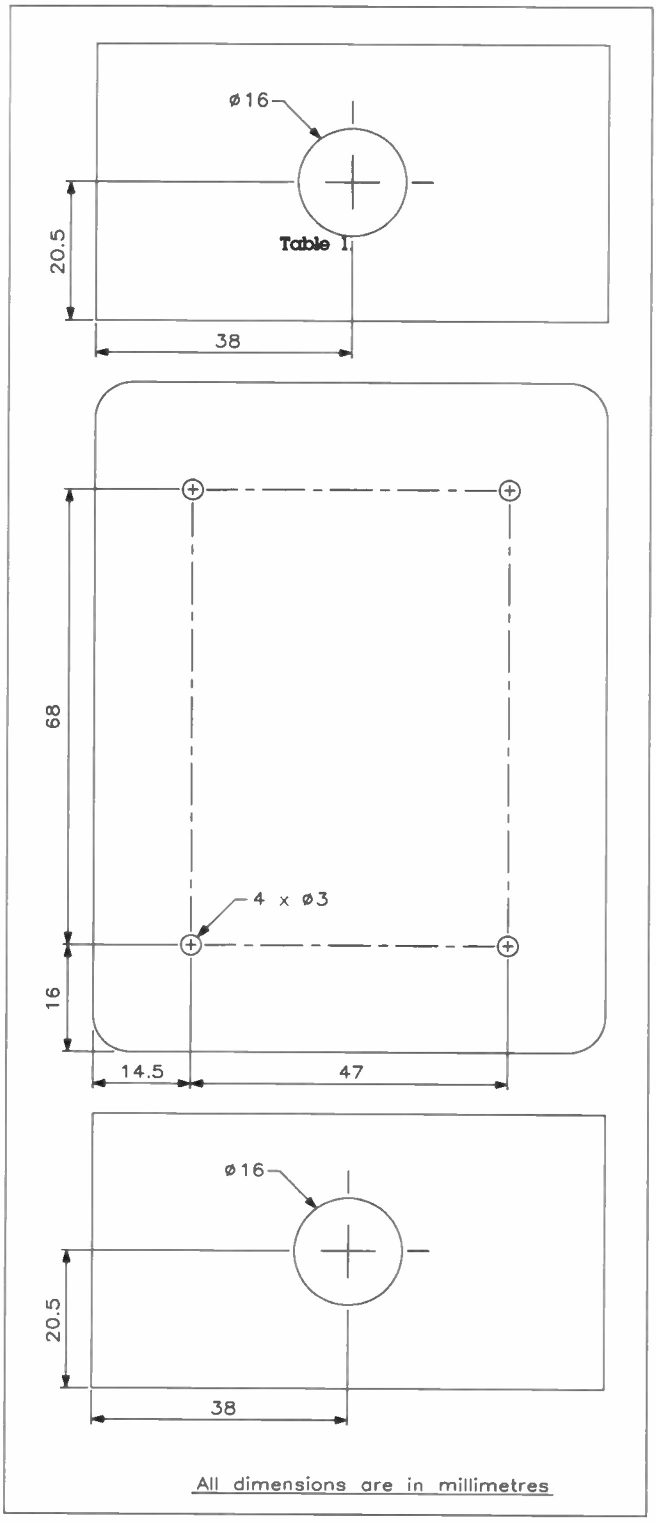



**Figure 5. MB2 box drilling details.**

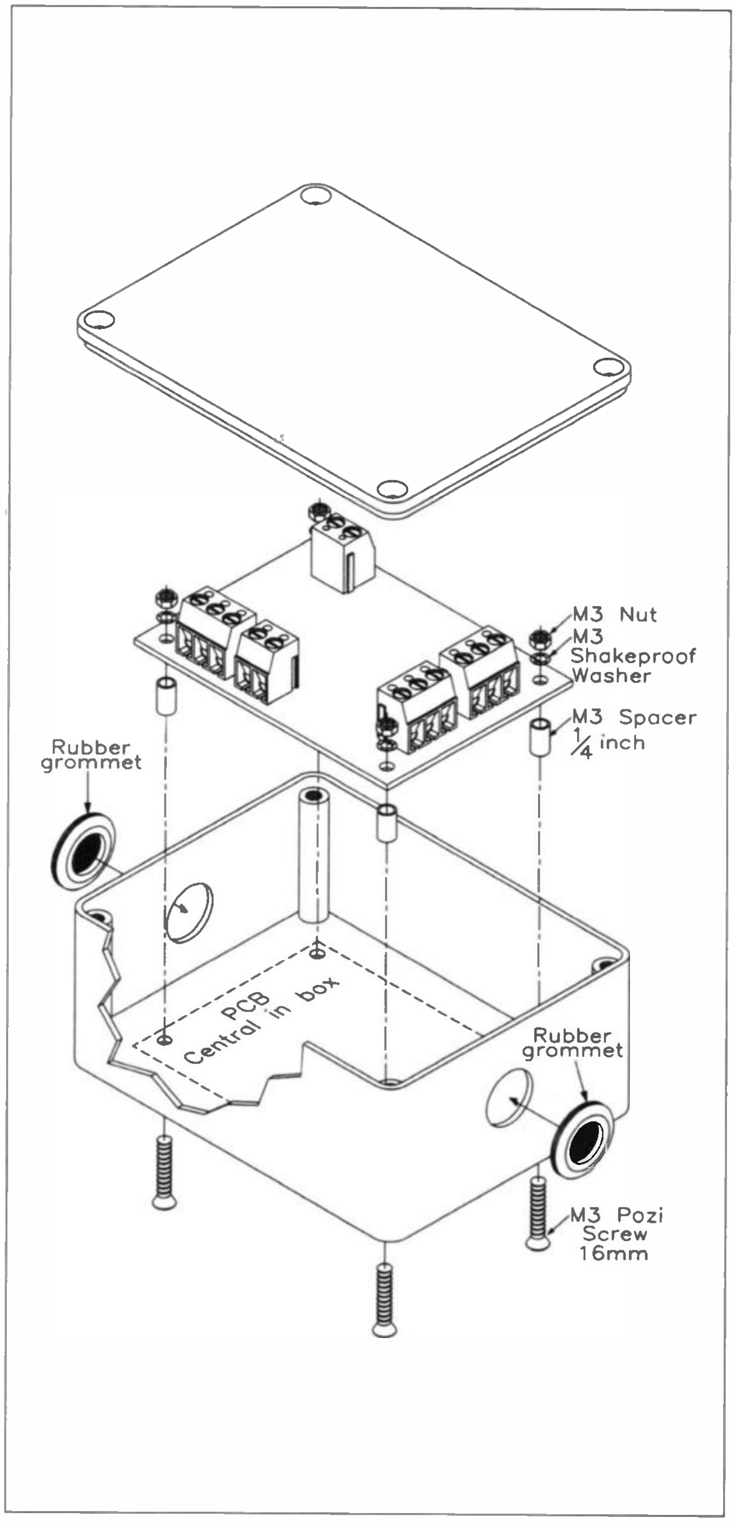



**Figure 6. Assembly of PCB into MB2 box.**

marked with an asterisk should be fitted, with the exception of D5. In this configuration R3 & R7 should be 1k. Refer to Figure 4b, the cathodes of D1 to D3 are connected to TB1, and link LK1 should be fitted to position 'B'. The time out period for the Intermittent mode of operation is determined by R13, choose whether you want a short or long period, and fit the appropriate value resistor, either 100k (short, seven seconds) or 220k (long, 15 seconds). You can, of course, experiment with other values to give a different time out period, generally R14 should be twice the value of R13. The value of R13 can be between 30k and 1M, this will give an approximate time out period of between two seconds and one minute 10 seconds, using the current values of R14 & C3.

Further details on setting up the frequency for the timing of the HCF4541BE is given in the current Maplin catalogue. Identify and fit the rest of the diodes ensuring that the band on each diode corresponds to that shown on the legend. Using off-cuts of wire, pre-shape and fit the rest of the links. Identify and fit the resistors again referring to Table 1. Next mount the ceramic and electrolytic capacitors, ensuring that the negative symbol on the electrolytics is located opposite to the positive signs on the PCB. When installing the transistors, make certain that each case matches its outline. Fit the IC socket making sure that the notch on the socket matches with the notch on the legend. The terminal blocks should be fitted next, ensuring their correct orientation on the board. The relay can now be placed into the PCB and soldered in position. Upon completion, check your work for possible solder bridges, whiskers, dry joints and misplaced components. When you are satisfied that all is well, carefully insert IC1 into its socket, ensuring that the notch on the IC corresponds with the notch on the legend and the socket.

The drilling details of the suggested optional box are shown in Figure 5 and assembly of PCB into MB2 box in Figure 6.

## Testing

To check for correct operation and spurious output, repeat the following procedure. Note – the relay should not operate other than the times indicated.

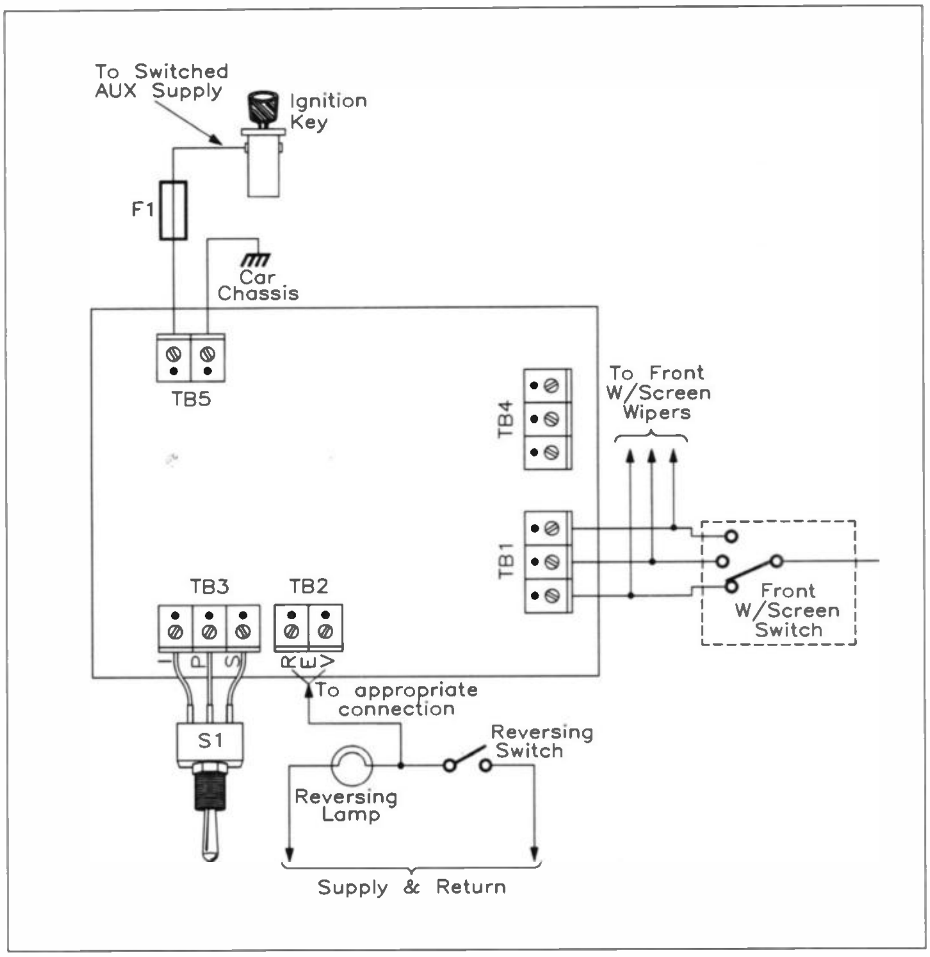



**Figure 7. Wiring diagram.**

Connect the switch S1 as shown in the wiring diagram Figure 7, set the switch to the centre position. Connect a +12V DC supply to the 'ignition input' and 0V pins on the module.

Connect a crocodile test lead (or something similar); from any of the three 'windscreen wiper' input pins to the appropriate supply connection (depending on whether positive supply or ground switching was chosen).

Move the toggle switch (S1) to the Single Shot position (remembering that when moving the toggle to the left, the middle and right terminals will be connected); the relay should operate for approximately one second, wait 15 seconds, the relay should not have timed out again, move the switch to the centre 'off' position again.

Move the switch toggle to the Intermittent position, the relay should operate briefly, and repeat after every time out period and carry on doing so until the toggle is moved to the centre position again.

Leave the toggle switch in the centre position and with the windscreen wiper lead still attached, connect a second crocodile lead from the appropriate 'REV'erse pin on the module to the appropriate supply connection, the relay should operate briefly and continue in the Intermittent mode.

Disconnect the crocodile lead from the 'windscreen wiper' input and the power supply; the auto windscreen wiper should stop.

The module is now fully tested and can be permanently installed into the vehicle. The module should be installed securely in the vehicle to prevent any possibility of it becoming dislodged and fouling vital control linkages, such as those for the brakes, etc. Similarly, cables should be run alongside existing looms and fixed in position using cable ties or adhesive tape.

## Installation

Always disconnect the battery before commencing any work on the vehicle.

Most 'base model' cars have only basic functions, and often spare switch positions on the dashboard are blanked off, these may be used for fitting S1; you may prefer to obtain a three position single pole (on,off,on) rocker or rotary switch to suit the switches already fitted to the vehicle.

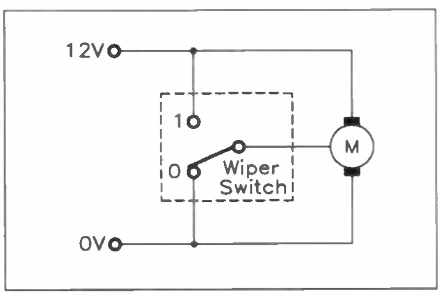



**Figure 8a. Typical wiring of a three wire wiper motor.**

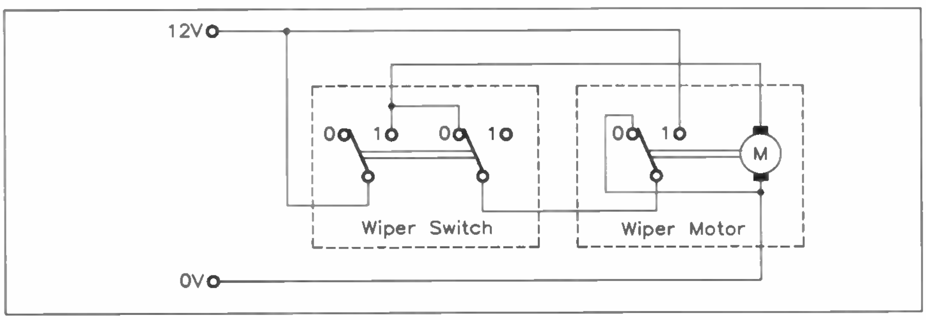



**Figure 8b. Typical wiring of a four wire wiper motor.**

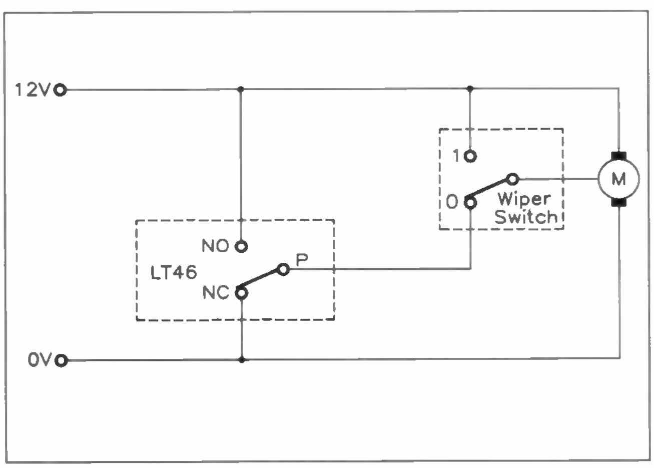



**Figure 9a. Wiring of the unit with a three wire motor.**

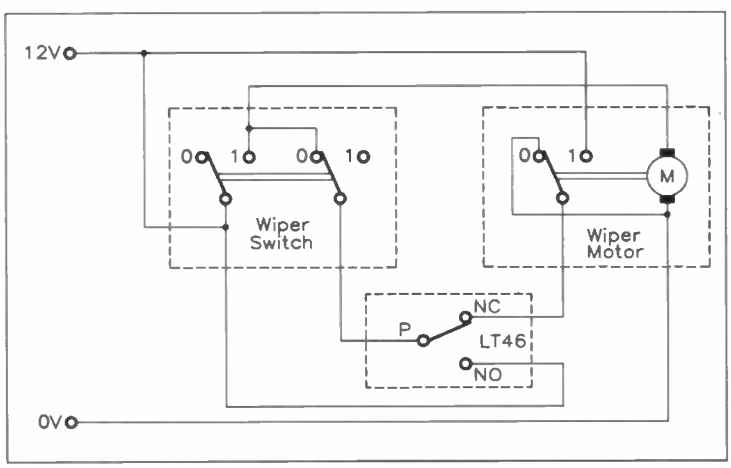



**Figure 9b. Wiring of the unit with a four wire motor.**

Refer to the Figures 8a and 8b, which show the wiring of 'typical' three and four wire single speed wiper motors. Figures 9a and 9b show the module's relay connected to 'typical' three and four wire systems.

Double-check all wiring before reconnecting the battery.

If everything has been connected correctly, the module should function as described. If problems are encountered, re-check the wiring and use a multimeter to check that correct voltages are present on the relevant cables. If this fails to reveal the problem, remove the module and repeat the test procedure. If this still fails to resolve the problem, contact an automotive electrician.

## AUTO REAR WINDOW WIPER CONTROLLER PARTS LIST

| | | | |
|---|---|---|---|
| **RESISTORS: All 06W 1% Metal Film** | | | |
| R1,5,10,11 | 47k | 4 | (M47K) |
| R2,4,6,8,12 | 10k | 5 | (M10K) |
| R3,7,9 | 1k | 3 | (M1K) |
| R13A | 100k | 1 | (M100K) |
| R13B | 220k | 1 | (M220K) |
| R14 | 470k | 1 | (M470K) |
| **CAPACITORS** | | | |
| C1,2 | 22µF 25V Radial Electrolytic | 2 | (FF06G) |
| C3 | 470pF Ceramic | 1 | (WX64U) |
| C4 | 470µF 16V Radial Electrolytic | 1 | (FF15R) |
| C5 | 100nF 16V Miniature Disc Ceramic | 1 | (YR75S) |
| **SEMICONDUCTORS** | | | |
| D1-7 | 1N4148 | 7 | (QL80B) |
| D8,9 | 1N4001 | 2 | (QL73Q) |
| TR1,3,5 | BC557 | 3 | (QQ16S) |
| TR2,4 | BC547 | 2 | (QQ14Q) |
| IC1 | 4541BE | 1 | (QQ47B) |
| **MISCELLANEOUS** | | | |
| RL1 | 12V 16A SPDT Relay | 1 | (YX99H) |
| S1 | Sub-Min SPDT Centre Off Toggle Switch | 1 | (FH01B) |
| TB1,3,4 | 3-way PCB Terminal Block | 3 | (JY94C) |
| TB2,5 | 2-way PCB Terminal Block | 2 | (JY92A) |
| | 14-Pin DIL IC Socket | 1 | (BL18U) |
| | PCB | 1 | (GH66W) |
| | Instruction Leaflet | 1 | (XU49D) |
| | Constructors' Guide | 1 | (XH79L) |
| | M3 Steel Nut | 1 Pkt | (JD61R) |
| | M3 Shakeproof Washer | 1 Pkt | (BF44X) |
| | M3 ¼in Spacer | 1 Pkt | (FG33L) |
| | 16mm Grommet | 1 Pkt | (JX77J) |
| | 6A BlackWire | As Req. | (XR32K) |
| | 6A BlueWire | As Req. | (XR33L) |
| | 6A RedWire | As Req. | (XR36P) |
| | 3A Black 10mWire | 1 Pkt | (FA26D) |
| | 3A Blue 10mWire | 1 Pkt | (FA27E) |
| | 3A Green 10mWire | 1 Pkt | (FA29G) |
| | 3A Orange 10mWire | 1 Pkt | (FA31J) |
| | 3A Red 10mWire | 1 Pkt | (FA33L) |
| | 3A White 10mWire | 1 Pkt | (FA35Q) |
| **OPTIONAL (Not in Kit)** | | | |
| | ABS Box MB2 | 1 | (LH21X) |
| | Bolt M3 x 16mm | 1 Pkt | (JC70M) |

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

***The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.***

**Order As LT46A (Auto Rear Window Wiper Controller Kit) Price £9.95.**

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new item (which is included in the kit) is also available separately, but is not shown in the 1994 Maplin Catalogue

Auto Rear Window Wiper Controller PCB

**Order As GH66W Price £2.75.**

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Placing an advertisement in this section of *Electronics* is your chance to tell the readers of Britain's Best Selling Electronics Magazine what you want to buy or sell, or tell them about your club's activities–Absolutely Free of Charge! We will publish as many advertisements as we have space for. To give a fair share of the limited space, we will print 30 words free, and thereafter the charge is 10p per word.

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### VARIOUS

**LEAD ACID BATTERY**, as new. Yuasa NP6-12 type, worth £26.95 - selling £16. 4 continuity testers, boxed, inc. instructions, ideal for hobbyist, ready for use £1.80. Prices inc. P&P. Tel: (0625) 431067.

**KENWOOD TH-26E 2M** Handheld Transeiver, excellent condition, £125. Tel: (091) 262 7532 (evenings or answering machine).

**MAGAZINE CLEAROUT!** *Electronics* magazine 1991-1993 23 issues – £5, *Everyday Electronics* 1971-1985 154 issues – £40, *Practical Electronics* 1977-1979 31 issues – £10. Tel: Andy (0635) 34540 (Newbury).

**NEW COMPONENTS**, plus free PCB Mounting Ni-Cd assorted resistors, capacitors, diodes, ICs etc. £10 per bag inclusive of postage and packing. Contact: Mr. D. J. Brown, 2 Glentworth Avenue, Whitmore Park, Coventry, West Midlands CV6 2HW.

**SWAP.** Thandar SC110A portable scope battery powered, 40mm screen, weighs only 1·2kg. Ideal field service aid. Will exchange for modern dual-trace bench scope. Tel: Mick 0375-844552.

**COMPLETE MULTI-SATELLITE.** Salora XLE 144 Channels, stereo sound and many features. Echo Star 1-2m dish unit actuator, feed/polariser and LNB. Complete with video crypt and D2MAC decoder. £300 (buyer collects). Tel: Martin (0702) 603557.

**GIANT CLEAR-OUT!** Long list of unused components including ICs, books, resistors, some in large quantities, all at bargain prices. Send S.A.E for details to: M. J. Dean, Blenheim, Walton Lane, Bosham, Chichester, West Sussex, PO18 8QF.

**FARNELL LFM/3** Sine Square Oscillator, excellent condition £185. Langport area Somerset. Tel: (0458) 250277.

### WANTED

**TREMELO UNIT** wanted – working, but home-built one is OK. To discuss price: Tel: Mike Parr (0742) 367582.

**LEAK TL25** plus valve amplifier, Leak stereo or mono valve preamplifier. Tel: (0702) 202556.

### AUDIO

**OMEGA POINT MENTOR** turntable £1,600. Ray Lumley class A M150 Power amps (pair) £1,500 (rebuilt with Holco H2 resistors, Kimber capacitors & high quality valves) Pioneer F91 tuner £150. VPI record cleaning machine (top of the range) – offers (cost £500). Farissa organ – offers. Marshall Lead 12 practice amp £50. Linn LP12 (Valhalla). Black Basik Arm. Goldring Eroica (Red). £350. Audio Innovations 1000 transformer (head amplifier moving coil magnetic pick-up stepped up to moving magnet level). £50. Tel: Alan, (0702) 554155 Ext. 247 (office hours).

### COMPUTERS

**FOR SALE:** Wyse terminals £50; Sharp MZ-80K £50; NEC spinwriter £50; bit-one synth £55; video game £10; Variac 0-270V £50; Casio MT-52 keyboard £40. Tel: Paul (0533) 810945. (Leics or Devon).

**SHARP MZ-80K**, interface unit MZ-80I/O and DOT printer MZ-80P3 with manuals, cassettes. £50 o.n.o. Buyer collects. D Hickman, 75 Carlton Road, Redhill, Surrey RH1 2BZ.

**PC AND AMIGA** modules, music, samples. 20 high density disks of modules, 20+ of samples. £2 per disk. S.A.E. for details to: Mike Brown, 2 Glentworth Avenue, Whitmore Park, Coventry, CV6 2HW.

**BBC 'B'** – Circuit diagrams, faults and remedies, various servicing info. send £5 + S.A.E. (A4) to: J. McMahon, 38 Honister Avenue, High West Jesmond, Newcastle-upon-Tyne NE2 3PA.

**SPECTRUM 48K** computer with joystick, cassette recorder, power pack, instructions and 'Dizzy', 'Ridler' and 'Type-Rope'. £50 post free. Contact: J. D. R., Westowan, Truro TR4 8AX.

**COMMODORE PET** 6502 chip, screen, data-cassette, manuals. Some attention required. Keyboard and case v.g.c. £25 plus carriage. Tel: (0454) 413380.

**Z80 CP/M** computer comprising processor/drive unit and Televideo VDU. Handbooks, circuit diagrams and BIOS listing, software. £100. Taxan 12in. monochrome monitor, IBM MDA/Hercules compatible. Hardly used, £40. Tel: (0306) 884719.

**Z80 STUFF** trainers like Microprofessor, Maplin Z80, etc. Also books, boards, electronic test gear. W.H.Y. buy or photo gear to swap. Tel: Mel (0533) 419742.

**ULTIMATE ELECTRONICS CAD** Ultiboard plus Ulticap, professional PCB and schematics software. Full version. Original disks. Only have introductory manual, hence, £80 the pair. Tel: Paul (0703) 592874 (Southampton University).

**TI-99/4A COMPUTER**, as new, with PSU, modulator, speech synthesizer unit and joysticks. Includes 8 cartridge games plus TI extended basic, mini memory, and terminal emulator II modules. Many cassette games and original texas manuals, including assembly language and TI basic/extended basic programming books and cassettes. £60 Tel: Tony (081) 670 8722 (after 7pm).

**AMSTRAD CPC464** green monitor, TV modulator, joystick, assorted games £75 o.n.o. Tel: Alan, (0702) 554155 Ext. 247 (office hours).

**PSION ORGANISER** Series 3 128K £80. Atari 1040STFM with book/magazines/ software etc. £160. Tel: Mike Walden (0604) 756380.

**BBC B COMPUTER** Issue 7 (2 of). 1 has APTL ROM/RAM board, £85 each. Panasonic KX-P1081 Printer £50. Z80 Second Processor £30. Single 40/80 track Disc Drive £30. Double 40 track Disc Drive £35. BBC B+ 128K Computer £120. Tel: (0709) 814010.

**ACNET V3.1** circuit analysis program for IBM PC. Calculates gain, phase, impedances, graphs – Epson, IBM, HP printers, £10. S.A.E. for details to: P. Montgomery, Downings, Bells Hill, Stoke Poges, Slough SL2 4EG.

**CONTROL PC SOFTWARE** for optoisolated card, PC and centronics relay cards. Function keys can be programmed to operate a set of relays. Once set up program can be left running in the background freeing computer. Send S.A.E. for details or cheque for £10 (state disk type) to Mr A. Harle, 56 Courtland Road, Torquay TQ2 6JR.

### CLUB CORNER

**WIRRAL AND DISTRICT AMATEUR RADIO SOCIETY** meets at the Irby Cricket Club, Irby, Wirral. Organises visits, DF hunts, demonstrations and junk sales. For further details, please contact: Paul Robinson (G0JZP) on (051) 648 5892.

# NEWS Report

## Orion Competition for Intel

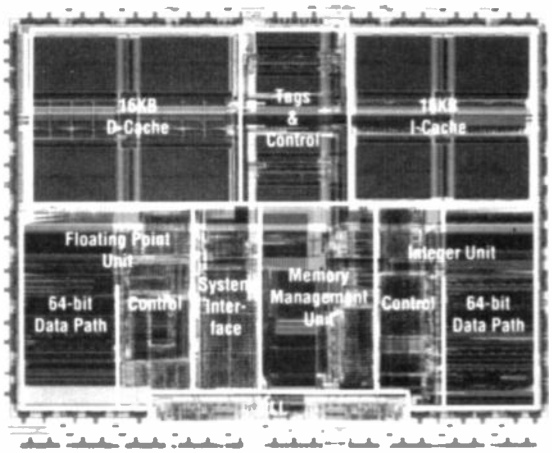
A RISC microprocessor based on the MIPS architecture has been introduced by Integrated Device Technology (IDT). The R4600 Orion microprocessor, is the first RISC processor offering 100MHz performance at a cost lower than Intel's microprocessor product line.

The high-performance Orion processor is targeted at 'green' PCs and servers running the Windows NT operating system, in an attempt to clobber the more conventional microprocessors. The IDT R4600 64-bit processor uses a 50MHz bus divided by two to give an internal clock rate of 100MHz and consumes less than 2·5W at 3·3V.

Orion claim the R4600 performs more than 5% faster than Intel's Pentium-66MHz in both integer and floating-point benchmark tests, while the price is less than one-third.

Contact: Integrated Device Technology (0372) 363734.

**IDT79R4600**
**64-Bit Orion™ Microprocessor**




## What's the Difference

How do you measure a small signal superimposed or modulated upon a much larger one? Well Gould Electronics from Hainault in Essex claim to have the answer.

The PB59 and PB60 differential probes allow a conventional earthed oscilloscope to be used to display and measure multiple in-circuit signals with high common mode voltages.

Using the new probes, a multichannel oscilloscope can be used simultaneously to display and store two or more floating signal waveforms while ensuring that correct phase relationships are maintained.

Each active probe incorporates dual high-impedance balance attenuators, a differential amplifier with high common-mode rejection and a DC/DC converter. Power is supplied from internal batteries or a 6V DC source.

Signal and common-mode voltages between each input and ground are attenuated via a two-position slide switch. The PB59 provides attenuation in the ranges of 200:1 and 20:1 with maximum input voltages of ±700V and ±70V respectively. Corresponding values for the PB60 are 100:1 and 10:1 for voltages of ±400V and ±40V respectively.

Each probe has two input leads terminated in 4mm retractable shrouds. The single-end and low-impedance output is connected via a coaxial cable with a BNC plug to the vertical input channels of any oscilloscope.

Contact: Gould Electronics Ltd (081) 500 1000.

## Computer Security

The end of last year saw a dramatic increase in the theft of computers, printers and other valuable equipment from offices around the country. But this can be stopped.

A new product called Minder, is available from Circle Security to help secure computers against theft. Minder locks the computer to the desktop in such a way to allow authorised personnel only to move it, if necessary.

If someone tries remove it illegally, Minder will stop them. The all-metal construction and seven-lever anti-pick safe lock will defeat even the most persistent of thieves.

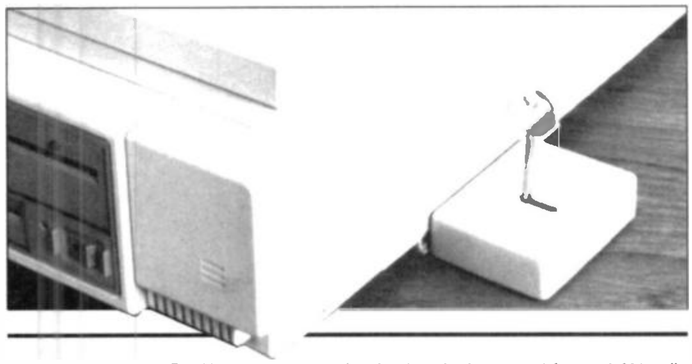
Minder is fixed to the desktop using skews and high bond adhesive, giving up to 500kg of tensile resistance to removal. If the skews supplied with the unit are used these go through the work surface and fix into a plate with pre-formed threads mounted under the surface. Circle Security claim this fixing is the strongest possible and means that the computer can only be stolen if the desk is taken as well.

For many businesses the real loss, following theft, is in the valuable data held on hard disk files. While insurance companies may replace hardware, only hours of hard work will replace stolen data and that is assuming a back-up procedure has been religiously maintained.

Police believe that most computers are being stolen to order and are immediately shipped overseas to markets in eastern Europe and the Middle East. Even computer dealers are being targeted, with showroom stock being cleaned out by thieves.

Minder is supplied with easy to follow instructions and everything required to fit it correctly. It will fit most computer systems from small towers to large footprint desktop units and can also be used to lock down expensive printers and other equipment. The list price for Minder is £59.50.

Contact: Circle Security Ltd (0442) 230925.



## Free Phone Calls

Companies seeking to generate savings can now eliminate office-to-office long-distance calls with a device that integrates data and voice communications.

The Sprinter from Californian company Micom Communications compresses voice calls eliminating all silences that punctuate the conversation. Meanwhile a similar technique is used to compress electronic data such as fax and local area network (LAN) computer messages.

A typical speech conversation is about 60% silent – Micom's suppression techniques are able to reduce the bandwidth required to transmit this by a further 60%

By combining the two forms of communication over a single telephone circuit, telephone and fax or LAN calls can be transmitted at the cost of a single call.

According to Micom, its speech compression, dynamic bandwidth allocation and silence suppression technologies provide a 10:1 bandwidth advantage over conventional transmission techniques.

Each Sprinter costs £1,320 and two are required to make a call between two sites. "Any company with over an hour of phone or fax calls a day will pay for their Sprinter connection within a year," says Mr. Ken Guy, MICOM Vice President of Corporate Strategy and Business and Development.

Sprinter supports analogue networks as well as digital, at speeds ranging from 9·6K-bit/s to V.Fast at 28·8K-bit/s.

Contact: Micom Communications (010 1) 805 583 8600.


## Inkjet Refill

System Insight have just launched a series of specialist new refill kits for some of the latest inkjet printers on the market; including refills for the Canon CLC-10, Canon BJC-800, Epson Stylus 800 and HP Deskjet 1200C. These new refills complement System Insight's existing range of Inkmun refills for most existing models.

System Insight's Inkmun refill kits allow inkjet users to refill their printer cartridges rather than having to bear the cost of purchasing a new replacement cartridge each time the ink supply has exhausted. The ink within each refill kit is matched as closely as possible to that of the original cartridge manufacturer.

Each specialised ink formulation is contained in a concertina style bottle, eliminating the need for syringes and sharp needles while also easing the refilling operation.

Inkmun refill kits are available by mail order from £14.98 for two, including VAT, same day despatch by first class post. Even better, System Insight are offering readers of *Electronics* 10% discount off any refill. Quote reference *Electronics* Magazine RB20 when ordering.

Contact: System Insight (0707) 3955000.

## Virtual Exhibition

The London Virtual Reality Expo 94 from January 31 to February 2 is a conference and exhibition for all those with a professional interest in virtual reality (VR).

During the conference a series of 'super-sessions' will highlight topic areas that are of current interest and which hold future promise for the virtual reality community. Guest speakers will present unique discussions about projects or VR areas of interest.

The showcase approach will provide attendees with fresh discussions about the potential of VR across a wide range of development areas from a number of nations; from arts to military, from architecture to medicine, from net-worked VR in business applications to VR technologies that will enrich the lives of disabled people.

Running alongside the conference will be an exhibition offering users and potential users of VR systems, the UK's widest display of VR technology. Even if you are unable to attend the conference, London Virtual Reality Expo will give you a chance to contact all the companies who are making VR happen.

Entry to the exhibition is by free ticket, or £10 at the door. Exhibition tickets will be available through exhibiting companies, distributed widely to the business, professional and academic communities, or may be requested by contacting organiser Meckler direct. Please note that this is a trade and professional event and is not open to the general public.

Contact: Meckler (071) 976 0405.

## National Computer Shopper Show

A couple of months ago we reported on the planned Computer Shopper Show at Olympia in London. This has been and gone and it is now the turn of the rest of the country. The National Computer Show is due to open in Birmingham from March 24 to 27 in a new purpose built exhibition hall at the National Exhibition Centre (NEC).

The retail environment in the Midlands and the North is much less developed than in London, although in the past two years, one million PCs have been purchased by home users in the Birmingham region.

Annually over £24million of business is conducted at the two Computer Shopper Shows and with the National Show taking place in late March the figure is expected to rise as education and business buyers spend budgets before the end of the financial year. "It is anticipated that visitors will jump at the chance to participate in an established show like Shopper, which offers a diverse range of hardware, software and computer peripherals at rock bottom prices," says Cathy Oates, Shopper's director.

The National Computer Shopper Show is for everyone from first time buyers to experienced business users. Features at previous shows have included multimedia, virtual reality, notebook test centres and free advice seminars.

Contact: National Computer Shopper Show (081) 742 2828.

## Reduced Capacitance

With a capacitance range from 0·1 to an incredible 2F, Panasonics's Series EL Gold Capacitor is claimed to be the world's smallest discrete electric double-layer capacitor. Measuring 6·8mm in diameter and 1·4mm in height, the circular coin-type capacitor is aimed at designers of memory cards, pagers and cellular telephones.

"Designers of portable electronic and computer equipment are looking to reduce both the size and weight of their products," says Dr. John Turner, Marketing Manager of Panasonic Industrial Passive Components Division. "With the EL series, Panasonic has produced a capacitor with the power, size and weight requirements to meet these demands."

Designed to provide memory back-up in cases of system power failure, the EL Gold Capacitor Series can be supplied with values of 0·1, 0·33, 0·47, 0·68 and 2F. The standard rated working voltage of the series is 2·5V over an operating temperature range of –25 to +70°C. Panasonic Industrial's EL Series has a proven reliability of over 100,000 cycles of charge/discharge.

Unlike film or aluminium electrolytic capacitors, double-layer capacitors use a physical mechanism to generate an electric double layer. In operation, the double layer is formed by a charge-discharge mechanism in which anions are formed on the cathode of the positive electrode and a layer of ions is formed on the negative.

Contact: Panasonic (0344) 853827.

## Increased Bandwidth with Quantum Lasing

Multiple-quantum well NDL7408Px lasers from NEC Electronics have the narrowest spectral width of any available. The spectral width is only 1·5nm, as opposed to 6nm available from devices currently on the market making it possible to fit even larger amounts of data on a fibre optic.

NEC's MQW lasers are particularly suitable for analogue systems, such as cable TV. Benefits over similar systems include low relative intensity noise performance, low intermodulation distortion and high linearity. The lasers operate effectively over a wide temperature range up to 85°C.

Multiple-quantum well devices are formed by alternating very thin layers of active semiconductor material, with equally thin layers of barrier material. The layers are around 5nm thick, confining atoms so that electrons form discrete and calculable energy levels. The electrons escape at frequencies corresponding to their trapped energy levels. Consequently, by varying the spacing between atoms during manufacture, it is possible to customise the frequency of lasers.

To conform to the European CCITT requirements, the lasers are available in two output powers, 0·2mW and 1·0mW.

Contact: NEC Electronics (0908) 691133.

## IEE Competition

A prize of £7,000 is up for grabs from the IEE for its 1994 5th Triennial Prize for Helping Disabled people. Launched by Kate Bellingham of Tomorrow's World, the competition is on the look out for unique projects which are helping disabled people that could be developed into a commercial product.

The rules are simple: an invention has to be original, have some electronic component and must be helping at least one disabled person, with the potential to help others.

Chairman of the judges, Sir James Redmond is confident of a high quality of entrants. There are normally around 50 entries, of which a dozen or more are selected for detailed scrutiny.

The past two winners – a robotic arm that allows paralysed people to eat without help and a newspaper broadcast to blind subscribers ready to read in the morning – have both been developed into commercial projects.

Contact: IEE (071) 344 5446.

## DIARY DATES

Every possible effort has been made to ensure that information presented here is correct prior to publication. To avoid disappointment due to late changes or amendments please contact event organisations to confirm details.

**1 to 8 January.** Model Engineer & Modelling Exhibition, Olympia Grand Hall, London. Details Tel: (0442) 66651.

**12 January.** Wirral and District Amateur Radio Club, Annual General Meeting at 20.00hrs at Irby Cricket Club, Irby, Wirral. Details Tel: (051) 648 5892.

**12 to 15 January.** BETT '94 – British Education, Training & Technology, Olympia National Hall, London. Details Tel: (071) 404 4844.

**15 January.** Crystal Palace & District Radio Club, QRP (Low Power) Home built Radio Equipment by Wayne Dillon, 19.30hrs All Saints Parish Church Rooms, Beulah Hill, Upper Norwood, London SE19. Details Tel: (081) 699 5732.

**23 to 26 January.** Furniture & Lighting '94, National Exhibition Centre, Birmingham. Details Tel: (081) 692 8848.

**26 to 27 January.** Virtual Reality '94, Olympia 2, London. Details Tel: (071) 931 9985.

**26 January.** Wirral and District Amateur Radio Club, Surplus Equipment and Junk Sale at 20.00hrs at Irby Cricket Club, Irby, Wirral. Details Tel: (051) 648 5892.

**29 January to 2 February.** British International Toy & Hobby Fair, Earl's Court 2. Details Tel: (071) 701 7127.

**30 January to 2 February.** European Lightshow, Earl's Court, London. Details Tel: (0952) 290905.

**8 to 10 February.** Integrated Communications '94 – The ISDN User Show, Wembley, London. Details Tel: (0733) 394304.

**9 to 10 February.** Instrumentation, Crest Hotel, Bristol. Details Tel: (0822) 614671.

**13 February.** Third Northern Cross Radio Rally, Rodillian School, A61 between Leeds and Wakefield. Details Tel: (0532) 827883.

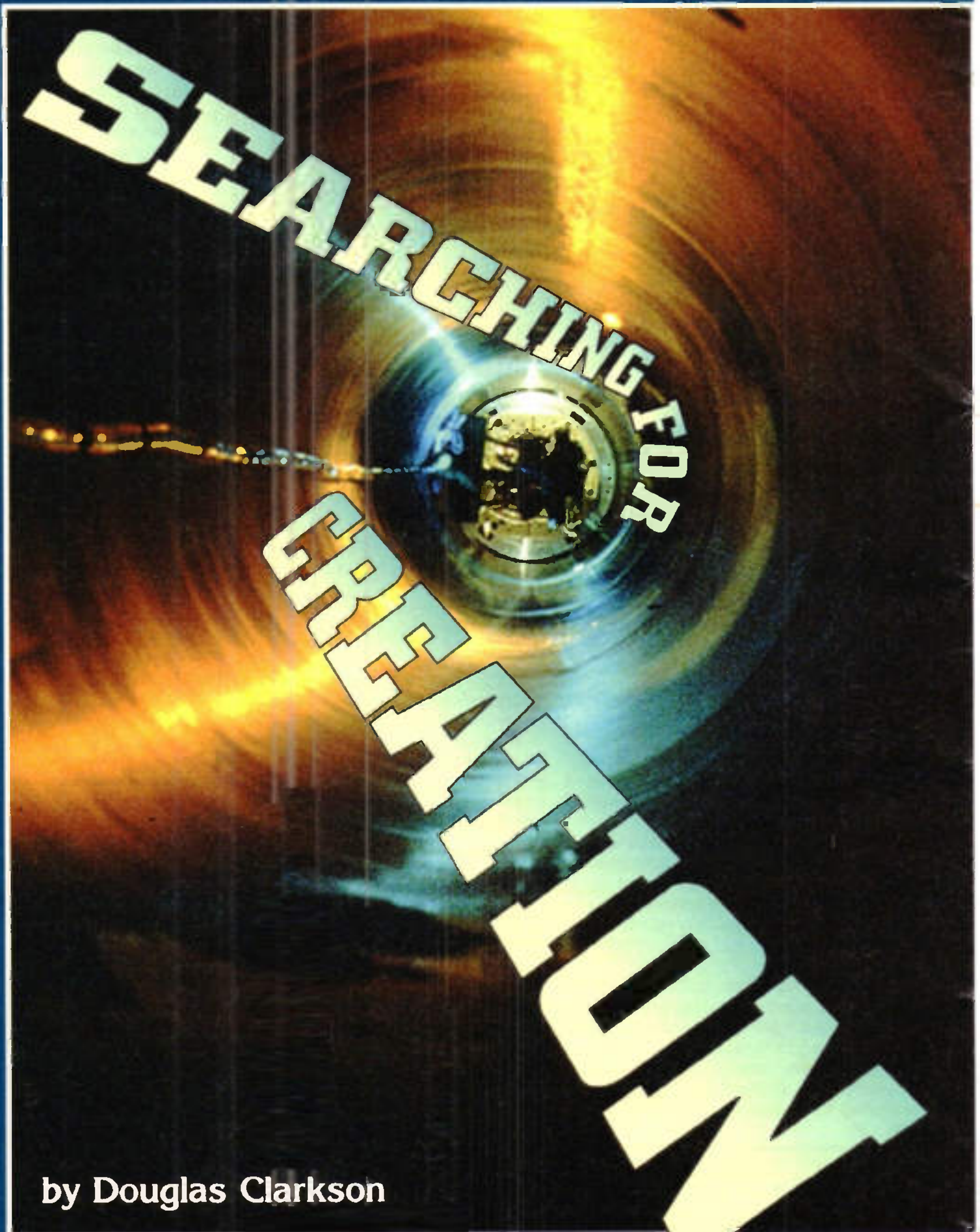
**15 to 17 February.** Smart Card '94, Wembley, London. Details Tel: (0733) 394304.

**16 February.** High Definition Television Conference, Financial Times Conference Organisation, London. Details Tel: (071) 251 9321.

**19 February.** Crystal Palace & District Radio Club, Annual General Meeting and Construction Contest, 19.30hrs, All Saints Parish Church Rooms, Beulah Hill, Upper Norwood, London SE19. Details Tel: (081) 699 5732.

**22 to 25 February.** The Windows Show 1994, Olympia Grand Hall & Conference Centre. Details Tel: (0256) 381456.

Please send details of events for inclusion in 'Diary Dates' to: The News Editor, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex SS6 8LR.




AT this time, towards the end of the 20th century, scientists are taking stock of what is known about the material world. Roughly 100 years ago conventional Newtonian Science was apparently making good progress towards explaining the phenomenon of the physical world. Electricity and magnetism had been eloquently described by James Clerk Maxwell. Heat and conduction theory had been satisfactorily explained. Important scientists of the time such as the American Albert Michelson were claiming that science was more the challenge of resolving various constants to higher degrees of accuracy than discovering anything fundamentally new. Such a view was possibly also held by Lord Kelvin. It was a time when science was beginning to be looked on as a drudge.

Then there was to come a series of startling discoveries and theories which were to break for all time the solid classical face of science. These were X-rays discovered by Wilhelm Roentgen in 1895, radioactivity discovered by Henri Becquerel in 1896, the electron discovered by J. J. Thompson in 1897 and Einstein's Special Theory of Relativity published in 1905. In 1911 Ernest Rutherford was able to demonstrate that atoms had a small massive nucleus surrounded by a cloud of electrons. The theory of Quantum mechanics was in turn developed in the 1920s to explain interactions at the atomic and molecular level.

Initially, the major scientific discoveries could be made in a few hours of laboratory time using low cost equipment and materials. Projects now on the drawing board such as the SSC (Superconducting Super Collider) in the USA and costed at $8 billion, look towards uncovering the next layer of Nature's secrets of how the physical world is constructed.

There is no doubt that at this time scientists are more idea rich about theories to explain various interactions of matter than at any time in the past. What is lacking, however, is a unified theory which can explain the working of strong nuclear forces, the electromagnetic forces, the weak nuclear force and last but not least, the gravitational attraction. Just as the understanding of the physical world has dramatically changed several times over the last 100 years, so present understanding may still undergo a fundamental review and rework. It is in the construction and operation of the large projects at CERN in Geneva and the SSC in Texas that will probably help find the clues to the universal theory explaining all aspects of the nature of matter and energy in the physical world.

## The Nature of Things

While there are a great many known high energy particles such as are detected in Cosmic Ray showers propagating through the atmosphere, interest is primarily centred on the nature of stable physical matter.

It is thought that matter is primarily composed of particles called quarks and leptons and that these can be described as belonging to three *generations*.

Table 1 shows present assessment of basic building blocks of physical matter. Values in brackets are the masses of the particles expressed in MeV (millions of electron volts).

So far the electron and the muon neutrinos have been detected though there is significant evidence for the tau neutrino.

Quarks seem constrained to bind with other quarks to form particles with integral charge. The neutron and the proton, for example, are composed of quarks.

Thus a proton can be considered to consist principally of two up quarks and one down quark (to give one unit of charge) while the neutron will consist primarily of one up quark and two down quarks (zero net charge). The more general family of particles assembled from quarks is called hadrons.

## The Fundamental Forces

As a child at school, Einstein was fascinated by simple experiments with a bar magnet. He could, however, get no

| | Lepton | | Quarks | |
|---|---|---|---|---|
| Generation | Charge −1 | Neutral | Charge +$^2/_3$ | Charge −$^1/_3$ |
| 1 | electron (0·51) | electron neutrino | up quark (340)* | down quark (340)* |
| 2 | muon (106) | muon neutrino | charmed quark (1,550) | strange quark (510)* |
| 3 | tau (1,784) | tau neutrino | top quark (>95,000) | bottom quark 4,720) |

* Indicates approximate value.

**Table 1 Present assessment of basic building blocks of physical matter.**

Right: Section of the tunnel showing a model of the LHC (Large Hadron Collider) on top of LEP. (CERN photo).
Below: Air view of the CERN sites just outside Geneva: Jura mountains in the background. The large circle shows the line of the LEP tunnel, 27km in circumference, the small circle shows the SPS tunnel, 7km in circumference. (CERN photo).
Bottom: LEP tunnel. (CERN photo).

useful explanation of why the magnetic field was produced or how two magnetic poles could be made to attract and repel. Gradually a picture has built up, however, of the basic forces or interactions of the physical world. The electromagnetic force is certainly one to readily demonstrate. The gravitational force is taken very much for granted. At the level of the atomic nucleus, however, the so called *weak* and *strong* interactions have been much more difficult to verify and also explain.

Quarks can be considered to be bound together by some kind of *glue* much stronger than the electro magnetic force. The nuclear physicist pictures a so called *field particle* of zero rest mass hopping between the quarks and forming a stable hadron particle. It can be considered to interact with the quarks to produce a stable unit.

The so-called weak force can be considered as a universal force which can influence all particles. It is, however, many times weaker in action than the strong force. The weak force is considered to be enabled by the exchange of a series of particles with a relatively high rest mass. The W+, the W– and the Zo have energies in excess of 80GeV (GeV = $10^9$ eV).

The gravitational force is considered to act on all particles with mass, with the gravitron being the mysterious entity which manifests the force of attraction. The gravitational force is in relative terms, extremely weak.

Table 2 summarises details of the basic forces of the physical world.

It is now thought that the weak and the electromagnetic forces are manifestations of a more general *electro-weak* interaction. This has tended to unify the theories explaining the basic forces of the universe.

## Quark Bashing

The additional insight into the basic nature of things has come from recent research at key high energy research laboratories. At the Fermilab Tevatron near Chicago, head on collisions between 900GeV protons and 900GeV anti-protons are scanned by a large detector known as the Collider Detector at Fermilab (CDF). Such experiments seek mainly to probe the ways in which quarks form stable hadrons. In the collision process 1800GeV (=1·8TeV) of energy is available to overcome the strong nuclear forces binding the individual quarks in the protons and anti-protons.

| Force | Field particle and rest mass | Strength relative to strong force at $10^{-13}$cm | Particles which experience |
|---|---|---|---|
| electromagnetic | photon (0) | $10^{-2}$ | all charged particles |
| weak | W+ (80·6GeV)<br>W– (80·6GeV)<br>Zo (91·16GeV) | $10^{-13}$ | all particles |
| strong | gluon (0) | 1 | quarks and hadrons |
| gravitational | G;Gravitron (?) | $10^{-38}$ | all particles with mass |

**Table 2. Summary of known forces of Physics.**

The object of the experiment was to force quarks unnaturally close to each other to determine what range of forces operated, and also whether the quark could be considered as infinitely small or if its size could be measured. This experiment was similar in many ways to that undertaken by Ernest Rutherford in 1911 when gold foil was bombarded by alpha particles.

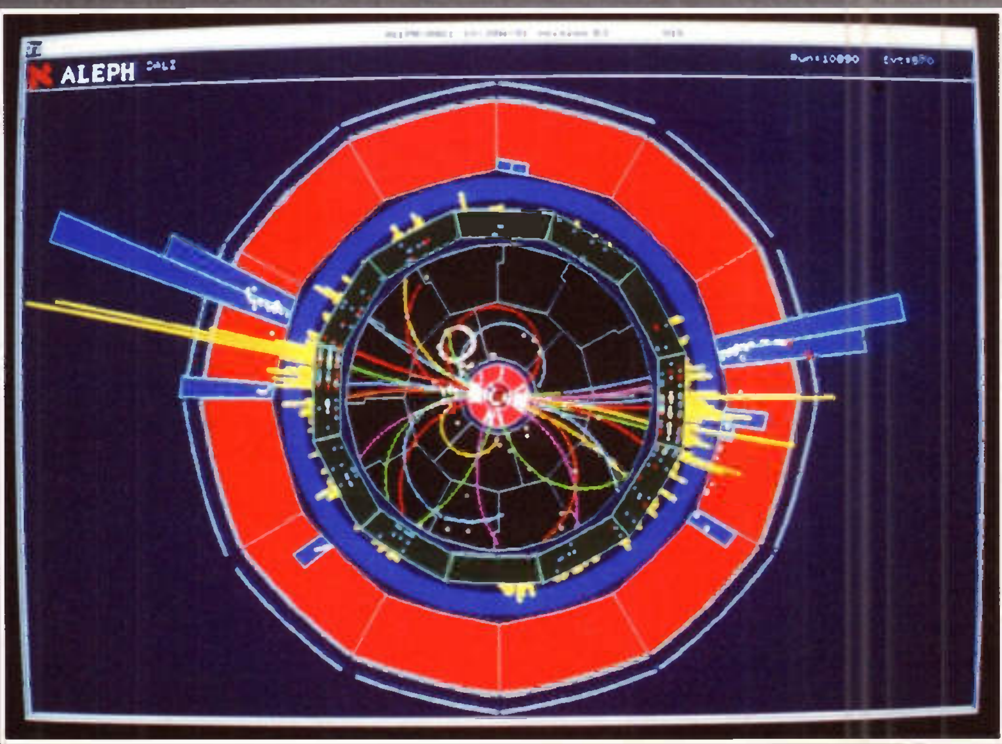
It was observed that back-to-back jets of mesons were ejected from collision centres as similar quarks interacted strongly together. When quarks receive sufficient energy to break free from a stable hadron such as the proton, then at distances larger than the nuclear diameter, they transform into a stream of mesons and quark-antiquark pairs. The tracks of the mesons confirm the present theory of strong interactions of quarks – known also as quantum chromodynamics. This provides a picture at present of quarks being point particles.

One of the main aims of the Fermilab is to determine the properties of the top quark and in particular to determine its mass. Present research indicates that its mass should be greater than 95GeV with researchers expecting a value of 200GeV. It is anticipated that this higher energy can be produced from the Fermilab Tevatron and so hopefully all the quarks will soon have been discovered.

## CERN – Electron-Positron Collider Results

During 1990 the European Centre for Nuclear Research (CERN) began to operate the Large Electron Positron Collider (LEP). This system is built into a large particle accelerator some 26·7km (16·6 miles) in circumference. The system collides electrons and positrons at energies in excess of 100GeV in order to probe the nature of particles which mediate the weak nuclear force. This project was initially approved in 1982.

In the LEP, electrons and positrons can be steered in the large ring by a common set of steering magnets. The separate beams circulate in opposite directions and can be made to interact at selected points by configuration of the local magnetic field. Where particle beams collide head on, considerably more energy is actually available to form potential new particles than if, for example, a fast moving particle is fired at a stationary one.




The weak force is thought to act by the exchange of relatively massive particles between the particles taking part in the interaction. From a large wealth of experimental data, the mass of the Z boson, one of these *force* particles, was determined with very high accuracy to be 91·1GeV with an experimental error of 0·06GeV.

Neutrinos of the three known types (electron, muon and tau) are produced as a result of separate decay processes of the Z boson. The lifetime of the Z particle is thought to decrease by about 6% for each additional neutrino type which is included. From observations with the LEP, there is evidence that the set of the three known types – electron, muon and tau – is complete.

## Cold Neutrons

Neutrons which form part of a stable atomic nucleus behave quite differently from neutrons which break free from an atomic nucleus. While an atomic neutron will be stable for billions of years, a free neutron will only survive for about 15 minutes on average. The half life of a free neutron has been shown to be related to the number of neutrino particles present. Experiments at the University of Bonn carried out by physicist Wolfgang Paul, developed a technique for magnetic containment of cold neutrons – neutrons with low values of kinetic energy – in order that a given population could be contained, and their rate of decay measured. While the neutron has no charge and therefore cannot be bent into a circular path like a proton, it does possess a finite magnetic dipole moment and so can be contained within specially configured magnetic fields produced by so called hexpole magnets.

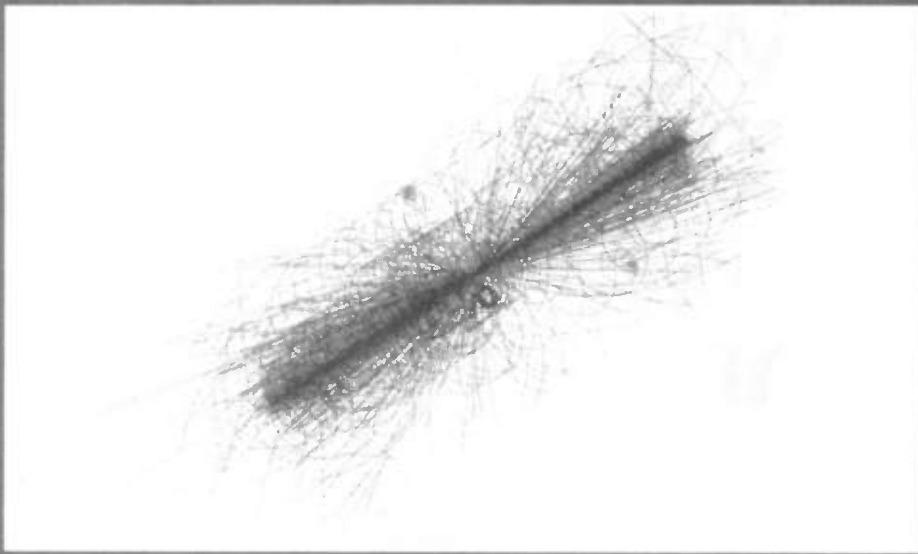
The most intense source of these so called ultracold neutrons is currently at Institut Laue Langevin at Grenoble in France. Scientists have determined that the lifetime of the exposed neutron is 888·6 seconds with an error of 2·6 seconds. Such a result confirms the data derived from the LEP site – there are only three types of neutrinos – the electron, the muon and the tau.

Outside observers may wonder what all the fuss is about – why do we need to have an understanding of the neutrino? While the neutrino can be thought of as a problem of the microcosm, it does also determine basic facts about cosmology. If, for example, neutrinos are massless then models of the universe predict a continually expanding universe. If, however, neutrinos do have finite mass, then it is possible for the universe to eventually collapse back on itself. So the debate continues.

## Levels within Levels

Research at various centres is also investigating the interactions between quarks within atomic nuclei. Since

**Left: Computer reproduction of the decay of a Zo particle via a quark-antiquark pair into many particles as seen in the Aleph detector. Front view. (CERN photo).**



Left: Simulation of a bunch crossing in a LHC detector. (CERN photo).

nucleons (protons and neutrons) are separated from each other by approximately their own diameter (1·7 femtometres : $10^{-12}$ of a metre), the energy states of the quarks in one nucleon can be considered to be influenced by the presence of other nucleons. This has led to studies at CERN and Fermilab to try and probe the energy structures of different nuclei as a function of quark interactions. At CERN, work was undertaken as part of the European Muon Collaboration project. Differences were initially detected in the behaviour of Deuterium (one proton and one neutron in the nucleus) and heavier nuclei. At present, the so called *scaling* theory in explaining such interactions is in favour, but much experimental work remains to be undertaken.

This indicates, however, that a true picture of the energy structures in the nucleus of the atom must take into account interactions between quarks.

## Enter the Higgs Particle

The Scottish physicist Peter Higgs has postulated the existence of a new particle (the Higgs particle) in order to explain various theories, but research so far, has failed to detect such a particle. Calculations show that it would be necessary to accelerate particles to extremely high energies in order to detect whether such particles exist or a new level of force interaction takes over. Some estimates indicate that around 40 trillion electron volts of energy may be required to verify current levels of theory. Rather than accelerate protons into a stationary target, it is vital that two separate beams, each with 20 trillion electron volts of energy are made to collide. Roughly only 10% of the energy of an incident particle is available for energy transformation reactions if it collides with a stationary target.

If and when the Higgs particle is detected and its energy calculated then this will be a significant breakthrough in producing a more cohesive theory about matter – comparable perhaps to the deciphering of the Rosetta stone in Egyptology. Then physicists will be able to explain why particles have specific masses and characteristics.

## Looking Ahead – CERN

At present there is no evidence to suggest that quarks are themselves composed of even smaller particles though scientists would perhaps not be surprised if this proved to be the case. At CERN two proton accelerators are being constructed in a so called Large Hadron Collider (LHC) in the pre-existing LEP tunnel. Each beam will be capable of accelerating protons to 8TeV so that the combined energy of a collision will be a massive 16TeV. Researchers at CERN hope that such energy levels will be sufficient to both test the present standard model of particle physics to its limit, and also discover the elusive Higgs particle.

At these energies the term *atom smasher* fades into insignificance. The term *nucleon smasher* would be more appropriate.

## Looking Ahead – The Superconducting Super Collider

In 1986 the Universities Research Association in the USA completed the design specification for such a system. A 10ft wide tunnel some 83km in circumference would contain 3840 bending magnets and 888 focusing magnets maintained at superconducting liquid helium temperatures. The high strength magnets are required to bend the fast moving protons into ellipsoidal paths.

After a process of lengthy assessment, Ellis County in Texas was chosen as the site for the SSC project and preliminary site preparation work was begun. Up until this time there was a high degree of interest in the project in congress – due perhaps to the possibility that the large project could make popular those who secured it for a specific location. Support for the project naturally fell away somewhat when the final winner – Ellis County was chosen. With finite funding being allocated each year to the project, however, the eventual completion of the SSC project cannot yet be guaranteed.

The use of superconducting magnets for the SSC project allows large magnetic fields to be produced at *economical* current consumption.

With such large sums of money involved, however, projects such as CERN look more attractive where the funding is secured from the science research budgets of numerous European countries. In the UK, however, CERN is not every scientist's view of how funds for basic scientific research should be distributed.

There are, however, undoubted benefits of an economic nature in developing technology using, for example, superconducting magnets since this very technology will tend to be of increasing importance in many future areas of technology such as power transmission and electric motor operation.

## Summary

In the closing years of the 20th century some of the most daring scientific experiments will be undertaken in the search to discover the nature of matter. It remains to be seen now the world of science is settling down, and structures require only to be fine tuned, if an amazing discovery will require the rewriting of the textbooks.

It is an interesting thought that as the particle accelerators of CERN and SSC eventually begin to produce particles of energies in the tens of TeV, that man is moving closer towards that time in the youthful universe, perhaps 15 billion years ago, when particles of such energy were expanding out to fill the void.

Physicists who work in such high energy fields are increasingly prone to philosophical thinking – of a kind. By probing for the very rules which determine the nature of the physical world, and developing theories which take account of all the interactions that they see, there is developing a new way of looking for how everything could have been created. It is this school of thinking which launched Stephen Hawkins to write his best seller *A Brief History of Time*. Whether anyone really understands how things came into being, people are beginning to wonder how.

So perhaps the super high energy experiments being developed now, and the ones people will propose in 50 years' time, could be driven by this yearning to understand better some very fundamental issues which are not just about revising the accuracy of physical constants in text books, but answering two basic questions – how and why are we here?

## Additional Reading

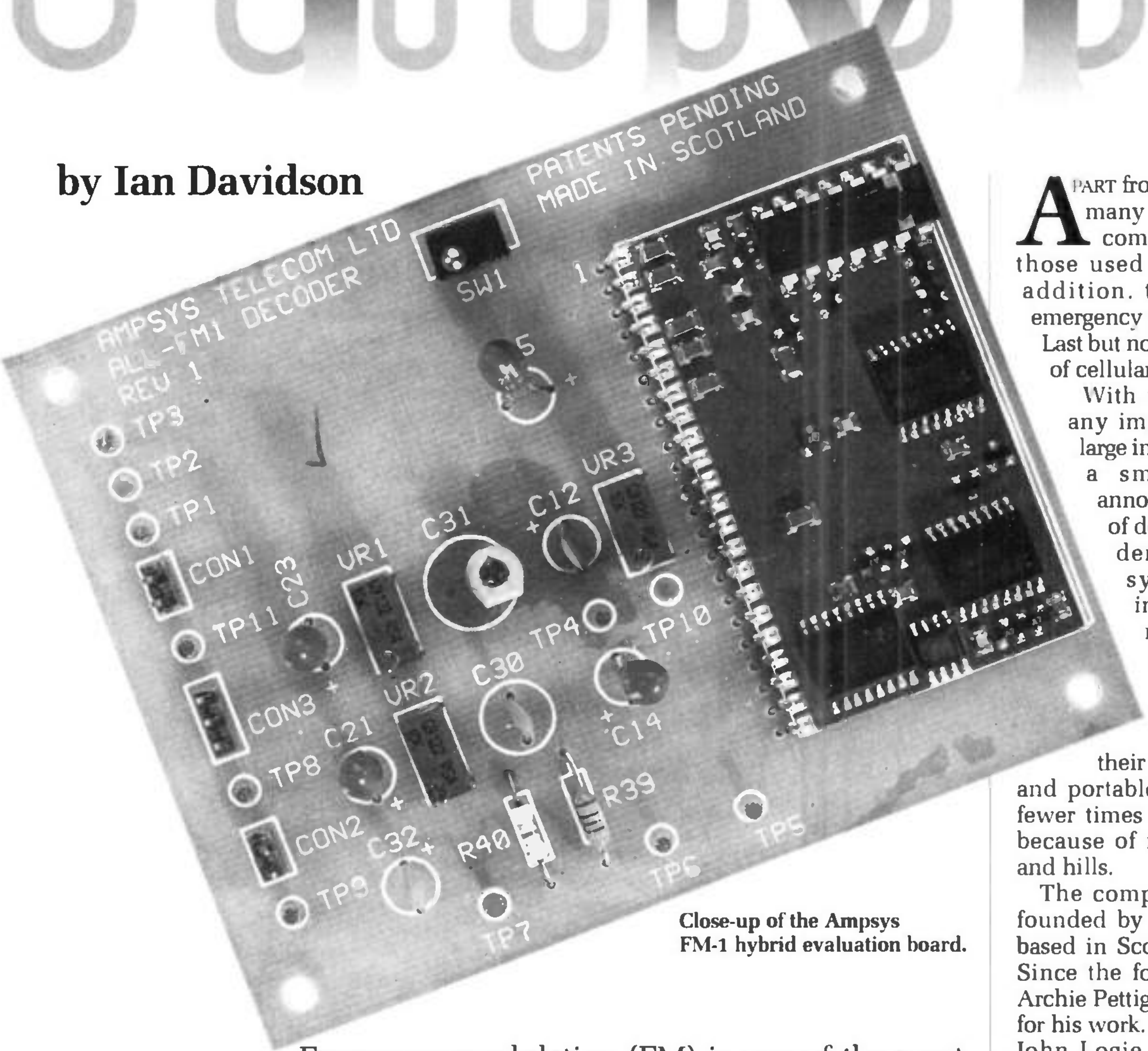
*Dreams of a Final Theory*, Steven Weinberg, Hutchison Radius.
*The First Three Minutes*, Steven Weinberg, Hutchison Radius.
*The Big Machine*, Robert Jingk, Andre Deutsch, 1969.

## Contact Details

For further information, contact CERN European Laboratory for Particle Physics CH-1211 GENEVA 23.
Tel: +041 22 767 41 01.

# THE AMPLITUDE LOCKED LOOP – A NEW WAY OF DEMODULATING FM

**by Ian Davidson**




**Close-up of the Ampsys FM-1 hybrid evaluation board.**

Frequency modulation (FM) is one of the most widely used methods of adding modulation onto a radio carrier signal. For example it is used for sound broadcasting on the VHF band between 88 and 108MHz. Nowadays more people listen to these transmissions than the amplitude modulation (AM) ones on the long and medium wavebands.

APART from this, FM is widely used in many other applications. Mobile communications systems, like those used in taxis also use FM. In addition, the systems used by the emergency services are all based on FM. Last but not least, the current generation of cellular telephones use FM as well.

With this extensive use of FM, any improvements would have a large impact on the market. Recently a small Scottish company announced an improved method of demodulating FM. It has been demonstrated that the new system can give a 6dB improvement in background noise at low signal levels. If this was implemented nation-wide mobile phone operators could see less problems in the use of their phones, and listeners to car and portable radios would experience fewer times when the signal breaks up because of reflections from buildings and hills.

The company, called Ampsys, was founded by Archie Pettigrew and it is based in Scotland at Paisley University. Since the foundation of the company, Archie Pettigrew has won several awards for his work. In June 1990 he received the John Logie Baird Prize for technical innovation, and then in September of the same year he received the Department of Trade and Industry SMART 1 Award. A year later he was presented with the SMART 2 award. All of these were for the Amplitude Locked Loop (ALL). Finally he has received the John Logie Baird Award for his work on contour biasing – a method of applying bias to magnetic media like audio tape.

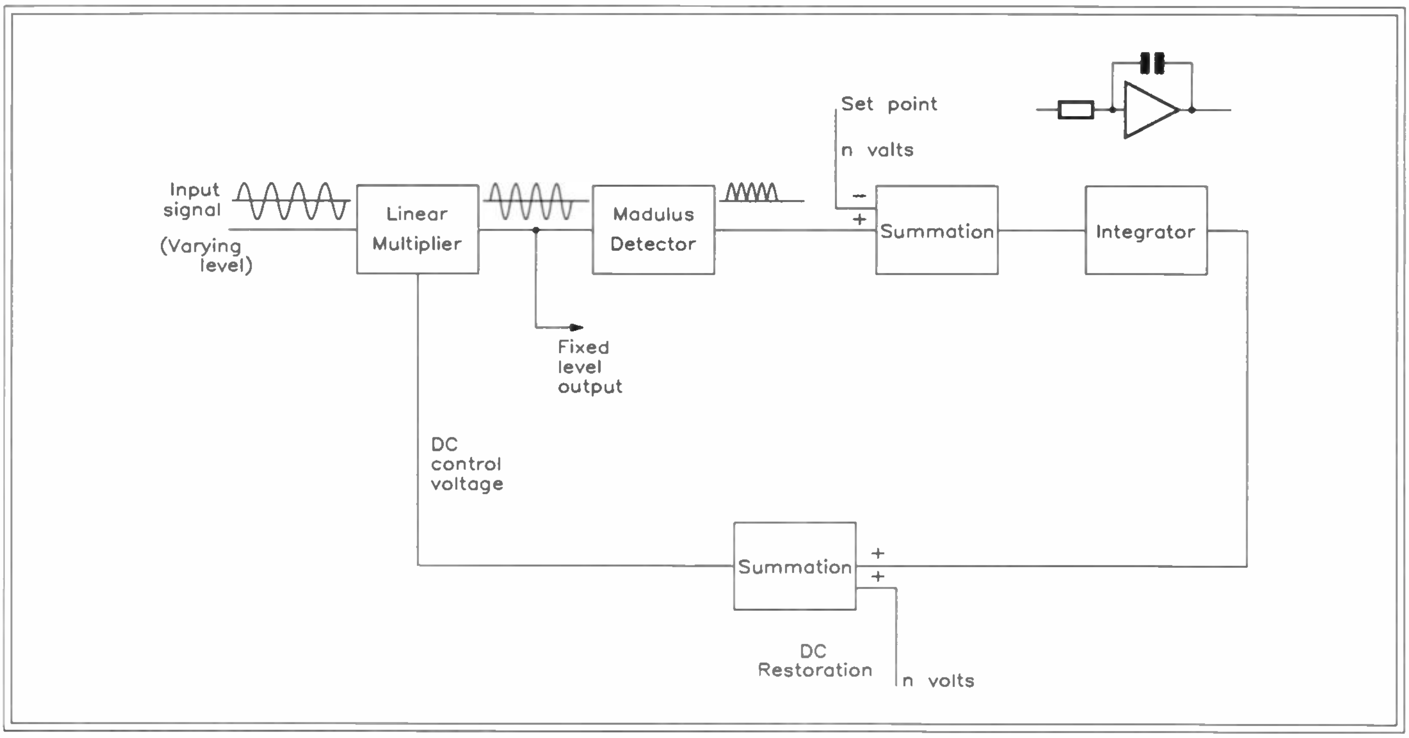



**Figure 1. Block diagram of the amplitude locked loop.**

## Basic Idea

In any radio system, noise is always a problem. It comes in many forms; it can be interference from other radio signals, or it may be car ignition noise, or possibly just ordinary thermal noise.

To reduce this noise and be able to copy weaker signals, there are two main approaches which can be adopted within the receiver. The one which is used most often is to reduce the bandwidth to exclude as many of the unwanted signals as possible. This approach is obviously very successful, but there comes a point beyond which the bandwidth cannot be reduced any further. If the bandwidth is made too narrow, then parts of the wanted signal will be rejected, resulting in distortion and loss of intelligibility.

Once this point has been reached, the other techniques have to be implemented if any improvements are to be gained. One of these involves generating a signal which consists of only the noise. This can then be subtracted from the incoming signal, which consists of the wanted signal plus the unwanted noise. In a perfect situation this would leave only the wanted signal. However, in reality it is never possible to subtract all the noise, but even so, it is possible to make a worthwhile improvement.

This technique has been used in a wide variety of applications. For example, it is used in the automotive industry where sensors are placed around the car to detect vibrations. These signals are analysed, processed and then transmitted in antiphase into the cockpit of the car to reduce the overall noise level.

The technique is not widely used in radio applications. The main problem is that it is not easy to obtain the noise alone signal. However, recent developments at Ampsys have enabled a noise alone signal to be generated for an FM signal. To achieve this, a new circuit called an ALL has been developed, and this is the key to the whole idea.

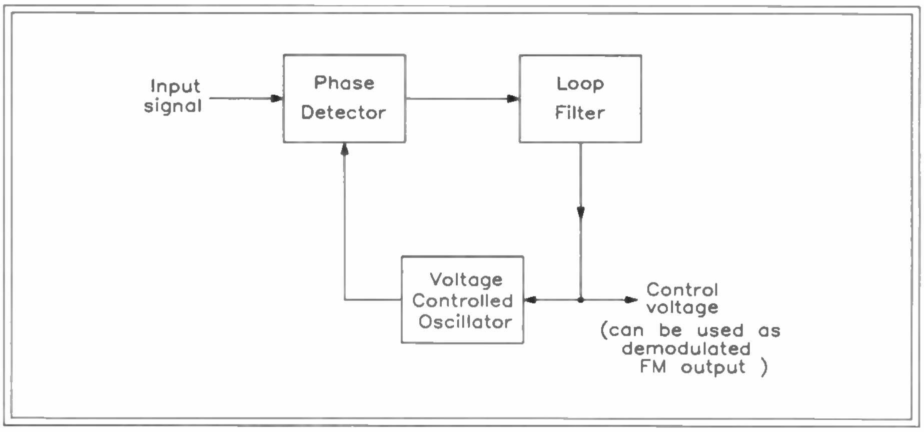



**Figure 2. Block diagram of a phase-locked loop.**

## Amplitude Locked Loop

The loop is basically a form of servo system, having feedback to maintain the level of the output signal, over a defined but finite signal range. As the loop has a very wide bandwidth, it is able to operate just as easily on a signal which is fluctuating with the movement of a car, as it is with a signal which has normal amplitude modulation imposed on it.

The basic block diagram of the ALL circuit is shown in Figure 1. The radio frequency signal enters one port of a multiplier circuit. Multipliers or mixers are widely used within electronics to perform such functions as frequency changing in a radio, where the output is formed by multiplying two signals together to produce the sum and difference frequencies. Whilst in radio application it is sometimes possible to tolerate a degree of non-linear performance, the multiplier in the ALL must be very linear if the correct performance is to be maintained.

The output from the multiplier is the same radio frequency signal which entered it, but controlled in amplitude by a DC voltage on the other port.

Once through the linear multiplier the signal is passed into a modulus detector. This is essentially a full-wave rectifier, but again this must be linear. The output from this circuit is a sine wave, but any negative going sections of the wave are mirrored back to become positive going as shown in the block diagram.

Next a DC offset is subtracted from the full-wave rectifier output, this sets the operating point of the loop. Then the signal is passed into a high gain integrator, which removes the component of the signal at twice the frequency of the incoming signal and provides the high bandwidth of the loop.

The next stage in the processing is to add the DC component which was previously subtracted. This control voltage is then applied back to the input of the linear multiplier to control the amplitude of the signal, holding it constant despite any variations in the level of the signal entering the loop.

From the description it can be seen that the ALL is essentially a multiplier which has a high gain servo loop placed around it. The amplitude variations are removed by the action of the high gain loop, leaving a fixed amplitude signal. In fact this has been achieved without the use of a noise sensitive hard limiter.

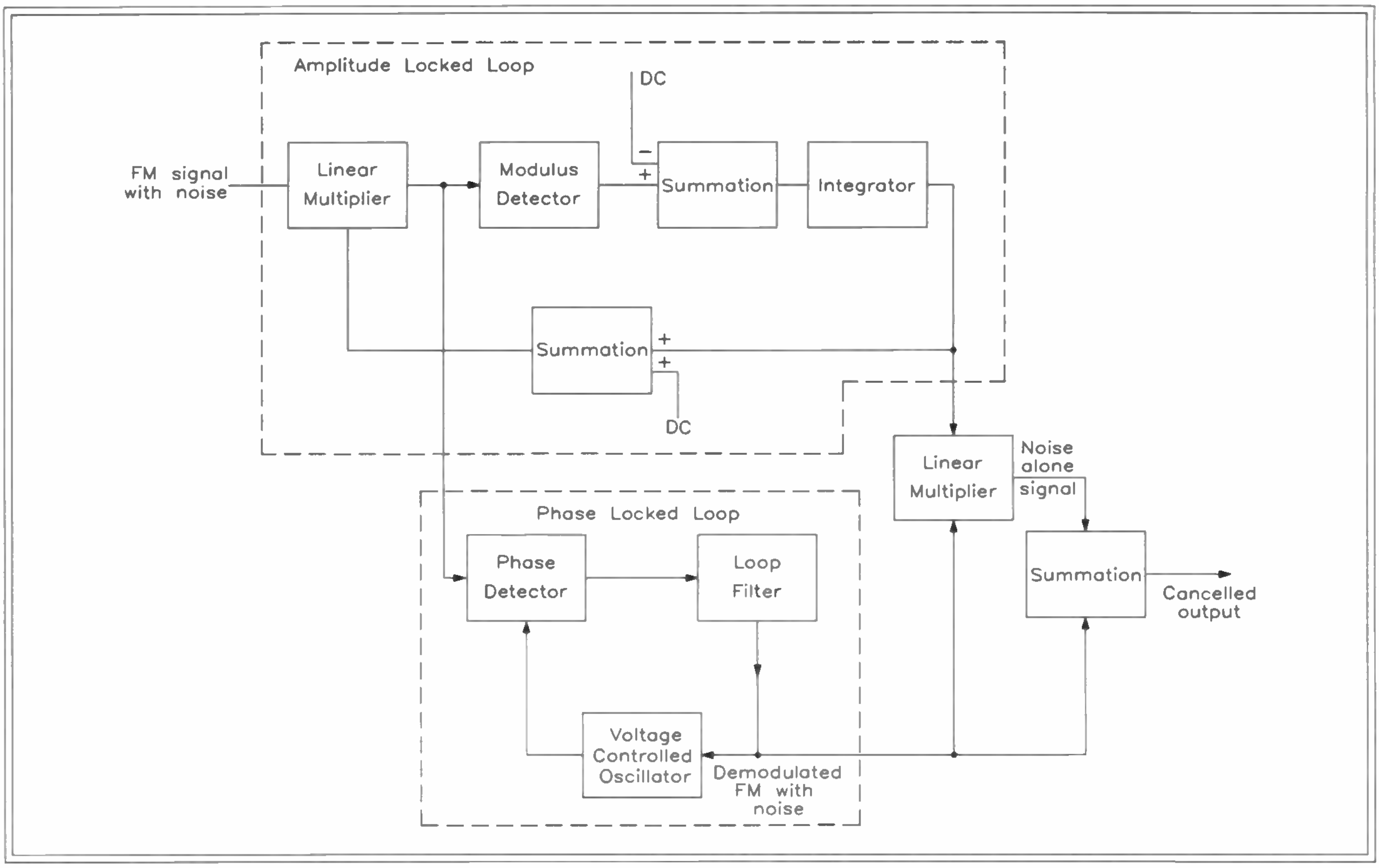



**Figure 3. Block diagram of the complete FM Noise Reduction System.**

## Phase-Locked Loop

Once the fixed amplitude signal has been generated, it is passed into a Phase-Locked Loop (PLL) for demodulation in the normal way. Whilst PLLs have been in existence and widely used for many years, a brief explanation may be fitting here.

Like the ALL, the PLL is a servo loop. Instead of detecting the amplitude of the incoming signal it compares the phase with that of an internally generated one. The basic block diagram is shown in Figure 2. From this it can be seen that the incoming signal and the internal signal from the oscillator both enter a phase detector. This circuit can take many forms. In many instances it will be a multiplier, but in others it might be a specialised digital circuit.

Whatever the circuit, the phase difference between the two signals is generated. This is then filtered to remove any components of the input signals. Then, this error voltage is applied to the control terminal of the voltage controlled oscillator (VCO). The sense of this voltage is such that it tries to reduce the phase difference between the two signals. Eventually a point is reached when there is a fixed, but constant, phase difference between the signals. When this happens the frequency of the two signals is *exactly* the same.

Once in lock, it is found that if the reference signal is varied in frequency then the VCO will follow it. However, for the oscillator to vary in frequency the control voltage must vary as well. It is this voltage which corresponds to the modulation on a frequency modulated signal. Therefore it is possible to amplify this signal and use it as the demodulated output.

## The Whole Story

Using an ALL in the demodulation of FM, the fixed amplitude signal is passed into the reference signal of the PLL to demodulate the signal in the normal way. However, this is not the whole story, since the ALL provides more than just a signal with a stable amplitude.

Mathematical analysis of the ALL shows that it is possible to obtain a term which very nearly equates to the interference signal at the output of the PLL demodulator. If this interference term could be isolated, it could be used to cancel out the interference appearing on the audio output.

In fact this is just what is done as shown in the overall demodulator block diagram in Figure 3. First the DC component is removed from the signal and then this output is multiplied with the demodulated FM output to give a noise alone signal. Finally, it is scaled and then subtracted from the audio from the phase-locked loop demodulator. In this way the noise should be cancelled out.

## Practical Performance

Whilst in theory it might appear that it would be possible to remove all the noise, this can never be achieved in practice. However, the ALL does offer a significant improvement. It is found that it gives a 6dB reduction in white noise and a 10dB reduction in 'spike' or 'click' noise when the system is operating at its limit and the background noise is rising. This is a large improvement and is well worth the additional circuitry.

The improvement is quite visible when monitored on an oscilloscope. Figure 4 shows two traces: the top one is the audio recovered directly from the output of the PLL without any noise reduction, and the spikes superimposed on the audio can be clearly seen. In view of their size and

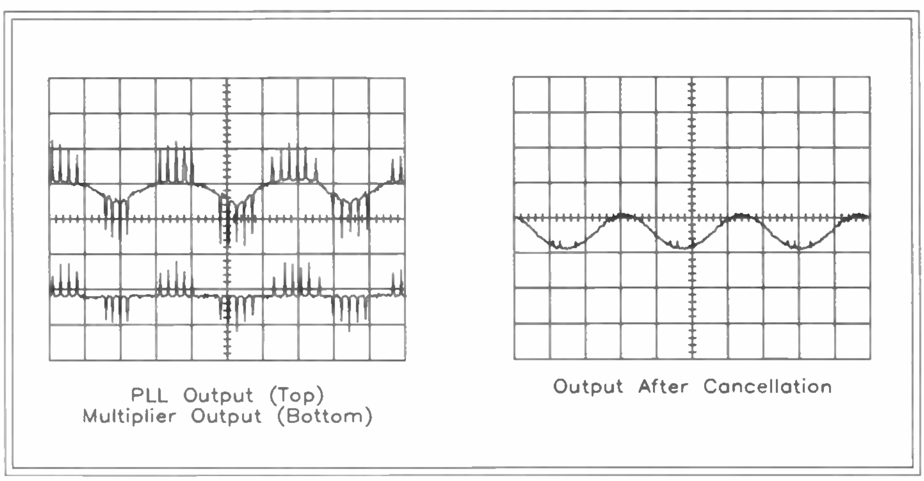



**Figure 4. Noise reduction for signal-to-noise ratios greater than unity.**

sharpness they sound very harsh and unpleasant. The bottom trace shows the noise alone output from the ALL. It can be seen that this is almost identical to the noise appearing on the audio output from the PLL. It only has to be adjusted to the correct level by a preset control in the circuitry before it is subtracted from the audio to give the final signal. Although this has small traces of the original noise, it is vastly reduced on its previous levels and the resulting signal is much more pleasant to the ear.

This test was carried out with a signal-to-noise ratio of greater than one. However, the system still operates at lower levels. Figure 5 shows what happens for a signal-to-noise ratio of less than unity. From this it can be seen that on the audio recovered from the phase-locked loop the noise spikes are inverted from those seen previously. This signal is exceedingly unpleasant to listen to, and it is difficult to detect the underlying audio. However, the ALL is still able to give some significant improvements. The final audio still has noise present, but the level has been significantly reduced, to the extent that it is possible to listen to the signal.

Tests have been carried out with a number of different types of interference. One of interest is multipath distortion, which users of an FM car radio will have experienced at one time or another. Again the system gives a marked improvement.

Whilst the previous diagrams show traces of the signal with and without noise cancellation they do not give a measure of the reduction. Figure 6 shows this, and a 6dB improvement can be seen clearly across the whole audio bandwidth.

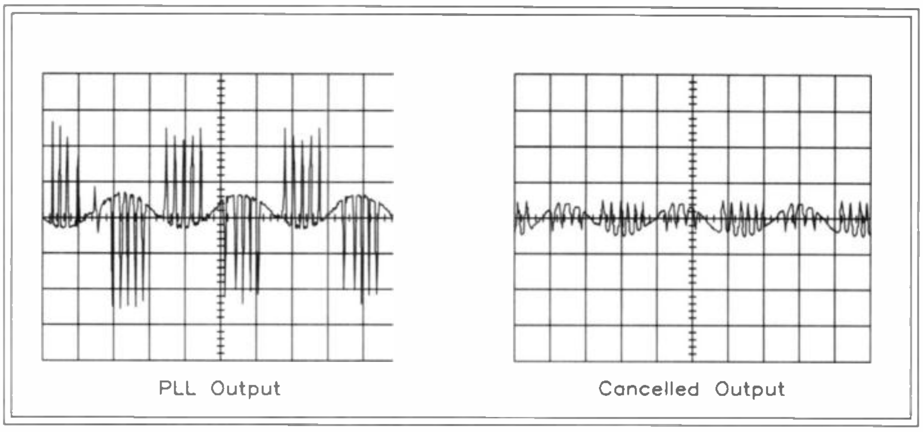



**Figure 5. Noise reduction for signal-to-noise ratios less than unity.**

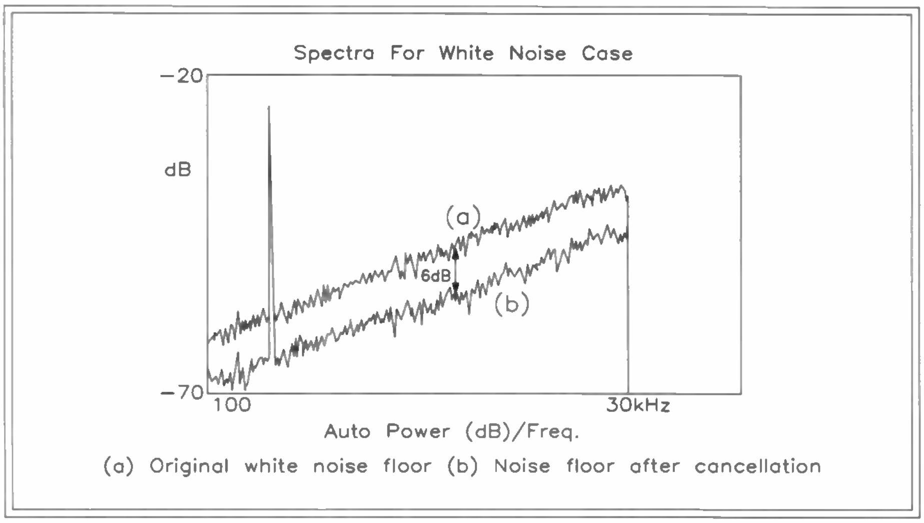



**Figure 6. Plot of signal-to-noise ratio with and without noise cancellation.**

## Applications

The ALL noise reduction system can be applied to any receiver or system using FM. As such it can be used in a very wide variety of areas. Car radios may be one of the first which comes to mind. However, point-to-point VHF and UHF communications could benefit, as could cellular telephones. Not only could the system give an improvement in sensitivity of the receiver, but it could give the option of having a lower transmitter power. This might be of great importance for systems located in areas with no mains supply.

In addition to these applications the system could be used within disk drives, satellite receivers and video recorders. With this number of applications, it should find widespread use.

## Other Uses

The use of the ALL is not just confined to FM demodulation. Being a very versatile circuit block there are a number of other uses. One of these is in demodulation of a form of amplitude modulation known as double sideband suppressed carrier. In this application the ALL produces a much better way of demodulating the signal than anything previously available. In addition to this the same circuit can also be used for the synchronous detection of AM with full carrier. One interesting use to which this could be put, is demodulating the stereo Left – Right signal on a VHF FM stereo broadcast transmission. Currently a 19kHz pilot tone is used as a reference, as shown in Figure 7. Using the ALL the pilot tone would become unnecessary since the carrier can be regenerated with precision phase accuracy even under noisy conditions.

Although there are many uses for the ALL, one new and interesting use could be for AM stereo demodulation. Although stereo broadcasting is normally associated only with VHF FM, AM can now carry this as well. There are several methods for broadcasting it, but one called C-QUAM (Compatible Quadrature Amplitude Modulation) is gaining popularity very quickly in the USA. In fact the ALL could be used to improve any quadrature amplitude modulation system, and may find widespread use in this application.

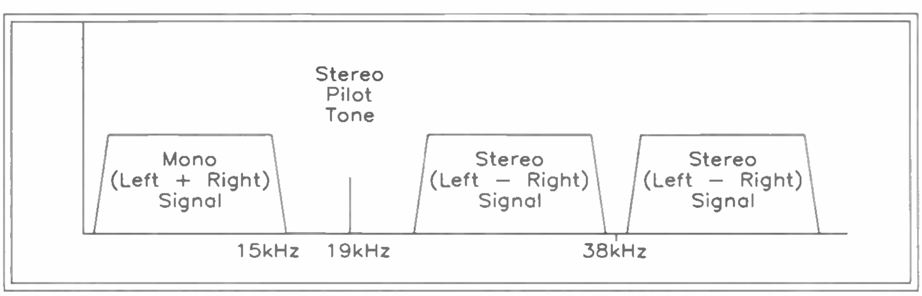



**Figure 7. Spectrum of the modulation of a VHF FM stereo transmission.**

## Conclusion

The ALL is a truly new and innovative idea. Patents have already been filed, and it is likely that the system will start to appear in a wide variety of new pieces of electronic equipment. For companies interested in the system the Ampsys FM-1 is offered as a hybrid evaluation board. Currently a number of companies are interested.

With its performance and the current level of interest, it is likely that the system will be widely adopted in the years to come. Its close relation, the PLL, is now very widely used. There is no reason why the ALL could not receive the same degree of interest and application in the future.

## Acknowledgment

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# ABOUT THIS ISSUE . . .

Hello and welcome to this month's issue of *Electronics!*

As I write, people across the whole of Britain are breathing a sigh of relief – a silent but deadly peril has passed by. What am I talking about? Simple, the threat of VAT on newspapers, books and magazines. During 1993 MPs, private individuals, trade bodies and publishers made strong representations to the Chancellor of the Exchequer not to impose taxation on reading material. It seems to have paid-off, for the time being at least. Daily life relies on published material to inform, entertain and educate. We must all be wary, because this threat could all too easily reappear. VAT would increase cover prices, reduce sales (increasing production costs), reduce choice of reading material (as publishers go out of business) and inhibit maintenance of educational resources in schools, colleges and libraries.

Two new people have joined the dedicated team that helps me put together *Electronics* every month. Robin Hall, an ex-merchant navy radio officer and avid amateur radio enthusiast, takes on the role of technical author on the editorial side. Steve Drake joins the production area, to help ensure that everything runs smoothly at page make-up stage and *Electronics* is on the bookstalls on-time every month. Welcome on board Robin and Steve!

Winter conditions and dark nights help to contribute further hazards to driving. In this issue there is an ingenious project that will help motorists keep car rear windscreens clear. Various operating modes are provided, but in simple terms the unit will operate the rear wiper, either with a single wipe or intermittent wipes, when the front wipers are switched on. Additionally the rear wiper will give a single wipe whenever reverse gear is selected and the front wipers are switched on. The idea being that in most instances it is completely unnecessary to have the rear wiper operating continuously. Often, such operation is likely to reduce wiper-blade life and scratch the window – simply because the rear windscreen does not usually get as wet as the front windscreen. The Auto Rear Windscreen Controller therefore, in most instances, alleviates the need for the driver to repeatedly operate the rear wiper control, which in many cars is not ideally located. Full attention can then be kept on the road ahead – particularly during adverse conditions.

FM is a widely used radio transmission mode and for many years the methods of demodulating FM signals have largely remained the same. However, more recently, developments have been made that allow signals to be usably received at greater distances than would otherwise be possible and also to recover signals swamped by background noise and interference. Ian Poole looks at the new techniques, explains how they work and examines applications where the technology can be put to good use.

John Woodgate and Ray Marston both make a welcome return to the pages of *Electronics* this month. John's new three-part mini series deals with the design and construction of subwoofer systems which are ideal for use in the domestic and car listening environments. Good news for Hi-Fi enthusiasts who yearn for extended bass response and Ford Cortina driving 'tish and thud merchants' who would like a bit more 'thud'! Ray's two-part feature deals with audio preamplifier ICs and how to get the best performance from them. Coming soon from Ray is another mini series on audio power amplifier ICs, which forms the ideal complement to articles this month and next month.

Of course there's lots more fun-to-build projects, fascinating features and usual regulars that I haven't mentioned; I'm sure you will find them all a jolly good read!

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## Project Ratings

Projects presented in this issue are rated on a 1 to 5 for ease or difficulty of construction to help you decide whether it is within your construction capabilities before you undertake the project. The ratings are as follows:

1 Simple to build and understand and suitable for absolute beginners. Basic of tools required (e.g., soldering iron, side cutters, pliers, wire strippers and screwdriver). Test gear not required and no setting-up needed.

2 Easy to build, but not suitable for absolute beginners. Some test gear (e.g., multimeter) may be required, and may also need setting-up or testing.

3 Average. Some skill in construction or more extensive setting-up required.

4 Advanced. Fairly high level of skill in construction, specialised test gear or setting-up may be required.

5 Complex. High level of skill in construction, specialised test gear may be required. Construction may involve complex wiring. Recommended for skilled constructors only.

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Write your order on the form printed in this issue and send it to Maplin Electronics, P.O. Box 3, Rayleigh, Essex, SS6 8LR. Payment can be made using Cheque, Postal Order, or Credit Card.

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If you have a personal computer equipped with a MODEM, dial up Maplin's 24-hour on-line database and ordering service, CashTel. CashTel supports 300-, 1200- and 2400-baud MODEMs using CCITT tones. The format is 8 data bits, 1 stop bit, no parity, full duplex with Xon/Xoff handshaking. All existing customers with a Maplin customer number can access the system by simply dialling (0702) 552941. If you do not have a customer number Tel: (0702) 552911 and we will happily issue you with one. Payment can be made by credit card.

If you have a tone dial (DTMF) telephone or a pocket tone dialler, you can access our computer system and place orders directly onto the Maplin computer 24 hours a day by simply dialling (0702) 556751. You will need a Maplin customer number and a personal identification number (PIN) to access the system. If you do not have a customer number or a PIN number Tel: (0702) 552911 and we will happily issue you with one.

Full details of all of the methods of ordering from Maplin can be found in the current Maplin Catalogue.

## Prices

Prices of products and services available from Maplin, shown in this issue, include VAT at 17·5% (except items marked NV which are rated at 0%) and are valid between 7th January 1994 and 28th February 1994. Prices shown do not include mail order postage and handling charges, which are levied at the current rates indicated on the Order Coupon in this issue.

## Technical Enquiries

If you have a technical enquiry relating to Maplin projects, components and products featured in *Electronics*, the Customer Technical Services Department may be able to help. You can obtain help in several ways; over the phone, Tel: (0702) 556001 between 2pm and 4pm Monday to Friday, except public holidays; by sending a facsimile, Fax: (0702) 553935; or by writing to: Customer Technical Services, Maplin Electronics plc., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Don't forget to include a stamped self-addressed envelope if you want a written reply! Customer Technical Services are unable to answer enquiries relating to third-party products or components which are not stocked by Maplin.

## 'Get You Working' Service

If you get completely stuck with your project and you are unable to get it working, take advantage of the Maplin 'Get You Working' Service. This service is available for all Maplin kits and projects with the exception of: 'Data Files'; projects not built on Maplin ready etched PCBs; projects built with the majority of components not supplied by Maplin; Circuit Maker ideas; Mini Circuits or other similar 'building block' and 'application' circuits. To take advantage of the service, return the complete kit to: Returns Department, Maplin Electronics plc., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Enclose a cheque or Postal Order based on the price of the kit as shown in the table below (minimum £17). If the fault is due to any error on our part, the project will be repaired free of charge. If the fault is due any error on your part, you will be charged the standard servicing cost plus parts.

| Kit Retail Price | Standard Servicing Cost |
|---|---|
| up to £24.99 | £17 |
| £25 to £39.99 | £24 |
| £40 to £59.99 | £30 |
| £60 to £79.99 | £40 |
| £80 to £99.99 | £50 |
| £100 to £149.99 | £60 |
| Over £150 | £60 minimum |

## Readers Letters

We very much regret that the editorial team are unable to answer technical queries of any kind, however, we are very pleased to receive your comments about *Electronics* and suggestions for projects, features, series, etc. Due to the sheer volume of letters received, we are unfortunately unable to reply to every letter, however, every letter is read — your time and opinion is greatly appreciated. Letters of particular interest and significance may be published at the Editors discretion. Any correspondence not intended for publication must be clearly marked as such.

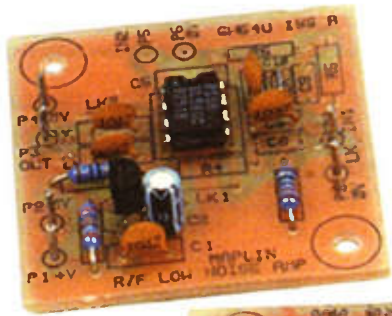
DATA FILE

'Data Files' are intended as 'building blocks' for constructors to experiment with, and the components suggested provide a good starting point for further development.

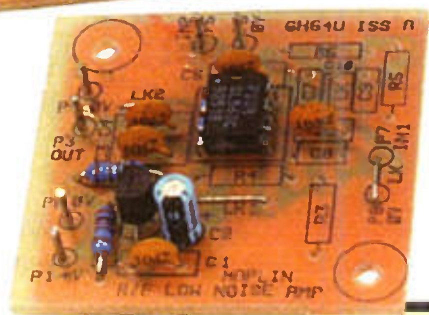
3 PROJECT RATING

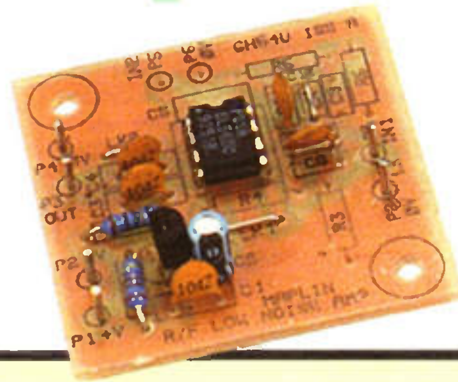
# SL560C Low Noise RF Amplifier

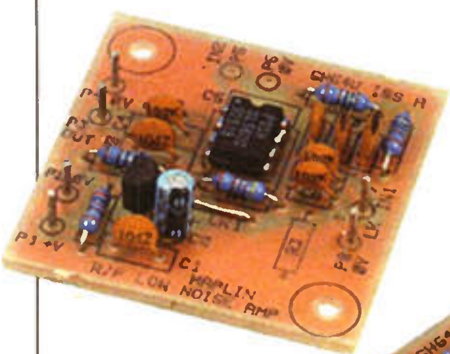
KIT AVAILABLE (LT42V) PRICE £6.45

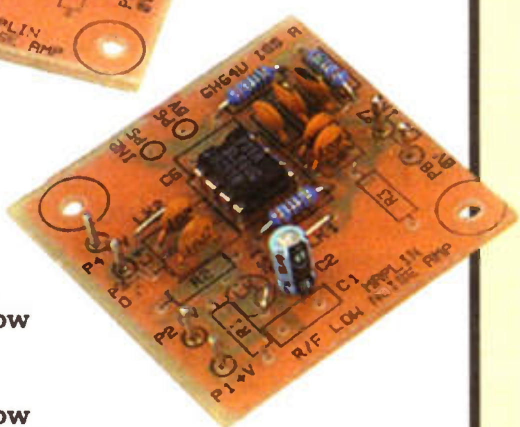


The SL560C PCB can be assembled in a variety of ways depending on the chosen application.









**FEATURES**
* Gain of over 30dB
* Potential noise figure less than 2dB
* Bandwidth up to 300MHz
* Supply voltage +2 to +15V DC
* Low power consumption

**APPLICATIONS**
* Aerial preamplifiers for HF/VHF radios
* 50Ω line drivers
* Low power wideband amplifiers
* Instrumentation preamplifiers


**Design by Chris Barlow**

**Text by Chris Barlow and Robin Hall**

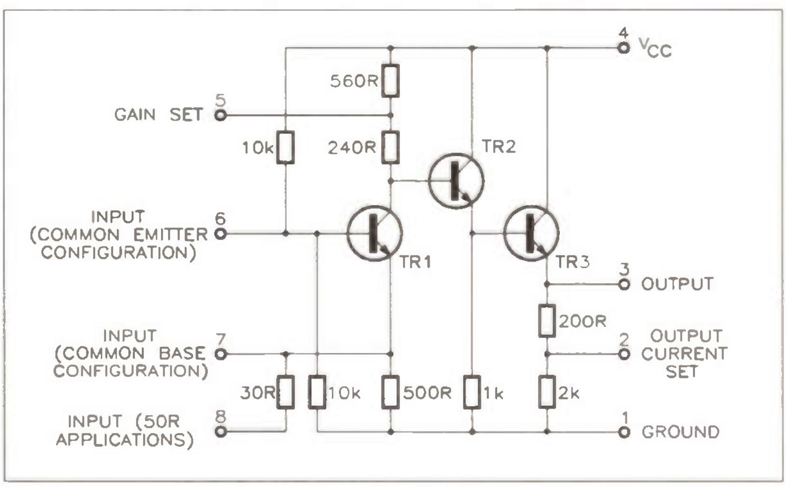




**Figure 1. SL560C internal circuit diagram.**

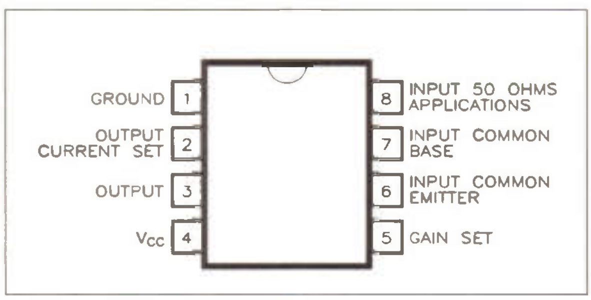



**Figure 2. SL560C pin connections.**

DATA FILE

**T**HE SL560C is a monolithic Integrated Circuit (IC) which can be configured to function in a number of different Radio Frequency (RF) amplification roles. Because component layout becomes more critical as frequency increases, a universal amplifier printed circuit board (PCB) has been created which supports all four configurations. The SL560C can be useful in many different RF applications, such as aerial preamplifiers for HF and VHF radios. Also as 50Ω line drivers, low power wideband amplifiers, and instrumentation preamplifiers.

The SL560C has an impressive specification and its possible applications are too numerous for just one article to cover. However, it is hoped that the information presented will provide a good starting point for further experimentation.

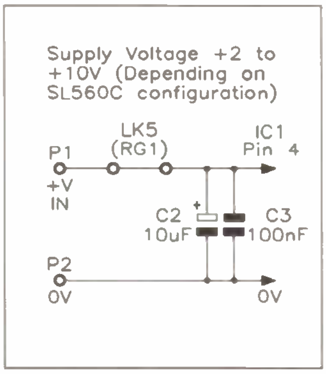



**Figure 4. Voltage regulator removed and link fitted.**

package, the pinout of which is shown in Figure 2. Table 1 details the absolute maximum ratings and electrical characteristics of the IC.

TR1, TR2 & TR3 are of identical geometry. Advanced design and processing techniques enable these devices to combine a low base resistance ($R_{bb}$) of 17Ω giving a good low noise operation, while their small physical size extends the transition frequency ($f_T$) in excess of 1GHz.

The input transistor, TR1, is normally operated in the common base mode, giving a well-defined low input impedance. The full voltage gain is produced by this transistor and the emitter followers, TR2 & TR3. To obtain maximum bandwidth the capacitance at the collector of TR1 must be minimised. Hence, to avoid bonding pad capacitance, this point is not brought out of the package. The collector load resistance of TR1 is split, the

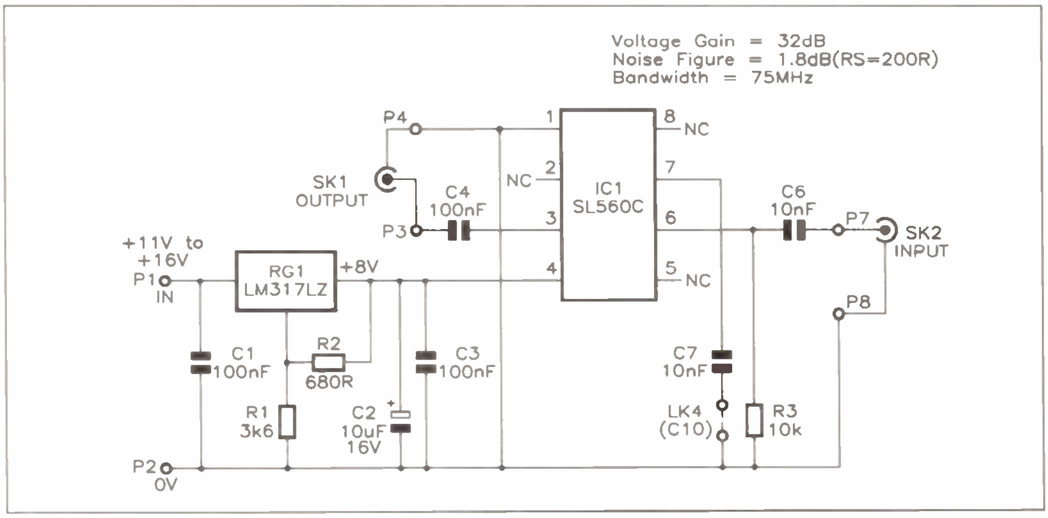



**Figure 5. SL560C Low noise preamplifier circuit diagram.**

| Characteristic | Value | | | Units | Conditions |
|---|---|---|---|---|---|
| | Minimum | Typical | Maximum | | |
| Small signal voltage gain | 11 | 14 | 17 | dB | |
| Gain flatness | | ±1·5 | | dB | 10MHz to 220MHz |
| Upper cut-off frequency | | 250 | | MHz | |
| Output swing | +5 | +7 | | dBm | $V_{CC}$ 6V |
| Noise figure (common emitter) | | 1·8<br>3·5 | | dB<br>dB | $R_S$ = 200Ω<br>$R_S$ = 50Ω |
| Supply voltage (Pin 4) | +2 | +6 | +15 | V | |
| Supply current | | 20 | 30 | mA | |
| Storage temperature | –55 | | +125 | °C | |
| Junction temperature | | +125 | | °C | |
| Test conditions: Frequency = 30MHz; $V_{CC}$ = 6V; $R_S$ = $R_L$ = 50Ω; $T_{amb}$ = 25°C. Test Circuit Figure 10. | | | | | |

**Table 1. Absolute maximum ratings and electrical characteristics.**

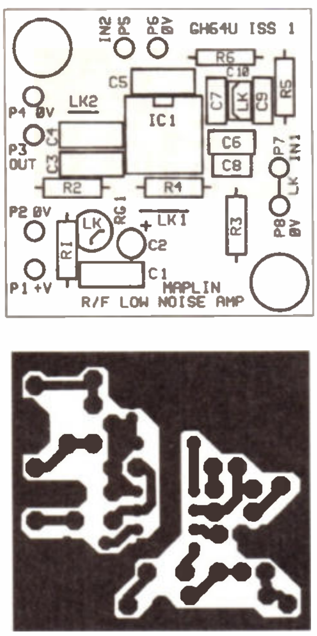



**Figure 3. PCB legend and track.**

## The SL560C Low Noise RF Amplifier IC

From Figure 1, it can be seen that the SL560C IC contains three very high performance transistors and associated biasing components. All these components are held in an eight pin Dual-In-Line (DIL) tapping being accessible via pin 5. If required, an external roll-off capacitor can be fixed to this point.

The large number of circuit nodes accessible from the outside of the IC package affords great flexibility, enabling the operating currents and circuit configuration to be optimised for almost any application.

## The Universal PCB

Using the universal SL560C amplifier PCB (stock code GH64U) it is possible to construct any of the four amplifier configurations. The track layout and legend for this PCB is shown in Figure 3. Once the circuit configuration best suited for the intended application has been chosen, care must be taken to fit only the components and values relevant to that circuit. Remember, only fit the wire links when they are called for, in the positions shown on the legend, which may, in some instances, be a dual symbol.

Because the transistors used in the SL560C exhibit a high value of $f_T$, care must be taken to avoid high frequency instability. Capacitors and resistors of small physical size should be used and their leads must be as short as possible to avoid oscillation brought about by stray inductance.

In addition to the amplifier circuit, a LM317LZ variable voltage regulator, RG1, has been provided to allow each configuration to operate at its optimum performance. The voltage output of RG1 is set by the values of R1 and R2. However, only the value of R1 is altered for each amplifier configuration. For the regulator to function correctly the input (P1) must be at least +3V higher than the required output voltage; e.g., P1 = +11V for +8V output to IC1 pin 4 (+$V_{cc}$). If the power supply being used is already at the correct voltage, then the regulator must be by-passed using a wire link as shown in Figure 4 and Photo 1.

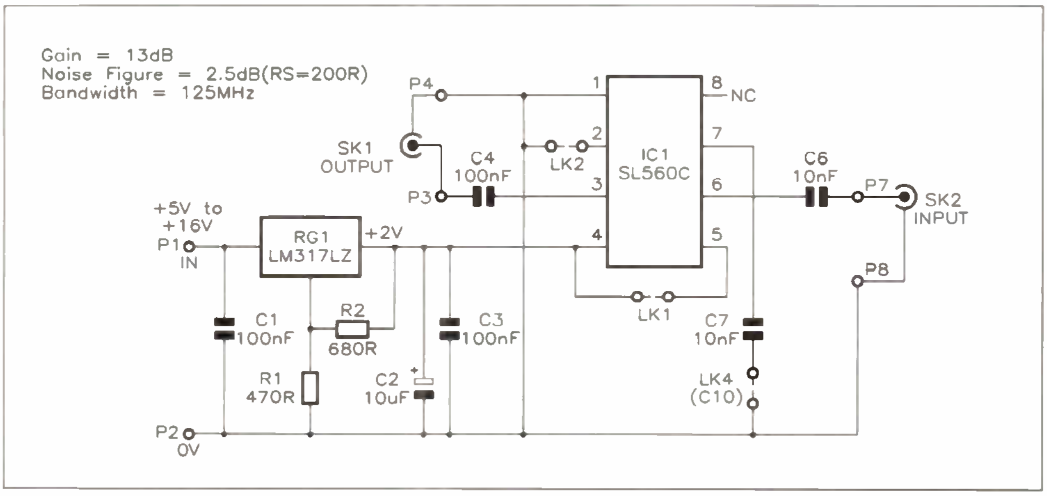



**Figure 7. Low power consumption amplifier circuit diagram.**

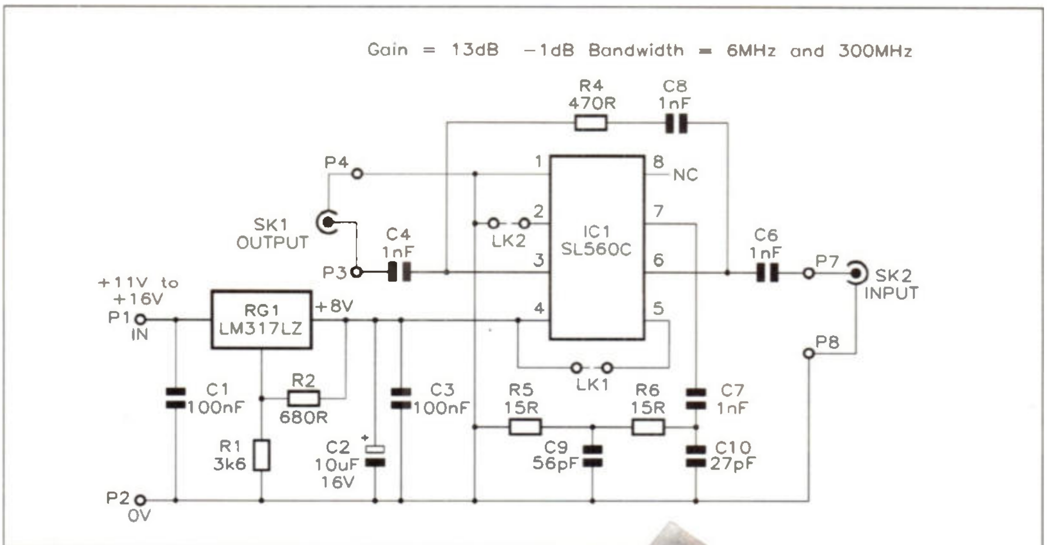



**Figure 8. Wide bandwidth amplifier circuit diagram.**

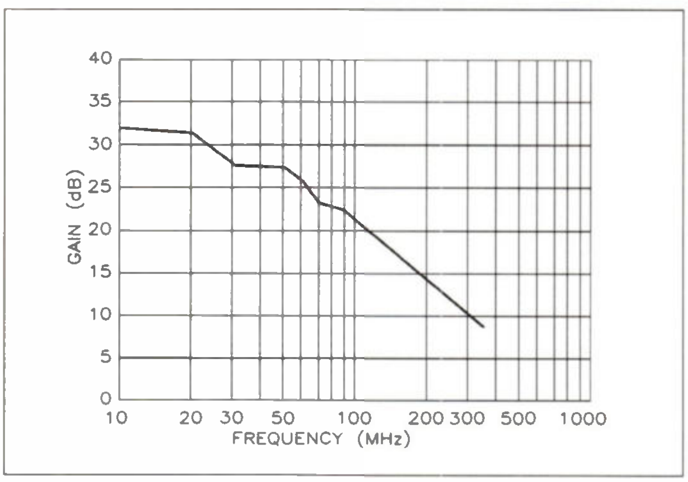



**Figure 6. Typical frequency response of preamplifier circuit.**

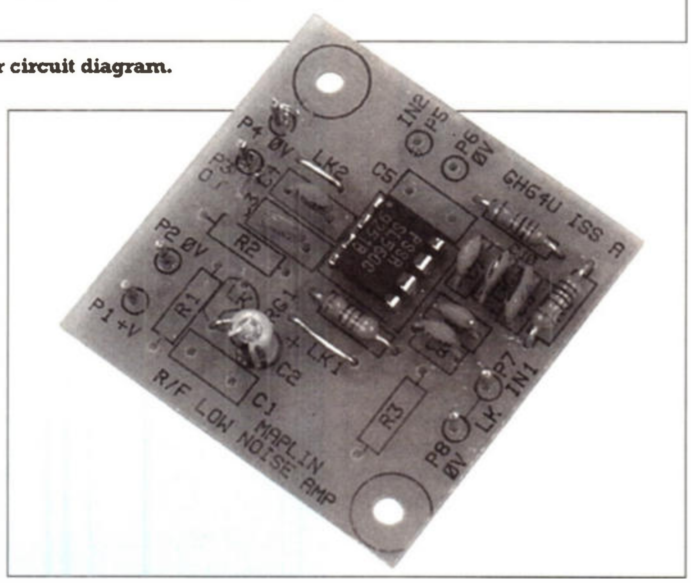



**Photo 1. Voltage regulator removed and link fitted.**

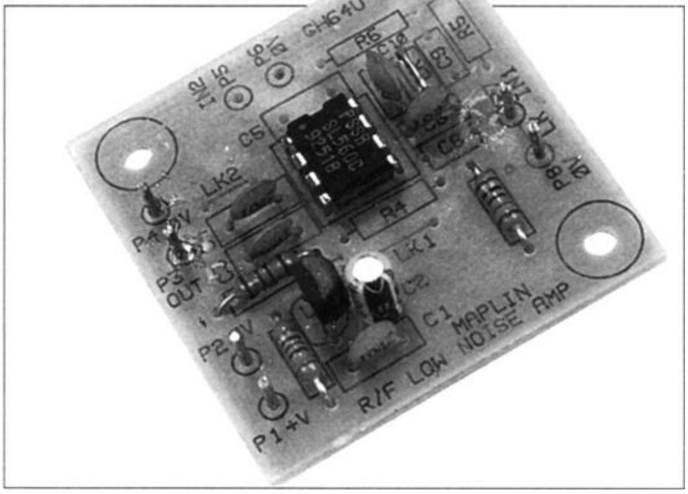


Photo 2. Assembled low noise preamplifier board.

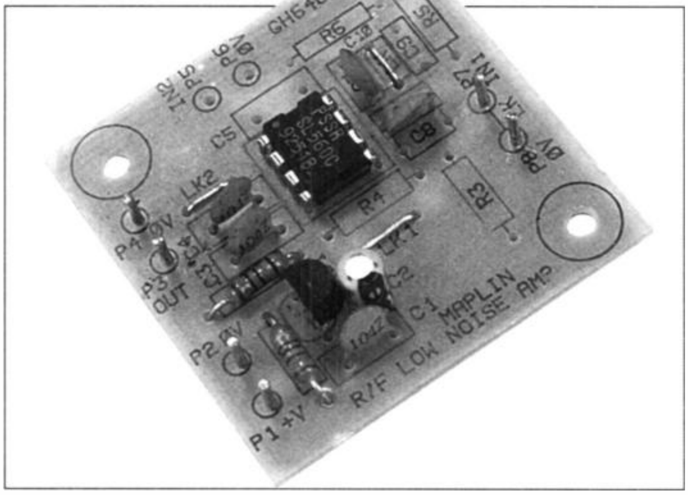


Photo 3. Assembled low power consumption amplifier board.

## The Low Noise Preamplifier

Figure 5 illustrates a low noise preamplifier, where the input transistor, TR1, inside IC1 can be operated in common emitter mode. This is achieved by decoupling pin 7 and using pin 6 as the input. In this configuration a typical noise figure of 2dB can be achieved, with a gain of 35dB and a bandwidth of 75MHz, as shown in Figure 6. Photo 2 shows the low noise preamplifier built on the universal PCB.

## The Low Power Consumption Amplifier

The amplifier shown in Figure 7 and in Photo 3 has a lower gain (13dB) than that of the previous one, but will run from a much lower voltage (+2V) and, in this configuration consumes only 3mA without the regulator RG1 fitted. In addition, its bandwidth is increased to 125MHz while retaining a low noise figure of typically 2·5dB.

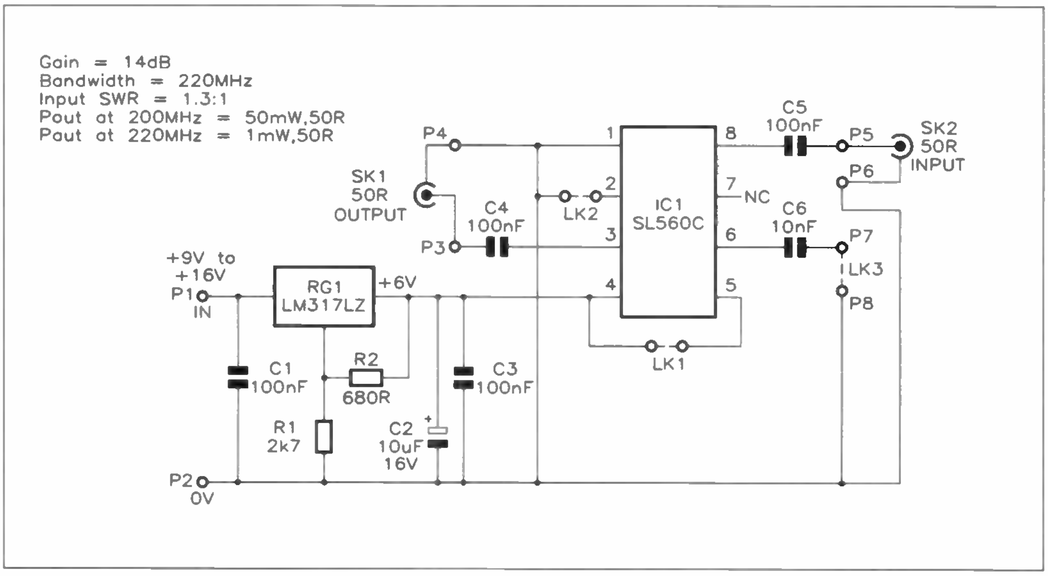



Figure 10. 50Ω line driver circuit diagram.

## The Wide Bandwidth Amplifier

With the addition of negative feedback, by the components R4 & C8 illustrated in Figure 8, it is possible to extend the bandwidth of the amplifier to 300MHz, as shown in Figure 9. Photo 4 shows the wide bandwidth amplifier built on the universal PCB.

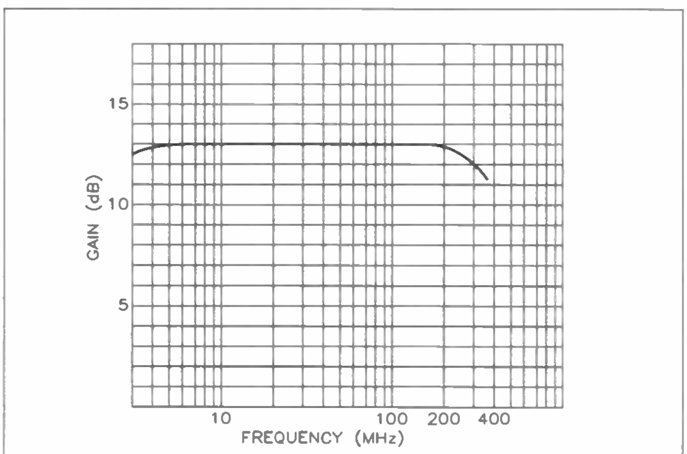



Figure 9. Typical frequency response of wide bandwidth amplifier.

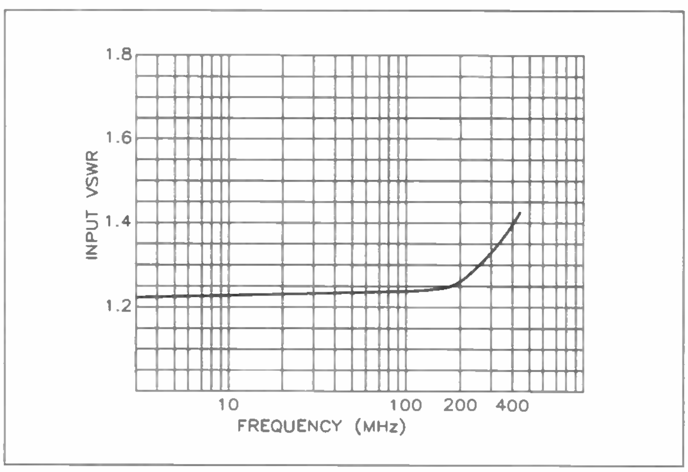



Figure 11. Typical input standing wave ratio of 50Ω line driver circuit.

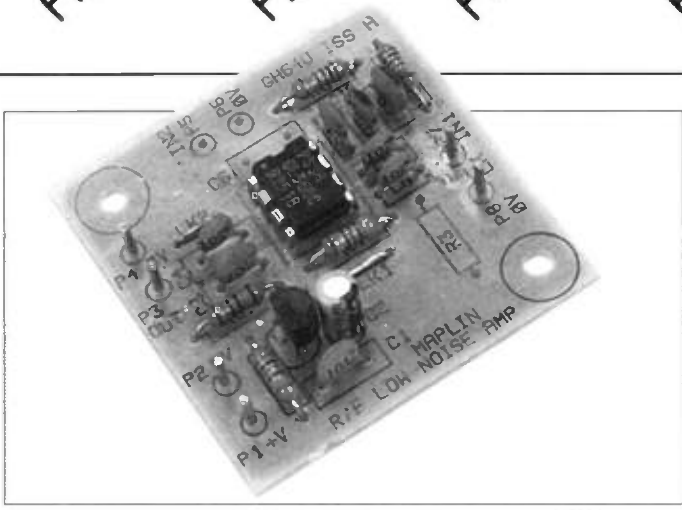



**Photo 4. Assembled wide bandwidth amplifier.**

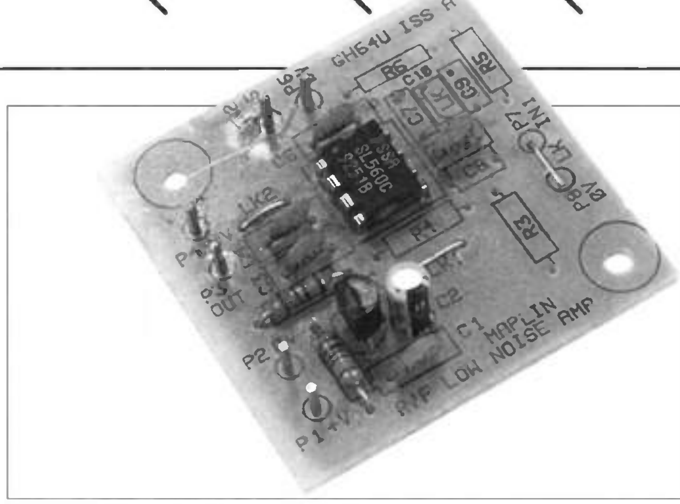



**Photo 5. Assembled 50Ω line driver.**

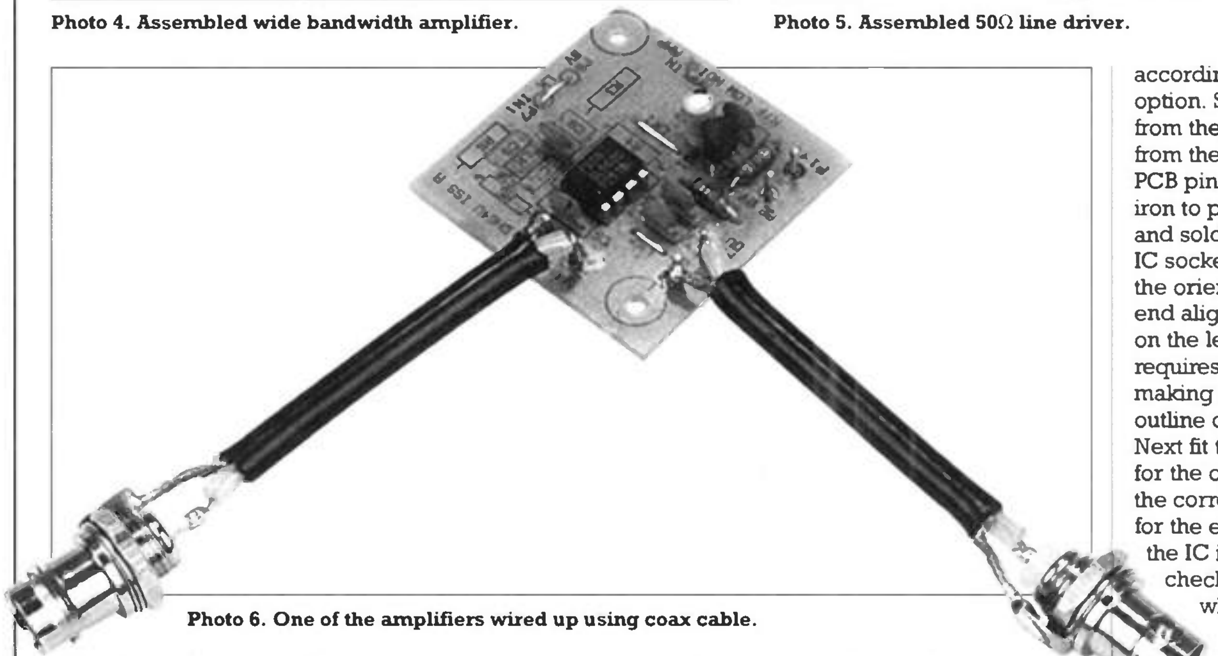


**Photo 6. One of the amplifiers wired up using coax cable.**

according to the selected option. Similarly fit any links from the off-cuts obtained from the resistors. Next fit the PCB pins, using the soldering iron to push home each one and solder in place. Install the IC socket, making sure that the orientation marker at one end aligns with the marker on the legend. If the option requires it, fit the regulator making sure it matches the outline on the PCB legend. Next fit the relevant capacitors for the option selected, with the correct polarity observed for the electrolytic. Finally fit the IC into the socket, and check that there are no whiskers of solder or 'shorts' on the board.

## The 50Ω Line Driver

Figure 10 shows a line driver configuration, where TR1 inside IC1 is used in its common base mode by decoupling pin 6 and using pin 8 as the 50Ω input. This amplifier has a gain of 14dB and bandwidth of 220MHz, with an input standing wave ratio (SWR) of typically 1·3:1, as shown in Figure 11. This final configuration is shown built in Photo 5.

## Construction

Firstly decide which configuration to build, and then refer to the required section and the relevant Parts List. Fit the resistors required in the positions on the PCB

## Wiring

All RF signal wiring to and from the amplifier module must be made using good quality screened 50Ω low-loss coaxial cable (XR19V), as can be seen in Photo 6.

## NEXT issue

In next month's super issue of *Electronics - The Maplin Magazine*, there are yet more terrific projects and features for you to enjoy. These include:

### AIRBAND RECEIVER

The radio reception of aircraft transmissions by air enthusiasts has been going on for many years, and a variety of receivers are available for this hobby. However, one does not require an expensive scanning receiver to pick up these transmissions, instead this dedicated receiver can be used, either by a hobbyist just starting out, or by an air enthusiast who wants to monitor a local frequency whilst keeping the scanning receiver free to scan the various channels.

### CCD CAMERA MODULATOR

The video output from the Maplin CCD camera modules cannot be connected directly to the majority of domestic TV sets. Some TVs do have a direct video input socket (for example Peritel, also known as 'SCART'), but most only have a UHF aerial input socket for the reception of TV stations. This project solves this problem by providing a low-cost UHF modulator to superimpose the video signals from the CCD camera, or a wide range of other units, onto a UHF carrier. Construction and alignment are simplified by the use of a pre-tuned modulator module.

### INTERMITTENT WIPER CONTROLLER

Ideal for car owners who only have the old, non-intermittent wiper system fitted. You can now update your wiper system by adding an intermittent timer controller module providing three different time intervals of 5, 10, and 15 seconds, which can be selected to match weather conditions. The advantages of this are manifold, not least extending the life of wiper blades, reducing mechanical wear in the wiper's motor and gearbox, and minimising scratch damage to the windscreen.

### TLC548I DATA FILE

The TLC548I is an 8-bit successive approximation sample and hold A-to-D converter. This Data File gives details of various applications for this device, mainly to do with the Maplin PC Weather Station project.

Plus all your regular items and favourite features including the concluding part of 'Using Audio Preamp ICs', showing ways of using the LM387, TDA3401, MC3340P, and NE570/571; 'Professional Audio' part 12 discussing equalisers; how to design your own subwoofer part 2, and a fascinating article about underwater Remote Operated Vehicles.

**ELECTRONICS - THE MAPLIN MAGAZINE**

BRITAIN'S BEST SELLING ELECTRONICS MAGAZINE

## SL560C LOW NOISE RF AMPLIFIER

RESISTORS: All 0·6W 1% Metal Film

| | | |
|---|---|---|
| R1 | 3k6 | 1 |
| R2 | 680Ω | 1 |
| R3 | 10k | 1 |

CAPACITORS

| | | |
|---|---|---|
| C1,3,4 | 100nF 16V Miniature Disc | 3 |
| C2 | 10μF 16V Sub-Min Radial Electrolytic | 1 |
| C6,7 | 10nF Metallised Ceramic | 2 |
| C10 | Fit Link (LK4) | 1 |

SEMICONDUCTORS

| | | |
|---|---|---|
| RG1 | LM317LZ | 1 |
| IC1 | SL560C | 1 |

MISCELLANEOUS

| | | |
|---|---|---|
| P1-4,7,8 | Single-ended PCB pin 1mm (0·04in.) | 6 |

## SL560C LOW POWER CONSUMPTION AMPLIFIER

RESISTORS: All 0·6W 1% Metal Film

| | | |
|---|---|---|
| R1 | 470Ω | 1 |
| R2 | 680Ω | 1 |

CAPACITORS

| | | |
|---|---|---|
| C1,3,4 | 100nF 16V Miniature Disc | 3 |
| C2 | 10μF 16V Sub-Min Radial Electrolytic | 1 |
| C6,7 | 10nF Metallised Ceramic | 2 |
| C10 | Fit Link (LK4) | 1 |

SEMICONDUCTORS

| | | |
|---|---|---|
| RG1 | LM317LZ | 1 |
| IC1 | SL560C | 1 |

MISCELLANEOUS

| | | |
|---|---|---|
| P1-4,7,8 | Single-ended PCB pin 1mm (0·04in.) | 6 |
| LK1,2 | Fit Link | 2 |

## SL560C WIDE BANDWIDTH AMPLIFIER

RESISTORS: All 0·6W 1% Metal Film

| | | |
|---|---|---|
| R1 | 3k6 | 1 |
| R2 | 680Ω | 1 |
| R4 | 470Ω | 1 |
| R5,6 | 15Ω | 2 |

CAPACITORS

| | | |
|---|---|---|
| C1,3 | 100nF 16V Miniature Disc | 2 |
| C2 | 10μF 16V Sub-Min Radial Electrolytic | 1 |
| C4,6-8 | 1nF Metallised Ceramic | 4 |
| C9 | 56pF Metallised Ceramic | 1 |
| C10 | 27pF Metallised Ceramic | 1 |

SEMICONDUCTORS

| | | |
|---|---|---|
| RG1 | LM317LZ | 1 |
| IC1 | SL560C | 1 |

MISCELLANEOUS

| | | |
|---|---|---|
| P1-6 | Single-ended PCB pin 1mm (0·04in.) | 6 |
| LK1,2 | Fit Link | 2 |

## SL560C 50Ω LINE DRIVER

RESISTORS: All 0·6W 1% Metal Film

| | | |
|---|---|---|
| R1 | 2k7 | 1 |
| R2 | 680Ω | 1 |

CAPACITORS

| | | |
|---|---|---|
| C1,3-5 | 100nF 16V Miniature Disc | 4 |
| C2 | 10μF 16V Sub-Min Radial Electrolytic | 1 |
| C6 | 10nF Metallised Ceramic | 1 |

SEMICONDUCTORS

| | | |
|---|---|---|
| RG1 | LM317LZ | 1 |
| IC1 | SL560C | 1 |

MISCELLANEOUS

| | | |
|---|---|---|
| P1-6 | Single-ended PCB pin 1mm (0·04in.) | 6 |
| P7,8 | Fit Link (LK3) | 1 |
| LK1,2 | Fit Link | 2 |

## SL560C LOW NOISE RF AMPLIFIER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film

| | | | |
|---|---|---|---|
| R1 | 3k6 (See text) | 1 | (M3K6) |
| R1 | 2k7 (See text) | 1 | (M2K7) |
| R1 | 470Ω (See text) | 1 | (M470R) |
| R2 | 680Ω | 1 | (M680R) |
| R3 | 10k | 1 | (M10K) |
| R4 | 470Ω | 1 | (M470R) |
| R5,6 | 15Ω | 2 | (M15R) |

CAPACITORS

| | | | |
|---|---|---|---|
| C1,3,5 | 100nF 16V Miniature Disc | 3 | (YR75S) |
| C2 | 10μF 16V Sub-Min Radial Electrolytic | 1 | (YY34M) |
| C4 | 100nF 16V Miniature Disc (See text) | 1 | (YR75S) |
| C4 | 1nF Metallised Ceramic (See text) | 1 | (WX68Y) |
| C6 | 10nF Metallised Ceramic (See text) | 1 | (WX77J) |
| C6 | 1nF Metallised Ceramic (See text) | 1 | (WX68Y) |
| C7 | 10nF Metallised Ceramic (See text) | 1 | (WX77J) |
| C7 | 1nF Metallised Ceramic (See text) | 1 | (WX68Y) |
| C8 | 1nF Metallised Ceramic | 1 | (WX68Y) |
| C9 | 56pF Metallised Ceramic | 1 | (WX53H) |
| C10 | 27pF Metallised Ceramic | 1 | (WX49D) |

SEMICONDUCTORS

| | | | |
|---|---|---|---|
| RG1 | LM317LZ | 1 | (RA87U) |
| IC1 | SL560C | 1 | (DB46A) |

MISCELLANEOUS

| | | | |
|---|---|---|---|
| | Single-ended PCB pin 1mm (0·04in.) | 1 Pkt | (FL24B) |
| | PCB | 1 | (GH64U) |
| | Instruction Leaflet | 1 | (XU48C) |
| | Constructors' Guide | 1 | (XH79L) |

OPTIONAL (Not in Kit)

| | | | |
|---|---|---|---|
| SK1,2 | BNC Round Socket 50Ω | 2 | (HH18U) |
| | Coax Cable | As Req. | (XR19V) |

The Maplin 'Get-You-Working' Service is not available for this project.

***The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.***
**Order As LT42V (SL560C Low Noise RF Amplifier Kit) Price £6.45.**

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new item (which is included in the kit) is also available separately, but is not shown in the 1994 Maplin Catalogue.
SL560C Low Noise RF Amplifier PCB
**Order As GH64U Price £1.95.**

# Air Your Views

***How Long is a Piece of Wire?***

Dear Sir,

My problem is one of trying to measure how far down, a cable becomes open circuit or short circuit. I realise that I could buy equipment to do this, but at a cost of at least £500. This equipment uses pulse reflection techniques to get a reading. Is it possible to use a couple of your projects or kits in combination to give the same results? This would be useful for household or factory type buildings where a short or open circuit is not visible or easily accessible to induction type testers. Ideally the gadget should be battery powered with possible switched ranges, e.g., 10ft., 100ft., etc. Am I asking too much for a reasonably priced project?

**D. Piper, Camberley, Surrey.**

*A gadget such as you mention can be used to determine the length of a cable, distance to a short circuit or distance to an open circuit, with just one proviso– the cable in question is coaxial or twisted pair, with known impedance and transmission characteristics. Reflections can therefore be detected and distance calculated against time. A pair of 'just any old' wires, however, will have considerably different characteristics and therefore the method is unlikely to work with any degree of accuracy. If a pair of cores in a cable are known to be short circuit, the resistance of a piece of identical, but known good, cable could be measured (cores joined at far end) using an accurate low-ohmmeter and compared with that of the faulty cable. The ratio of the resistances multiplied by the length of the test cable will give the distance to the short circuit. However there is plenty of room for error to creep in, so allow a fair bit of tolerance either way. If a core or cores in a cable have gone open circuit, measuring the capacitance of a known good cable and comparing with the faulty one will yield similar results. Other cables, metal conduit, etc., may cause errors, so again allow for this!*

*In answer to your request for a project, I think that the interest and scope of use for most home constructors versus the cost would not justify the project's existence. In most instances a multimeter and live-wire detector, used thoughtfully, will provide the most help. If you really need such a specialised unit, try one of the electronic instrument rental companies, it will probably be the cheapest option. The idea of a low-ohmmeter with reasonable accuracy is interesting, I'll suggest it to the boys in the lab.*

## S·T·A·R L·E·T·T·E·R

This issue, Mr H. Foster, from Combe Martin in Devon, receives the Star Letter Award of a £5 Maplin Gift Token for comments about Ni-Cd cells.


***Rechargeable, Providing . . .***

Dear Sir,

I have always understood that if Ni-Cd cells are recharged before they are fully discharged then they develop a 'memory'. A feature about Ni-Cds in Issue 28 gives the example: "If it [the battery in the torch] is discharged every night as the occupier puts the cat out for about ten minutes, the result over a period of time is that the torch will now deliver no more than ten minutes of light." Another instance, in Issue 25, says: "it is almost impossible to know the state of charge of a battery at any one time so that charge times can be calculated, therefore it is desirable to discharge the battery first." Latest catalogue says: "If a Ni-Cd is not charged frequently from a condition other than fully discharged the capacity will be significantly reduced." The 'not' is obviously a misprint and is relatively unimportant, but . . . The write-up for the solar battery charger says "For best results batteries should be recharged at the first sign of 'weakness'. Batteries will last up to four times longer if charged after only 50% of discharge." This is true of lead-acid cells but certainly not, in my opinion, Ni-Cd cells.

*I agree that Ni-Cd cells should be discharged completely before recharging. Lead-acid cells should never be completely discharged. For applications where it is necessary to use a battery until it 'drops dead' (racing cars, camcorders, etc.) Ni-Cd cells are ideal. For cyclic applications where partial discharge and immediate recharge are required, lead acid cells are the best choice. However, there are certain types of Ni-Cd cells that are designed for cyclic use, such as used in memory back-up batteries in computers. There are also certain types of lead-acid cells, such as used in marine/leisure batteries, that can be regularly drained to almost flat without adverse effect. Thanks for pointing out the catalogue blunders, your comments have been passed to the Catalogue Editor.*

***Changes in The Magazine***

Dear Sir,

I purchase *Electronics* every month regularly, and the thought occurred to me why don't you print the Price Change List in the magazine every month? It is the same size as the magazine, and it would save on envelopes and postage into the bargain.

**R. E. Howes, Bromley, Kent.**

*When* Electronics *was published quarterly (prior to 1989) the Price Change List was printed in the magazine because publication conveniently coincided with quarterly price changes. However, the problem was that often the list would take up rather a lot of pages. The majority of readers preferred the pages to carry interesting projects and features, not boring prices, so it was phased out. Maplin now holds prices current for six months (excluding computer equipment), so there is no need to publish changes every month. Current prices are valid until 28th February 1994, after this date you can write to, or phone Maplin, or visit a Maplin Store and ask for a price change list (CA99H) – it's free of charge! The period of validity for prices in the magazine is printed on page 2 under the Prices heading.*

***Reminiscing – About Valves, What Else?***

Dear Sir,

As a fairly old 'old timer' in the field of electronics, I was most interested to read the survey of audio amplifiers of the past, as reviewed by Graham Dixey. I had at one time or another built most of them. Garner, Baxandall, Williamson (Willie), etc. D. T. N. Williamson died about 18 months ago, leaving his design behind, which was regarded as a benchmark for quality sound reproduction.

In the late forties and fifties a friend and I used to pool resources to build sound equipment. Our star achievement was constructing Sinfield's sine and square wave generator from a *Wireless World* circuit. We did not have an oscilloscope to tell whether or not the unit was operating above our hearing range. A flash of inspiration had us borrowing next door's dog, who duly sat with ears twitching!

The Ultra Linear amplifier was

built as soon as the American *Radio Electronics* circuit was published. We used a RadioSpares multi-tapped output transformer, feeding the screens from one of the secondary taps, and it was massive. By that time we had a 'scope from a design by Tusting and Puckle. Currently I still use an Armstrong stereo valve amplifier and a Leak valve FM tuner, for which I built a stereo decoder.
Putting the clock back even further, during the height of the 'Cold War' British companies were constructing radio transceivers based on valves, because solid state radio systems would have lasted only just until melt-down time!
**Frank Thomas, Narberth, Dyfed.**

*What's particularly interesting about Mr. Thomas's letter is that, at the time he is talking about, you couldn't get, or afford, ready-made test equipment even second-hand, and so you had to build your own before you could go on to more ambitious circuit building. The Williamson amplifier is still rated by many as a valve amp benchmark.*

### *Computer Noise*

Dear Sir,
I like listening to music when working at my computer (386SX) but cannot listen to FM radio because of the interference caused by the computer.
A 2 metre transceiver situated several feet away is not affected, but the radio, with internal or external aerial, mains or battery, is. Is there any way of overcoming this?
**C. C. Cresswell, Newquay, Cornwall.**

*The problem is worse if the system unit case is plastic; steel ones offer much better screening. However, a lot can be done to reduce conducted and radiated emissions from connecting cables. Ferrite noise filters are available from Maplin (page 159 of the current catalogue) these simply clip over cables (no need to remove connectors) and attenuate HF/RF noise. Three sizes are available to suit cables of different diameters – up to 6·5mm (KW37S), up to 10mm (BZ33L) and up to 13mm (BZ34M). Fit these onto power cables of both the system unit and monitor, and also the monitor video cable. Fitting a filtered mains plug (KU19V) will help reduce noise being back-conducted into the mains supply wiring and also offer protection to the computer against spikes and noise originating from the mains.*
*Check that the earth connections to the computer and metal case-panels are effective, as high resistances here will increase radiated noise levels and affect safety.*
*Using an external aerial, for example an FM antenna mounted on the roof or in the loft and connected to the receiver with a coaxial downlead will also help in extreme cases.*

### *Unusable Circuit*

Dear Sir,
I am writing to complain about the lack of component values given for the '300W Mono MOSFET Power Amplifier' featured in *Electronics* Issue 70 (October).
My preference, and that of others that I know, is to modify published designs to suit my requirements and to use various spare components that I happen to have. Leaving out the component values from this design makes understanding how it really works impossible.
I realise that, rather than a true design, it is an advert for a Maplin kit – "some items not available separately" tells a very sad story for the electronics enthusiast!
So, in conclusion, please either publish the component values or don't publish at all – don't cheat your readers.
Incidentally, it is a 150W *rms* amplifier, *not* a 300W amplifier. Leave 'music power' to the gullible buyers of far-Eastern audio equipment.
**N. McGann, Cambridge.**

*Point taken, I have discussed this matter with our very capable Drawing Office and they are happy to oblige, all circuits drawn henceforth will now include component values where these are appropriate to the operation and understanding of the circuit. However, be warned that there may be an odd circuit or two already drawn and in the publishing pipeline without values.*
*The amplifier power ratings for various loads were clearly detailed in the Specification table. Incidentally, 'watts rms' strictly speaking is technically incorrect too! (see Impedance Matching by Bob Pearson,* Electronics *November 1993).*

### *Improbably Rechargeable*

Dear Editor,
I have seen at least one instance of a battery charger for sale that is stated to be able to "recharge *ordinary* batteries as well as Ni-Cds." I note that in the Maplin catalogue there are several chargers for Ni-Cds, but do you supply one that will recharge 'ordinary' batteries also?
Also can you kindly confirm that 'C' and 'D' sizes are what one often refers to as 'R14' and 'R20'?
**H. V. Kirby, Hayling Island, Hampshire.**

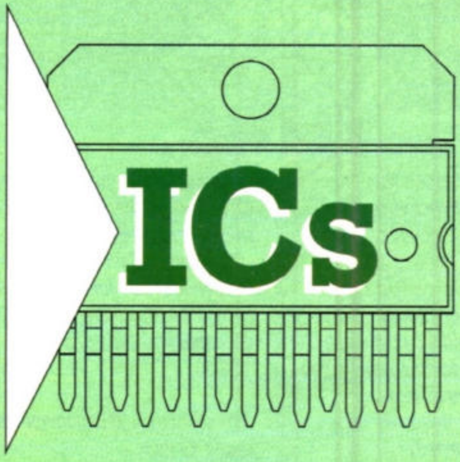
*This is not the first query about the so-called 'ordinary battery' charger. The quick answer is Maplin do not currently stock a charger designed to charge primary cells.*
*I am unable to comment either way as to how effective these charger units are as I have not tried them. Essentially cells (which are combined to form a battery) are classed as being either primary or secondary. Both make use of electrochemical reactions: in a primary cell the process is one way – as the cell discharges through use, the active chemicals are depleted and eventually the cell is exhausted; when this point is reached it must be discarded and replaced with a new cell. In a secondary cell the process is two way – when the cell is exhausted, the chemicals can be converted back into their original form by passing an electric current through the cell (charging). It has been shown that primary cells, do to some extent, exhibit secondary cell behaviour between certain points of their discharge curve.*
*I do not know of any authoritative work or papers published on this subject (perhaps some readers do?), but I have over the years read many articles in the popular electronics press explaining this theory. Often practical designs of chargers were presented too, some were dubious in operation, some were plausible and others were downright lethal! European battery manufactures actively discourage any attempt to recharge their cells and clearly state that doing so may cause the cells to explode. It is worth remembering that secondary cells are deliberately vented to release any pressure build up caused by incorrect charging.*
*If it can be proved that primary cells do exhibit worthwhile secondary cell behaviour, perhaps battery manufacturers could be persuaded to include a suitable venting system.*
*But, in their eyes, why should they – after all if you recharge your batteries, you'll buy fewer and they'll make less money. On the other hand, fewer batteries thrown away mean less environmental pollution, but that's another story . . .*
*As far as the IEC sizes go, I've found out the following: LR1 = N, LR03 = AAA, LR6 = AA, LR14 = C, LR20 = D, and 6LF22/6LR61 = PP3. Extra/different letters may indicate the type according to the manufacturer, e.g., zinc-carbon, zinc-chloride, alkaline, etc.*

### *Electronic Biking*

Dear Sir,
I was most interested in the Ignition Amplifier as described in Issue 68 (August). Not, of course, for the car, as that has full electronic ignition already, but for my motorcycle that is a good deal older. The snag is, however, that it has a six volt electrical system, and the circuit is designed for 12V. Is there any way in which the kit could be modified to accept a 6V supply?
**A. E. N. Ogle, Kingswood, Bristol.**

*This could be done with suitable resistor changes to retain the same operating current levels in the circuit where the supply is reduced from 12V to 6V, plus a margin (down to 4V).*
*The main limiting factor to performance is the $V_{CE\,(sat)}$ (saturated on voltage drop) of output transistor T2. E.g., if this is 1V then, as a fair proportion of a 6V supply, it leaves only 5V for the coil, reducing power. It is not of course such a problem at 12V. If you decide to try it (or anyone else), please let me know how you get on.*

# USING AUDIO PREAMP ICs



## PART ONE

**Ray Marston shows ways of using some popular audio preamplifier ICs in this special two part article.**

EACH channel of a modern audio system consists of a few interconnected circuit blocks, as shown in Figure 1. Input signals from a radio tuner, a tape (cassette) deck, or a phono preamplifier, etc., are selected via SW1 and then fed to the power amplifier, via a tone control system and a volume control.

The tone control system usually needs to be driven by input signals with mean amplitudes of a 100mV or so. Suitable signals are usually available directly from the output of a tape or tuner unit, but not from the output of a magnetic phono pick-up, in which case the signals must be passed on via a suitable preamplifier stage. Several manufacturers make dedicated ICs for use in audio preamplifier and tone control applications. Their 'preamp' ICs feature excellent power-supply ripple rejection, low signal distortion, a wide bandwidth, and a very low noise figure. Among the best known of these devices are the LM381/ LM382/ LM387 family of dual audio preamps. A number of special 'audio' ICs that provide voltage-controlled gain are also available; amongst the best known of these are the MC3340P 'electronic attenuator', and the NE570, or NE571, dual 'compander'. This two part article shows practical ways of using all of these ICs.

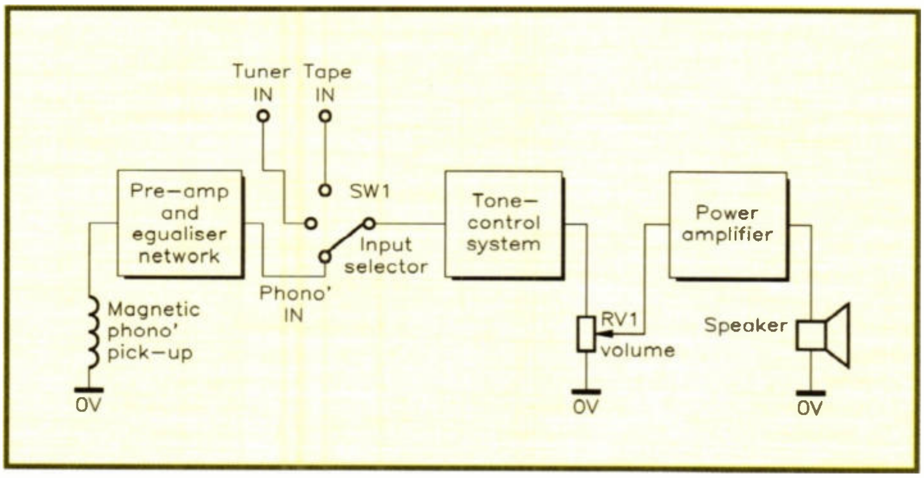



**Figure 1. Block diagram of one channel of an audio system.**

## LM381/LM382/LM387 ICs

National Semiconductors produce a range of five low-noise dual preamp ICs, these being the LM381 and LM381A, and the LM387 and LM387A – the 'A' suffix devices are simply premium versions of their type, with superior low-noise figures. Figures 2 to 4 show the outlines of each of these ICs, together with the actual circuit of one of the identical pair of amplifiers that are housed in each package. Figure 5 gives a summary of their performances.

Each of these ICs is designed to operate from single-ended power supplies, and incorporate internal feedback compensation, comprehensive power supply decoupler/regulator circuitry, and have a wide power bandwidth and can give large output voltage swing. They all use the same basic amplifier circuitry, but differ in minor circuit details and in their pin-outs. The various ICs differ in the following respects:

The LM381 and LM381A have provision for externally optimising their noise figures and for adding external compensation (for narrow-band or low-gain applications). These ICs are normally used in the differential input configuration, but can be used in the 'single-ended' input mode in ultra low-noise applications.

The LM382 has no provision for adding external compensation or for operation in the single-ended input configuration. However, the device has a built-in resistor matrix that lets the user select a variety of closed-loop gain options and frequency response characteristics.

The LM387 and LM387A are utility versions of the LM381 and LM381A, with only the input and output terminals of each

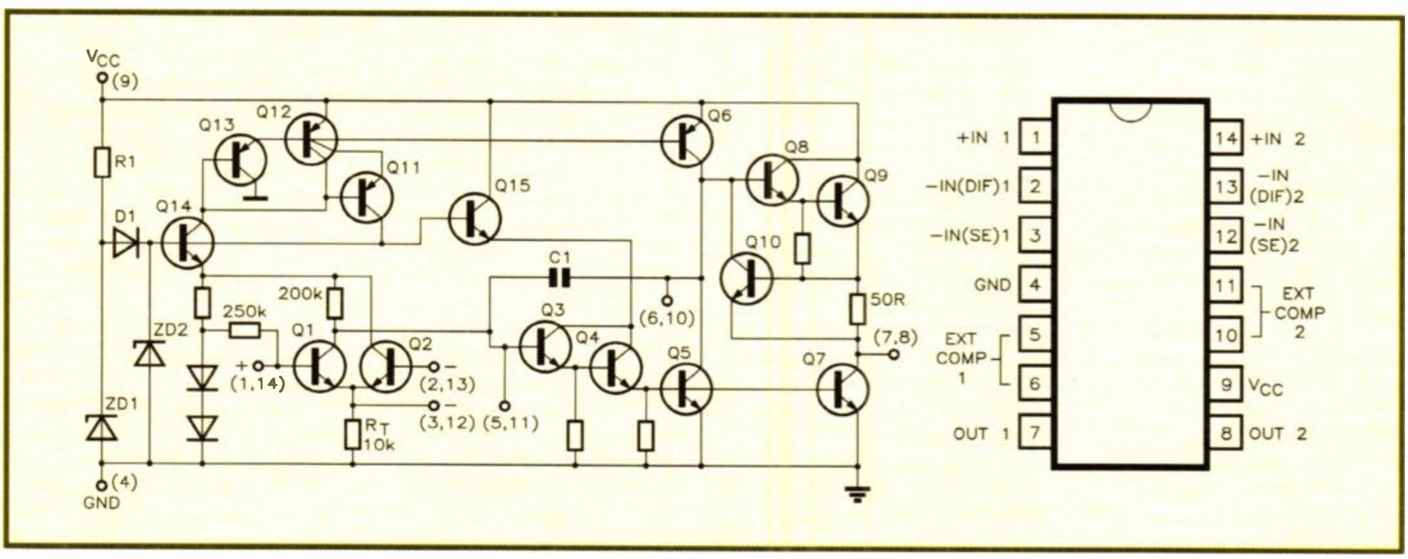



**Figure 2. Circuit and outline of the LM381/LM381A dual low-noise preamplifier.**

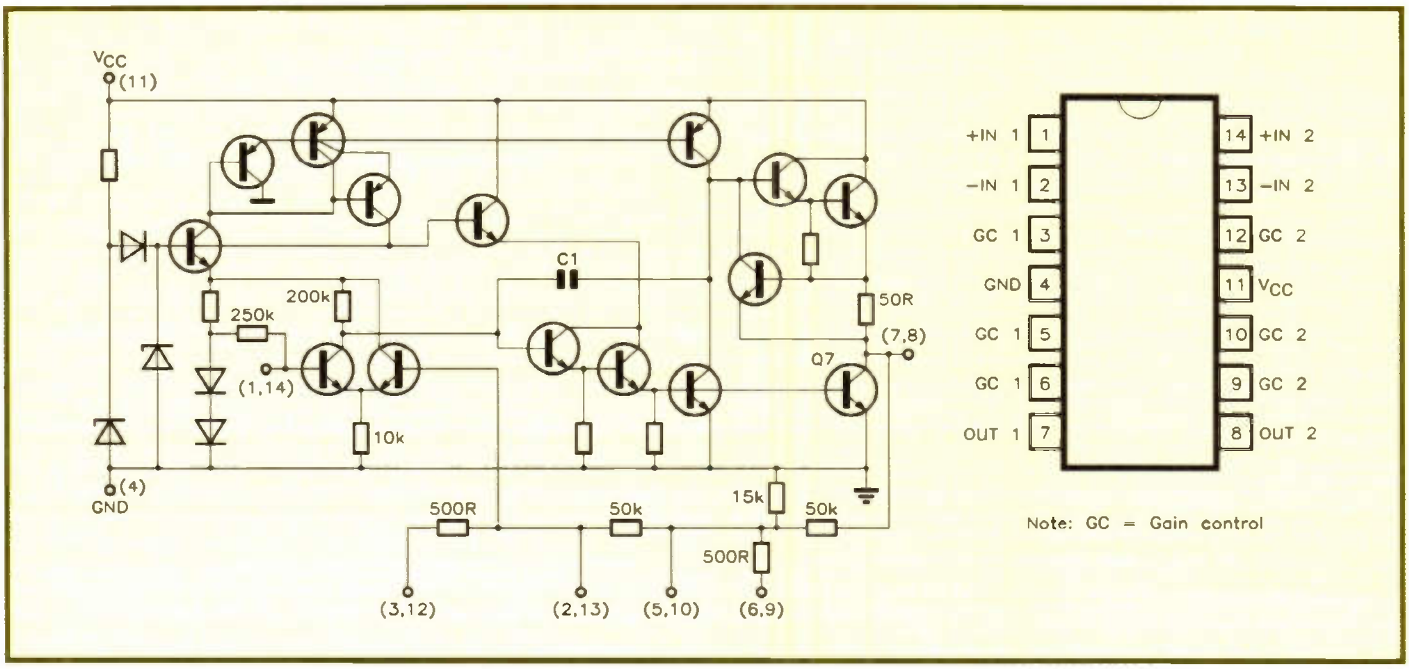



**Figure 3. Circuit and outline of the LM382 dual low-noise preamplifier.**

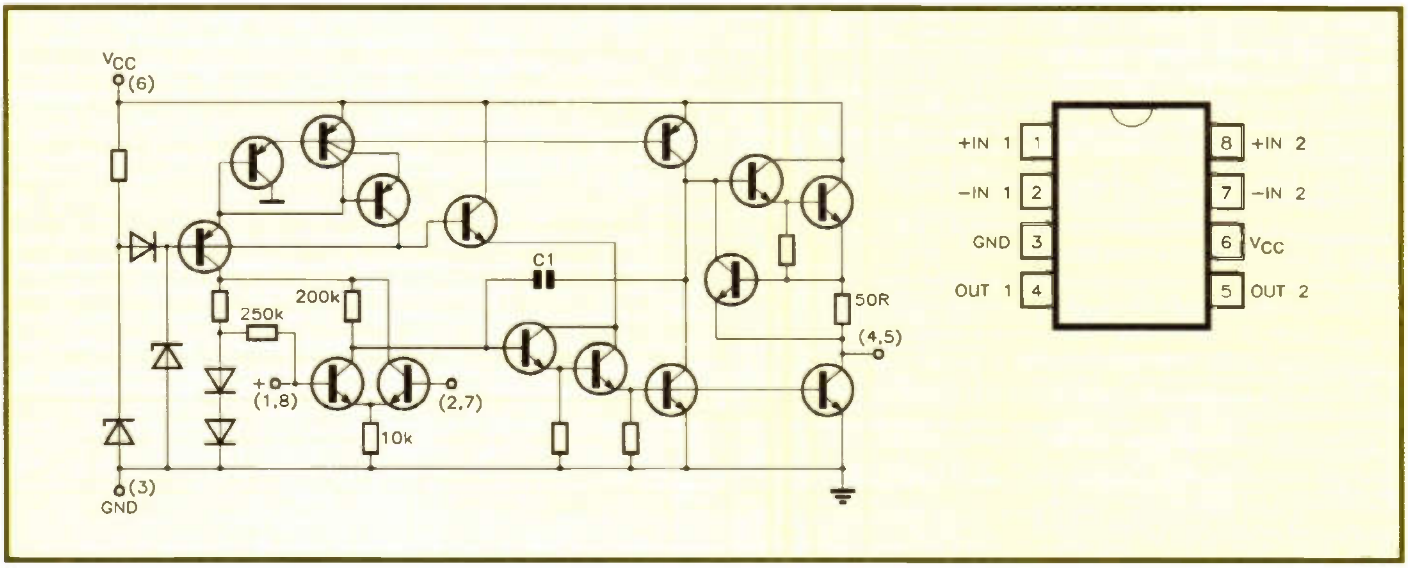



**Figure 4. Circuit and outline of the LM387/LM387A dual low-noise preamplifier.**

amplifier externally accessible. Provision is not made for external frequency compensation or for single-ended input operation.

## LM381/LM381A Basics

The LM381/382/387 range of dual preamp ICs all use the same basic internal circuitry, but differ in minor details. The operation of the entire range of devices can thus be understood by taking a close look at the circuitry of the LM381/LM381A as shown in Figure 2. In fact, this circuit comprises four major sections, these being a 1st stage amplifier (Q1 and Q2), a 2nd stage amplifier (Q3 to Q6), an output stage (Q7 to Q10), and a biasing network (Q11 to Q15). Figure 6 shows a simplified 'equivalent' circuit of the complete preamplifier, showing its four major sections.

The Q1 and Q2 1st stage input amplifier of the IC is powered via the internal biasing network, and has a biasing potential of 1·2V permanently applied to Q1 base, via a 250kΩ series resistor. This 1st stage can be operated as either a differential or a single-ended amplifier (a differential stage generates 41% more noise than a single-ended stage).

When used in the differential mode, the Q1 and Q2 amplifier must be balanced by feeding 1·2V to Q2 base via an external biasing network connected as shown. When used in the ultra low-noise single-ended mode, Q2 must be turned off by grounding its base, and Q1 must be balanced by feeding 0·6V to Q2 emitter via the external biasing network. This 1st stage amplifier gives a voltage gain of x80 when used in the differential mode, or x160 in the single-ended mode.

| | LM381 | LM381A | LM382 | LM387 | LM387A |
|---|---|---|---|---|---|
| $V_{supply}$ | 9V to 40V | 9V to 40V | 9V to 40V | 9V to 30V | 9V to 40V |
| $I_{quiescent}$ (typ) | 10mA | 10mA | 10mA | 10mA | 10mA |
| Power bandwidth (20V Pk-to-Pk) | 75kHz | 75kHz | 75kHz | 75kHz | 75kHz |
| Supply rejection ratio at 1kHz (typ) | 120dB | 120dB | 120dB | 110dB | 110dB |
| Equivalent noise input figure, µV RMS (typ) | 0·5 | 0·5 | 0·8 | 0·8 | 0·65 |
| Equivalent noise input figure, µV RMS (max) | 1·0 | 0·7 | 1·2 | 1·2 | 0·9 |

**Figure 5. Performance characteristics of the five dual preamplifier ICs.**

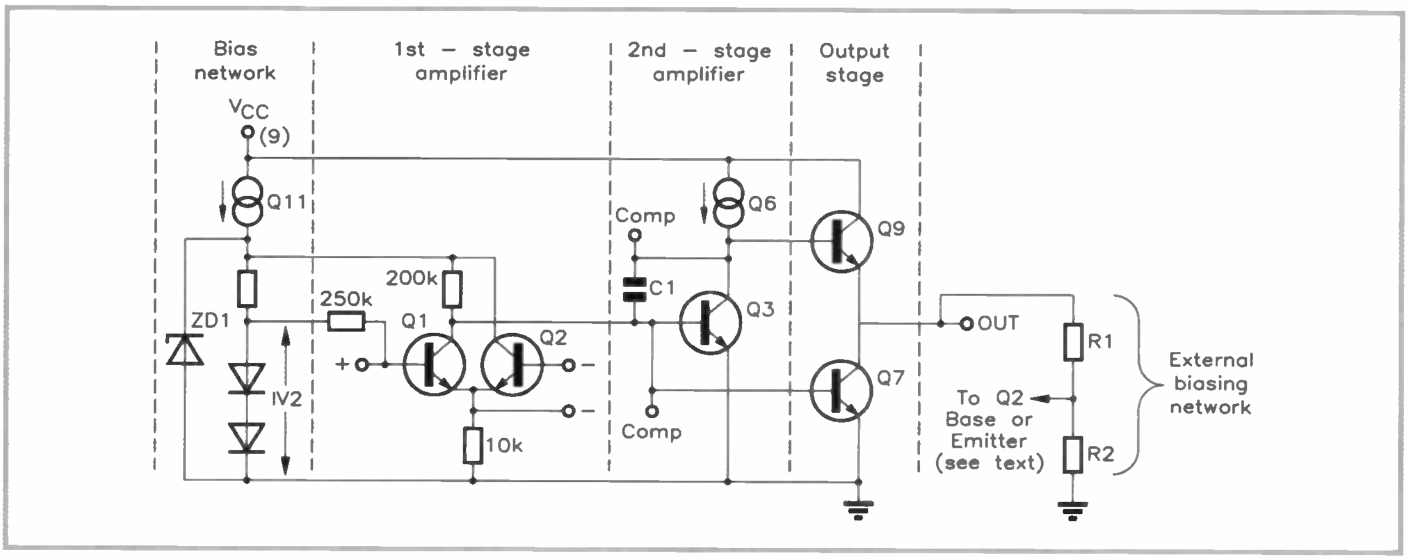



**Figure 6. Equivalent circuit of the LM381/LM381A amplifier.**

The 2nd stage amplifier comprises common emitter stage Q5 (with constant current load Q6) and is driven from Q1 output via Darlington emitter follower Q3 and Q4. This 2nd stage amplifier gives an overall voltage gain of x2000, and is internally compensated, via C1, to give unity gain at 15MHz. This compensation provides stability at closed-loop gains of x10, or greater. At lower gains, an external capacitor can be wired in parallel with C1 to provide suitable compensation.

The output stage of the amplifier comprises Darlington emitter follower Q8 and Q9, which is provided with an active current sink via Q7. Transistor Q10 provides short-circuit protection by limiting the output current to 12mA.

The amplifier's biasing network is designed to give a very high supply signal rejection ratio (120dB), and consists essentially of a very high impedance constant current generator Q11, Q12 and Q13, which is used to generate a ripple-free reference voltage across Zener diode ZD2. This reference voltage is then used to power the first two stages of the amplifier via Q14 and Q15, and to provide internal biasing to Q1 base.

## Differential Operation

The LM381 or LM381A IC can be operated in either the differential input or the single-ended input modes. Differential input operation is suitable for use in all general-purpose applications in which a 'good' low-noise performance is required. Single-ended input operation is recommended for use only in applications where an ultra low-noise performance is needed.

To use a LM381, or LM381A, preamp in the differential input mode, the IC must first be biased so that its output takes up a positive quiescent value that is independent of variations in the supply voltage. This can be achieved by connecting potential divider R1 and R2 between the output and the non-inverting input of the IC, as shown in Figure 7, thus forming a DC negative-feedback loop. The inverting input terminal of the IC (Q1 base in Figure 6) is internally biased at about 1·2V above zero. Consequently, when R1 and R2 are

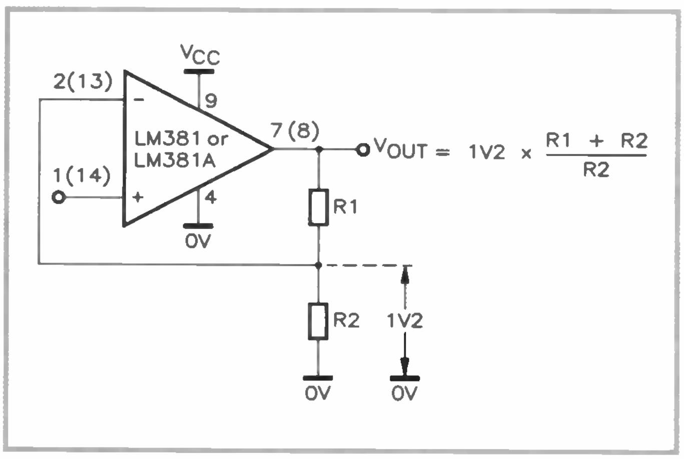



**Figure 7. Differential biasing of the LM381 or LM381A.**

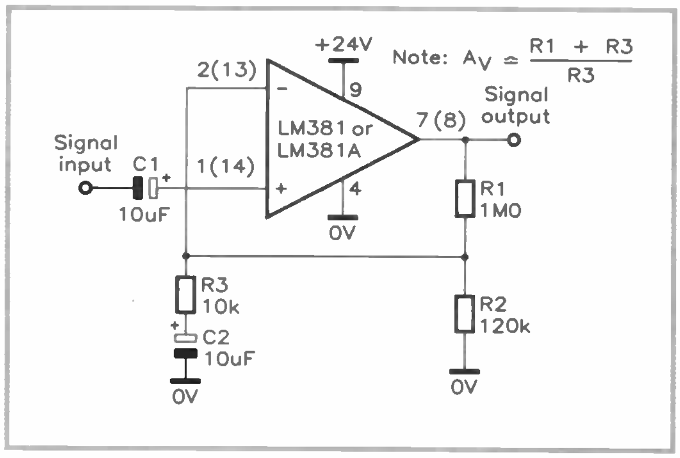



**Figure 8. Low-noise x100 non-inverting amplifier.**

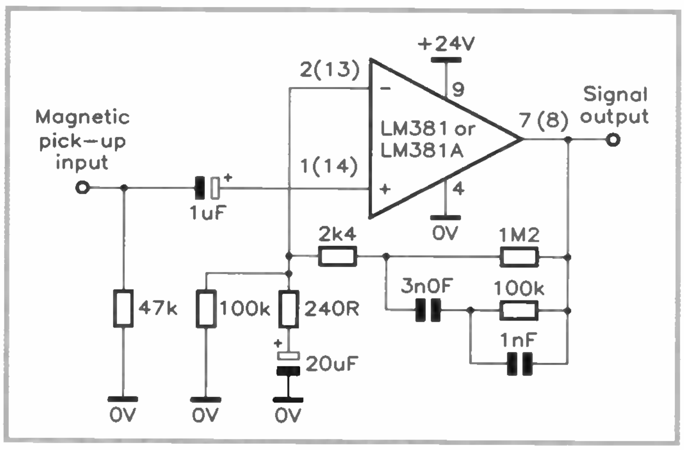



**Figure 9. Low-noise phono preamp (RIAA).**

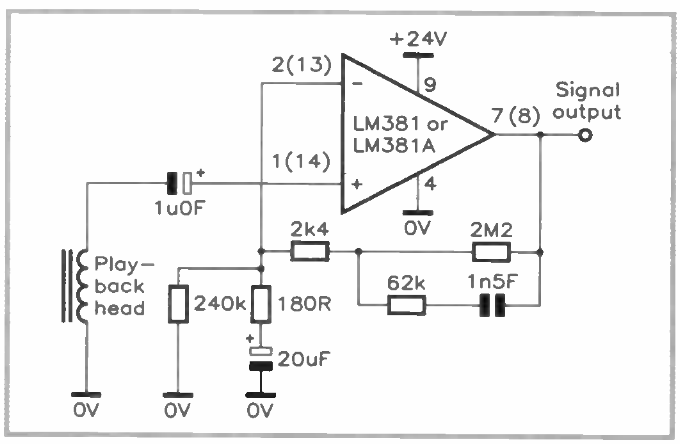



**Figure 10. Low-noise tape playback amplifier (NAB).**

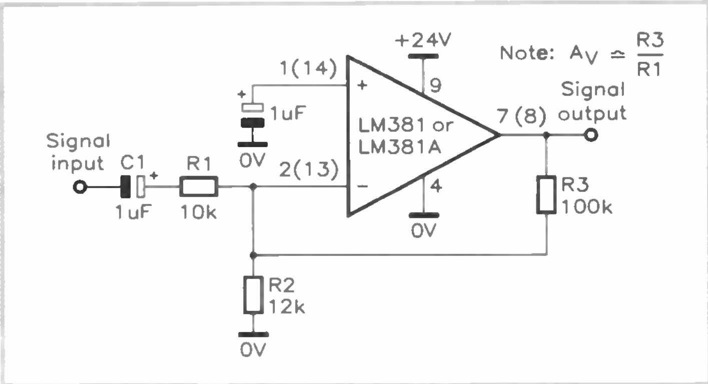



**Figure 11. Low-distortion (<0·05%) x10 inverting amplifier.**

In a future issue of '*Electronics*' Ray Marston will cover in depth the use of Audio Power Amp ICs. Don't Miss It!

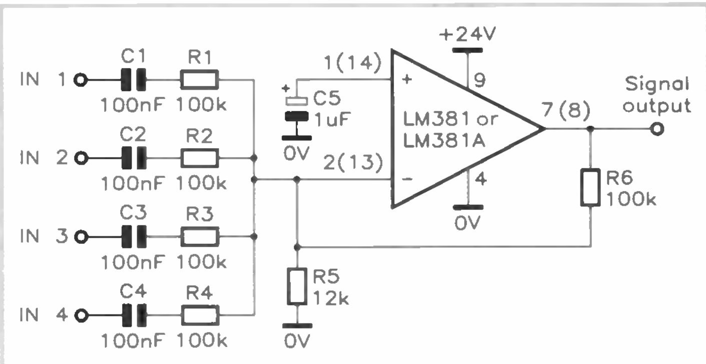



**Figure 12. 4-input unity-gain audio mixer.**

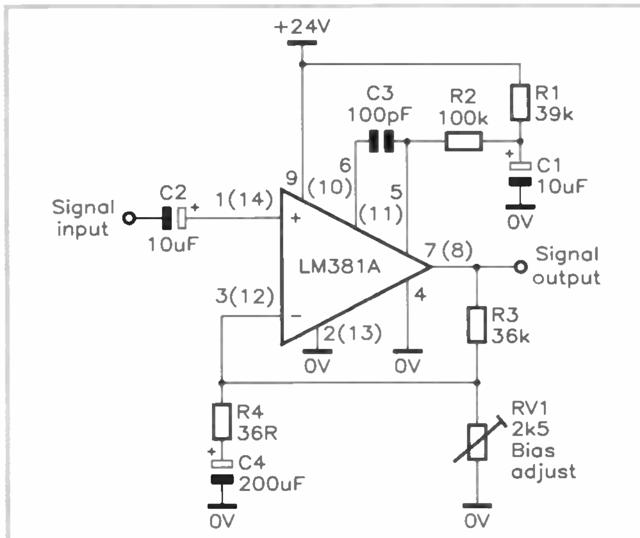



**Figure 14. Ultra low-noise x1000 preamplifier.**

connected as shown in Figure 7, DC negative feedback causes the non-inverting input terminal to take up a value equal to that of the inverting terminal (1·2V). Therefore, the amplifier output attains a DC value of 1·2V x (R1+R2)/R2, and can be set at any desired value by a suitable choice of the ratio R1 and R2. In practice, R2 should have a value of less than 250kΩ.

The circuit of Figure 7 can be made to act as a non-inverting AC amplifier by simply AC coupling the input signal to the amplifier's non-inverting input terminal – in which case the circuit's input impedance is about 250kΩ. However, input signals must be limited to 300mV RMS maximum, to avoid excessive distortion.

The DC voltage gain of the circuit is determined by R1 and R2. If the desired AC gain differs from the DC value, the desired AC gain be obtained by AC shunting one or other of the bias network resistors. For example, Figure 8 shows the circuit of a low-noise x100 non-inverting amplifier, in which the DC gain is determined by R1 and R2 and is less than x10, but the AC gain is determined mainly by R1 and R3, and is approximately x100.

The above 'shunting' technique can easily be expanded to provide frequency dependent AC gain in various 'filter' applications. Figure 9 shows the circuit of a low-noise phono preamp with RIAA equalisation, and Figure 10 shows a tape playback amplifier with NAB equalisation.

Figure 7 shows a circuit that can be made to act as an inverting AC amplifier by AC grounding the non-inverting terminal and feeding the input signal to the inverting terminal via a gain determining resistor, as shown in Figure 11. Here, bias resistors R2 and R3 give a DC gain of about x10, and thus set the quiescent output at +12V.

However, the AC gain, is determined by the ratio R2 to R1, and has a value of x10 in this example – the input impedance roughly equals the value of R1. Finally, Figure 12 shows how the above circuit can be made to act as a unity gain 4-input audio mixer by simply providing each of the four input channels with its own series input resistor.

## Single-ended Operation

The LM381A can be operated in the single-ended input mode in applications where an ultra low-noise performance is needed. The mode can be understood with the aid of Figure 13, which shows (within the dotted lines) a simplified representation of the IC, together with external biasing components, etc.

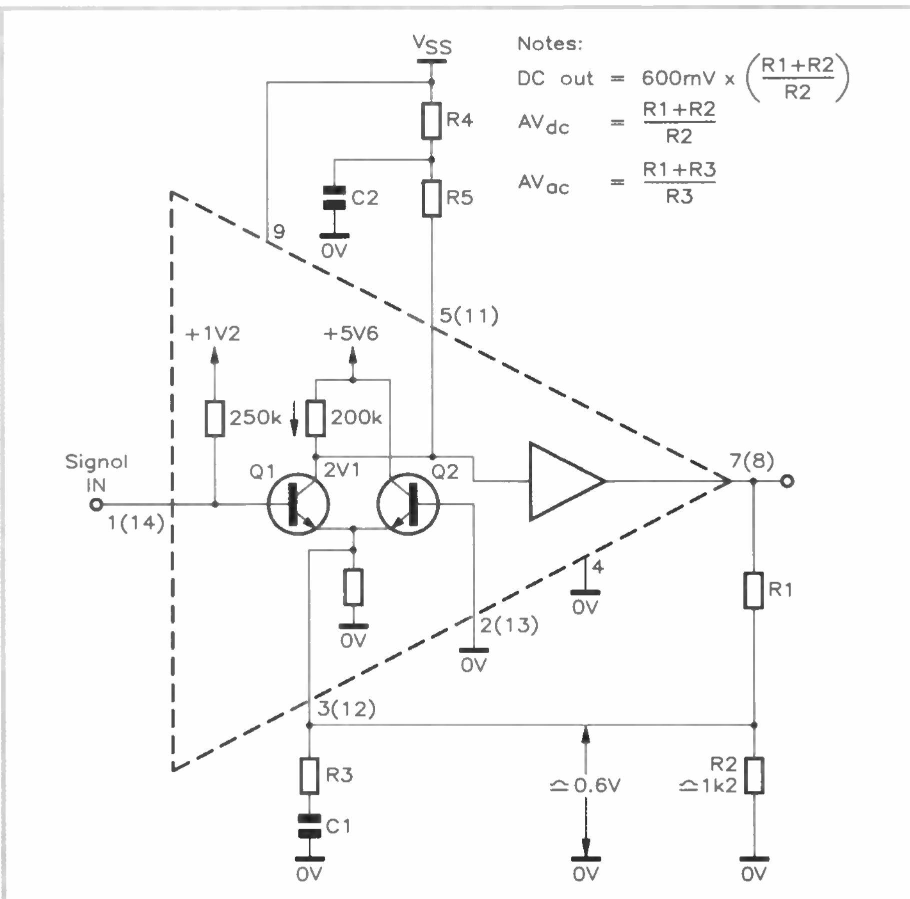



**Figure 13. LM381A with external components for single-ended varied-current-density operation.**

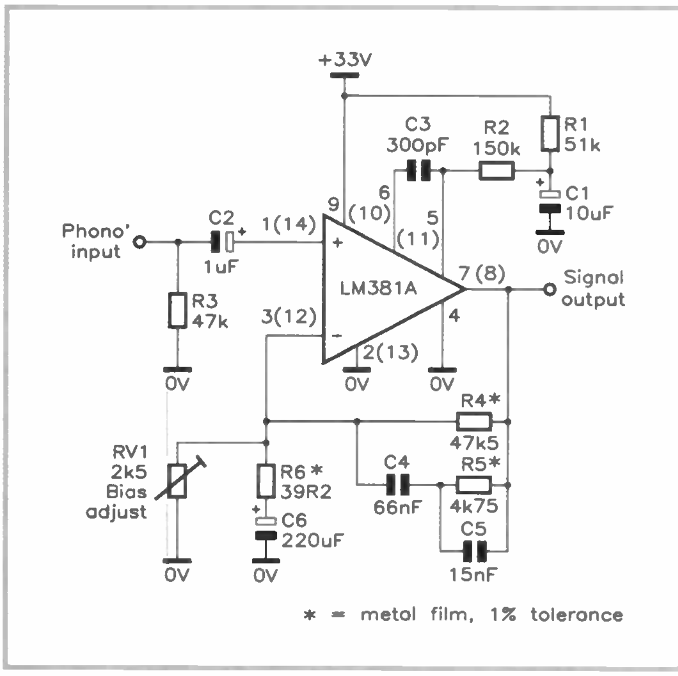



**Figure 15. Ultra low-noise magnetic phono preamp with RIAA equalisation.**

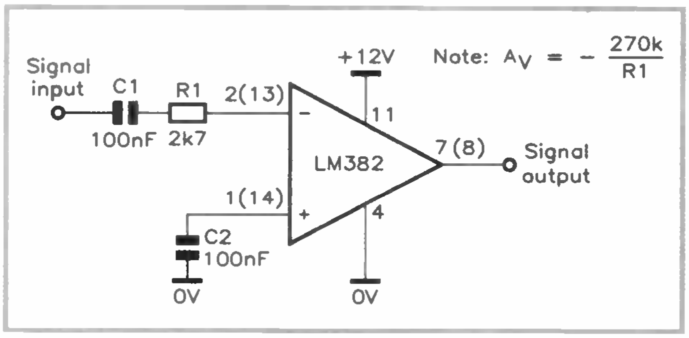



**Figure 17. 40dB inverting amplifier.**

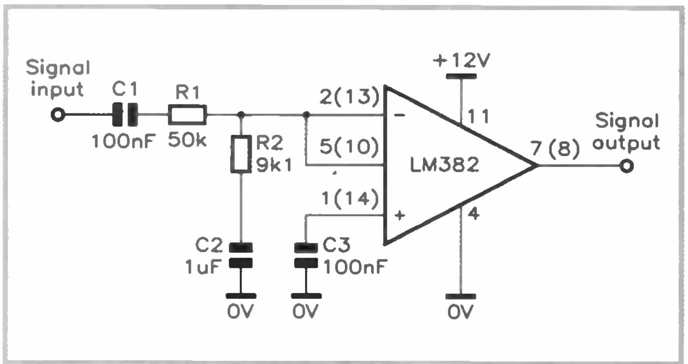
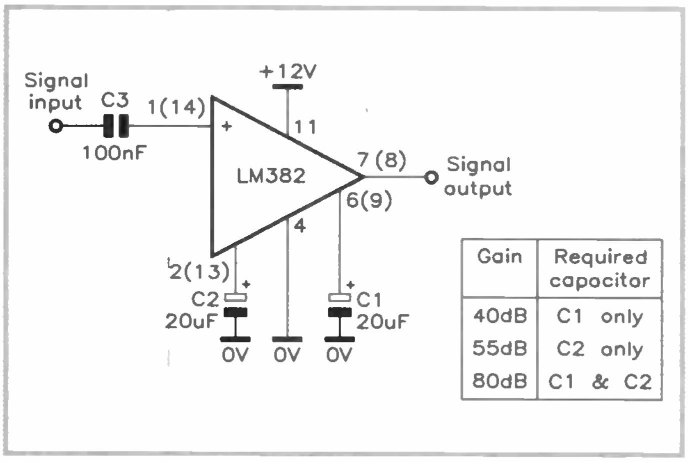



**Figure 18. Unity-gain inverting amplifier.**




| Gain | Required capacitor |
|---|---|
| 40dB | C1 only |
| 55dB | C2 only |
| 80dB | C1 & C2 |

**Figure 16. LM383 used as a fixed-gain non-inverting amplifier with a 12V power supply.**

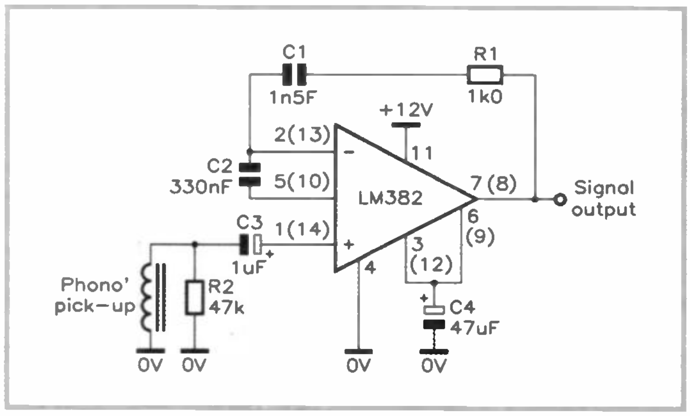



**Figure 19. Phono preamp (RIAA).**

In Figure 13 the Q1 and Q2 differential 1st stage amplifier is shown powered via the internal 5·6V regulator, and has its Q1 collector signal fed to the output via a DC amplifier. The IC can be connected into basic 'single-ended' configuration by simply grounding Q2 base as shown, thereby disabling Q2. However, the circuit can no longer be DC biased via Q2 base to Q2 emitter.

Suitable DC biasing can be obtained by connecting potential divider R1 and R2 as shown, so that roughly 600mV is developed across R2 when the IC output is at the desired DC voltage level. Thus, if a quiescent output of +12V is needed, R1 and R2 must give a DC voltage gain of x20. If desired, R2 can be shunted by R3 and C1, to give an AC voltage gain that is greater than the DC value.

Note that in this biasing circuit, R2 is in fact wired in parallel with the internal 10kΩ emitter resistor of Q1, and thus causes the Q1 emitter and collector 'current density levels' to increase above their normal values of about 15µA. However, in practice it can be shown that the noise generation of Q1 varies with collector current density, and is at a minimum at a density of about 170µA. Consequently, the circuit generates minimum noise when R2 has a value of about 1·2kΩ. To prevent Q1 collector from saturating at this current level, the internal 200kΩ collector resistors of Q1 must be bypassed, with the major part of the current provided via external load resistors R4 and R5, which are decoupled via C2.

Figure 13 shows a 'single-ended' circuit that is intended for use as a non-inverting amplifier only, and has a typical input impedance of about 10kΩ. Ideally, input signals to the circuit should have source impedances below 2kΩ, and all resistors should be low-noise metal-film types.

Figures 14 and 15 show a pair of practical versions of the ultra low-noise circuit. Figure 14 is a x1000 amplifier and has the upper 3dB point of its frequency curve limited to 10kHz via C3, and Figure 15 is a magnetic phono preamplifier with RIAA equalisation. In both cases, RV1 is used to set the DC output voltage at half the power supply value.

## LM382 Circuits

The internal circuitry of each half of the LM382 is identical to that of the LM381 except for the addition of a 5-resistor matrix, and the elimination of certain terminal connections. The elimination of certain terminals means that this IC cannot be used in the 'single-ended' input mode and has no facility for external compensation. However, the addition of the resistor matrix enables bias and filter network design to be greatly simplified – note that this matrix is specifically intended for use in applications in which the IC is powered from a 12V supply.

Figures 16 to 19 show various ways of using the LM382 with a 12V supply. Figure 16 shows how to use the IC as a non-inverting amplifier with an AC gain of 40, 55 or 80dB. Figure 17 shows the circuit of an inverting amplifier with a gain of 40dB, and Figure 18 shows a unity-gain inverting amplifier. Finally, Figure 19 shows a phono preamplifier with RIAA equalisation.

## NEXT ISSUE...

The second part of this superb article will show ways of using the LM387, TDA3410 also the MC3340P, and NE570/571 ICs.

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# Stray Signals

by Point Contact

A little while ago, Mr. and Mrs. PC went to London for a day out, as occasionally happens, taking in a Prom concert in the evening. (You will realize from this, if you hadn't before, that these notes are penned some months in advance of publication.) The train fare for two being considerably more than the cost of petrol for her economical little Metro, we (perhaps deplorably) opted to go by road rather than rail, so adding to road congestion (we were lucky, there wasn't any), air pollution and the greenhouse effect. We arrived a little earlier than planned and headed for one of the few places in central London offering free all-day parking; they do exist if you know where to look. This particular little car park has to be empty between 10.00 a.m. and 11.00 a.m., thus preventing it clogging up with office workers or other commuters. Arrival timing is a little tricky; if you arrive much before 11.00 a.m. a Traffic Warden may pop up, shooing all those jumping-the-gun out, to drive around for a while, whilst if you arrive much after 11.00 a.m. the place is full.

Having successfully parked for free, we wended our way gently through the Royal Parks, pausing by the lake in St. James's Park to eat our packed lunch – we always go around London on foot, avoiding traffic clogged streets wherever possible. We were sharing one of the park benches with two little old ladies who were also lunching, and we speculated afterwards as to whether they were the original 'Gert and Daisy', but decided that they didn't look old enough for that. Then on again to see the bustle in Covent Garden market, now full of trendy boutiques, purveyors of craft wares selling from barrows, and buskers – the most memorable of these being a very competent quartet playing the famous '*Canon*' by Pachelbel. From there over Waterloo Bridge and along the south bank pedestrian walkway to Blackfriars Bridge – where can all this be leading, you may ask? The answer is back over the bridge to the BT building just east of Blackfriars BR Station, where there is an exhibition which should interest any reader of this magazine; the BT Museum 'The Story of Telecommunications'. This fascinating exhibition, worth at least a couple of hours of anyone's time, tells the story of communication-at-a-distance, from smoke signals and semaphores to satellites and optical fibres, so you can see it covers both line and wireless communications. In addition to both modern and early equipment, including coherers and magnetic detectors (original ones but alas not working, though various other old exhibits are), you will see biographical snippets on many of the famous names in the business, such as the memorably obscurantist remark "Wireless is all very well, but I'd rather send a message by a boy on a pony", from none other than Lord Kelvin! (As the father of practical line-comms, a certain scepticism regarding


the new-fangled *wireless*-comms was perhaps understandable.) My illustration this month, from the museum's archives, is of an early telephone operator at a small switchboard. If a further incentive to visit the exhibition were needed, perhaps I should mention the entrance fee: *there isn't one.*

We have heard a lot lately about the state of the National Health Service, but this country is not alone in being in difficulties with State health care; many countries in Europe are in the same boat, and in the USA the same complaints are being voiced. An interesting letter from a reader of *SPECTRUM*, the Journal of the American IEEE published in the July 1993 issue, makes an interesting suggestion to relieve the pressure on hardworked GP's surgeries. Why not put a computer-based expert system in every main public library? Sit down in front of one of these, equipped with a user friendly menu driven MMI (Man-Machine Interface), feed in all your symptoms and the system will give you a diagnosis (with a recommended treatment – non-prescription and available over the chemist's counter wherever possible) if its percentage confidence factor in the result is high enough, or if not advise you to visit your GP. The idea is not so daft as it sounds at first sight: the system could be fitted with sensors for non-invasively measuring parameters such as temperature, pulse-rate, blood pressure and possibly others, and the resulting diagnoses would probably be at least as accurate as those from a few minutes' consultation with a hard-pressed GP. Remember, a computer has an infallible memory and thus won't miss the significance of symptoms pointing to a rare condition, one which a GP may never have encountered since learning about it (and subsequently forgetting) at medical school. The computer would of course calculate appropriate dosages, given the data fed in by the patient as to age, weight, gender etc. The writer even quotes putative per-system costs, say $5,000 for a state of the art PC system plus the same again for a suite of sensors. Of course, occasionally the wrong diagnosis would result, but consider any failure you can imagine, and then ask yourself if the same would be absolutely impossible from our present NHS arrangements.

**An operator at the early Croydon exchange. Photo reproduced by kind permission of BT Archives.**
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Talking of medical problems, one thing that PC does not suffer from, thankfully, is insomnia. Nevertheless, that is not to say that sleep comes instantly the old noddle hits the pillow. PC arranges a quarterly reunion over a pint with two old colleagues, during which our conversation ranges far and wide over politics, economics, music, even our old profession of electronic engineering, and the state of the world in general. At a recent such reunion, held as usual at the Bat and Ball, we got around to discussing what we did by way of mental exercise when abed but before drifting off to sleep. John said he seemed to have a fixation with numbers, and would tussle with the mental arithmetic resulting from the numerical implications of the day's news. Mick's version was more eclectic; he said that, for example, only the previous night he had been mentally verifying that he could still do Integration by Parts. As it happened, at the same time, PC had been busy convincing himself that the substitution of (s + 1/s) for s in the transfer function of a low-pass filter did indeed transform it into a bandpass filter. Oh well, it takes all sorts to make a world.

Yours sincerely,

*Point Contact*

*The opinions expressed by the author are not necessarily those of the publisher or the editor*

**4**
**PROJECT RATING**

# THE MAPLIN MILLENNIUM 4-20

## 20W VALVE POWER AMP

## Part 2 BUILDING THE AMPLIFIER

**In Part One (*Electronics* January 1994 Issue 73) the Amplifier was described briefly, and its Power Supply Unit detailed. In this part the construction of an actual amplifier module is dealt with.**

Designed and Written by Mike Holmes

**A finished stereo version of the Millennium 4-20.**

### Circuit Description

Figure 1 shows the circuit diagram of the amplifier. As mentioned in Part One, it is of a Class AB1 design and has three distinct stages. The overall design hinges on that of the output stage, centred on the most important single component, the output transformer T1.

Because valves are high impedance devices, some means is required for converting the high voltage, low current output power into a lower voltage and higher current form able to drive a loudspeaker load. This is the function of the transformer, used here as an impedance changer. Starting here, and working backwards, the remainder of the stage comprises the driver devices, in this case EL34 power pentodes V3 and V4.

### The Power Output Stage

The first aspect about the output stage is its class of operation, which is AB1. Operating mode is pure class A for approximately the first two thirds or so of output power, breaking into B near the maximum. The qualification 'AB1' simply means that the grids are not over-driven to cause current flow between the grid and cathode.

The second unusual aspect has to do with how the 'ultra-linear' tag was derived. Normally, pentodes are operated with their screen grids tied to some constant, DC reference, usually roughly equal to the biased anode level. However, while pentodes offer the greatest signal gain, triodes offer the least 3rd harmonic distortion. In 'ultra-linear', the screen grids are tapped into the transformer primary, which then becomes a 'distributed load'.

This results in two things. One, screen grid current contributes to the output and is not merely wasted, and two, the screen grid voltage level 'tracks' with the anode level by a ratio determined by the position of the taps. Most often a position of 43% from CT (Centre-Tap) is recommended (but 25% is also possible). While about half of the amplifying capability of the pentode is retained, linearity is improved by it also being made to operate halfway toward triode mode.

## FEATURES

* Class AB1 Push-Pull Output
* Non-Hybrid Traditional 4-Valve Design
* Simplified Construction Using PCBs
* Expandable Modular Concept
* Mono or Stereo Options
* No Setting Up Required
* Minimal Test Equipment Needed

## APPLICATIONS

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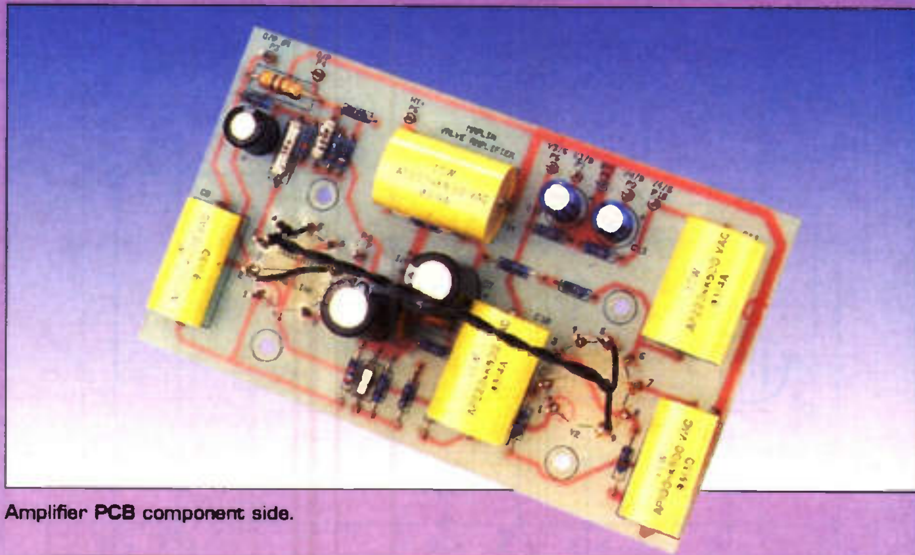
Although triodes produce more 2nd harmonic distortion than pentodes, this is eradicated in the push-pull output transformer. Thereafter, reducing the remaining pentode 3rd harmonics is achieved by carefully choosing the transformer primary impedance. In this case the manufacturer's (Mullard) advice is taken. See 'Valve Technology' Part Seven, *Electronics* Issue 73 (January), for more data.

EL34s are particularly successful in this type of output stage and their total harmonic distortion, *before* negative feedback is applied, is only 0·8% at 20W. Each operates well within its anode dissipation rating of 25W, and within the maximum anode voltage (800V), and so is 'low-stressed', promoting longer life.



Amplifier PCB component side.


## Specification of Amplifier

| | |
|---|---|
| Amplifier type: | Class AB1 'Ultra-Linear' |
| Line supply voltage (HT): | 400 to 450V DC |
| HT current consumption: | 125mA nominal (HT = 440V) |
| Heater current consumption: | 3·5A |
| Maximum output power: | 20W r.m.s. (27W absolute max., HT = 440V) |
| Gain: | 30dB |
| Input sensitivity: | 220mV for 20W Output |
| Frequency response: | 25Hz to 30kHz ± 0·5dB @ 20W<br>–3dB @ 75kHz @ 20W<br><10Hz to <40kHz ± 0·5dB @ 1W |
| Risetime (1kHz square-wave): | 4μs |
| Overshoot and ringing (1kHz square-wave): | ≈ 10% |
| Phase shift error: | 20° @ 20kHz |
| Signal-to-noise ratio: | 89dB |
| Output noise (input grounded), hum: | <3mV peak |
| white noise: | <2mV peak |
| Harmonic distortion: | 0·05% (0·1% @ 27W) |
| Intermodulation distortion: | 0·7% of carrier (1% @ 27W)* |
| Beat-note distortion: | 0·25% (0·3% @ 27W)† |
| Output impedance: | <0·2Ω |
| Damping factor: | 50 approx. |
| Output Transformer Details | |
| Primary anode-to-anode impedance ($R_{a/a}$): | 6·6kΩ |
| Screen grid taps: | 43% from CT |
| Winding distribution | Five sections of interleaved primary and secondary windings |
| Speaker load matching: | 8Ω only |
| Low frequency cut-off: | 25Hz @ 20W throughput |
| Primary resonant frequency: | 80kHz approx. |

* 10kHz carrier modulated with 40Hz at a ratio of 4:1.
† Equal amplitude signals of 14 and 15kHz.

Items marked (*) and (†) are based on Mullard's equivalent prototype amplifier. Some of these values may vary slightly for different kit amplifiers.

Linearity is maintained at powers over 15W by adding 1kΩ resistors (R23 & R24) in series with the screen grids. The slight reduction in peak power handling capacity which results is not significant in practice. As regards balancing the output stage, separate cathode biasing resistors (R21, R22) are used to limit any out-of-balance DC in the transformer primary (which if excessive could impair the performance of the transformer).

It is then necessary for each cathode to be decoupled to 0V signal ground by 47μF capacitors C12 & C13, to restore signal gain. Of course closest balance is best assured through the choice of a matched pair of valves.

## The Phase Splitter Stage

The antiphase, push-pull signals driving the output stage grids originate from a phase splitter comprising an ECC83 double triode configured as a cathode coupled, long-tailed pair (V2 in Figure 1). Losses incurred in coupling the source signal through from V2a to V2b via the common cathode connection are easily rectified by merely increasing the anode load of V2b slightly (R11), by adding an extra small resistance (R12). In the prototype this reduced the discrepancy to around 2%, which is of no significance for all practical

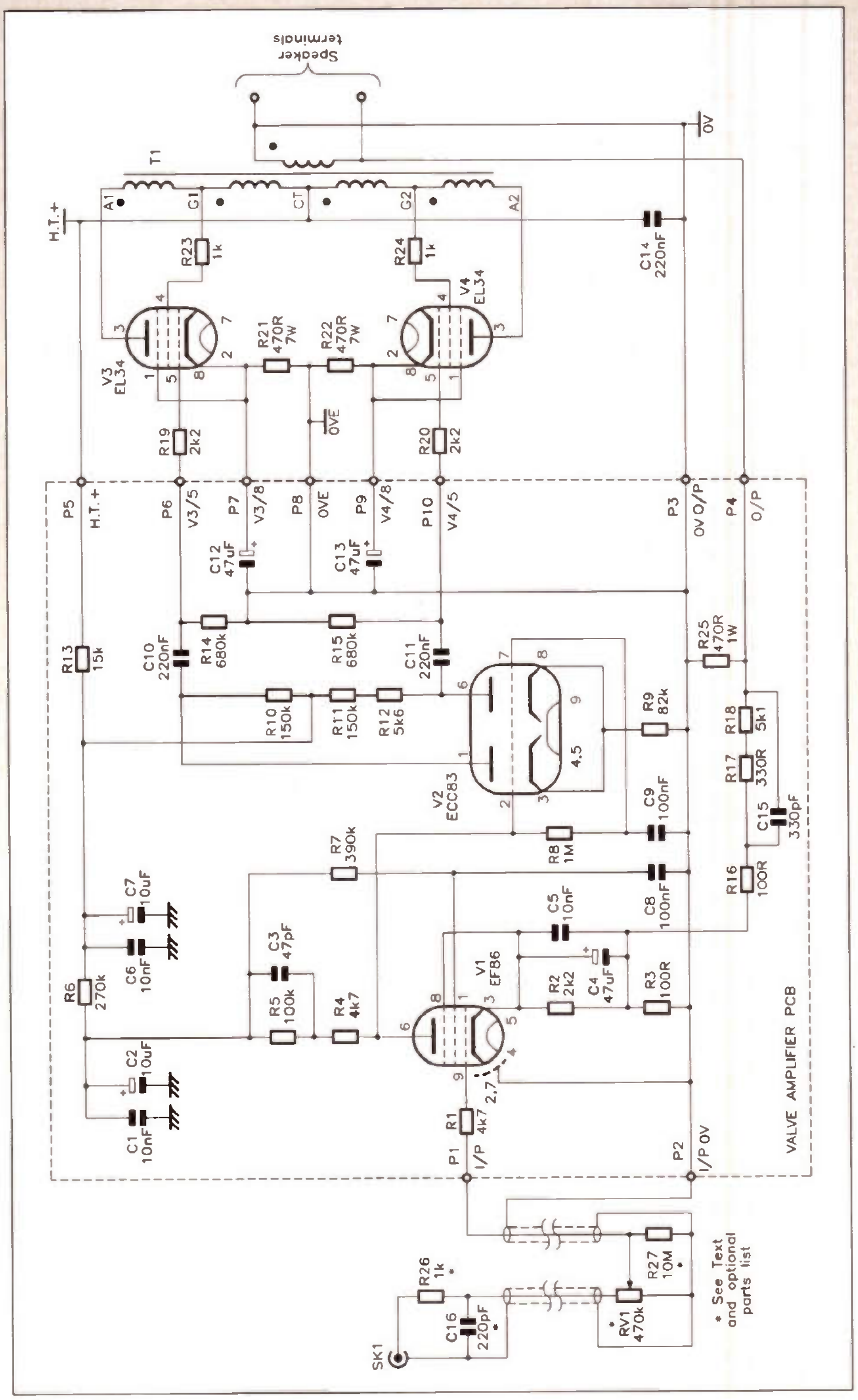
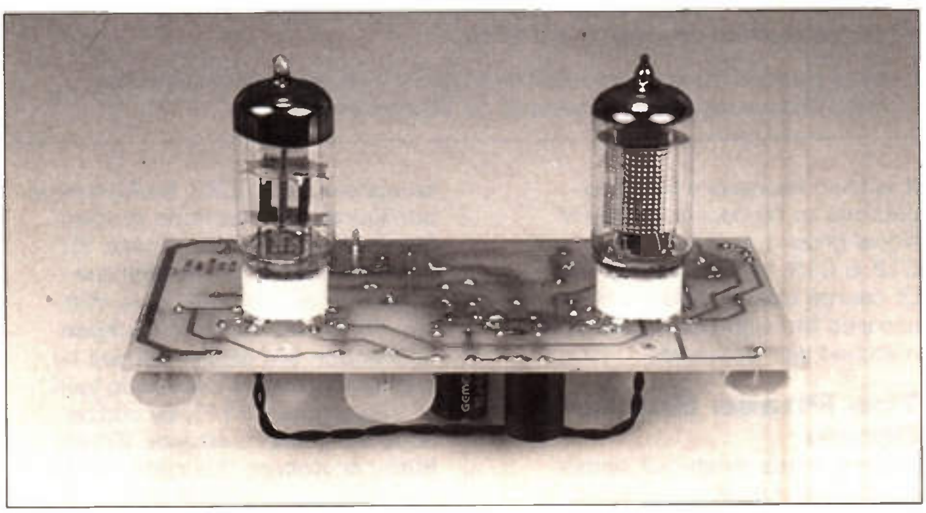



**Figure 1. Circuit diagram of amplifier.**



**Amplifier PCB showing attached valves (side view).**

purposes. Using the two closely matched triodes within the same envelope minimises imbalances arising from drift and ageing.

The outputs are AC coupled to V3 & V4 signal grids via C10 & C11, and these are the only coupling capacitors in the whole circuit, all other signal paths being DC coupled. R14 & R15 are the grid leak resistors for V3 & V4, while the curiously placed R19 & R20 actually promote stability in the output stage by encouraging a loss of sensitivity at high frequencies.

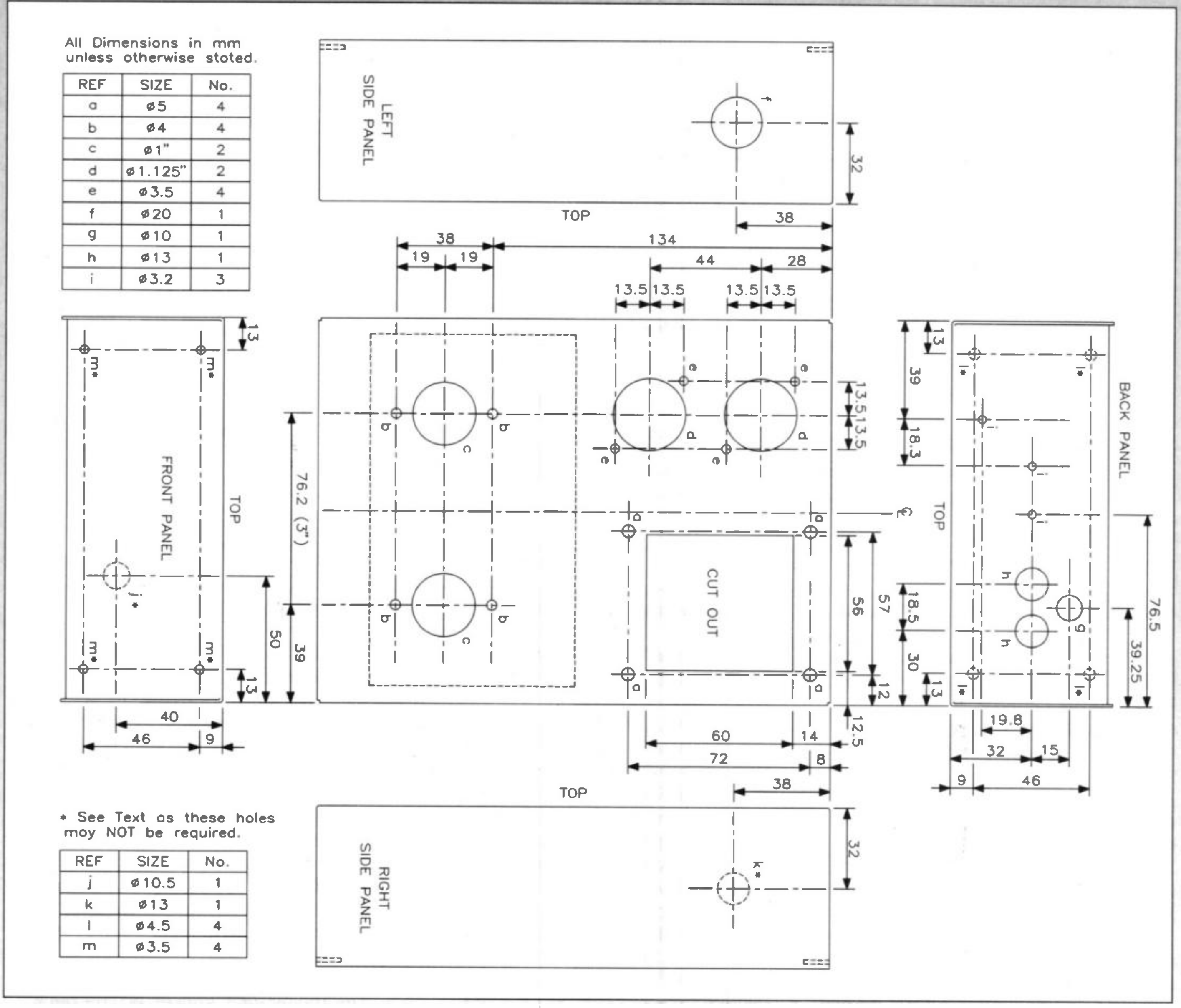
The signal grid of V2a is DC coupled directly to V1 anode, and this sets the DC bias condition of both V2a and b. The V2b signal grid is DC biased from the same source as V2a, but decoupled and referenced to signal ground by R8 & C9. Thus, while V2a operates in common cathode mode and is inverting, V2b operates in common grid mode and is non-inverting.

## The Input Control Stage

This is a little more complicated because here the active device, V1, is doing several things at once. Firstly it establishes the DC bias for V2 at its anode, simultaneously amplifying and passing on a signal received at its input. This is subject to modification through negative feedback, and so V1 controls the whole amplifier as a closed loop system. V1 is an EF86 low-noise, AF pentode specifically for small signal applications. R3 is part of the negative feedback divider chain. The remainder of this comprises R16 to R18 to set the closed loop gain, and C15 which is chosen for a flat frequency response with a load of 8Ω. This must be a high stability type. R16, effectively in series with C15, is a safety measure to prevent (the remote) possibility of frequency instability in the closed loop.

The cathode bypass decoupling capacitor C4 is a high frequency (SMPS type) component, and is in parallel with a high grade 10nF C5; the choice of these specific components greatly improves the closed-loop high-frequency control and fidelity of the amplifier, and reduces overshoot on fast transients. The 'front end' is entirely stable in the open-loop condition due to further stability promoting components R1, which operates as R19 & R20 described earlier, and C3 & R4, which deliberately reduce the anode load impedance of V1 at high frequencies, reducing its bandwidth.

R7 & C8 provide the screen grid DC, AC decoupled to signal ground. It has been found that the value of C8 must not be increased beyond 100nF, otherwise low frequency




| REF | SIZE | No. |
|---|---|---|
| a | ø5 | 4 |
| b | ø4 | 4 |
| c | ø1" | 2 |
| d | ø1.125" | 2 |
| e | ø3.5 | 4 |
| f | ø20 | 1 |
| g | ø10 | 1 |
| h | ø13 | 1 |
| i | ø3.2 | 3 |

| REF | SIZE | No. |
|---|---|---|
| j | ø10.5 | 1 |
| k | ø13 | 1 |
| l | ø4.5 | 4 |
| m | ø3.5 | 4 |

**Figure 2a. Chassis drilling details.**

instability results. This lowish value provides LF roll-off for the screen grid circuit, which controls the gain of the pentode.

The signal input arrangement is open to users' preferences. That shown uses a phono socket followed by R26 & C16 forming a high-end, low-pass filter, which not only helps limit unwanted HF (FM pilot tone, tape bias leakage during record, RF leakage, etc.) but also helps prevent HF reflections along a connecting screened input lead. If possible these components should, preferably, be omitted.

VR1 is a volume control and can be either mono or stereo ganged, or excluded altogether. The value of R27 depends on whether VR1 is used or not; if not, it is 1MΩ and forms the input impedance of the amplifier. If VR1 is present, then R27 is 10MΩ (wired between the wiper and 0V side of VR1) and is only included to ensure grid bias is still available for V1 in the event that the track of VR1 may become dirty and go intermittently open circuit. Under no circumstances, however, should R27, in one form or another, be omitted. Note also that the input is DC coupled from input socket SK1 through to V1 grid.

## Choosing a Configuration

In Part One it was mentioned that, since this system is modular in concept, various amplifier

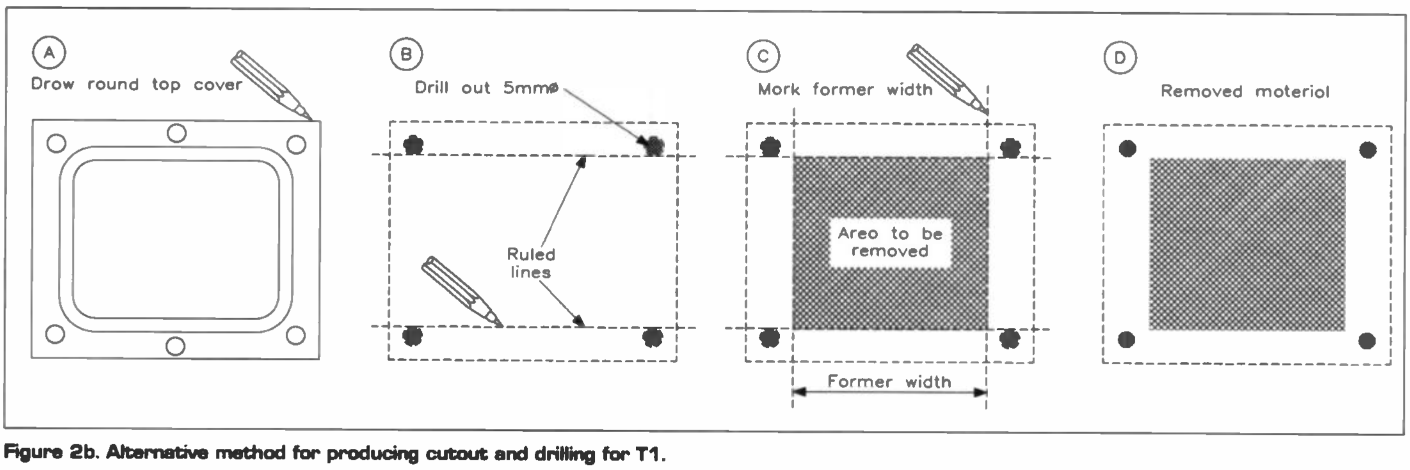



**Figure 2b. Alternative method for producing cutout and drilling for T1.**

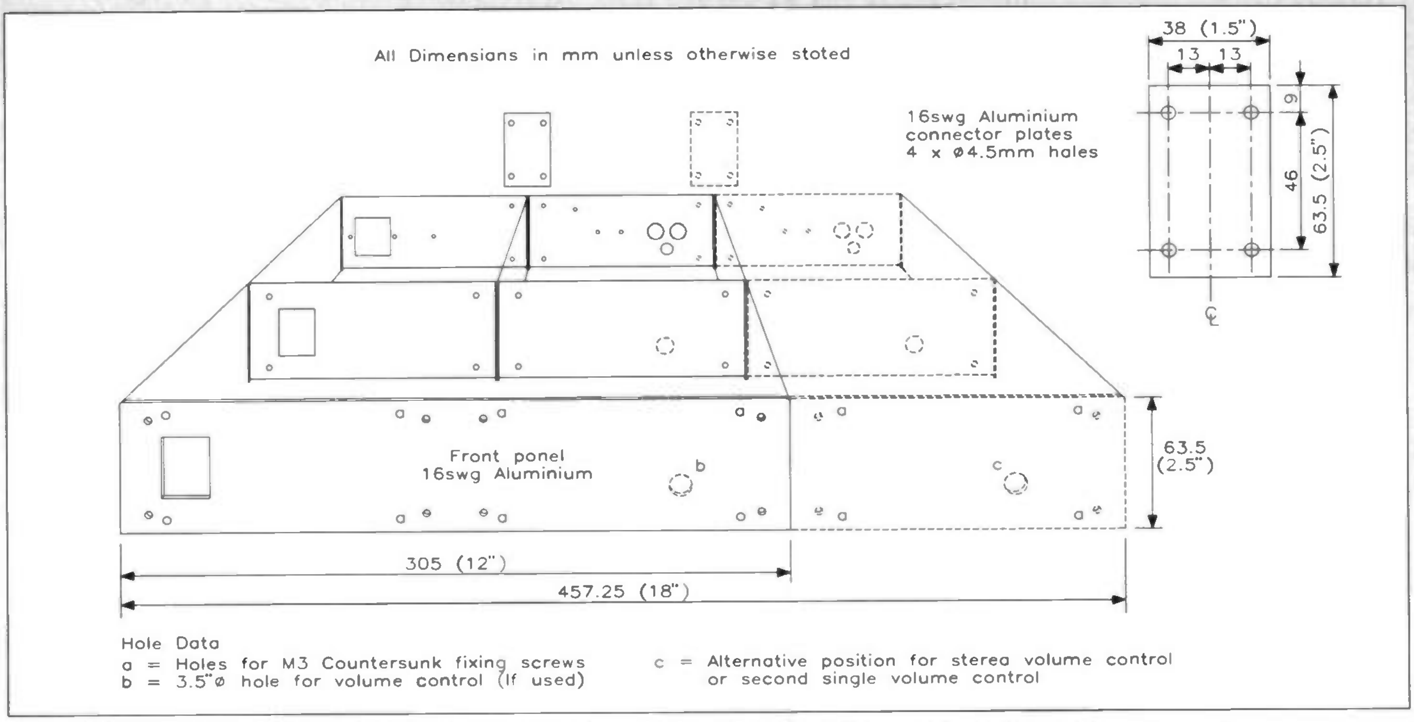



**Figure 3.** Suggested method for joining two or more chassis together to create a final monobloc or stereo assembly.

configurations are possible. A single Power Supply Unit (described in Part One) is capable of powering a stereo pair of amplifier modules, although it will, in this case, be working at its limit.

To get the best from a stereo configuration it may be worth considering building a pair of 'monoblocs', that is, two amplifiers each of which has its own individual PSU attached.

If this is not important then, and particularly for the majority of domestic applications where a small reduction in maximum output power capability is not a problem, the single, large stereo assembly (configured as was the original prototype, as seen in the photographs) with one PSU is usually adequate. The choice is yours.

**IMPORTANT**: the layout of both the amplifier PCB and the amplifier chassis is based on the assumption that the PSU chassis will be attached to the *left-hand side* of the finished amplifier chassis. This will ensure that the sensitive input end is as far away from the PSU as possible. *Do not* attach the other way around! For a complete stereo assembly, the PSU *must* be at the extreme left-hand end, *not* in the middle!

**WARNING!**

Before proceeding with any kind of work on this circuit, take heed – high voltages **CAN KILL!** NEVER touch any high voltage part of the circuit with either fingers or uninsulated tools unless the power is OFF! While power is on, you should only touch any part of a circuit with an *insulated* test probe when *required*. Every time you switch off, adopt the following industrial safety procedure, known by the anacronym 'SIDE', which spells out the following steps:

**SWITCH OFF** – Switch off the main PSU front panel rocker switch, and switch off at the mains outlet wall socket.

**ISOLATE** – Pull the mains lead out of the mains inlet socket at the back of the PSU.

**DISCHARGE** – Discharge the main line HT reservoir capacitors to zero volts (**NOT** with a screwdriver!).

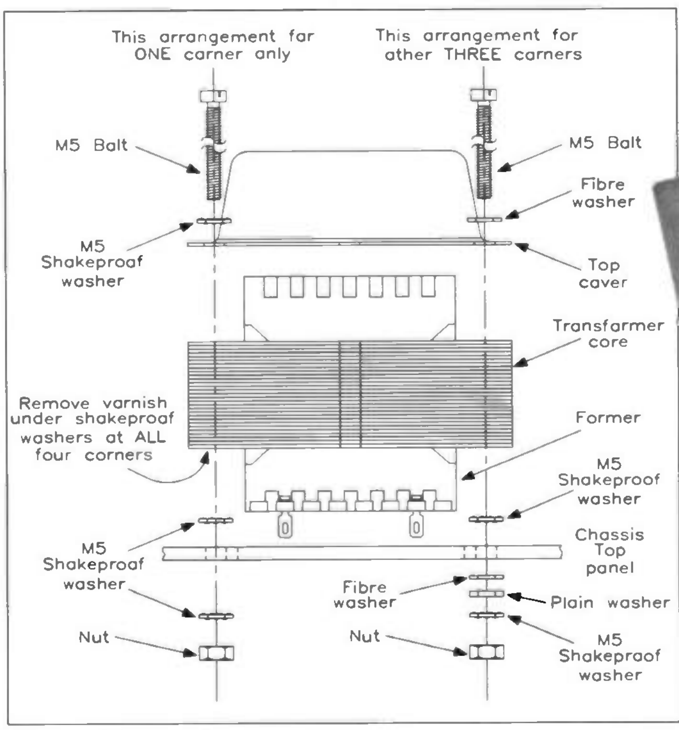
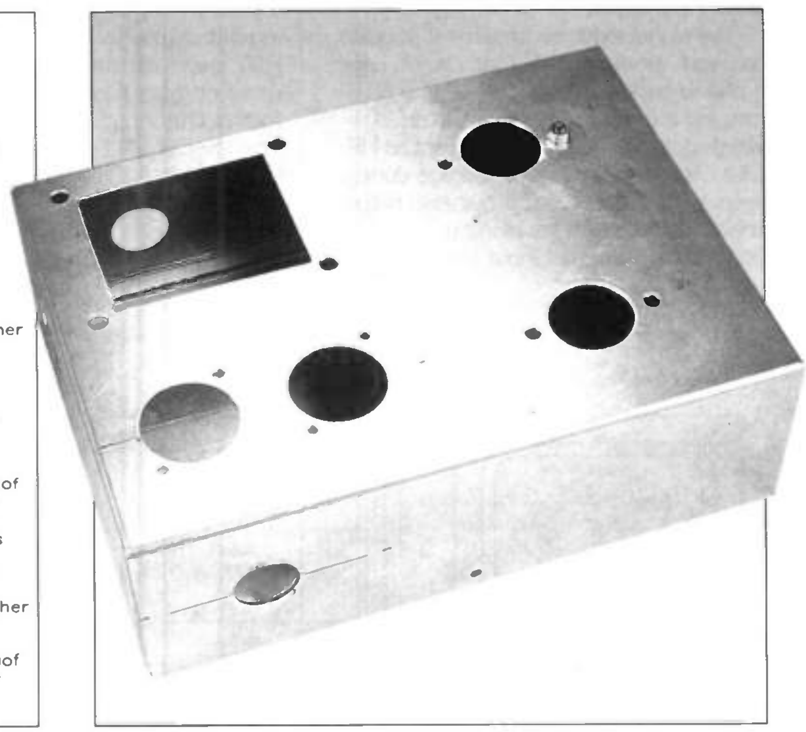



**Figure 4.** Mounting T1.



Amplifier chassis prior to assembly.

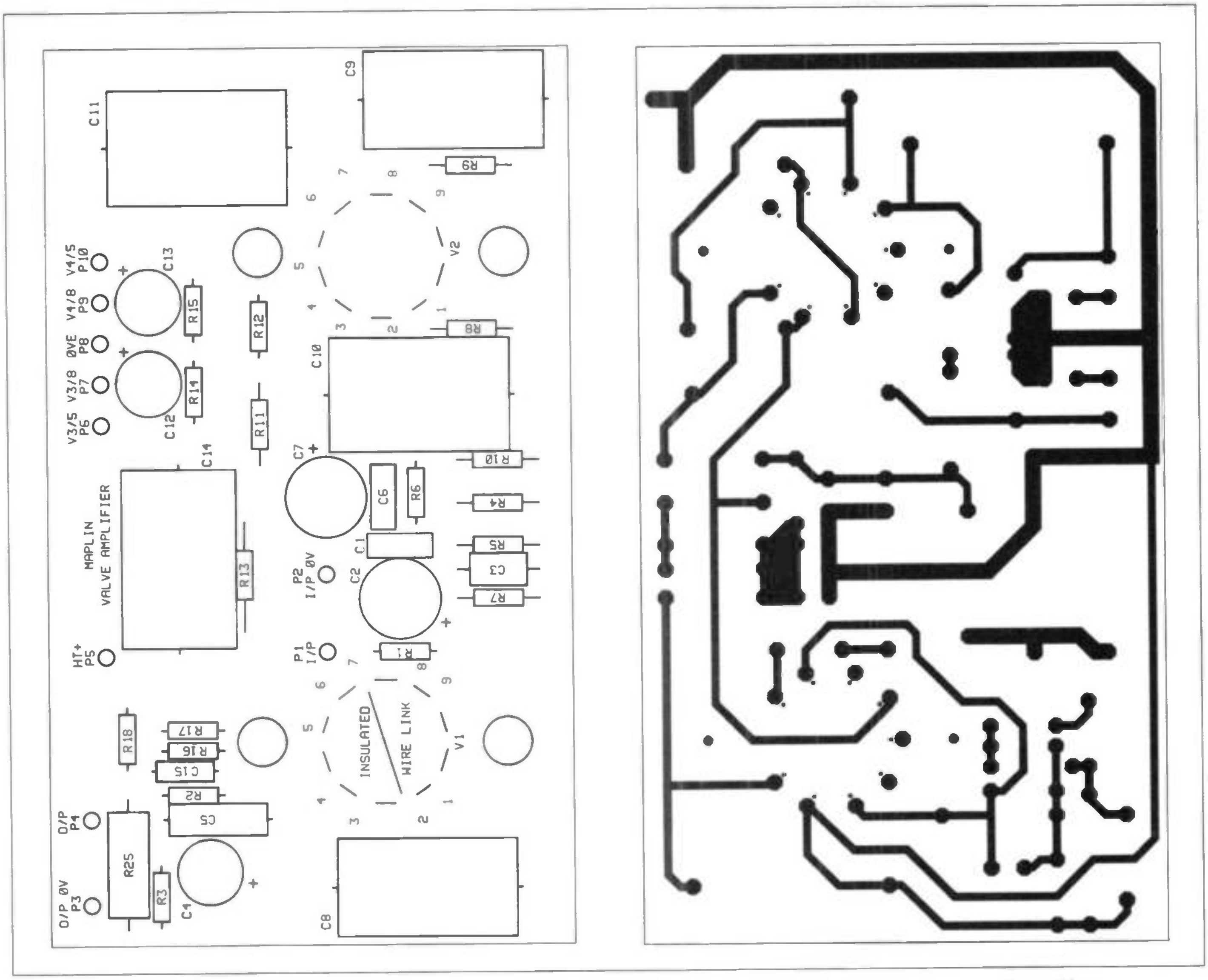



**Figure 5. PCB legend and track details. Important Note: for safety reasons the ready-made PCB must be used, since this has a solder resist. PCB track is shown here for information only.**

**EARTH** – Earth the main line HT to chassis 0V with a leakage resistor to prevent any electrolytics recovering a charge from their own dielectric absorption.

In the design of the PSU 'discharging' and 'earthing' is automatically taken care of by R1 in the PSU circuit. To make doubly sure, you **MUST** test the main line HT with a multimeter set to high DC volts before touching any part of any circuit. This shall hereon be referred to as 'the SIDE procedure'. **DON'T CUT CORNERS!**

## Amplifier Construction

As with the PSU, construction is essentially in two parts, the PCB, and the remainder of the chassis.

A simple, single-sided PCB is employed to make construction much easier. The majority of components are mounted onto the PCB, as are valves V1 & V2 (or, more specifically, their valveholders). This leaves only a small number of remaining components to be 'hard-wired' between this board and the octal valveholders for V3 & V4, and the transformer T1, plus ancillary wiring.

For convenience it may be best to commence with cutting out the holes in the chassis first. As with the PSU chassis, the holes are cut in the main body of the box and *not* the removable cover, which will become the *bottom*, not the top. With reference to Figure 2a, the cut-outs are as follows:

Rectangular cut-out for T1 with four 5mm dia. bolt holes *(a)*;

Two 1⅛in. dia. holes for octal valveholders for V3 & V4 *(d)* with 3·5mm dia. fixing holes *(e)*;

Two smaller 1in. dia. clearance holes for V1 & V3 *(c)*, since these are mounted on the PCB and will protrude through the top panel, together with four 4mm dia. clearance holes for the PCB supporting pillars *(b)*;

Two ½in. dia. holes for mounting the twin terminal post used for speaker connection on the rear panel *(h)*, with an adjacent ⅜in. hole *(g)* for the recommended, single gold-plated phono socket with insulating washers; a single ⅜in. hole in the front panel for a volume control if used *(j)*, (see Optional Parts List).

It can be rather awkward making the cut-out and drilling for T1, but a good trick is to proceed as illustrated in the alternative method Figure 2b.

In a similar manner the PCB can be used as a template. Drill mounting holes out to 4mm diameter, and drill and cut valve clearance holes to a diameter of 1in. (e.g., with a round sheet metal punch).

The positions of the holes for the octal valveholders are found according to Figure 2a. Note that the 3·5mm dia. holes for the securing bolts are offset to an angle of approximately 45°; this is important for aligning the numbered pins in the necessary positions. The valve bases are 1⅛in. diameter.

Prepare also the speaker terminal and input socket mounting holes in the rear panel. The rear panel should also have a 3·5mm hole at its centre for the earthing strap connection(s) (central hole *(i)* in Figure 2a), more of which later.

## Wiring Communication Options

Finally, drill the cable loom access hole(s) *(f)* and *(k)*** in Figure 2a. These must line up with any matching holes in other chassis which will be joined. Where the PSU module has a ½in. hole with a grommet at the power supply access position on its right-hand side, the adjoining amplifier module must have a corresponding ¾in. hole *(f)*, to clear the outer diameter of the grommet, on its *left-hand* side. This is all that is necessary for a monobloc.

If, however, the final assembly is going to be a complete stereo amplifier, then supply cables will also need to communicate completely through the central amplifier chassis.

In addition, if a single stereo ganged volume control is going to be used for a stereo assembly, then this hole arrangement is repeated again, near the front ends of the two common amplifier chassis side panels, to allow the signal leads from one to access a common ganged volume control mounted in the other.

## Joining the Chassis Together

At this point you should decide how the amplifier is going to be attached to the PSU module and any other module(s). If a 'monobloc' is intended, then only this and the PSU chassis are joined. If a complete stereo assembly is desired, then three chassis will be joined. Joining the chassis is best done using aluminium connector plates bridging across the front and rear panels which is the strongest method; *do not* screw the side panels directly together as these have no support. They are *not* strong enough to carry the weight of the finished assembly. Preferably a long front panel can be made from 16swg aluminium sheet to cover the front faces of all the chassis (2½in. high x 12in. (monobloc) or 18in. (stereo unit)), and fixed with countersunk M3 bolts and nuts, as was the prototype. It is then possible to hide these screws with a stick-on front panel design. An illustration of this method of assembly, which has proved to be very successful in terms of strength and neatness, can be seen in Figure 3.

## Initial Assembly of the Chassis

With all holes prepared, and before moving on to PCB assembly, begin by mounting T1 with reference to Figure 4. First of all, to comply with Class 1 requirements for mains powered equipment, we must ensure that the core and top cover of T1 are satisfactorily earthed to the chassis metal-work on fitting. This is not necessarily automatic because the core is varnished and may be insulated. The procedure for fitting T1 using the extra M5

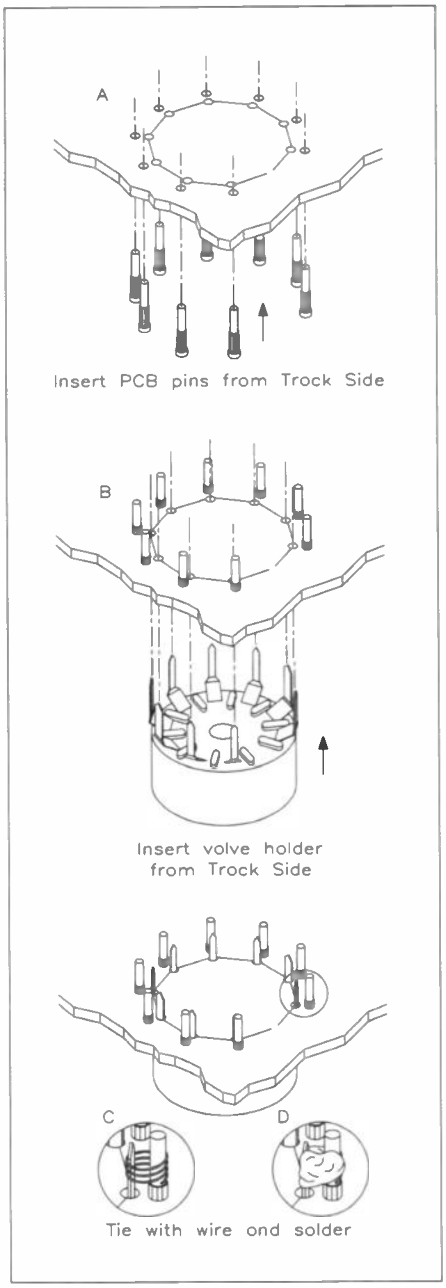



**Figure 6. Mounting valve sockets for V1 & V2 to the PCB. (A), fitting the PCB pins; (B), inserting the socket; (C), joining each connection with wire; (D), final soldered joint.**

shakeproof washers is identical to that of the mains transformer in the PSU, described in Part 1.

Speaker connections are made via a two-way, gold-plated terminal post assembly mounted on the outside of the rear panel in a position adjacent to T1, and secured with its own fittings into the pair of ½in. diameter holes. Note that these include securing nuts and locking nuts. The single phono socket is mounted into the adjacent ⅜in. hole using its plastic insulating washers, tagged lock-washer and nut. At this point you might also wish to mount a 8·2Ω dummy load resistor nearby, in the blank area adjacent to V4 (see Optional Parts List), using optional holes *(i)* in Figure 2a.

The dummy load *must* be used if for any reason you are going to run the amplifier without a speaker connected (e.g., for high impedance headphones); you *must not* operate the valve amplifier without the correct 8Ω output load connected.

Mount the two octal valveholders from the inside of the chassis using two M3 x 10mm bolts, shakeproof washers and nuts for each. **IMPORTANT:** in each case, pins (solder tags) numbers 1 & 8 *must* both be turned toward T1! It only then remains to mount the four rubber couplings, used here as insulated mounting pillars for the PCB, using M4 nuts at the four PCB mounting points (described in Figure 7). The flexible mountings also add extra anti-microphony measures to the valves that will be carried on the board (that is, a certain degree of protection against physical shock and vibration which will otherwise be amplified by the valves and heard, *but* only up to a point).

At the same time prepare the ⅜in. hole for a single or stereo ganged volume control in the front panel if used. This item and its wiring must remain clear of the PCB position and components.

## PCB Construction

With reference to Figure 5, insert and solder all PCB pins P1 to P10, noting that the single large pin is inserted into the corresponding large hole at P8 ('OVE') near the top right-hand edge of the board (legend side). Of the others, because the PCB is single-sided, the remaining eighteen are used for securing the B9A PCB valveholders for V1 & V2, as follows.

With references to the sequence shown in Figure 6a to d, insert and solder nine pins from the track side into the *outer* of the two concentric rings of holes for each valveholder; that with the smaller holes (a). Next, carefully insert the B9A valveholder into the board from the *track side*, into the inner ring (larger holes) until it is fully seated flat on the PCB (b). Each pin of the valveholder is then bound to its corresponding PCB pin with a turn of bared bell wire and soldered to it ((c): don't be sparing with the solder). The result is indicated in Figure 6d.

Lastly, but importantly, an insulated wire link using black bell wire is to be included between pins 2 & 7 of the valveholder for V1.

With this fiddly bit done you can now begin installation of the more familiar components. It will be preferable to fit all the smaller ones first, as some of these may be obscured or made inaccessible by some of the larger items. When fitting PCB components, make sure to bend over the component leads tightly on to the copper solder pads before soldering. This will ensure good quality joints which will give the best sound reproduction by

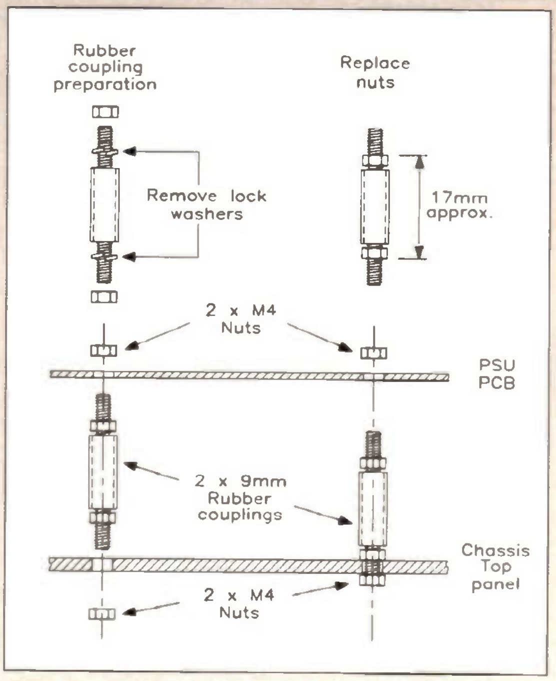
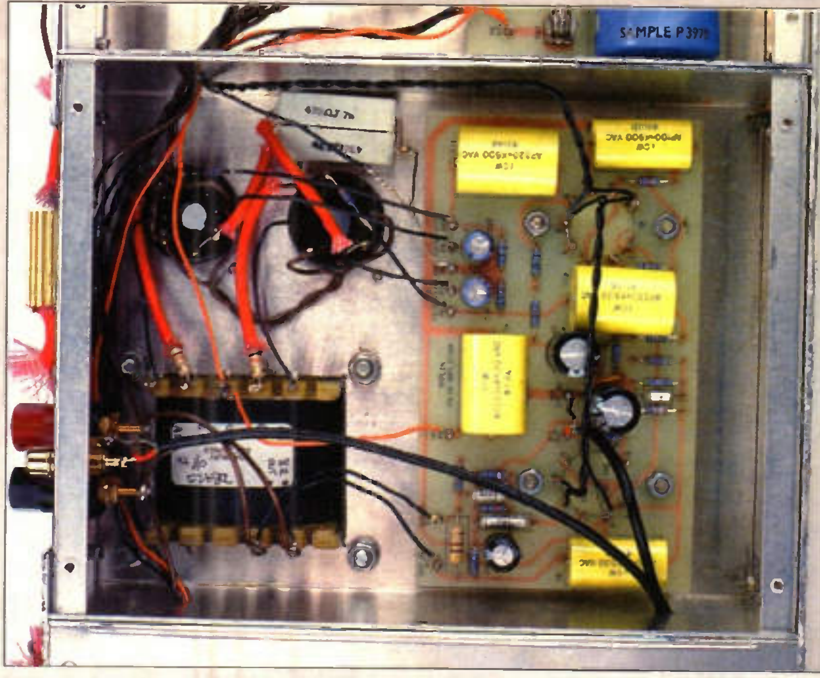



**Figure 7. Mounting the PCB in the chassis.**



**Internal view of assembled chassis, amplifier section.**

excluding as much solder as possible from the short conduction path.

Identify, insert and solder all resistors according to the Parts List and the PCB legend (Figure 5). R25 is a 1W carbon type. Fit also C4, the 47µF HF radial electrolytic where the negative lead, identified by a stripe and (–) sign on the body, must be inserted in the hole opposite that marked (+) on the legend, followed by C5 (10nF 1%).

Install the 47pF polystyrene capacitor C3 with the pink or red end toward the C2 position (if coloured). This only identifies which wire lead connects to the outer foil of the capacitor, which ideally should be referenced to ground via C1 & C2 for screening purposes, but this is not vital.

Next insert and solder the two 10µF 450V radial electrolytics at positions C2 & C7, where again the positive lead must be inserted in the hole marked (+). In parallel with these are fitted the 10nF HV ceramic discs C1 & C6. These ensure HF decoupling to ground of the respective supply rails of V1 & V2 stages, and again serve to promote good high-frequency performance of the amplifier. Similarly install electrolytics C12 & C13 (47µF 63V).

Finally the five large yellow polypropylene capacitors can be installed, with values of 100nF at C8 & C9, and 220nF at C10, C11 & C14. That completes construction of the PCB; remaining components *outside* of the dotted line in Figure 1 are *not* wholly mounted on the board, and their turn will come later. These are R19 & R20, R21 & R22, and R23 & R24.

Now closely examine the PCB for correct placement and orientation of components, bad solder joints, solder bridges, etc., especially around the valveholders. If any joint looks suspicious, resolder. Double-check and sort out any problems *now*, because once the board is wired-up in the chassis it will be quite awkward to remove again for repairs! The PCB includes a solder resist on the track side, as does the PSU PCB. In both cases track side solder joints should be covered with a conformal coating, after removing flux with a PCB cleaner, to help the solder resist prevent creepage, or tracking, between points of high potential difference. Some areas are over 100V, in one case (around C14) at the full HT line potential.

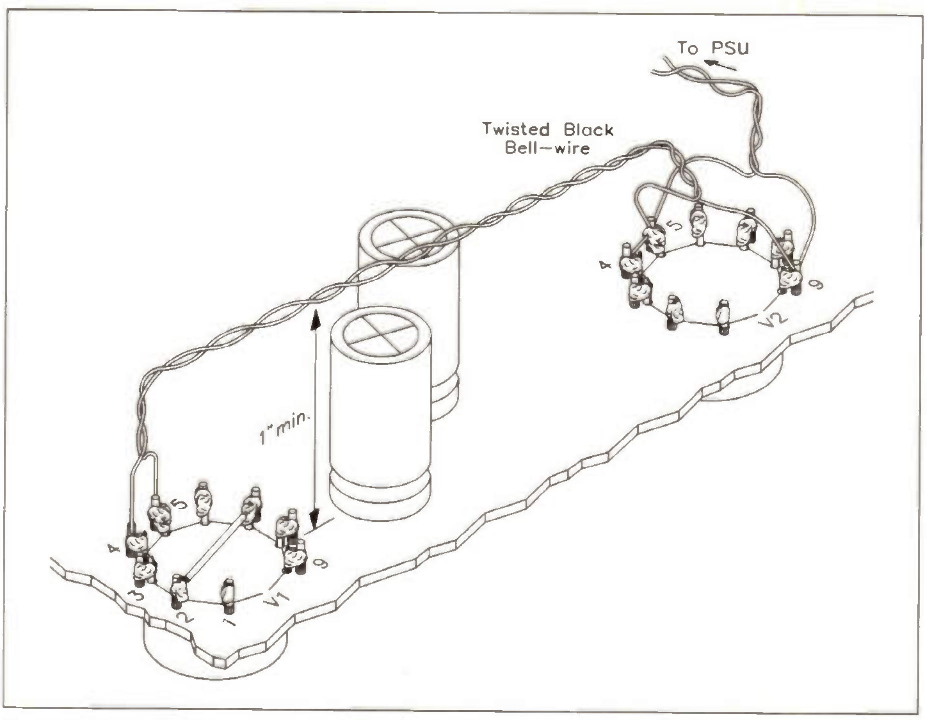



**Figure 8. Heater wiring details for PCB mounted valves V1 & V2.**

## Installing The PCB

With the chassis upside down, the board is mounted on its support pillars component side uppermost and with the *top edge* (remember?) towards T1 & V3 & V4 valveholders (the tops of the V1 & V2 valveholders on the track side lining up with their 1in. clearance holes in the chassis top).

The support pillars used are rubber couplings, chosen for their insulation strength and also to add protection against physical shock for the PCB to help prevent microphony. They are prepared by removing and discarding the lock washers, which are supplied with them, and then replacing the original nuts as shown in Figure 7. The nuts are screwed down to the end of the stud thread, making a total distance of approximately 17mm. Attach these to the underside of the chassis top panel, and then the PCB to the pillars, using eight extra

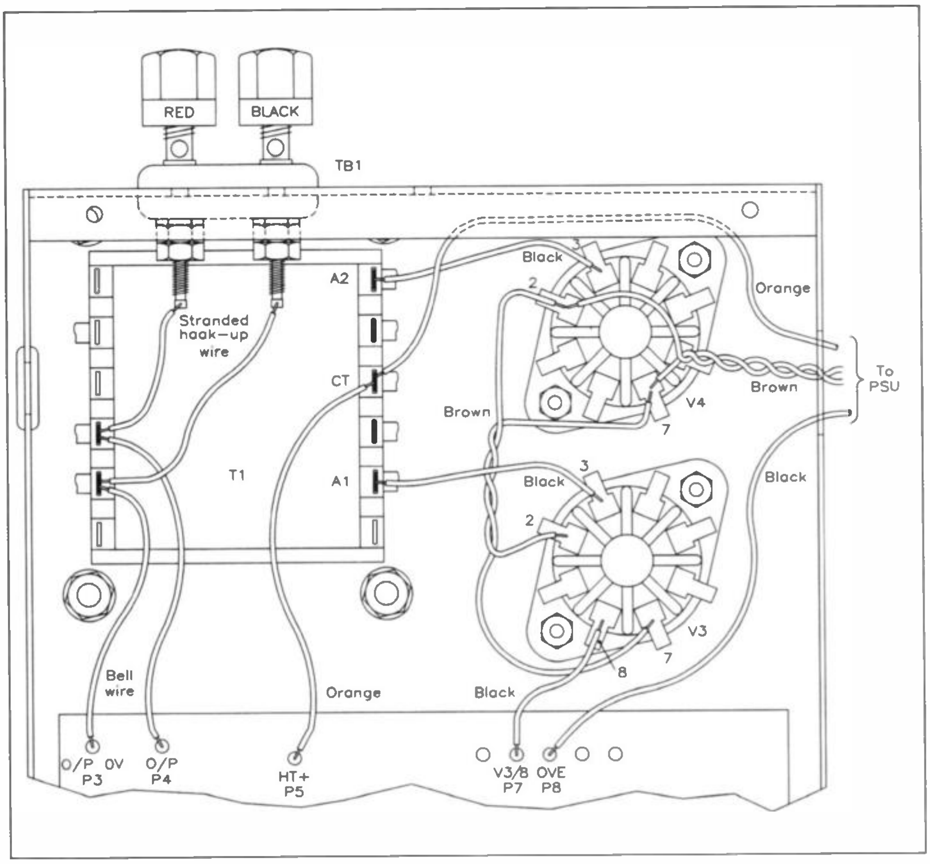



**Figure 9a. Wiring the PCB, T1 and octal sockets for V3 & V4 T1 and PCB supply, PCB earth connections and speaker connections, anode links to T1, wire link between V3 pin 8 and PCB.**

M4 nuts as also shown in Figure 7. Do not overtighten, or the rubber couplings may split. Only tighten enough to hold the board securely.

## Wiring the Output Stage and PCB

If all mechanical aspects of fitting are correct, then you can begin the final stage of completion. This mainly involves hard-wiring the PCB to the output stage and the power supply.

If this module is going to be physically joined to further chassis, you will need to make up an earthing strap from 6A green/yellow wire with a M3 solder tag at each end. Upon two chassis being bolted together, the earthing strap must connect both electrically by being attached to each via dedicated fixings, using M3 x 10mm bolts, shakeproof washers and nuts at each tag washer. A M3 clearance hole should be provided in the rear panel of each chassis for this purpose.

Figures 8, 9a, 9b, 9c and 10 show the wiring of the PCB to the output stage and PSU in sequence.

More detailed instructions for this stage of construction are provided in the leaflet, but the following aspects are worth mentioning here.

Figure 8 shows how the heaters for valves V1 & V2 should be connected. This rather convoluted arrangement ensures that the absolute minimum heater wiring is anywhere near any signal paths on the PCB, thus preventing hum injection. *Twisted pairs* of solid core bell wire are used for stability and their runs must be 1in. above the PCB or more.

In Figure 9a, the heater supply pins, 2 & 7, of both octal valveholders are connected in parallel with a *twisted pair* of brown hook-up wire 16/0·2, approximately 4cm long. A twisted pair of the same wire reaches from the valveholder V4 to the heater supply terminal block in the PSU (don't attach it to this yet) via the rear cable access holes in both chassis. (You cannot use the bell wire for *all* the heater wiring because it is only rated at 1A.)

Wire up the speaker output of T1 both to the amplifier PCB and the rear panel mounted terminal posts as also shown in Figure 9a. Note

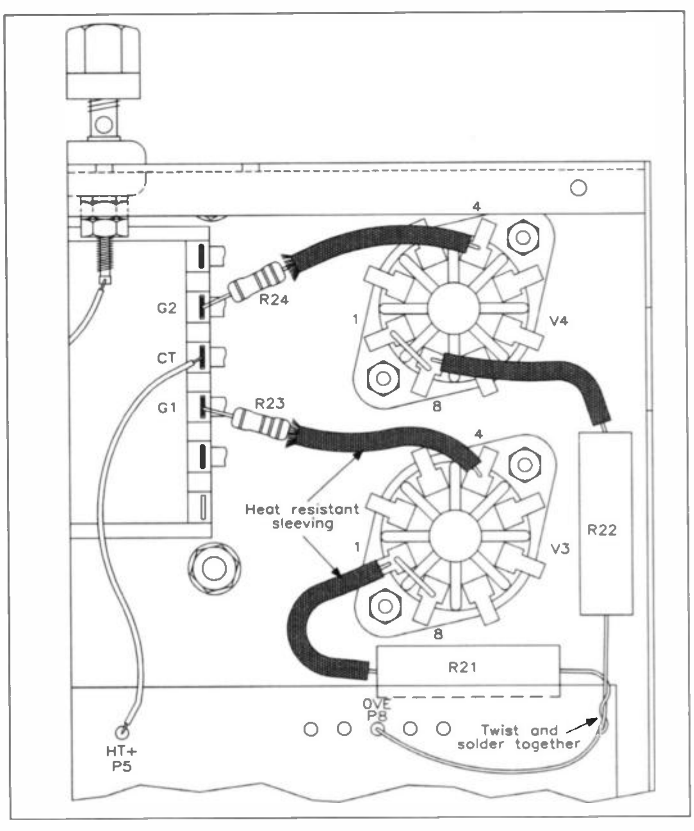



**Figure 9b. Connecting resistors R21 & R22, R23 & R24, wire links between pins 1 & 8 of both V3 & V4.**

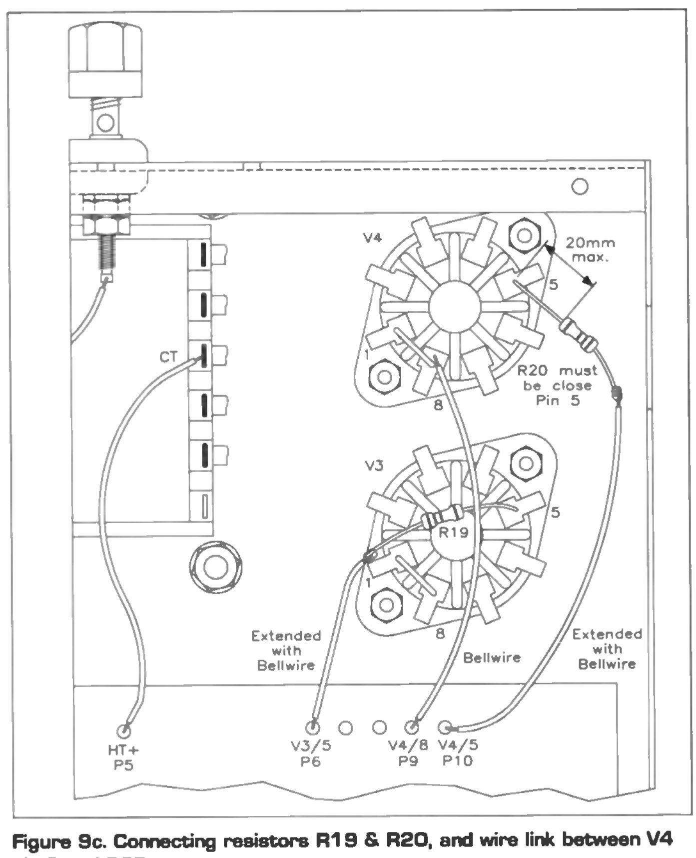



**Figure 9c. Connecting resistors R19 & R20, and wire link between V4 pin 8 and PCB.**

that bell wire is used to connect between the secondary terminals of T1 and the speaker feedback connection pins on the amplifier PCB, but thicker brown hook-up wire is used to connect to the terminals.

Moving on to Figure 9b, first install R23 (1kΩ 1W) between V3 pin 4 and T1 tag G1. Also R24 (1kΩ 1W) between V4 pin 4 and T1 tag G2. Cover all exposed wires with heat resistant red sleeving.

R21 & R22 (470Ω 7W) are large ceramic block encapsulated wire-wound resistors, and should be paired together and joined at one end by twisting their leads and soldering.

In Figure 9c, resistors R19 & R20 are connected between the phase splitter outputs from the PCB 'V3/5' (P6) to pin 5 of V3, and PCB 'V4/5' (P10) to pin 5 of V4 respectively as indicated. Extend leads with bell wire as necessary and cover with heat resistant sleeving. NOTE: the body of each resistor must be physically close to pin 5 of the respective valveholder, no further away than 20mm!

Finally, connect 'V4/8' (P9) of the PCB to V4 pin 8 with black bell wire.

Now double-check all these connections and the quality of solder joints. In particular resistors R19 & R20 *must* be properly connected, otherwise the affected valve may have no proper grid bias and will attempt to short-circuit the HT supply, possibly damaging itself in the process!

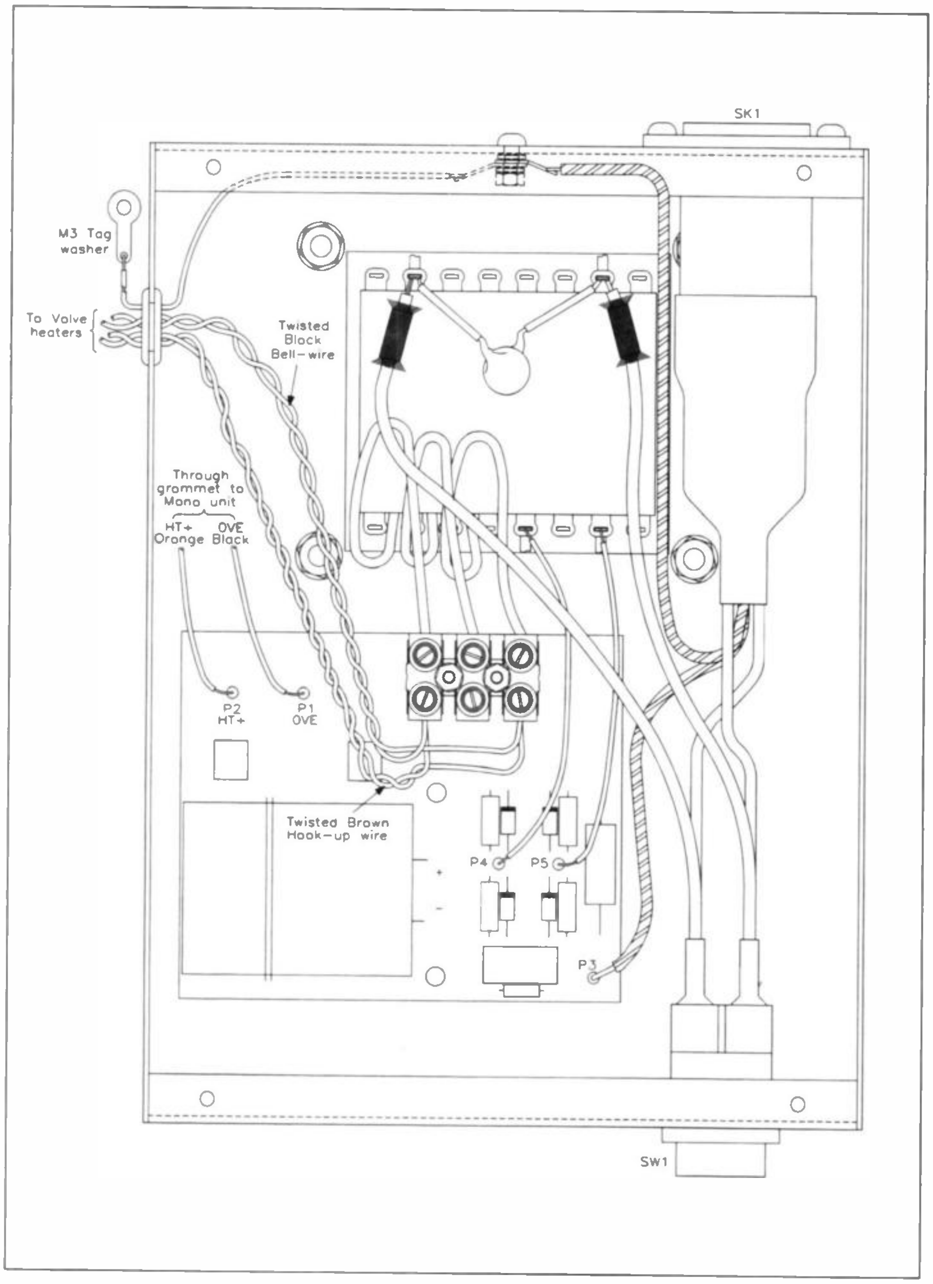



**Figure 10. Terminating the supply and all heater wiring shown at the power supply PCB.**

## Heater Wiring

At the power supply end (Figure 10), strip and twist the V3 & V4 brown heater pair together with the V1 & V2 black heater pair (trim as necessary). Insert each twisted and joined end into the two end connectors of the heater terminal block TB1 (never to the centre of the block) on the PSU PCB, on the side *opposite* the heater secondary wires from the mains transformer. If the PSU is shared between two amplifier modules, then two sets of twisted heater wires will be inserted together. Tighten the screw terminals sufficiently for a good connection.

Connect the black '0VE' wire to the PSU PCB pin '0VE' (P1), but do not connect the orange 'HT+' amplifier supply wire to the PSU '+HT' output pin yet.

## Wiring Up the Input Sockets and Earths

Correct input and earth wiring has proved to be a critical stage; the amplifier is very sensitive to hum injecting earth loops. Supply '0VE' earth comprises a length of black bell wire connecting the large '0VE' pin on the amplifier PCB to '0VE' on the PSU board via the rear supply loom. It does *not*, however, share direct continuity with the chassis which is subject to the *mains* earthing system, more details later.

Figure 11 shows two alternative input configurations, (a) and (b). In either case signal earth is carried through from the PCB input earth pin (P2) to the body of SK1 via the braid of good quality screened cable. The body of SK1 *must* be electrically isolated from the chassis; the gold chassis phono sockets specified in the Optional Parts List come with insulating washers. R26 & C16 (if used) are hard-wired direct to SK1. From the junction of these the signal is taken to VR1 if used. Note that the 0V ends of VR1, if a stereo ganged version is used, *must not* connect directly to 0V by any route other than the cable screen, neither must they be linked together; these actions create a local earth loop causing hum.

In Figure 11a, example without VR1, R27 connects directly between either the centre conductor of SK1, or the R27/C16 junction, and the socket's earth tag washer, and is 1MΩ. In Figure 11b with VR1 added, R27 is 10MΩ and is connected directly between VR1 wiper and its 0V pin. In the latter configuration VR1 provides the grid leak bias for V1, and R27 is only a 'safety' resistor to prevent noise due to a scratchy track in VR1, etc. However, in Figure 11a R27 is the grid bias resistor. The amplifier must not be powered up without either configuration of grid bias properly connected!

Figure 11 also shows the earthing strap connections to the rear panel of the amplifier module. The second strap is only necessary if a second amplifier module is to be connected onto the end of the first one for a stereo assembly.

## Initial Testing

It's the moment of truth time! Identify and plug in the valves: V1 = EF86, V2 = ECC83, V3 & V4 = EL34

Main line HT = 410V (tested example, will vary)
Junction of R23 & C14 = 380V. Junction of R6 & C4 = 150V.

| V1 Pin No. | V1 Volts | V2a Pin No. | V2a Volts | V2b Pin No. | V2b Volts | V3 Pin No. | V3 Volts | V4 Pin No. | V4 Volts | |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 0 | 2 | 80 | 7 | † | 5 | 0 | 5 | 0 | Signal grid |
| 3 | 1·9* | 3 | 81·5 | 8 | 81·5 | 8 | 29 | 8 | 29 | Cathode |
| 6 | 80 | 1 | 305 | 6 | 305 | 3 | <410 | 3 | <410 | Anode |
| 1 | 90 | | | | | 4 | <410 | 4 | <410 | Screen grid |

All measurements positive with reference to 0V, taken with multimeter of 20kΩ/V set to 1000V DC, except (*) (10V DC). All valves must be plugged in. (†) = high impedance, don't attempt to measure.

**Table 1. Voltage test points (values are approximate).**

(see Figure 12). Note that when inserting or removing the EL34 valves into or out of their sockets, they must be gripped at their plastic bases, *never* by the glass envelope! When inserting V1 & V2 they may feel imprecise and 'squidgy', this is only because of movement of the PCB due to free play at the rubber mounting pillars.

Remember that at this stage the orange 'HT+' supply wire should *not* be connected at the PSU yet, but the heater supply should be.

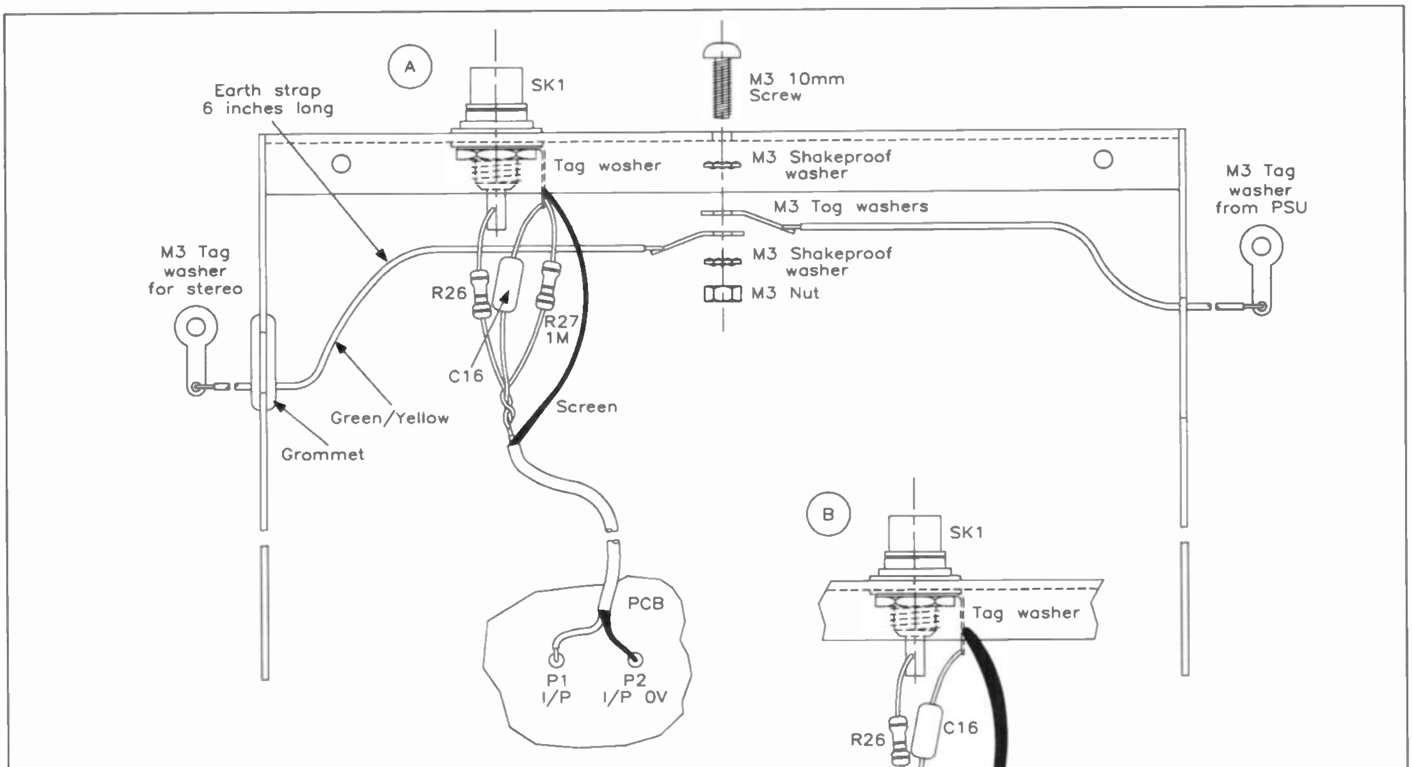
Plug in a euro mains lead and switch on, and wait to make sure that all valve heaters are glowing. It's often very difficult to see the cathode of the EF86 at all (V1), but it should get warm if its heater is operating. If not there is a heater supply wiring fault somewhere which must be rectified.

Carry out the full SIDE procedure. Remove all valves *carefully*; they will be *hot*, especially V3 & V4; protect your hands with the use of thick rag if necessary.

Connect up the main line 'HT+' supply orange bell wire from the CT terminal of T1 in the amplifier module to the '+HT' pin on the PSU board (P2 in Figure 10); the wire is routed along with the rest of the rear supply loom. Ideally a dummy load should now be connected across the speaker terminals; any old largish (several watts) 8Ω to 10Ω resistor will do for the time being.

Replace all valves again in their proper places. Support the entire assembly on end or upside down on sturdy blocks of wood or strong boxes, with sufficient clearance to allow it to be operated with all valves plugged in, *and* with the underside accessible for testing with a multimeter. If fitted with a volume control, turn down to minimum.

Firstly set the multimeter to 50V AC or equivalent. Re-insert the mains lead and switch on. Monitor the speaker output terminals with the multimeter. If, after warming up, a strong reading appears on the meter, it means the amplifier is oscillating because the secondary of T1 is wired up the wrong way



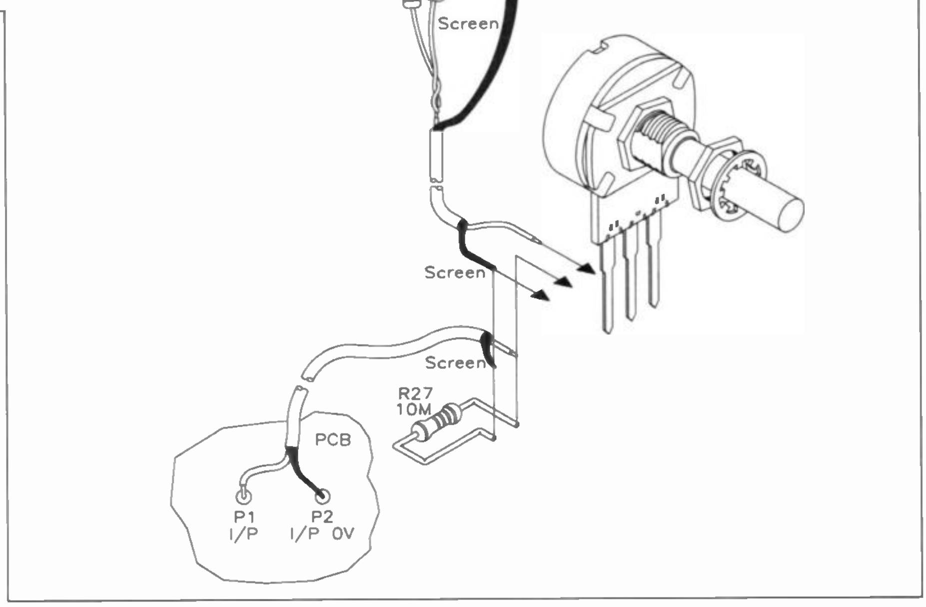
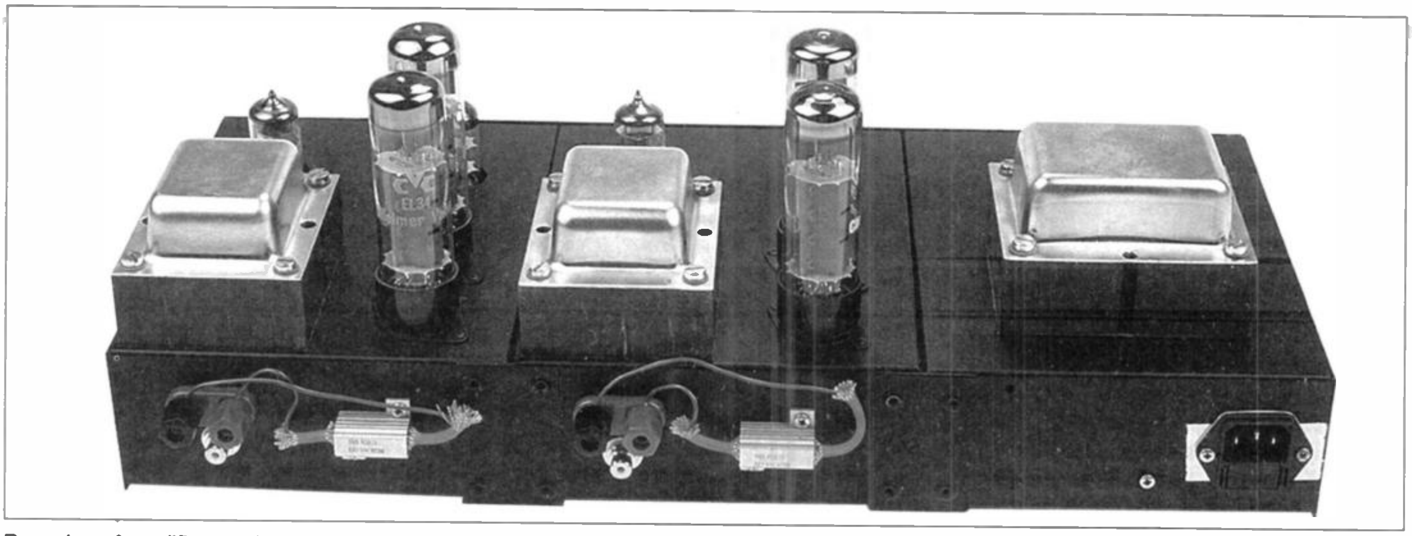



**Figure 11a. Wiring up the input signal path and connecting earthing strap(s): (a) without volume control; (b) with volume control.**



**Rear view of amplifier section exterior (prototype).**

round, resulting in positive feedback; switch off immediately. Carry out the remainder of the SIDE procedure. Reverse *all* connections at the two secondary tags of T1, and retry.

If correct the multimeter should show zero when connected across the speaker output terminals after warm-up time. Next check for the necessary DC voltages as shown in Table 1. All valve pins are readily accessible. The multimeter must be set to the highest DC volts range, except when checking pin 3 of V1. It is not critical to get exactly the same readings as shown in Table 1, but they should be fairly close. A genuine problem should show a drastic difference.

If it's anything like the original prototype it should power up for the very first time with far less fuss than I've had from many solid-state equivalents! Although frequency response is completely flat from 25Hz to 30kHz (at maximum output), rolling off to –3dB at 75kHz – at lesser outputs, up to around 5W or so, the frequency response improves considerably and is totally flat from <10Hz to nearly 100kHz! The output transformer primary winding has a natural resonance at around 80kHz, which is not at risk of interfering with audio frequencies.

Finally, it might be a good idea to cut out Figure 12 (or make a copy) and tape it to the bottom of the chassis, just in case in the future you may forget which valves go where, and these instructions have been lost.

## Installing and Using the Amplifier

There are various considerations to be taken into account when it comes to installing, connecting up and using the amplifier. Not least of these is the fact that it gets HOT. Therefore it should be installed in a roomy position where a free flow of air is able to circulate around it. Some parts of it are hot enough

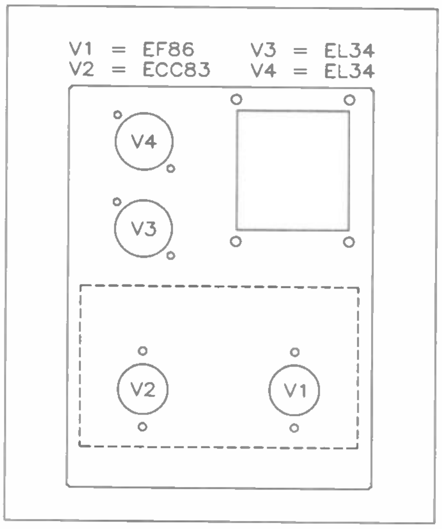



**Figure 12. Valve positions guide.**

to be dangerous, the valves in particular which will *burn* skin if grabbed, and the transformers may be hot (particularly the mains transformer). Even the chassis can become quite warm. In view of this keep it out of reach of small children and animals. This heat output could be a problem if you intend enclosing it somehow or hiding it from view; generally it manages to dominate the stereo system as a whole.

Secondly there is the size and weight factor; a complete single stereo assembly is quite heavy. My 1in. thick, pine shelving built into an alcove coped okay; lesser arrangements could cause problems!

## Connecting Up

During development the prototype amplifier (a stereo assembly) proved to be extremely intolerant of 'earth loops'. An earth loop is a situation where two separate wired connections join chassis potential to the earth of another piece of equipment simultaneously. This frequently happens where the screens of signal leads share an earth connection with the earth wire of a mains supply lead; with the valve amplifier the eddy currents that result will be amplified and made audible as hum. However, in the case of the 'Millennium 4-20', the function of the 100Ω resistor, R2, in the PSU module is to block any earth loop formed between chassis mains earth and circuit or signal earth, without the two completely losing contact for screening purposes. If internally wired up properly as described, it is possible to connect a stereo amplifier to a stereo source with a stereo screened lead having continuous screens in both cables, commoned at the source end by the source's common earth. The effect is to increase hum output by 100% on both channels, but since it is only 2 to 3mV to start with, you are still not going to hear it. (The stereo cable should not be less than 1m in length.) To minimise hum, you can make up a special stereo screened lead where the screen of one side only is continuous from end to end. The screen of the other channel should be earthed at source.

## Speakers and Loads

As mentioned earlier, you *must not* operate the valve amplifier without the correct 8Ω output load connected. Without a load to draw the output from the transformer, it is possible that high EMF pulses, that may appear across the primary as a result, may over-stress the valves. (To a lesser extent core saturation may be a risk also.) It is generally true that a valve amplifier may tolerate a short circuit but not an open circuit, in fact the exact opposite of the 'do's-and-don'ts' for a solid-state amplifier. If you wish to be able to disconnect the speakers for headphone use, then you must contrive a method for switching over to a dummy load (a high power, e.g., 25W, 8.2Ω resistor will do, see Optional Parts List), and feed the 'phones via dropper resistors, especially if they are not 32Ω or 100Ω high impedance types; 22Ω or more will suffice. R25 (see

Figure 1) is present to deal with very occasional and short duration 'accidents' of the open circuit variety, but should not be relied upon for complete valve protection against large signal open circuit output.

## The Burning Question

There is also of course the eternal debate about how much time should be allowed for 'warming-up'. Obviously a valve amplifier is not ready to spring into action immediately it is switched on, unlike a transistorised one. Basically it will begin to operate as soon as the various cathodes are able to emit electrons, but a period of five to ten minutes seems reasonable to allow for the valves to reach full working temperature and settle down. Beyond that there seems to be an improvement in performance after about one to one-and-a-half hours of running, but I make this statement guardedly as it is highly subjective.

## First Impressions

Initial listening tests were with a CD player directly connected to the valve amp with no other intervening electronics. The first immediate impression was that, as far as bass response is concerned, it runs rings around my Pioneer system. For the first time bass drums sound like proper bass drums and it was actually showing up imperfections in the speakers that were not previously all that noticeable with the Pioneer.

Basically it took everything the CD could throw at it and churned it out again with, apparently, nothing very much being lost in the process. Time and again I was hearing little details I hadn't heard properly before, mainly due to the rich midrange, especially for stringed instruments and voice, and a detailed treble. Bass power and an enriched midrange is a characteristic practically unique to valve amplifiers, which makes them firm favourites with blues, rock and classical music fans.

Considering that such an amplifier was 'state-of-the-art' thirty years ago, it makes you wonder what progress is all about. It was really well worth the trouble of putting it all together.


## Acknowledgments

I would like to thank the following people for their contributions, input and general constructive criticisms, both large and small, for helping make this project a reality, and their collective enthusiasm which helped get the thing off the ground. These include Maplin staff members Alan Williamson, Dave Goodman, John Mosely, Simon Gregg, Martin Pipe, and Robert Ball. Also the drawing office for coping with a mass of unfamiliar illustrations. Outside contributors: Graham Dixey, Dave Brooks (Danbury Electronics), Chelmer Valve Co., L.C.R. Components, P.M. Components.


## VALVE AMPLIFIER MONO PARTS LIST

| | | | |
|---|---|---|---|
| **RESISTORS: All 1% Metal Film (Unless specified)** | | | |
| R1,4 | 4k7 | 2 | (M4K7) |
| R2,19,20 | 2k2 | 3 | (M2K2) |
| R3,16 | 100Ω | 2 | (M100R) |
| R5 | 100k | 1 | (M100K) |
| R6 | 270k | 1 | (M270K) |
| R7 | 390k | 1 | (M390K) |
| R8,27 | 1M | 2 | (M1M) |
| R9 | 82k | 1 | (M82K) |
| R10,11 | 150k | 2 | (M150K) |
| R12 | 5k6 | 1 | (M5K6) |
| R13 | 15k | 1 | (M15K) |
| R14,15 | 680k | 2 | (M680K) |
| R17 | 390Ω | 1 | (M390R) |
| R18 | 5k1 | 1 | (M5K1) |
| R21,22 | 470Ω 7W Wire-wound | 2 | (L470R) |
| R23,24 | 1k 1W Carbon | 2 | (C1K) |
| R25 | 470Ω 1W Carbon | 1 | (C470R) |
| R26 | 1k | 1 | (M1K) |
| **CAPACITORS** | | | |
| C1,6 | 10nF HV Disc Ceramic | 2 | (BX15R) |
| C2,7 | 10µF 450V Radial Elect. | 2 | (JL11M) |
| C3 | 47pF Polystyrene | 1 | (BX26D) |
| C4 | SMPS Cap 47µF 50V | 1 | (JL47B) |
| C5 | 10nF 1% Polystyrene | 1 | (BX86T) |
| C8,9 | 100nF HV Polypropylene | 2 | (FA21X) |
| C10,11,14 | 220nF HV Polypropylene | 3 | (FA22Y) |
| C12,13 | 47µF 63V Radial Elect. | 2 | (FF09K) |
| C15 | 330pF 1% Polystyrene | 1 | (BX51F) |
| C16 | 220pF Polystyrene | 1 | (BX30H) |
| **VALVES** | | | |
| V1 | EF86 Low Noise AF Pentode | 1 | (DM56L) |
| V2a,b | ECC83 Double Triode | 1 | (CR27E) |
| V3,4 | EL34 Power Output Pentode | 2 | (CR28F) |
| **MISCELLANEOUS** | | | |
| | Chassis AC86 | 1 | (XB68Y) |
| | Bell Wire Black | 1 Pkt | (BL85G) |
| | Bell Wire Orange | 1 Pkt | (BL90X) |
| | 3A Hook-Up Wire Brown | 1 Pkt | (FA28F) |
| | 6A Green/Yellow Wire | 1m | (XR38R) |
| | Screened Cable | 1m | (XR16S) |
| TB1 | Twin Terminal Post | 1 | (JK24B) |
| | M5 Shakeproof Washer | 1 Pkt | (BF42W) |
| | 9·5mm Grommet | 1 Pkt | (JX63T) |
| | M3 x 10mm Bolt | 1 Pkt | (JY22Y) |
| | M3 Nut | 1 Pkt | (JD61R) |
| | M3 Shakeproof Washers | 1 Pkt | (BF44X) |
| | M3 Solder Tag | 1 Pkt | (LR64U) |
| | Rubber Coupling | 4 | (FB98G) |
| | M4 Steel Nut | 1 Pkt | (JD60Q) |
| | Heat Resistant Sleeving Red | 1m | (BL70M) |
| | 1mm PCB Pin | 1 Pkt | (FL24B) |
| | 1·3mm PCB Pin | 1 Pkt | (FL21X) |
| T1 | 20W Valve O/P Transformer | 1 | (DM53H) |
| VB1,2 | B9A PCB Valve Base | 2 | (CR32K) |
| VB3,4 | Octal Chassis Valve Base | 2 | (CR30H) |
| | PCB | 1 | (GH60Q) |
| | Instruction Leaflet | 1 | (XU46A) |
| | Constructors' Guide | 1 | (XH79L) |
| **OPTIONAL (Not in Kit)** | | | |
| | 8·2Ω 25W Wire-wound Resistor (dummy-load) | 1 | (P8R2) |
| RV1 | 470k Single Pot Log | 1 | (FW27E) |
| or | 470k Dual Pot Log | 1 | (FX14Q) |
| R2 | 10M (alternative, see text) | 1 | (M10M) |
| SK1 | Gold Chassis Phono Skt Red | 1 | (JZ06G) |
| or | Gold Chassis Phono Skt Blk | 1 | (JZ05F) |
| | Stick-On Feet Square | 1 Pkt | (FD75S) |
| | M3 x 10mm Steel Screw | 1 Pkt | (JY22Y) |
| | M3 Steel Nut | 1 Pkt | (JD61R) |
| | M3 Shakeproof Washer | 1 Pkt | (BF44X) |

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

***The above items are available as a kit, which offers a saving over buying the parts separately.***

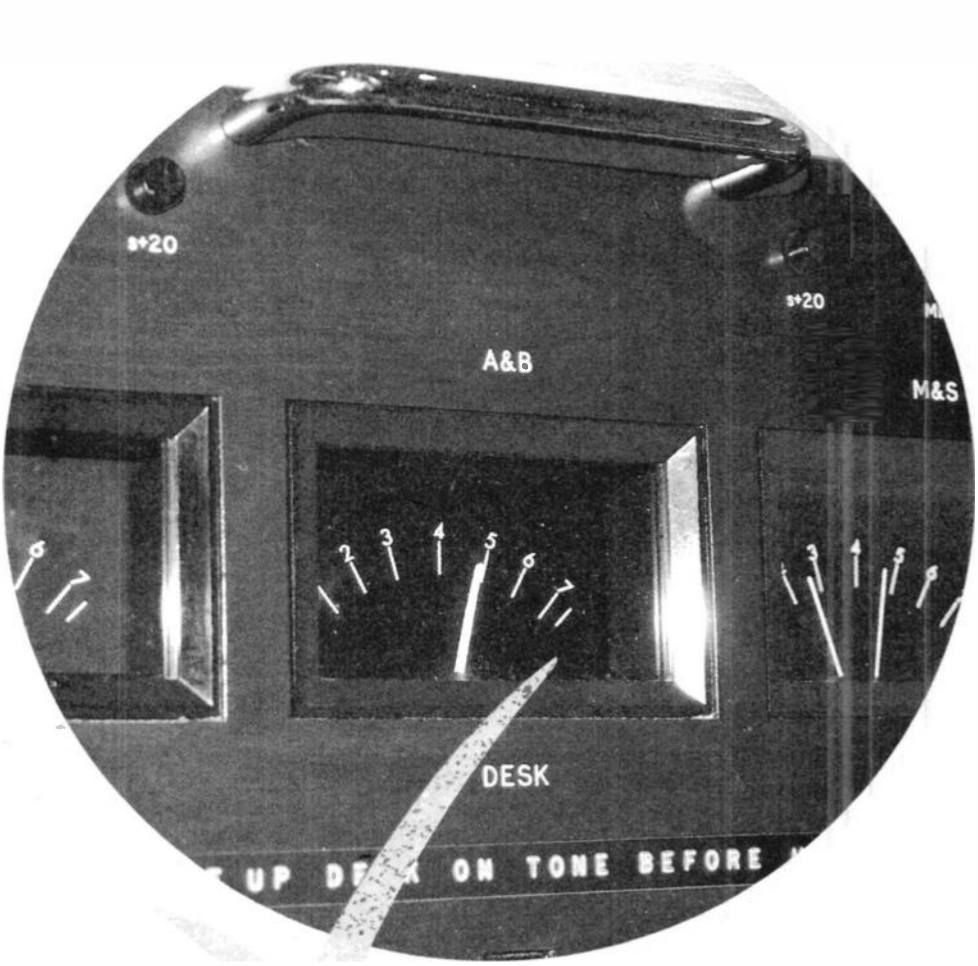
**Order As LT45Y (Valve Amplifier Mono Kit) Price £79.95 C6.**

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately, but are not shown in the 1994 Maplin Catalogue.

Valve Amp Mono PCB **Order As GH60Q Price £3.65.**

20W Valve O/P Transformer **Order As DM53H Price £24.95 C5.**




# A GUIDE TO PROFESSIONAL AUDIO PART ELEVEN

by T. A. Wilkinson

**At the time of writing, Sony's MiniDisc system, shown in Photo 1, is barely a few weeks old having being launched in December 1992. So what is MiniDisc all about? Well, MiniDisc is a digital record/replay system, disc based of course, which probably represents the latest advancement in tapeless recording technology, at least as far as the domestic scene is concerned, for this is the real market for Sony's new baby.**

THE disc itself is about half the size of a CD, measuring only 64mm in diameter and is housed in a plastic cartridge measuring 72 x 68 x 5mm. Photo 2 shows two versions with 60 and 74 minutes of playing time. When removed from the machine the shuttered disc is fully enclosed and is thus protected from the harsh elements of the outside world.

In order to squeeze 74 minutes of playing time onto such a small disc (if MiniDisc was recorded in the same way as CD then only 10 minutes of playing time would be possible), MiniDisc makes use of an efficient method of data compression, which allows a significant reduction of the data without proportionally reducing the audio quality!

The MiniDisc data compression technique is known as 'ATRAC' (Adaptive TRansform Acoustic Coding), and is based on established psycho-acoustic principles. While CD uses 16 bits of data for every 0·02 of a millisecond sample, regardless of signal amplitude, ATRAC analyses the same 16 bits of digital data for waveform content, and extracts and encodes only those frequency components which are actually audible. The whole ATRAC concept relies on two different psycho-acoustic principles – threshold of hearing and simultaneous masking.

Threshold of Hearing relates to how the sensitivity of the human ear varies with frequency, being most sensitive to sounds around 4kHz. Sensitivity decreases at frequencies above and below this point, thus, in theory, sounds below the lowest audible limit can be removed without affecting the perceived sound quality. ATRAC takes advantage of this.

Simultaneous Masking occurs when a sound becomes all but inaudible due to the presence of a louder sound at an adjoining frequency, *providing* that it is within a band called the 'critical bandwidth'. The closer the two frequencies, the greater the masking effect, and of course the further away the two frequencies are, the poorer the effect.

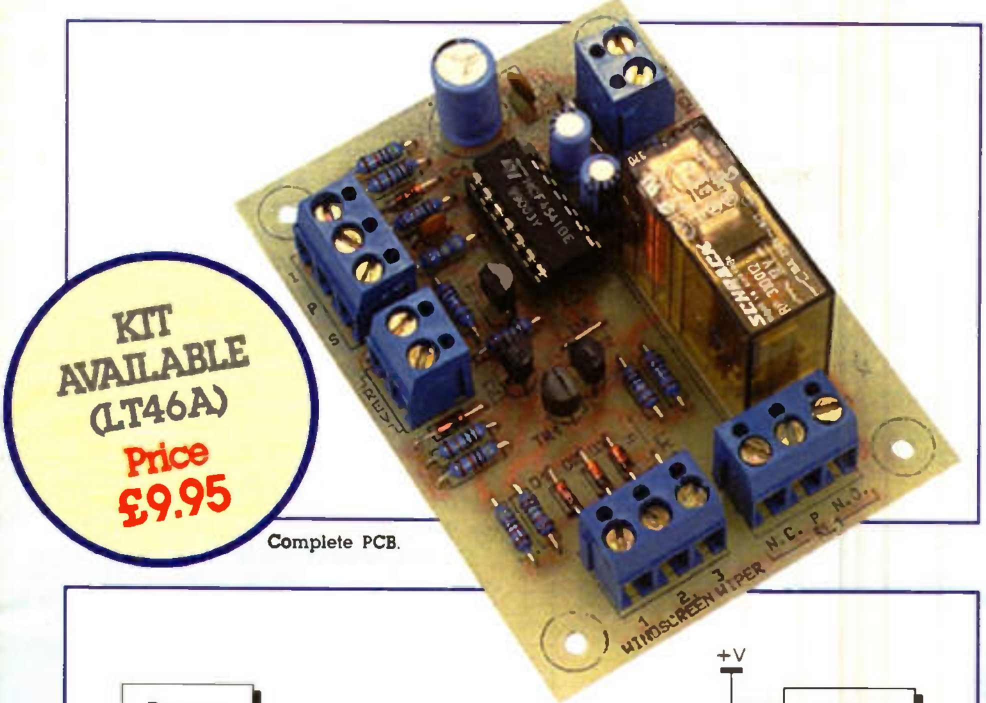
The result of this ATRAC data compression technique is a vast reduction of digital data, typically being reduced to $\frac{1}{5}$ of that required by CD.

As MiniDisc is definitely intended for portable and trendy 'on the move' use like the current 'Walkman' range (incidentally, as a rule of thumb, if you can hear any audio coming from personal stereo earphones at a distance of 1 metre, it is very likely the person wearing the earphones is doing serious damage to their hearing!), Sony have developed shock resistant operation for MiniDisc. The MiniDisc system makes it possible for data to be read from the disc at a much faster rate than playback actually requires. It is possible for the laser 'to read ahead' so that a certain amount of music data can be stored in a memory, which helps to eliminate any effects of the laser being displaced by shock or movement.

MiniDisc uses a 1Mb D-RAM which holds up to three seconds of music in reserve, so that even if the player is jarred momentarily, the music will continue while the laser pick-up re-establishes its position and resumes the reading of digital data.

Two kinds of discs are available, these being playback only MiniDiscs and recordable MiniDiscs, both of which are capable of a sound quality, Sony say, comparable with CD. Interestingly, the two MiniDisc types are read in different ways, and cannot be played back using the same pick-up device, thus MiniDisc format utilises a dual function pick-up allowing both types of disc to be replayed on the same hardware.

The dual function pick-up is similar to that of a conventional CD player, but modified to read both 'Magneto-Optical' and optical playback signals. Playback signals are passed through a lens and mirror arrangement, analysed to detect which type of signal is being read, and




Complete PCB.

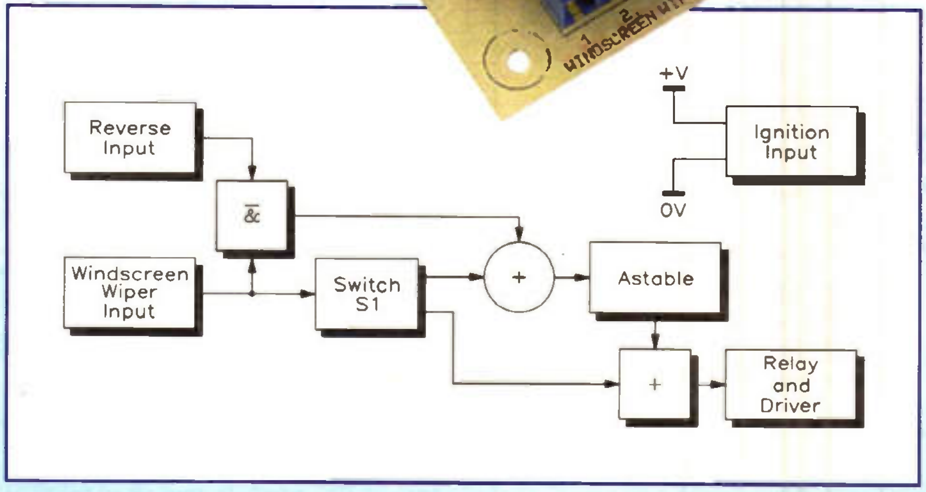



**Figure 1. Block diagram.**

There are many more benefits as well, when travelling in rain, most of the time a rear window is dry, and will only require wiping occasionally to clear any spray kicked up by the back wheels or passing vehicles (particularly HGVs!). Continuously wiping a dry window will not only prematurely wear out the wiper blade, but more importantly, it will *scratch* the window.

The advantage of fitting the Auto Rear Wiper Controller is not only that the life of the wiper blade is extended, it reduces the possibility of a scratched rear window, and the mechanical wear of the motor and gearbox is lessened.

The modes of operation offered by the controller are 'Single Shot', 'Intermittent', 'Off' and 'Auto Wipe on Reverse'; the first three modes are selected by operation of a toggle switch:

**Single Shot** – in this mode, whenever the front wipers are switched on, the rear wiper will give a single sweep and then stop.

**Intermittent** – in this mode, whenever the front wipers are switched on, the rear wiper will a give single sweep, stop and after a preset time period, give a single sweep again; this cycle will repeat until the front wipers are switched off or the controller is switched to 'off'.

**Off** – in this mode, the rear wiper will not operate unless manually overridden by the original wiper switch or by the Auto Wipe on Reverse Mode (see below).

**Auto Wipe on Reverse** – in this mode, whenever the front wipers are switched on and reverse gear is selected, the rear wiper is forced into Intermittent mode, regardless of the toggle switch position.

## Preliminary Checks

First of all, the car electrics need to be looked at. If you have a proper service manual (not the handbook supplied with the car!), such as the popular *Haynes* series, a quick look at the electrical wiring diagram will show you whether the reversing lights and the front windscreen wiper control are positive supply or ground switched. It would probably be advisable that you grab your multimeter and wander out to the car to investigate anyway. Whilst there, look for a suitable location for the module, and identify the wires on the wiring looms.

## Circuit Description

The operation of the Rear Window Wiper Controller can be seen from the block diagram and circuit diagram, shown in Figures 1 and 2. TR1, TR2 and associated

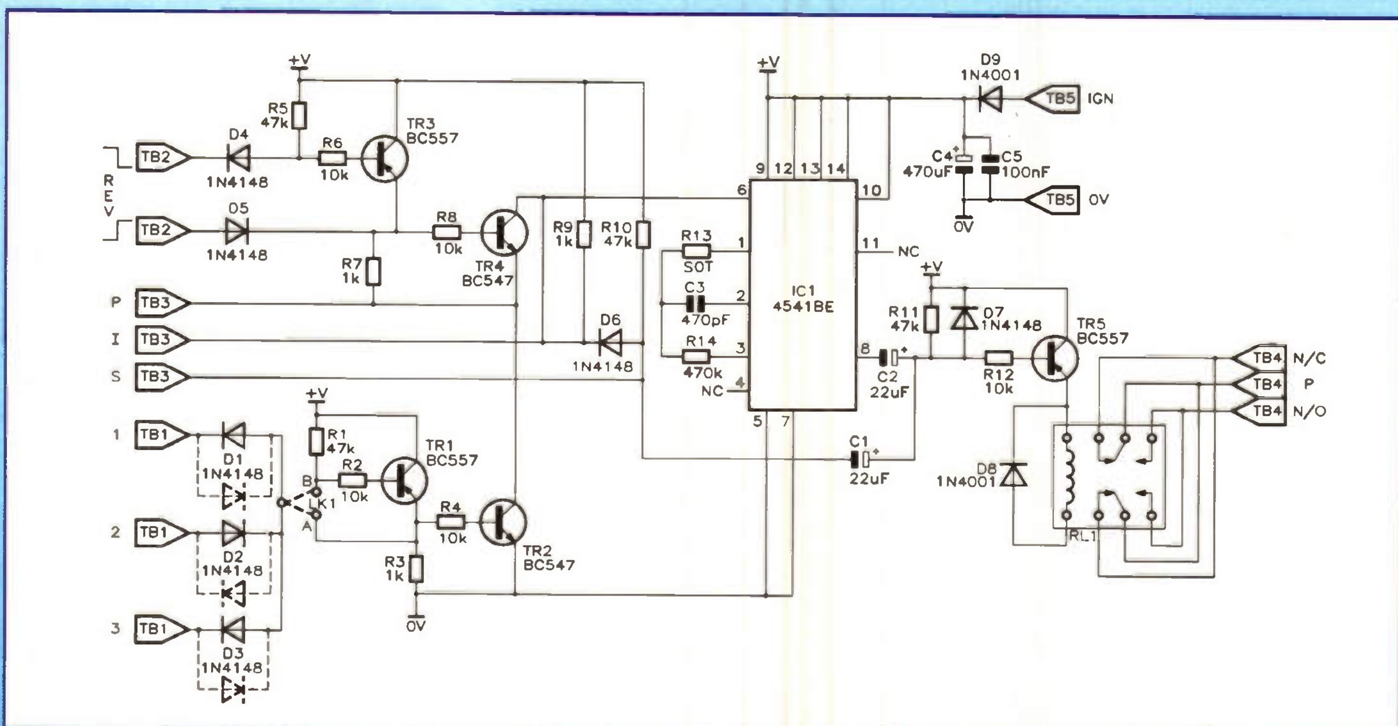



**Figure 2. Circuit diagram of Auto Rear Window Wiper Controller.**


**Photo 1. The Sony MZ-1 MD Walkman Recorder can also record onto 'magneto-optical' disks as well as play ordinary MiniDiscs.**

then directed to the appropriate photo detector for conversion back to a '1' or '0'.

A laser pick-up is used to read data from a playback only disc in a manner similar to CD, where light reflected directly back signifies a land (or more precisely the absence of a pit) corresponding to a digital '0', whilst in the presence of a pit, light is diffracted and reflected back to the laser at a much lower level, corresponds to a digital '1'.

Recordable MiniDiscs are also played back using a laser device but in quite a different way. The very essence of the record/playback capability of MiniDisc is the fact that reflected light from the disc differs according to its magnetic orientation, this magnetic orientation is dictated during the recording process.

When the light emitted from the laser strikes a specific area of the disc, the polarised light will be reflected back along one of two opposing directions, with the polarising plane rotating slightly in a forward or reverse direction according to the direction of the magnetic signal.

A polarised beam splitter is used to distribute the reflected light between two photo detectors, the proportion of light conveyed to each detector varies

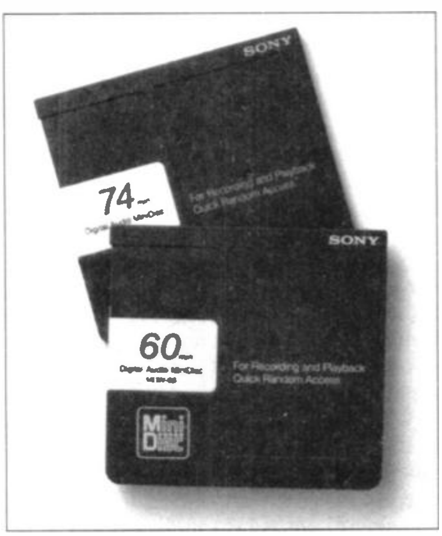



**Photo 2. Up to 74 minutes of audio can be stored on one recordable MiniDisc.**

depending on the direction of polarisation. The two photo detectors convert the received light into small electrical impulses, and, from the differing levels of these, it is possible to deduce whether a received signal is a '1' or a '0'.

Playback only discs are designed specifically for replaying pre-mastered music from your favourite artists, and, as with CD, almost instant track access is possible with the usual search, skip, repeat and random play, etc., facilities. But at launch date only 250 music titles were available, although this number is expected to have reached 1,500 by now.

Recordable MiniDiscs are just that. These 'MO' (Magneto-Optical) discs can be recorded over and over again, in fact Sony claim no degradation of sound quality after 1,000,000 (yes, one million!) recording cycles, and that the discs are not affected by strong magnetic fields and other harsh elements.

The discs are recorded magnetically using both a laser beam and a magnetic type recording head, this process being referred to as Magnetic-field Modulation Overwrite (MMO). Each recordable disc contains a stable layer of magnetic material which allows magnetic flux reversal using a low power magnetic head. The polarity of magnetic flux at each point of the disc can be changed and thus enables the creation of magnetic fields of differing lengths, these can be compared to the lands and pits of a CD.

During the recording process, the magnetic head, which is positioned on the upper surface of the disc, works in unison with a laser beam acting on the *underside* of the disc. The laser's prime objective is to generate sufficient heat to warm a particular spot on the disc to 180°C. As soon as the laser passes by, the disc spot temperature falls; this process is repeated and when the magnetic head applies a specific polarity to the spot, a polarity representing the presence or not of a pit is produced, which in turn represents a digital '1' or '0' in the data stream.

MMO allows a disc to be overwritten (re-recorded) almost an unlimited number of times, or at least as many times as anyone is ever likely to want or need to.

Currently there are three hardware packages available, a playback only MD Walkman, a record/play Walkman and an in-car system. The recordable discs are priced at around £9.00. On the face of it the discs do seem a little on the pricey side, but then this *is* new technology and, as other manufacturers get in on the act, we may well see software and disc prices coming down.

At the moment a professional version of MiniDisc does not appear to be forthcoming, but I have a feeling that the compact nature, convenience and potential quality of MiniDisc could, in time, offer a challenge to other recording formats and make inroads into many areas of the industry, not least the ENG and radio journalist sectors.

For a more detailed look at the workings of MiniDisc, refer to Ian Poole's article on the subject in *Electronics* Issue 73 (January 1994).

## Digital Compact Cassette – (DCC)

A strange thing seems to be happening with DCC at the moment – nothing! Or at least very little. I like to think that I try to keep up to date with new and developing audio systems and formats, after all it's not difficult since the manufacturers and distributors are constantly bombarding us with news about new products. Your favourite mag *Electronics* is also pretty good at passing on to its readers hot news of new bits of gear, but how much have you seen or heard about DCC, except for Ian Poole's article in *Electronics* Issue 72 (December 1993)? I suspect very little. Have you spotted one in the shops yet? Do you know anyone who owns one? No, I didn't think so.

At this time, having not had the chance to feel, touch, listen to or play with a DCC machine, I must admit to knowing very little about this format, and all I will say is that I can't help feeling that DCC may well be tarred with the stigma of the standard compact cassette which has never been considered as a professional tape format. Furthermore, although DAT has not made massive inroads into the domestic consumer market it is now a very established professional format. In fact DAT is now the *de facto* standard for the international exchange of recorded audio material. You may think that I am dismissing DCC before it's had a chance, but I have a sneaking feeling that it could turn out to be the 'Video 2000' of the nineties.

## Floppy Disk

Last month we looked at audio cartridge recorders and players, the type of machine used for jingles and programme trails into radio shows.

Although the system works well and is very well established, its monopoly is now being challenged by new technology in the form of floppy disk based machines. There are currently two types of these systems manufactured in the UK, Sonifex of Northants whose cart machine was featured last month, produce the DISCART system and ASC of Berkshire the DART system.

It is the latter of these that feature here, see Photo 3. DART is marketed as a direct replacement for analogue cartridge machines, it looks like a cart machine, operates like a cart machine and to all intents and purposes is a cart machine. The big difference being that the tape cartridges are replaced by high density floppy disks, and of course this is a digital audio recording and replay system.

With DART comes all the operational simplicity of cart players but with none of the mechanical limitations. In fact the additional features of DART make it an incredibly flexible recording tool!

DART is based on separate record and replay modular topology. Three modules are available, these being the record module, master player and slave player. If you simply need a method of reproducing pre-recorded disks then all that is required is a slave player unit. For more complex operations such as editing a master player must be used and by adding the record module the full range of recording capabilities is realised.

The two player modules are available with either 4Mb or 10Mb disk drives fitted. The record module has no disk drive, and only acts as an interface unit.

Now, storing digital audio on a floppy disk requires some quite clever trickery, as the mass of data is quite large. ASC use a method of data compression called APT-X, which seems to produce the necessary compression in a fairly innoxious way. APT-X allows five minutes and ten seconds of stereo audio to be stored on one 10Mb floppy (these floppies are actually 13Mb, but only 10Mb is usable after formatting). At the other end of the scale, 63 seconds of stereo audio can be stored on a conventional 1·44Mb floppy, albeit at a reduced sampling rate of 26kHz with a subsequent reduction of bandwidth, but still very useful for voice work. Incidentally, the quoted storage times are doubled if working in mono, as may well be the case on some radio stations.

Around 600 different sampling rates are available from a single crystal. These are factory set at 22·05, 26, 32 and 44.1kHz, but any sampling frequency up to 50kHz is available. As with any other digital audio system, the higher the sampling rate, the wider the bandwidth and the better the frequency response will be. At a sampling rate of 48kHz, DART offers a frequency range of 10Hz to 22kHz, whilst at 32kHz this is reduced to a still very useful range of 10Hz to 15kHz.

Within this short feature it is impossible to list all of the clever tricks possible with this type of system, but anything you can do with a cart machine can be done with DART and much more besides. Plug in the supplied PC style keyboard and you can take advantage of the extraordinarily useful and flexible features that only digital, microprocessor controlled technology can give.

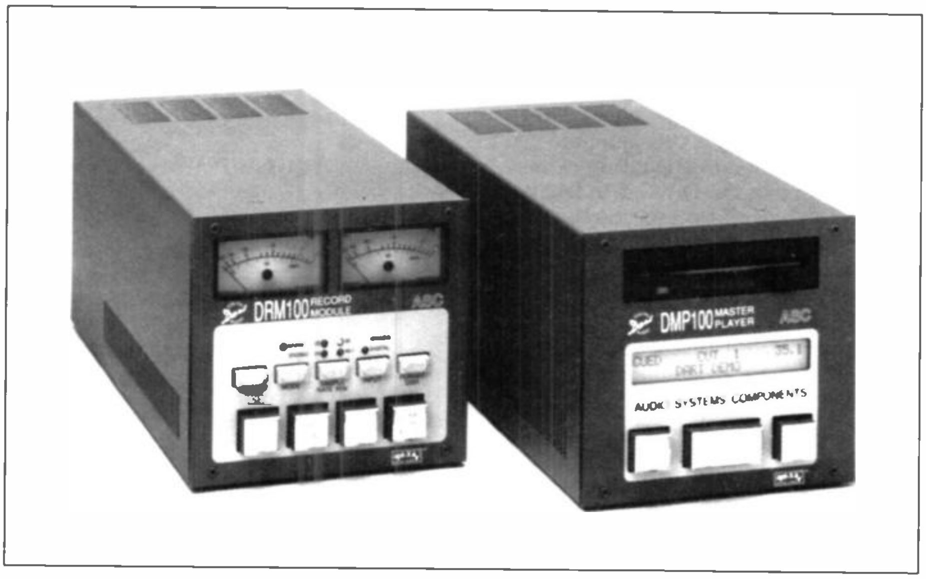


**Photo 3. The ASC DART system, a digital based 'cart' replacement.**

One very nice feature is 'start on audio'. In this mode the user sets the recorder to start on audio, puts a floppy into the drive and, when ready, supplies audio to the unit. On detecting the audio, the recorder automatically begins recording onto the disk. Using start on audio allows a very tight beginning to the recording without having to worry about pressing record and start buttons, opening faders and firing tape machines all at the same time!

Once the recording is down on disk you can edit it, loop it, add titles, etc. If you make a mistake, no problem – DART will overwrite the previous recording instantly without the need of a bulk eraser or eraser/splice-finder. Once completed, it is possible to review the first and last 1·5 seconds, irrespective of the length of the recording and, using only one key, check and edit start and finish times, if necessary without deleting the original recording (non-destructive editing).

You can make or unmake the recording into a loop at the touch of a key and use the keyboard to add titles and other programme information such as an 'outcue' which can be used to identify the end of a particular recording. This is quite useful as several short recordings can be made on each disk each having its own title and outcue info, also it is possible to mix each tracks mono/stereo and sampling rate configurations on the disk. Thus on one disk, for example, musical recordings could be stereo at 48kHz and full bandwidth, with simple voiced pieces in mono at say 26kHz, all with titles and precise timing information displayed on the front panel LCD! The possibilities seem endless, as the ease with which this type of system can be manipulated will bring to many a desire to further express their creative talent, which was thus far a time consuming business.

DART is of course just one of an ever growing number of floppy disk based systems, and I suspect this type of storage media will increase for use in audio recording as and when technology allows greater storage capacity on this medium with improved quality.

## Digital Multitrack Recorders

At last, after much speculation, affordable, quality digital multitrack packages are here, and here to stay! At the time of writing, there are at least two of these now available, but many more are to come in the not too distant future.

The first really affordable example of this new generation of machine was the Alesis ADAT launched in 1992, a fully featured, 8-track digital recorder for around £3,000. The ADAT is based around a S-VHS tape transport. Hot on the heels of this came the DA88 from TASCAM (see Photo 4), which again has loads of facilities and eight digital audio recording tracks. Unlike the ADAT, the DA88 uses a sophisticated 'Hi-8' 8mm video tape transport system built into the recorder, specifically developed for this machine by TASCAM themselves.

The DA88 has a choice of two sampling frequencies, these being 44·1 and 48kHz, both catering for the full 20kHz audio bandwidth, and at 48kHz a maximum recording time of 113 minutes is possible. Audio specification is impressive, with a dynamic range of >92dB and distortion so low (0·007%) it's hardly worth considering! As you would expect with almost all current digital tape recorders, the wow and flutter element is non-existent and quoted as 'immeasurable'. A-to-D (Analogue-to-Digital) conversion is 16-bit linear, 64 times oversampled and the D-to-A (Digital-to-Analogue) is 18-bit with eight times oversampling.

The head drum (40mm diameter) is, as expected, rotary and has four heads, and rotates at 2,000 r.p.m. The drum size and speed are the same as standard DAT, but the linear tape speed of 16mm per second is almost twice that of DAT. The tape wrap is considerable at 226°. While on the face of it this amount would seem to make tape lacing rather slow and clumsy, the DA88 is in fact not affected to any great degree, as the tape remains in contact with the heads in all modes but 'Stop'.

A dedicated sync facility allows up to 16 DA88s to work together, giving a maximum of 128 digital audio tracks, and, unlike many analogue multitrack machines, none of these audio tracks are taken up by the sync code information!

Facilities offered by both the ADAT and the DA88 are, to say the least, comprehensive, and search, shuttle, locate, etc. functions are fast and accurate. No doubt the lure of these, and the audio quality coupled with attractive pricing, are features that are making this type of equipment extremely popular in many semi-professional and professional environments. ADAT has already become a byword for digital multitracking!

And finally, a quick mention of what is probably the smallest digital tape recorder in the world, the Sony 'Scoopman' NT1. The most remarkable aspect of this tiny, palm sized digital recorder is the size of the tape cassette, not much bigger than a postage stamp!

The tape and components within the NT1 are all of miniature proportions, and the whole of the rotating head assembly actually fits inside the cassette shell!

The Scoopman has limited audio bandwidth and is probably of limited use for high quality music material, and therefore is aimed at the consumer rather than the professional market. In fact Sony say "The ultra compact NT micro-cassette is ideal for memo and quality voice recording". Up to two hours of recording time per tape is possible, and the recorder will run continuously for seven hours from a single AA size alkaline battery! Features include a real time counter and 'tape remaining' indicator, with four basic tape transport controls: 'Stop', 'FF', 'REW' and 'Pause'. While the NT1 is by no means a professional format, it has great novelty value and could end up as the 'Walkman' of tomorrow.

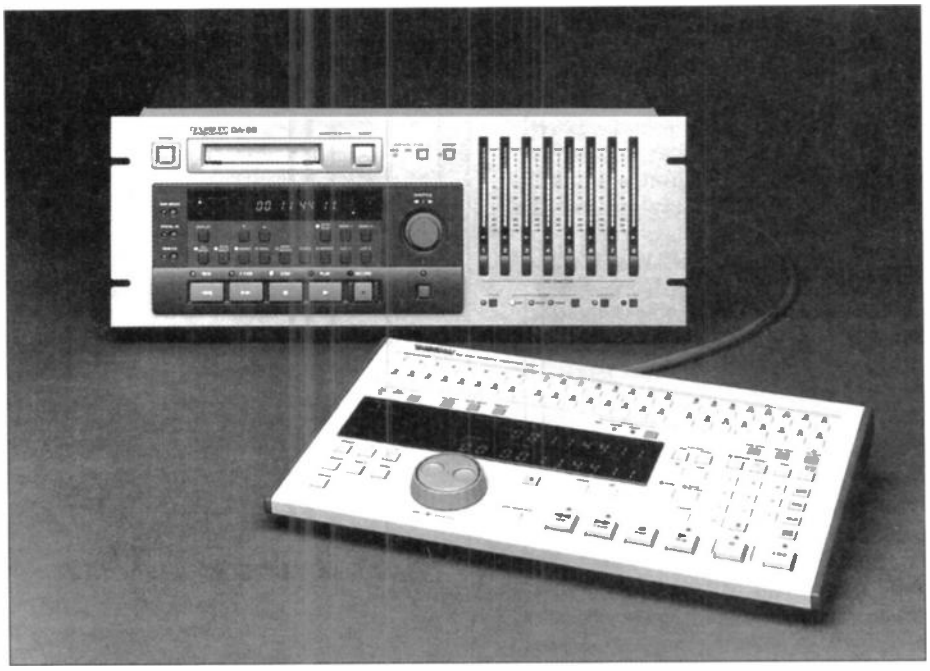
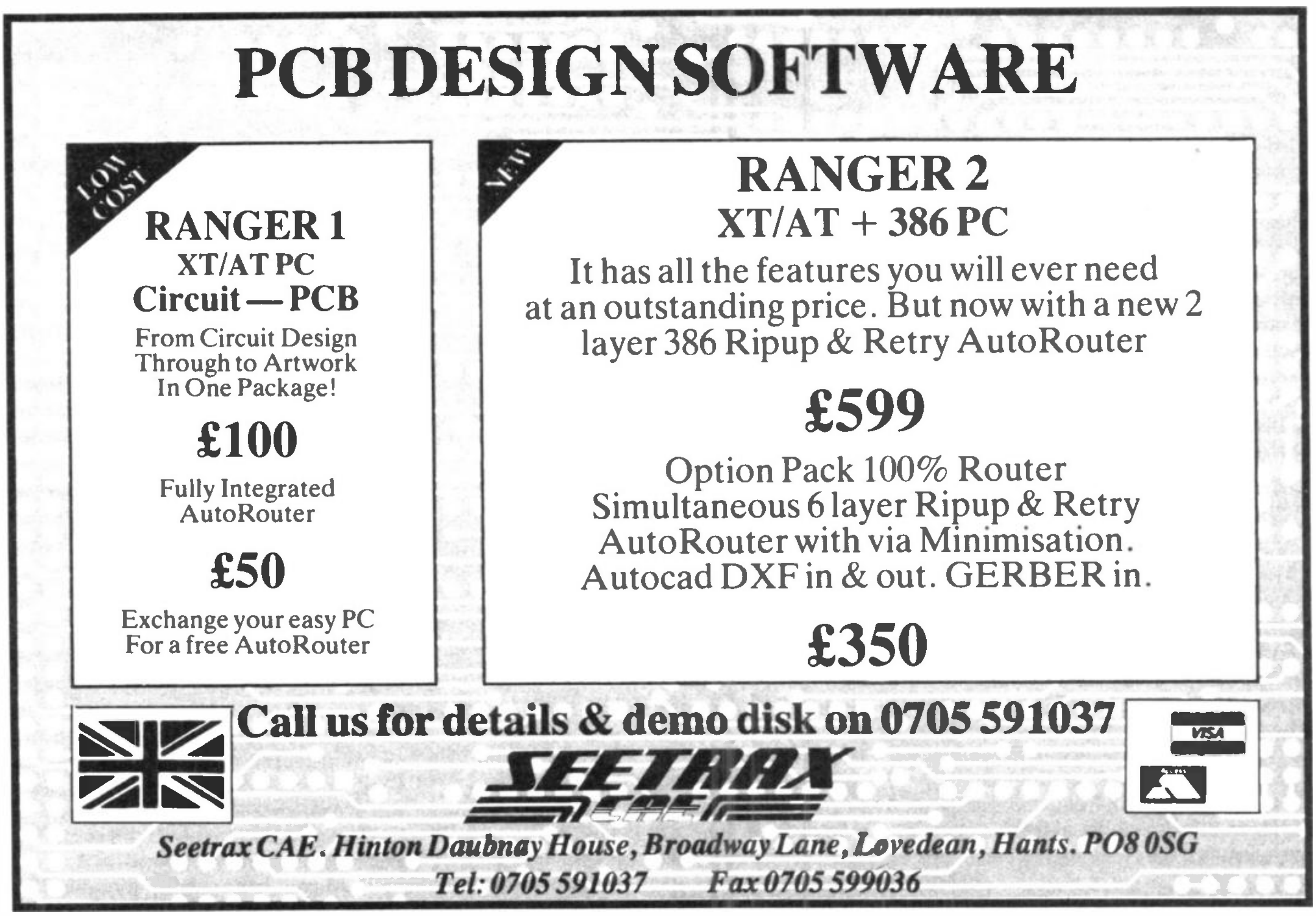
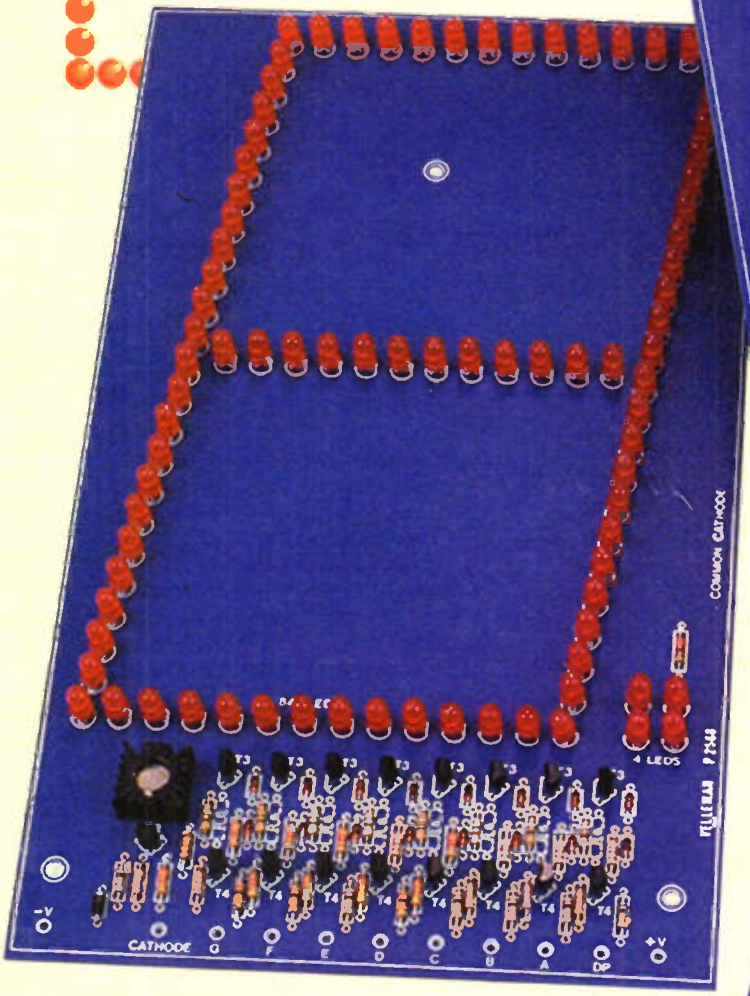


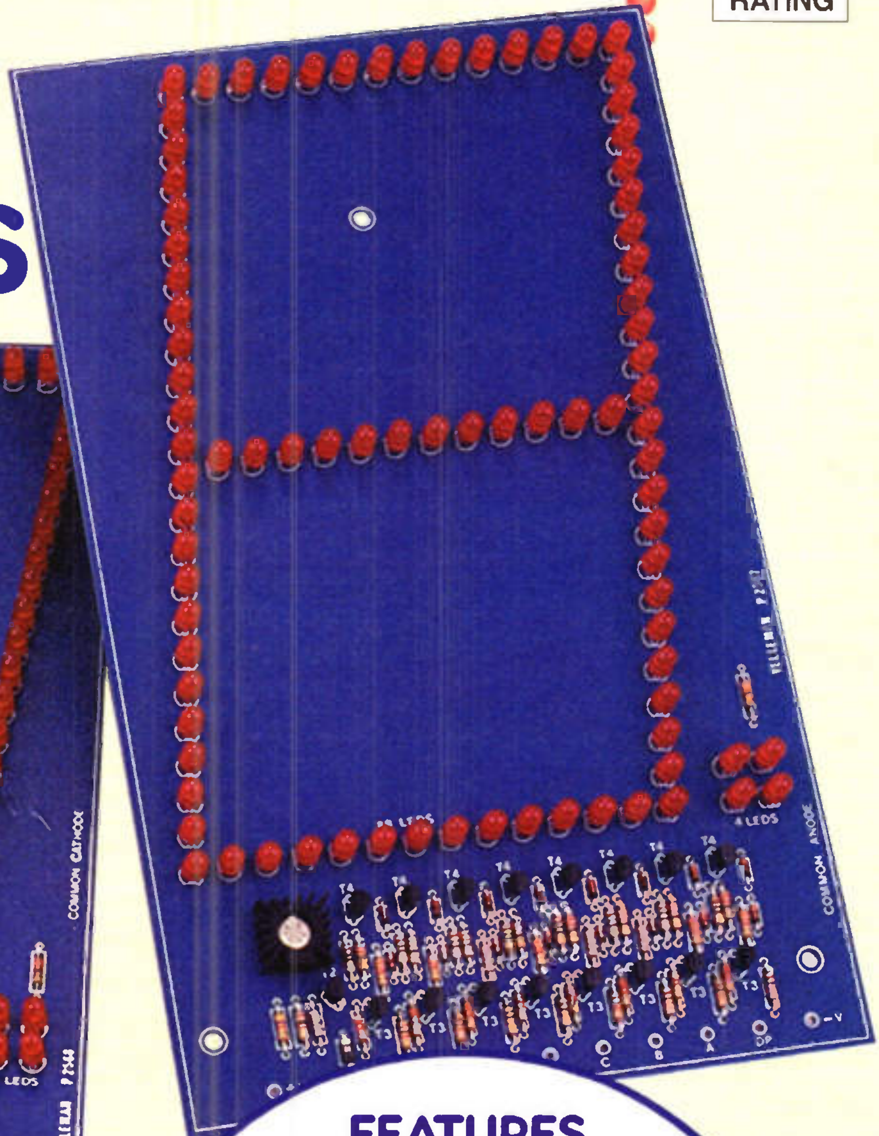
**Photo 4. The Tascam DA88 eight track digital recorder.**

# LARGE 7-SEGMENT NUMERIC DISPLAY MODULES

2
PROJECT RATING




## FEATURES

- 12 red LEDs per segment
- Single 22 to 26V DC supply
- On-board drivers and current conversion
- 400mA max. current
- Brightness independent of supply
- Very high input sensitivity

## APPLICATIONS

- Can be connected in parallel with original 7-segment display
- For static and multiplexed operation
- Available in common cathode or anode versions

Text by Nigel Skeels and Mike Holmes

These modules are designed to be connected to existing 7-segment display drivers, which might be part of any kind of circuit, and will provide a very large display (7½ inches high) of the output. Such uses could, for example, include clocks in large work areas, factory production run counters, athletic timers and lap counters, school classroom calculators, and many other applications too numerous to mention.

All that is required to complete the project is a suitable power supply and the driver circuitry; if the driver circuit has the output capability to drive conventional 7-segment LEDs, then the large display can be run *in parallel* with the driver's original and conventional small display (which must be an LED type).

There are two different versions, these being common anode and common cathode types, the choice being dependent upon whether the original driver uses common anode or common cathode mode. This can include multiplexed displays.

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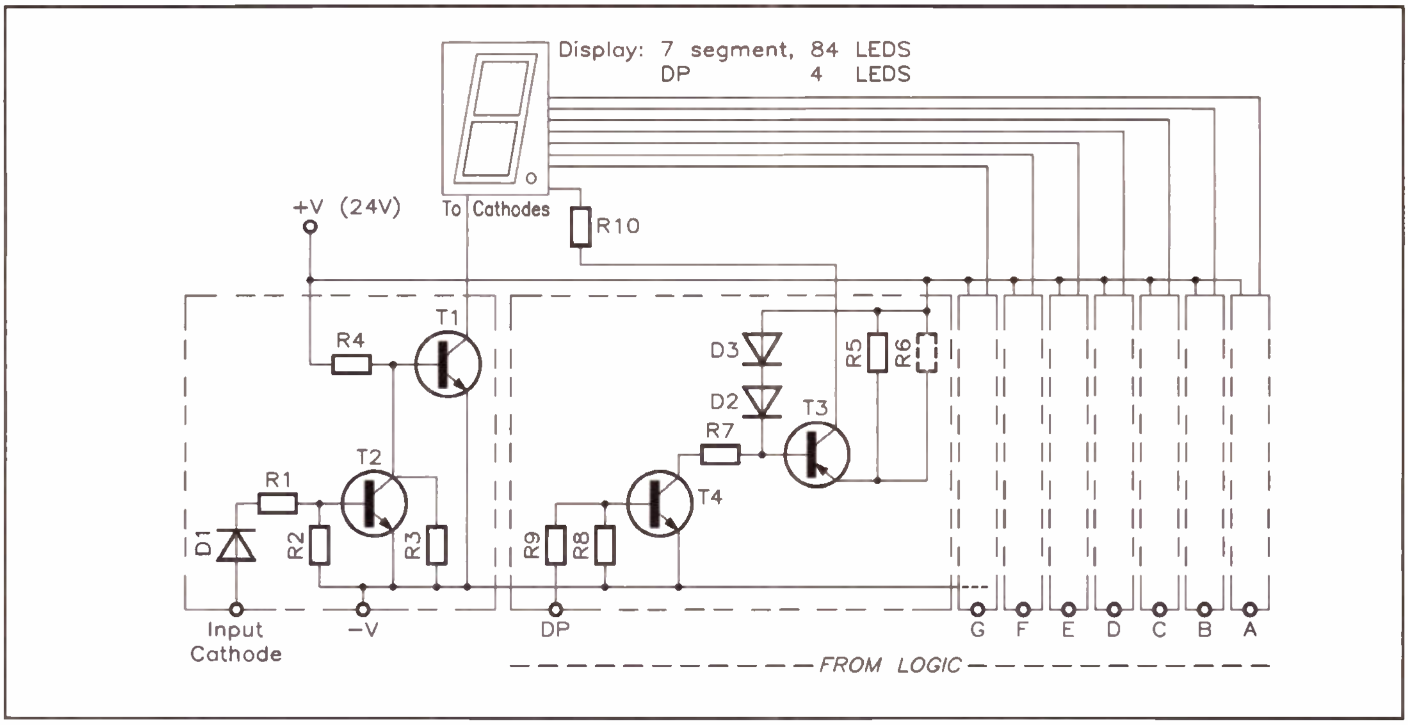


**Figure 1. Circuit diagram of common cathode display module.**

## Circuit Description

Whether common anode or common cathode, the whole module is assembled onto one 255 x 150mm PCB, which is effectively treated as one complete 7-segment display digit. To make up a display of several digits, several such modules are joined side by side. The module is approximately half an inch deep with components mounted (to the height of the LEDs), and can be easily mounted behind a viewing window. Each actual digit is 190 high x 135mm wide, including the decimal point.

Each segment of the display is made up of twelve standard 5mm size red LEDs connected in series. This keeps the overall current consumption within reasonable limits, at the expense of requiring a fairly high supply voltage (24V DC absolute minimum).

The forward voltage drop across each LED in any one segment chain is approximately 2V. T3 (common cathode version, Figure 1) or T4 (common anode version, Figure 2) together with R5, D2 & D3 form a constant current source to supply the chain when required. The available current is determined by R5 and/or R6 (more of which later). T4 (T3 in common anode version) is the controlling switch to turn on the constant current source, allowing current to flow through the segment chain. This group of components is duplicated for each segment chain and the decimal point, which uses only four LEDs and includes a series dropper resistor (R9 or R10, Figure 2).

T1 is the common cathode or anode supply pass switching transistor, supplying power to all the LED segment chains, with T2 as its controlling switch. This stage is provided so that all segments of the module can be switched on and off by the 'strobing' action of a multiple-digit, multiplexed display driver if required.

The polarity of this, and all the other individual segment control inputs, between the two types of module are of course opposed. Since each type is designed to emulate a conventional 7-segment LED display, then, in the case of the common cathode type module, illustrated in Figure 1, the common 'INPUT CATHODE' input is 'active low' – ignoring the fact that in reality only a positive signal via D1 is able to switch *on* T2, yet this achieves the desired effect by clamping the junction of bias chain R3, R4 to ground, switching off T1 and the display.

Similarly, the eight identical segment and decimal point inputs are 'active high', biasing on T4 via R9 in each case.

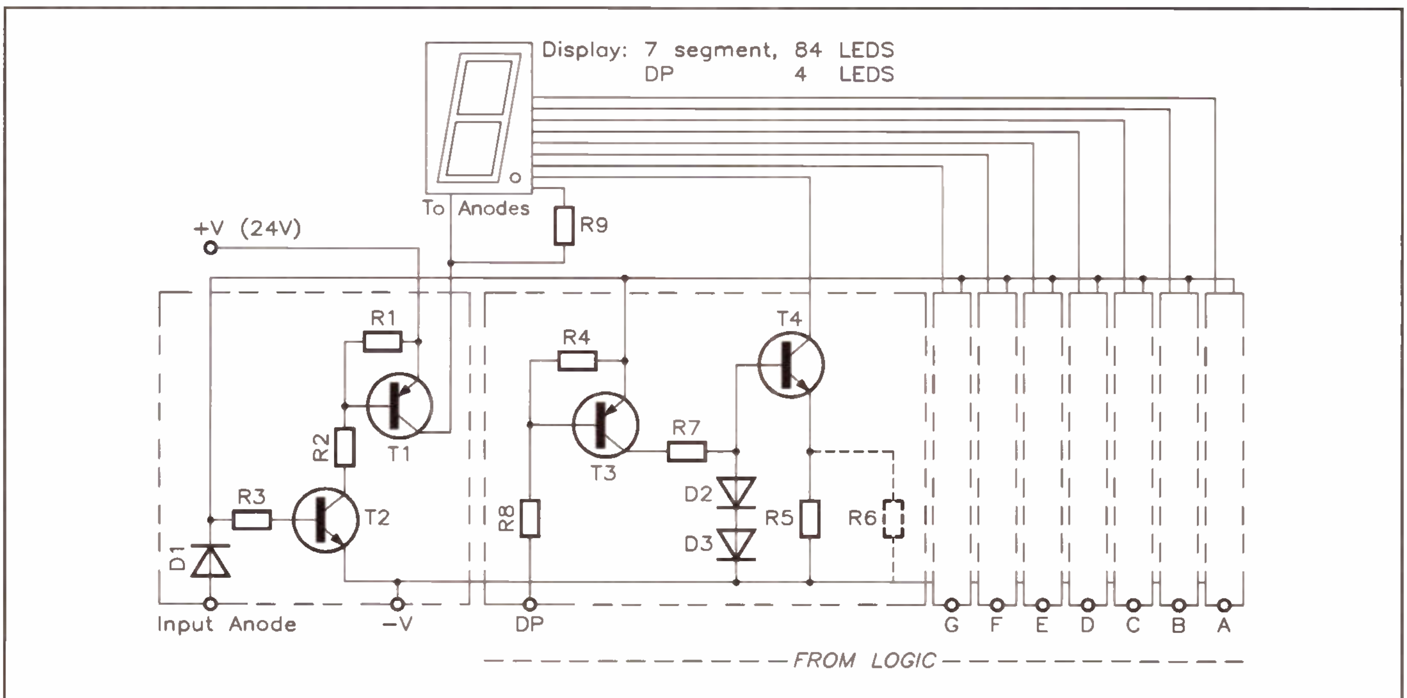


**Figure 2. Circuit diagram of common anode display module.**

T3, a PNP type, is then also switched on, illuminating the chain, and made to operate as a current source by the action of diodes D2, D3 and R5.

Conversely, in the common anode version shown in Figure 2, T2 switches *on* T1, and as the latter is a PNP device, the display is also turned on.

For the segments, the inputs 'DP' and 'A' to 'G' are truly 'active low', where T3 is switched on via R8, then biasing on T4. T4 behaves exactly as its equivalent in the common cathode version, but is a NPN device and is 'inverted' in function; instead of switching the segment chain to common 'minus' via T1 as in the common cathode version, it switches it to common 'plus'.

In most instances, the input impedance of any stage is approximately 10kΩ demanding only a small current; the exception being the 'INPUT ANODE' connection of the common anode module which supplies all the T3 input stages. Otherwise a module can be satisfactorily driven with TTL levels.

## Construction

Construction is quite straightforward and is dealt with in greater detail in the leaflet supplied with the kit. However, the following notes are also worth mentioning.

As a recommended sequence of events, first mount all the diodes D1 to D2/1-8, D3/1-8. Note that D1 is a rectifier type and is characterised (most often) by a black body with a white or silver cathode marker band at one end. The others are (low current) signal diodes and are normally red with a black cathode band. Ensure that the cathode marker of each aligns with the identifying stripe on the PCB legend.

Next fit the resistors. It may be a good idea to insert these all in the same direction as regards their colour coding, although this has no electrical effect it helps value checking later if there are any problems. *Do not* fit resistors R6/1-8 yet! The transistors can then be installed, and the PCB legends indicate the orientation of these. The 'D' shaped plastic packaged transistors align with the 'D' shaped legends. Ensure that none of them stand higher than 10mm above the PCB. T1 is a round metal TO5 packaged device, but its orientation should be obvious as the triangular lead pattern will only fit the corresponding holes in the PCB one way round. (The tab on the edge of the case, if any, identifies the emitter lead and should point towards upper left.)

With all other components except the LEDs in situ, carefully press the finned heatsink over T1.

Lastly, all 88 LEDs can be fitted. Again, the PCB legend shows the correct orientation; each diode has a flat on one side of its package base. In addition, the leads all have 'stops' limiting the distance they can be inserted into the PCB, thus maintaining an even overall height. This makes the installation of so many LEDs much easier.

The PCB is now complete; but before attempting to use the module, carefully check your work for poor solder joints, solder bridges, 'whiskers' and misplaced components. The best way to test the module is to use it for its intended purpose.

## Testing and Setting Up

The setting up required for both module versions may involve the fitting of resistor R6. R6 is *only* used if the driver circuit that you are going to connect the display to is of the multiplexed type; if the display is *not* multiplexed (in other words it is 'static') then R6 should *not* be fitted.

A 'static' display is one where all digits are illuminated continuously, each one being controlled by its own group of 7-segment driver outputs. This type consumes the most power, because all active LEDs are energised together.

The 'multiplexed' method is often used to conserve power and reduce the number of control lines connecting the driver circuit to the display as a whole. It works by having a single bus of seven segment lines plus a decimal point (eight in all), connecting *all* digits in parallel. The digits are then 'strobed', whereby the segment pattern is set up on the bus and then each digit's common control pin is switched on in sequence, at a speed too fast for the human eye to notice. However, because of the significantly reduced 'on' time of each segment there is a reduced light output. To compensate for this it is usual for the LEDs to be driven at a higher current. In the case of each of these modules, this is the purpose of R6/1-8. If you are going to operate these displays in multiplexed mode, you may need to install resistors R6/1-8 which are connected in parallel to R5/1-8, to increase the current through each segment chain during the on time.

## Common Anode

To test the unit, connect points '+V' and '–V' on the board to a suitable power supply of +22V to +24V DC. This supply need not be regulated. Connect the 'ANODE' input to the '+V' supply. To illuminate each segment, connect in turn the 'A' to 'G' and 'DP' inputs to the '–V' supply rail.

## Common Cathode

To test the unit, connect '+V' and '–V' to a suitable power supply as above. Connect the 'CATHODE' input to the '–V' supply. To illuminate each segment, connect in turn the 'A' to 'G' and 'DP' inputs to the '+V' supply.

If any segment of the display (whether common anode or common cathode) fails to illuminate, check to see if an LED has been incorrectly orientated or a dry solder joint exists.

## Using the Modules

To use the unit the first thing that must be established is if the circuit is multiplexed, for the reasons explained above.

The resistors R6/1-8 *must not* be fitted when using the display in static mode, otherwise the increased current will permanently damage the LEDs. When using the display, make sure that the unused 'DP' inputs are connected to +V (if common anode) or –V (if common cathode) to prevent spurious operation, as the inputs are very sensitive.

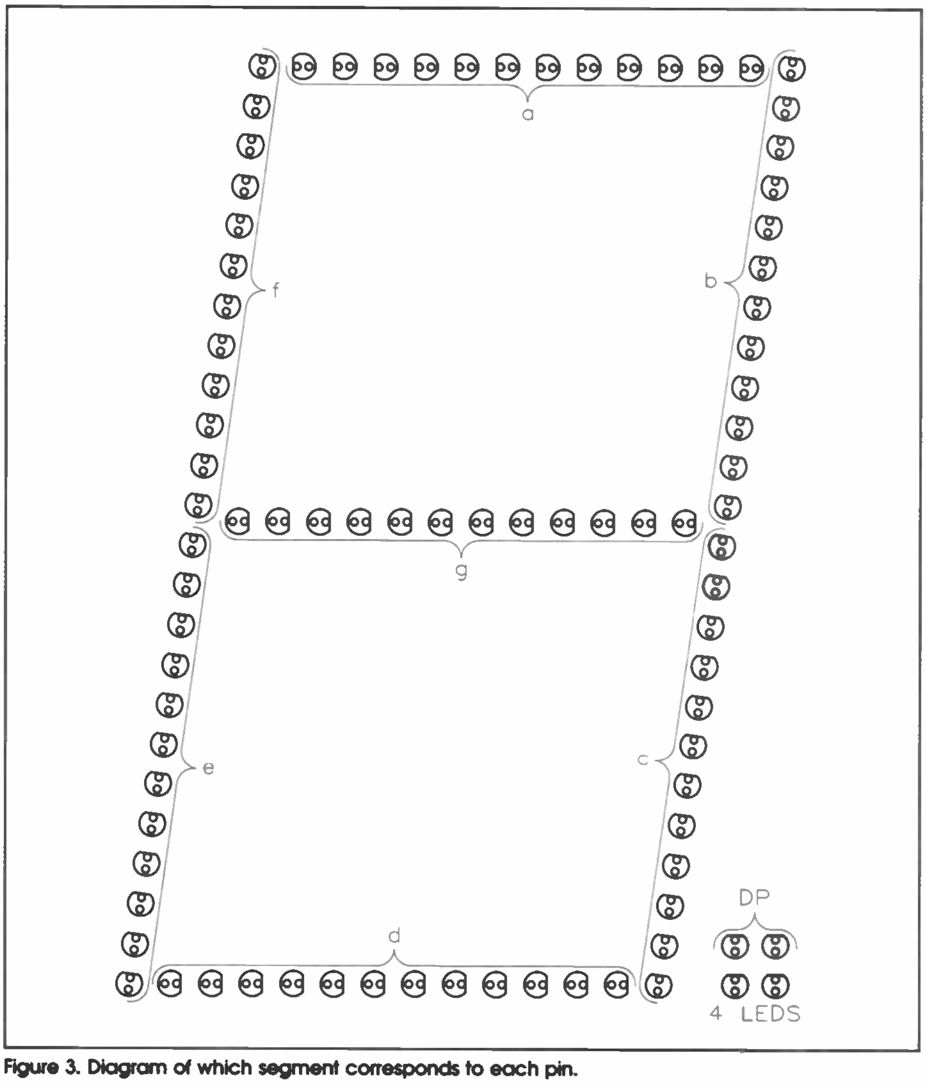


**Figure 3. Diagram of which segment corresponds to each pin.**

## COMMON CATHODE 7-SEGMENT DISPLAY PARTS LIST

| | | |
|---|---|---|
| **RESISTORS: All 5% Metal Film** | | |
| R1,R9/1-8 | 10k | 8 |
| R2,3,R8/1-8 | 33k | 10 |
| R4 | 1k8 | 1 |
| R5/1-8 | 15Ω | 8 |
| R6/1-8 | 22Ω | 8 |
| R7/1-8 | 3k3 | 8 |
| R10 | 330Ω | 1 |
| **SEMICONDUCTORS** | | |
| D1 | 1N4004 (1N4005, 1N4006, 1N4007) | 1 |
| D2/1-8,D3/1-8 | 1N914 (1N4148) | 16 |
| T1 | 2N1613 | 1 |
| T2,T4/1-8 | BC237 (BC238, BC239, BC547, BC548, BC549) | 9 |
| T3/1-8 | BC307 (BC308, BC309, BC557, BC558, BC559) | 8 |
| **MISCELLANEOUS** | | |
| | LEDs Red | 88 |
| | TO5 Lobe-Finned Heatsink | 1 |
| | PCB | 1 |
| | Instruction Leaflet | 1 |

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
***The above items are available in kit form only.***
**Order As VF01B (Common K Display Kit) Price £32.95.**
Please Note: Some parts, which are specific to this project (e.g., PCB), are not available separately.

## COMMON ANODE 7-SEGMENT DISPLAY PARTS LIST

| | | |
|---|---|---|
| **RESISTORS: All 5% Metal Film** | | |
| R1 | 47k | 1 |
| R2 | 1k | 1 |
| R3 | 3k3 | 1 |
| R4/1-8 | 33k | 8 |
| R5/1-8 | 15Ω | 8 |
| R6/1-8 | 22Ω | 8 |
| R7/1-8 | 3k3 | 8 |
| R8/1-8 | 10k | 8 |
| R9 | 330Ω | 1 |
| **SEMICONDUCTORS** | | |
| D1 | 1N4004 (1N4005, 1N4006, 1N4007) | 1 |
| D2/1-8,D3/1-8 | 1N914 (1N4148) | 16 |
| T1 | 2N2905 | 1 |
| T2,T4/1-8 | BC237 (BC238, BC239, BC547, BC548, BC549) | 9 |
| T3/1-8 | BC307 (BC308, BC309, BC557, BC558, BC559) | 8 |
| **MISCELLANEOUS** | | |
| | LEDs Red | 88 |
| | TO5 Lobe-Finned Heatsink | 1 |
| | PCB | 1 |
| | Instruction Leaflet | 1 |

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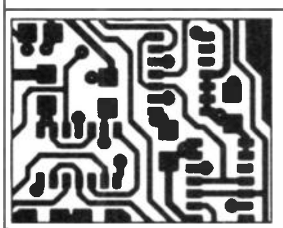

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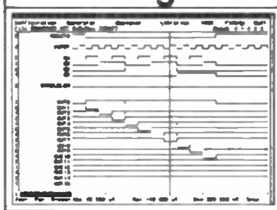

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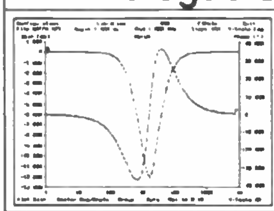

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# SUB-WOOFER FOR HOME OR CAR

## Part 1: How to Begin

by J.M.Woodgate
B.Sc.(Eng.), C.Eng., M.I.E.E., M.A.E.S., F.Inst.S.C.E.

You can make a woofer by stuffing any old loudspeaker in any old box, but it is not likely to work as well as you would like, and the driver unit may blow its cone out rather too often. This is particularly true of installations in cars – a huge driver in an apology for an enclosure is a waste of money (and I'm not talking about Cyril Smith in a mini!). So when someone asked me for a sub-woofer to go in the back of a Range Rover, the first question I asked was, "What sort of box did you have in mind?" When he got over the initial shock, we agreed that a rear-facing extra bench seat, 250 x 200 x 1000mm would fit nicely in the back, and would divide into four 25 litre compartments. Two of these would hold existing, non-Maplin (shame!), bass/mid drivers in sealed compartments, while the centre pair would hold two Maplin 6½in. 8Ω drivers (XP25C) in vented enclosures, to be used as sub-woofers with a proprietary crossover and 2-channel bass amplifier. The same design will work for the discontinued GK04E or GK77J. The widths of the two centre compartments were adjusted so that the internal volumes were actually 26 litres each, thus allowing 1 litre for the volume of the driver magnet and cone and the tunnel associated with the vent.

### STEREOPHONY AT LOW FREQUENCIES

The theory of two-channel stereophony tells us that there is no stereo information in the frequency range below about 200Hz, but this is only true for live two-channel recordings made with coincident microphones (Blumlein stereo). It is not true either for two-channel recordings made with spaced microphones, or for multichannel recordings on tape or CD. For analogue discs, the presence of different low-frequency signals in the two channels corresponds to vertical movement of the stylus, i.e. a groove which gets deeper and shallower. A deeper groove does not matter too much, but a shallow one can lead to tracking failure, particularly as the record press stamper wears, so low-frequency crosstalk is introduced to minimise differences between the channels. Naturally, we are not about to discuss playing analogue discs in a car (although it has been done!).

### ONE AMP OR TWO?

If we could assume that there were identical signals in the two channels, we could use only one amplifier and one loudspeaker to produce the signals below 200Hz. What we cannot do is to connect two amplifier outputs in parallel to one loudspeaker, because any difference in the output signals would make one amplifier 'see' the other as a virtual short-circuit load, with damage or gross distortion, probably both, as the result. It is possible to combine *low-level* signals at the input to a final amplifier and then to drive one loudspeaker from that amplifier, and we shall see later how to do this (and more).

### THE LOUDSPEAKER SYSTEM AS A HIGH-PASS FILTER

It has been known for a very long time that mechanical and acoustic systems obey the same mathematical equations as AC circuits, and can be 'translated' into electrical equivalent circuits for analysis. It is perhaps surprising, that it was not until 1961 that A. N. (Neville) Thiele specifically developed, in practical terms, the point (first stated by J. F. Novak in 1959) that a vented-box system is effectively a high-pass filter with two outputs, one from the cone of the driver, and one from the vent or port. The idea of a filter with two outputs should not be strange for that is exactly what a two-way crossover network is in practice. Perhaps, the reason that the penny took so long to drop is because the outputs appear across the 'radiation resistances' of the cone and vent, and these are small. This is a bad thing as it means that the efficiency of the system is low, but a good thing as well, because they are not well-behaved, unlike fixed resistors. Instead, while being undoubtedly real power-dissipating resistors, their values are proportional to the frequency-squared, and the only electrical 'component' that behaves like that is the radiation resistance of a rod antenna. So, it

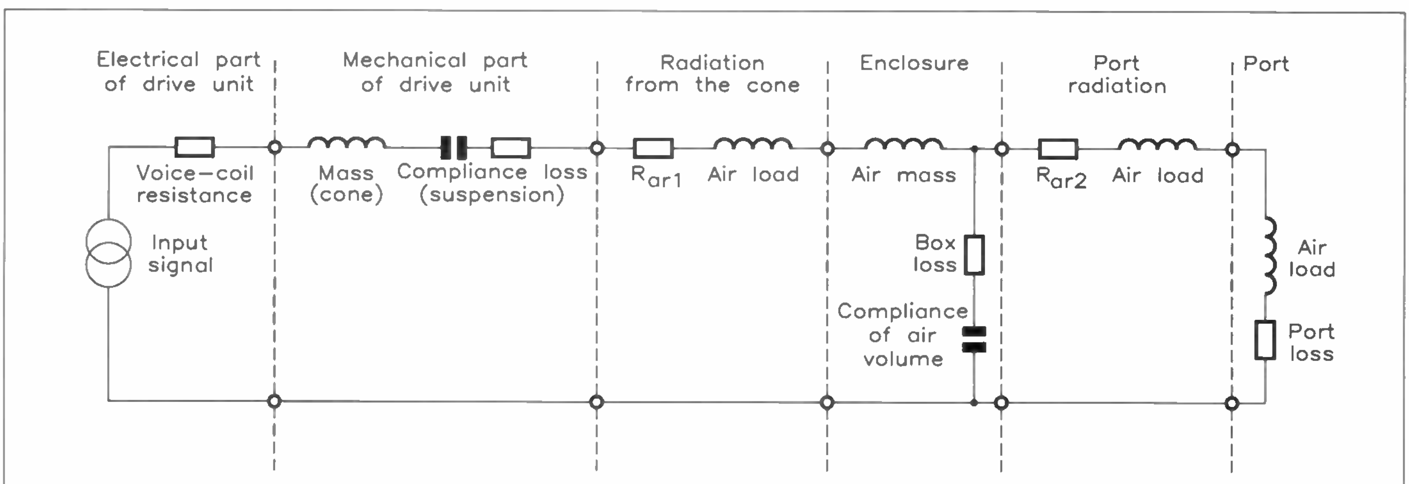


**Figure 1. Acoustical equivalent circuit of a loudspeaker in a vented-box.**

was usual to take advantage of these resistances being small to eliminate them from the equivalent circuit, thereby eliminating the filter output terminals as well! Obviously, the resulting network is, thus, not a filter, and attempts to analyse it would not get very far.

A great deal of theoretical work has been done on filters, mainly because they are very important in advanced telephony. Once the loudspeaker system had been recognized as a filter, many useful conclusions could be drawn and design methods could have gone from a 'black art' to reasonably straightforward, practically, overnight. I say 'could have', because Thiele published his work in Australia (where he lives), and it was hardly noticed elsewhere until it was republished by the Audio Engineering Society in 1971, ten years later. Incidentally, Thiele pronounces his name as 'teal', halfway between the German 'tealer' and the English 'theal'.

## THE EQUIVALENT CIRCUIT OF A VENTED BOX

For the low-frequency analysis, we assume that the cone of the driver moves as a solid object. The frequency range for which this is true, is called the 'piston range'. Above it, the cone does not behave as a solid – different parts vibrate with different amplitudes and phases. You might regard this as a disaster, and unless the way in which it vibrates is carefully controlled you would be right. On the other hand, if this effect, called 'break-up', did not occur, the sound output from the cone would be quite low at higher frequencies and the distribution of the sound would be very directional, like a searchlight beam.

There are two ways of 'translating' acoustic and mechanical systems into electrical equivalent circuits, and the one we are going to use makes mass equivalent to inductance, compliance (springiness) equivalent to capacitance and resistance equivalent to resistance. Unfortunately, there is one complication (there always is!). The electrical equivalent of a moving-coil motor system is a *gyrator*, a rather mysterious 'component' that you cannot buy from Maplin, but you can make with an op amp or even a transistor. It has been rather jokingly described as 'the square root of a transformer', because two gyrators in tandem do indeed act as a transformer. What it effectively does is to 'twist' everything into its complement or 'dual', that is voltage becomes current, inductance becomes capacitance, resistance becomes conductance, series becomes parallel and vice versa for all eight. We do not have to worry too much about this, because the forms of the various equivalent circuits are well established, and are shown in Figures 1 to 4. Here, we begin in Figure 1 with the circuit in acoustical form but with the electrical and mechanical components included as well. We can see that the useful sound output is represented by the currents through the radiation resistances $R_{ar1}$ and $R_{ar2}$. It is worth mentioning that the sound output is expressed in terms of volume velocity rather than sound pressure. We shall see later that there is a relationship between the sound pressure at a distant point and the phasor sum of the two volume velocities, from the cone and the port, at the loudspeaker. The symbol consisting of two interlinked circles is a *current generator*. It is the 'dual' of a voltage generator and thus has infinite source impedance and drives a constant current into whatever is connected to its terminals. Figure 2 simplifies this circuit by lumping together series elements of the same type and, true to tradition, disregards the radiation resistances as too small to matter. We have, however, kept the output *currents*, which are what really count. In Figure 3, we convert from acoustic values to mechanical values, by multiplying all impedances by the square of the area of the piston which is equivalent to the cone. This is the area of a circle slightly smaller than the actual cone diameter. Finally, in Figure 4, we bite on the gyrator bullet and translate everything to the electrical side of the motor system, where the inductors now represents *compliances* (they do look like springs, after all!), the capacitors represent masses, and the parallel resistor actually represents a conductance, so it is labelled $G_{es}$ rather than $R_{es}$. We can, most conveniently, use Figure 4 to study the electrical input impedance of the system as a function of frequency, while Figure 2 is convenient for looking at the frequency response. We should really have included in Figure 4, in series with the voice-coil resistance, the inductance of the voice-coil and the loss resistance associated with it. However, these have negligible effects for sub-woofer applications (say, up to 200Hz), and only have to be considered if we are going to use the system as a bass/mid-range system with a passive crossover network to a tweeter at about 2kHz.

It is very difficult to measure the frequency response of a sub-woofer by normal methods, because even large anechoic rooms do not behave well at very low-frequencies. However, we shall see later that there are two methods which are simple enough for the home laboratory that require no special room. Furthermore, we can find a very great deal of information about the system and its driver from measurements of the input impedance.

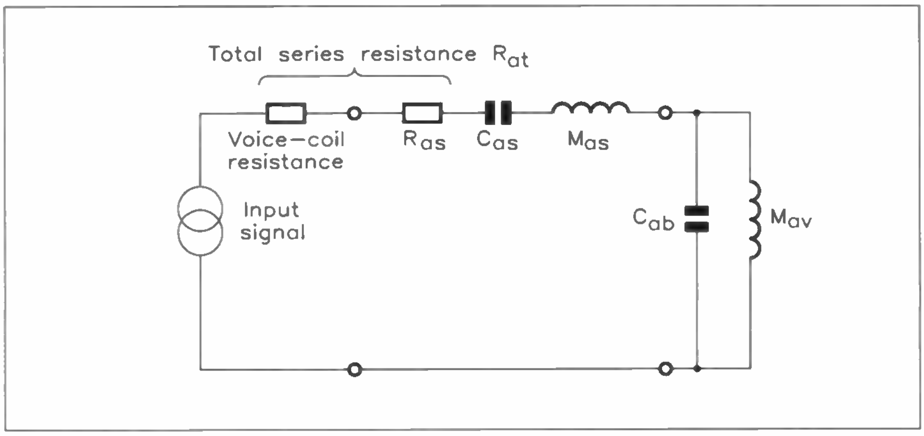

**Figure 2. Simplified acoustic circuit of a vented-box system.**

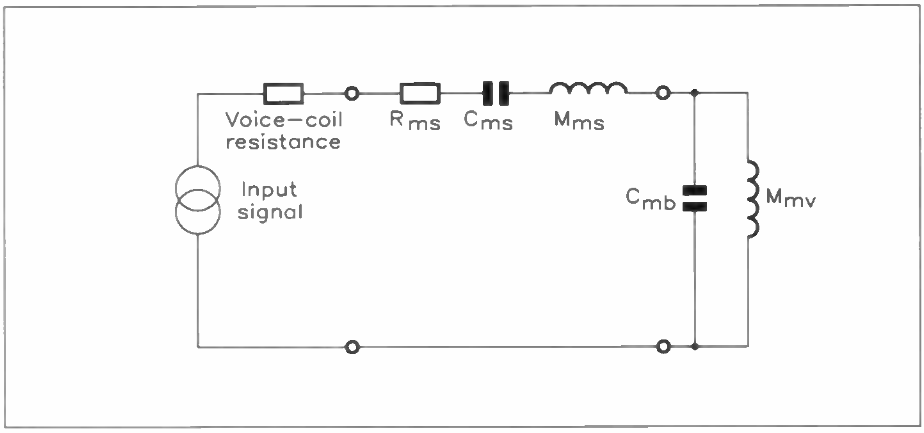

**Figure 3. Simplified mechanical circuit of a vented-box system.**

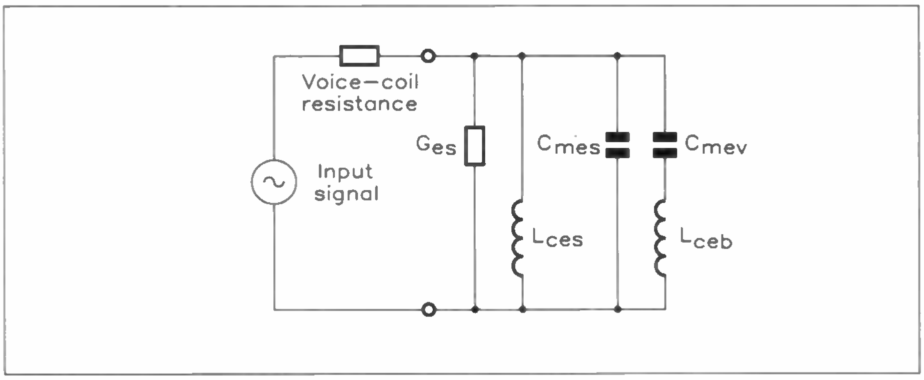

**Figure 4. Simplified electrical equivalent circuit of a vented-box system.**

## FREQUENCY RESPONSE

It can be shown (the mathematics really is too cumbersome – not complicated, but lengthy – to include here) that the frequency response depends on three variables. We could choose these three in many ways; for example, we could choose certain values from Figure 2 directly, but it is most convenient to choose some variables derived from Figure 2:

$T_b$, the box time-constant = $\sqrt{M_{av} C_{ab}}$

$C_{ab}$, the compliance of the air-volume in the box, and

$Q_T$, the driver total $Q = \dfrac{\sqrt{\dfrac{M_{as}}{C_{as}}}}{R_{at}}$

It is useful to note that the driver total $Q$ is inversely proportional to $R_{at}$, and that most of $R_{at}$ is the voice-coil resistance, typically 4Ω or 8Ω. It is thus nonsense to talk about a few tenths of an ohm resistance in the loudspeaker connecting lead having a major influence on 'damping', and the same applies to the output source resistance of the amplifier. Many years ago, James Moir pointed out that the confusion is caused by the definition of the *damping factor* as $R_{vc}/R_{ex}$, where $R_{vc}$ is the voice-coil resistance and $R_{ex}$ is the sum of the amplifier source resistance and the resistance of the connecting lead. The quantity that *really* expresses the effect of $R_{ex}$ on the damping is the *damping ratio* $R_{vc}/(R_{vc} + R_{ex})$, but we still see damping factors of amplifiers being quoted as if they meant something useful! In any case, we are going to take the connecting lead into account in the design, by doing all the measurements at the amplifier end of the actual lead we are going to use with the loudspeaker.

Since $C_{ab}$ appears both by itself, and as a factor in $T_b$ it is particularly significant. Furthermore, it is directly proportional to the box volume, and thus it might appear that the bigger the box, the better it is likely to be. However, it is possible to have too big a box for a given loudspeaker. We can make $T_b$ as big as we like (i.e., make the box resonant frequency very low) by providing a very 'massive' vent or port, in the form of a small hole backed by a long pipe. But, if the area of cross-section is too small, there will be problems with whistling noises and losses, due to air turbulence. You can get the same effect by blowing across the top of an empty wine bottle: the small volume, only 0·75l, resonates at a low-frequency because of the high effective mass of the 'plug' of air in the narrow neck, but there is a lot of noise with the musical (?) note. A port area of about 2,500mm² is a practical minimum. It is possible to alter the value of $Q_T$, which is basically determined by the magnet system of the driver unit, by playing tricks with the amplifier's output source resistance, but we want our system to be usable with any decent amplifier, which we can assume has negligible output source resistance. Luckily, the good basic design of the Maplin unit ensures a realistic value for $Q_T$ in the final design.

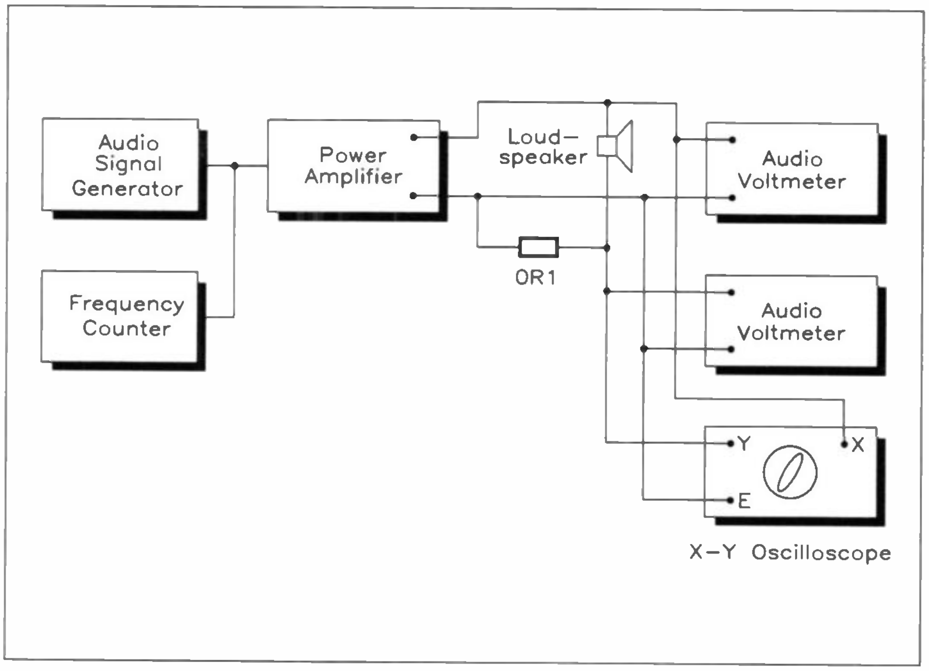


**Figure 5. Circuit for measuring the impedance characteristics of a loudspeaker driver or system.**

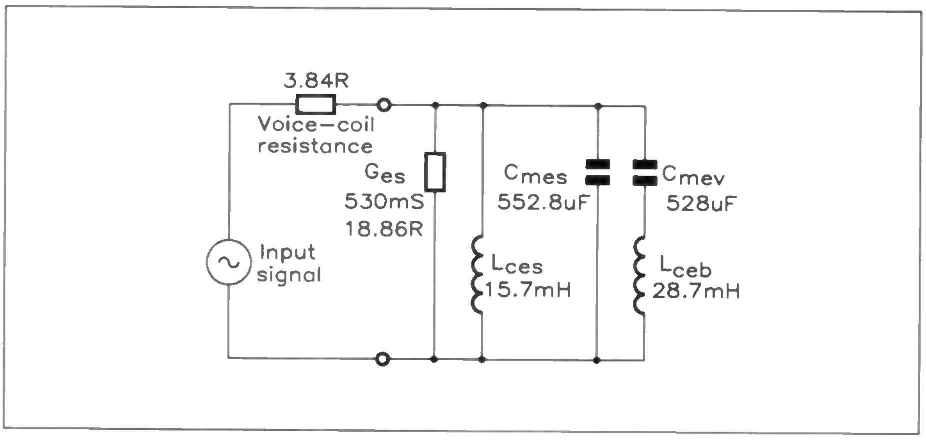


**Figure 6. Electrical equivalent circuit with component values.**

## TOO MANY CHOICES

With three independent variables, even though the values we can achieve are limited by practical considerations, there are an infinite number of possible frequency responses that we could aim at, not all of them good ones. In his original paper, Thiele gives twenty-eight examples of what can be done. In our case, we can limit the choice to a manageable one, for we have already fixed the box volume $V_{ab}$, and therefore $C_{ab}$ is determined. Also, since we have chosen the drive unit, $V_{as}$ is also fixed. $V_{as}$ is one of the well-known 'Thiele-Small parameters' quoted in driver specifications, such as that for the XP25C in the Maplin Catalogue, although quoting the value to five significant figures is a bit OTT. Here we have a bit of luck, because $V_{as}/V_{ab} = C_{as}/C_{ab}$, and Thiele tabulates his examples in terms of $C_{as}/C_{ab}$. However, I was just a little bit suspicious of the $V_{as}$ value quoted in the Catalogue. The values of $C_{ms}$ and $M_{ms}$ are consistent with $f_s$:

$$4\pi^2 f_s^2\, C_{ms}\, M_{ms} = 1$$

is true, so the quoted value of $C_{ms}$ is likely to be accurate, and the other two relationships we need are:

$$C_{as} = C_{ms}\, S_d^2 \text{ and } V_{as} = C_{as}\, \rho_0\, c^2$$

where $S_d$ is the area of the part of the cone which behaves as a rigid piston ($\pi r_d^2$, where $r_d$ is the piston radius), $\rho_0$ is the density of air (1·14kgm⁻³ at 20°C) and $c$ is the speed of sound in air (343ms⁻¹ at 20°C). The Catalogue value of $V_{as}$ leads to a piston radius of 65mm (but the value of $S_d$ leads to 63·5mm), which is practically that of the whole cone, whereas the piston radius is normally that of the middle of the surround, 62mm in this case. Taking $r_d$ as 62mm, we get a value for $V_{as}$ of 11·9 litres. It may be surprising that a difference of only 5% in $r_d$ makes a much larger difference in $V_{as}$, but in fact this follows directly from $V_{as}$ being proportional to the fourth power of $r_d$. Luckily, we can calculate the true value of $V_{as}$ directly from quite simple electrical measurements on the partially completed system, without having to use $r_d$.

## ALIGNMENTS

Thiele calls his examples of different frequency responses 'alignments', so we can do the same. For the 25 litre box, we have (taking the Maplin Catalogue value for $V_{as}$):

$$\frac{V_{as}}{V_b} = \frac{13{\cdot}7}{25} = 0{\cdot}548$$

which is quite close to Thiele's alignment 8; a fourth-order Chebyshev response with 0·9dB pass-band ripple. That sounds impressive, but it is not as complicated as it looks. The basic vented box is a fourth-order high-pass filter, with a cut-off rate of 24dB per octave at very low frequencies. Although the response can be 'fiddled' to give a 'quasi-Butterworth' response, with an 18dB per

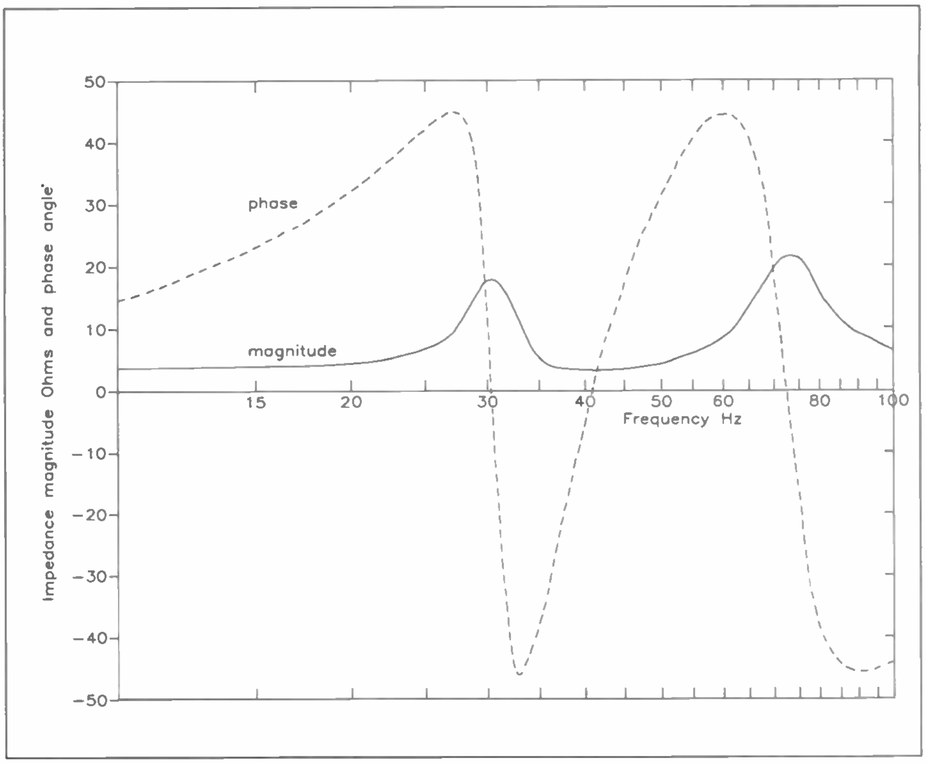


**Figure 7. Impedance magnitude and phase angle as functions of frequency for the equivalent circuit shown in Figure 6.**

octave cut-off rate, there is no point in doing so except under very special conditions. Chebyshev is the name of the Russian mathematician who studied curves which wriggle between set limits before plunging – in this case the 'set limits' are ±0·45dB, which is quite acceptable. Thiele's data also includes two more very helpful facts about alignment 8:

$$\frac{f_3}{f_s} = 0{\cdot}641 \text{ and } \frac{f_3}{f_b} = 0{\cdot}847$$

where $f_3$ is the frequency at which the response is 3dB down, the conventional cut-off frequency, $f_s$ is the resonant frequency of the driver unit alone (56Hz in the Catalogue which is another Thiele-Small parameter, and 54Hz measured on the particular samples that I used), while $f_b$ is the resonant frequency of the box and port, which will tell us what port diameter and tunnel length we need. We can see at once that the response will be –3dB at $f_3$ = 34·6Hz, which is encouragingly low for a modest sub-woofer design! We have to tune the box to $f_b$ = 40·9Hz, well below the resonant frequency of the driver. Thiele's data also tells us that the value of $Q_T$ should be 0·518.

## ELECTRICAL EQUIVALENT CIRCUIT

We now need to look at Figure 4, because we are going to use measurements of the electrical impedance of the system to find or check essential design values, such as $V_{as}$. It can be shown (either mathematically or by experiment) that the equivalent circuit has two impedance peaks, at frequencies we may conveniently call $f_l$ and $f_h$, separated by a local minimum at a frequency $f_m$. Remembering that the components in an equivalent circuit are ideal, we note that the inductor $L_{ces}$ has zero DC resistance, and that (to a certain approximation) the driver unit in free air is represented by the same equivalent circuit but with $C_{mev}$ and $L_{mev}$ omitted. This circuit has only one impedance peak, at a frequency we can call $f_s$, and the peak value is equal to the voice-coil DC resistance and $G_{es}$ in series. We can measure the DC resistance with a Maplin digital multimeter (with any 'zero ohms' control carefully adjusted) and the impedance at resonance, with the circuit shown in Figure 5. At resonance, the phase angle of the impedance is zero, which can be seen as the collapse of the Lissajou ellipse to a straight line as displayed on the oscilloscope. The values for the drivers that I used were:

DC resistance $R_E = 3{\cdot}84\Omega$

Impedance at resonance $R_E + \frac{1}{G_{es}} = 22{\cdot}70\Omega$

Resonant frequency $f_s = 54Hz$

So $1/G_{es}$, which we can call $R_{es}$, is 18·86Ω, because the ideal capacitor and inductor in parallel have an infinite impedance at the resonant frequency.

We can also determine the Q of the resonance, $Q_{ms}$, by the following process. First, we find $r_0$, the ratio of the above impedances, and thence $\sqrt{r_0} = 2{\cdot}43$. Next, we find the two frequencies $f_1$ and $f_2$ at which the impedance is $R_E\sqrt{r_0}$, and these were 38·1Hz and 75·2Hz. Then:

$$Q_{ms} = f_s \frac{\sqrt{r_0}}{(f_2 - f_1)}$$

and this gave a value for $Q_{ms}$ of 3·54. We now have a parallel tuned circuit, of which we know the resonant frequency, $f_s$, the Q and the resonant impedance, $R_{es}$. We can calculate from these the inductance and capacitance:

$$L_{ces} = \frac{R_{es}}{2\pi f_s Q_{ms}}$$

and

$$C_{mes} = \frac{Q_{ms}}{2\pi f_s R_{es}}$$

which give values of 15·7mH and 552·8μF respectively. The values of all the components in the electrical equivalent circuit of the driver are thus known. To obtain the value for the box compliance, we use the compliance ratio, which we found above to be 0·48. The value of $L_{ceb}$ is thus 15·7/0·548 = 28·7mH, and this resonates with $C_{mev}$ at $f_b$ = 40·9Hz, so $C_{mev}$ = 528μF. We now have a completely specified electrical equivalent circuit, see Figure 6, and we can use a circuit analysis computer program to study its characteristics.

We could, alternatively, build the circuit and measure its characteristics, but the component values are not very practicable. But, we could scale all the values appropriately to, for example, ten times the impedance and ten times the frequency, which would give capacitors in the region of 5μF. This idea was developed much further by Dr. Richard Small for his doctoral thesis, the contents of which are, perhaps, not as widely known as they should be. Figure 7 shows the input impedance, and its phase angle, as a function of frequency, and from this we can deduce several useful facts.

We can see the two familiar impedance peaks of a vented-box system, and we can see that the phase angle of the impedance is zero (so that the impedance is pure resistance) at the peaks, and also at the local minimum between the peaks. The detection of zero phase angle gives a very sensitive indication of these three frequencies, particularly of the middle one, which is not easy to determine accurately by looking for the minimum value. However, as we shall see, the zero phase condition does not always coincide with the impedance maximum or minimum, and in that case we have to use the frequency of the maximum or minimum in calculations, not the zero-phase frequency. The phase check can easily be done with the set-up shown in Figure 5, by watching for the Lissajou ellipse displayed on the oscilloscope to collapse to a straight line. Also, in spite of this circuit representing an idealised design, the impedance maxima are NOT necessarily equal in value. The concept of equal maximum values used to be held as the criterion of an optimum design, but it is not valid.

## BUILDING THE BOX

Now we know what the impedance/frequency characteristic should look like, we could build and measure our system and see if it really does perform as expected. However, we have one more job to do, which is to design the vent. It is usually most convenient to use a circular tunnel, and plastic rain-water pipe is quite suitable. The minimum area of cross-section is set by the need to avoid turbulence, and the 2·5in size is therefore chosen; this has an internal diameter of 63·5mm. We saw above that we have to tune the box to 40·9Hz, and Thiele's paper gives a formula (translated into metres):

$$l_v = \frac{1{\cdot}19 \times 10^5\, S_v}{\omega_b^2 V_b}$$

where $l_v$ is the length of the tunnel, $S_v$ is its cross-sectional area and $\omega_b = 2\pi f_b$. This gives $l_v$ as 0·228m, or 9in. We should check that this is less than one eighth of a wavelength at $f_b$, which is $c/f_b$ = 343/38·7 = 8·9m, so there is no problem. If the tunnel were very long, it would not act as a lumped mass but as a transmission line. Due to the way the sound radiation spreads out from the end of the tunnel, the tunnel actually appears slightly longer than its physical length. This end-correction is proportional to the diameter of the pipe, and is 46mm for the rain-water pipe. So our tunnel should be cut to 182mm actual length.

We can now build the box. It is absolutely essential to use a thick, rigid material: the original box was made out of a type of plywood nearly one inch thick, which happened to be available. Blockboard and medium-density fibreboard (MDF) are suitable. Chipboard, even 18mm, is not sufficiently rigid for a sub-woofer. If weight is a problem, 18mm chipboard lined with soft building-board might, surprisingly, be acceptable. This idea is based on some early work by the BBC, and the explanation of its effectiveness is elusive. It is essential that all the joints are airtight; the use of glued and screwed joints, with continuous joint-blocks, should ensure this. Use wood glue, such as Evostik Wood Glue (Resin W), and avoid impact adhesives such as ordinary Evostik or Thixofix, whose solvents could affect the driver. The cable could be brought out through the port in order to eliminate one source of leakage; otherwise the exit must be of minimum size to pass the cable. It should not be necessary to put any damping material inside the box if it is used as a sub-woofer, but a layer of 100mm rockwool glued to the top, back and base of the box (inside!) would be advisable if it is intended to use the system above about 300Hz. The driver may be front-mounted in order to allow all the box joints to be glued, and it is advisable to bed it on to a strip of self-adhesive felt or foam plastic to ensure an airtight seal around the rim.

## MEASUREMENTS ON THE BOX

Perhaps we had better start with the question, "Why measure at all? You have explained how to design the box properly, and it is bound to work, is it not?" In an ideal world, that would be true, but one can never be sure that something is not quite right – for example, I found by measurement that the original box had a significant leak between two compartments which was quite invisible.

We shall not be able to deal with acoustic measurements in this part, so you will have to be patient, but meanwhile there are numerous electrical measurements which are well worth doing. There was a time when the home constructor could not easily obtain measuring equipment, and therefore had a good excuse not to bother. But there is now an excellent range of low-cost gear, either in kit form or ready-made, available from Maplin (and other sources, but we won't mention them), so that it is now very easy to do measurements. You are then not working 'in the dark', and can prove, to your own satisfaction and that of others, that your design is based on valid principles and performs correctly. As shown in Figure 5, you need an audio signal generator, a counter to measure its frequency accurately, an amplifier, at least one audio voltmeter and an oscilloscope with X-Y display facility. Unless you are going to do distortion measurements (for which you need a distortion meter as well), you can use a function generator to provide the audio signal. The following equipment listed in the Catalogue is believed to be suitable, but obviously I have not tried all units or combinations (see table above).

| | |
|---|---|
| **Audio signal generator:** | Very low distortion audio oscillator.<br>Low-cost audio waveform generator.<br>Signal generators YB81C, YN55K or GL46A. |
| **Counter:** | Low-cost 10MHz counter LP37S.<br>Note: It is important to use a counter which can measure low audio frequencies to ±0·1Hz. |
| **Power amplifier:** | 20W power amplifier (LM1875) TDA2006 applications circuit (only the split-rail version).<br>TDA2030, TDA2005M or TDA1514A applications circuits.<br>Note: It is important for the amplifier to have a flat frequency response down to below 20Hz and a low output source impedance. For this reason, the chosen amplifiers do not have output coupling capacitors. On the other hand, only a modest power is needed, about 2W maximum. |
| **Audio voltmeter:** | Most of the digital multimeters are probably satisfactory. However, they are not so good for high audio frequencies (above 10kHz).<br>You may need to change the 0·1Ω to 0·5Ω to get enough volts to measure, but this will decrease accuracy. It would be better to add a simple op amp stage with a gain of exactly 10 or 100. The AC millivoltmeter XM31J is excellent.<br>Note: Although Figure 5 shows two meters, you can swap one from point to point. You may only need to check the amplifier output voltage occasionally. |
| **Oscilloscope:** | Any oscilloscope with X-Y display facility will do. |

We can now measure the impedance of the loudspeaker in the box, and we need to do a minimum of three measurements, although to produce a complete graph of the interesting region requires about 20 measurements between 20Hz and 100Hz. The three measurements we are interested in are those at the frequencies where the impedance is a maximum or (local) minimum. For the equivalent circuit, these are also the frequencies at which the phase angle of the impedance is zero, but the effects which may occur in a 'problem' box can cause the maximum or minimum impedance and zero phase frequencies to differ, so we should, in general, look at both the maximum and mini-mum frequencies and the zero-phase frequencies.

To do these measurements, the driver must be operating in a very low distortion mode (but a little distortion in the input signal is tolerable), so the input voltage $V_1$ should be set at 1V for a 4Ω driver or 2V for an 8Ω driver. The current in amps is obviously equal to ten times the voltage $V_2$ across the 0·1Ω resistor (preferably made from ten 1Ω ±1% resistors, Order Code M1R, in parallel), and the impedance $Z$ is thus $V_1/10V_2$. The following values were obtained using a 23 litre box which proved to have a problem:

Applied voltage $V_1 = 1V$

$f_h = 71{\cdot}8Hz$ $Z_h = 18{\cdot}3\Omega$
(maximum impedance and zero phase at the same frequency)

$f_m = 38{\cdot}5Hz$ $Z_m = 6{\cdot}28\Omega$
(minimum impedance)

$f_l = 26{\cdot}5Hz$ $Z_l = 7{\cdot}85\Omega$
(maximum impedance)

There were no frequencies below 71·8Hz at which the impedance had zero phase angle, but there was a minimum phase angle at 32·12Hz. The value of this minimum phase angle is not very important, because we can immediately see that something is seriously wrong. The precise diagnosis will have to wait until Part 2, but we can still make use of these results to some extent. Because we cannot find zero phase frequencies, we need to do one more measurement, which is the frequency $f_{sc}$ of maximum impedance with the vent blocked up. This proved to be 67·8Hz, and the impedance was 20·83Ω. From these measurements we can calculate the true $V_{as}$ of the driver, and the frequency to which our port has tuned the box. The formulae are:

$$V_{as} = \frac{V_b\,(f_h^2 - f_{sc}^2)\,(f_{sc}^2 - f_l^2)}{(f_h^2 \times f_l^2)}$$

and

$$f_b^2 = f_h^2 + f_l^2 - f_{sc}^2$$

which give the values $V_{as}$ = 13·8 litres and $f_b$ = 35·5Hz. The value of $V_{as}$ confirms the Maplin Catalogue data, while the $f_b$ value is too low. Investigation showed that a longer tunnel had been fitted because the box volume was only 23 litres instead of 25 litres, but this had been overdone: the tunnel was 250mm long, whereas it should have been about 200mm. However, correcting this did not solve all the problems, as we shall see next time (together with amplifier and active crossover circuits, with a bit of luck!).

# POWER ELECTRONICS IN THEORY & PRACTICE

## Part 4

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## TRIGGER PULSE GENERATORS

APART from simple RC phase-shift circuits, other methods of triggering SCRs and Triacs use trigger pulse generators, which are essentially relaxation oscillators. In these there is a timing function, defined by an internal switching mechanism, which discharges a capacitor at the end of the timing cycle. This is used to generate a trigger pulse which fires the thyristor itself. The cycle then repeats at a frequency determined by the time constant of the trigger circuit. Two specific devices that function as trigger pulse generators of the relaxation oscillator type are the Unijunction Transistor (UJT) and the Programmable Unijunction Transistor (PUT). The principles of circuits based on these two devices are the subject of this article.

## THE BASIC RELAXATION OSCILLATOR

Figure 1 shows the general idea behind any relaxation oscillator, the generalised circuit appearing in Figure 1a and its characteristic in Figure 1b. A variable resistor R1 (variable in order to vary the time constant and, hence, frequency of operation) in conjunction with a capacitor C forms an RC charging circuit with an input voltage V1. The trigger device has its right-hand terminal grounded through a second resistor R2 while its left-hand terminal is subject to the exponentially rising voltage across C. An increasing voltage V across it and a current I into it will cause it to switch from a non-conducting to a conducting state when $V = V_S$ and $I = I_S$. These co-ordinates are shown in Figure 1b close to the point 1. At this time the current in the trigger device rises rapidly as the capacitor C discharges, following the curve shown: this is inherent in the types of trigger device represented by the block in Figure 1a. Between points 1 and 3, the current through the trigger device rises while the voltage across it falls, thus displaying a negative resistance characteristic. After this region, between points 3 and 2, the characteristic reverts to that of a positive resistance device. Any device that displays a negative resistance characteristic is capable of acting as an oscillator. Therefore, it is important to ensure that operation takes place in this region.

Examination of Figure 1b shows that load lines have been plotted for the two resistors, R1 & R2. The pair of load lines for R1 indicate that the range of resistance covered by this variable device neatly brackets the extremes of the negative resistance region. Where R1 has a maximum value its load line intercepts that of R2, the upward projection of which intercepts the characteristic at the point $I = I_p$. Since the load line for R2 is tangential to the device characteristic at point 1, one can infer that the negative resistance numerically equals the value of R2 at this point. This point is just past the one defined by the co-ordinates $V_S$ and $I_S$, since the latter point occurs where the device characteristic is vertical, that is just turning the corner. When the operation transfers from point 1 to point 2 on the characteristic, the flow of current through R2, out of the capacitor C, generates a pulse across R2 whose magnitude is equal to $e_p$. This is shown on the horizontal axis as the difference between the voltages $V_S$ (the switching voltage referred to earlier) and $V_F$ (the forward voltage at the final point). The resistor R2 would normally include the input resistance of the thyristor being triggered. Once the capacitor has discharged, the current through the trigger device falls and operation moves down the characteristic to

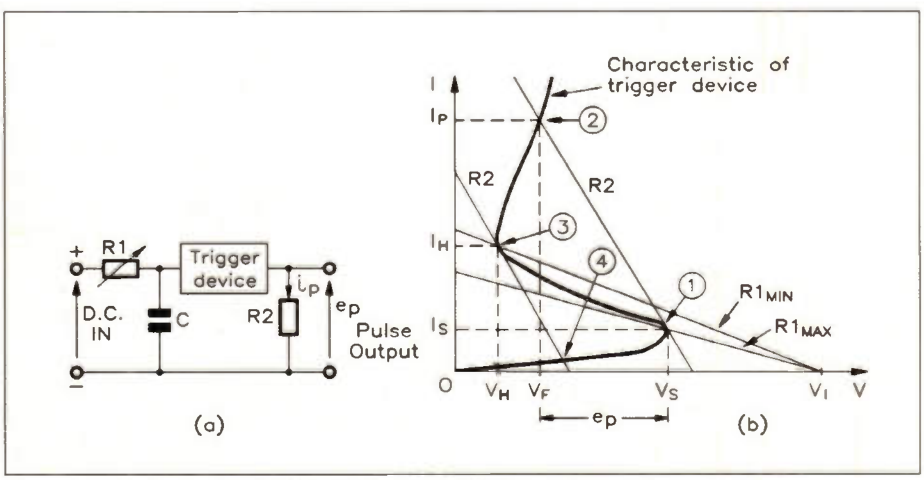


**Figure 1. (a) Basic relaxation oscillator circuit. (b) Relaxation oscillator characteristics.**

point 3, where once again the slope of the characteristic equals that of R2. This is just below the point defined by the co-ordinates $V_H$ and $I_H$, these symbols standing for *holding voltage* and *holding current* respectively, and marking the point where the trigger device returns from the conducting state into which it has been recently switched to its previous non-conducting state. Once it has done so, the capacitor is able to commence a new charging cycle and the sequence repeats. If R1 is larger than the value $R1_{MAX}$, then the operating point never reaches the negative resistance part of the characteristic and oscillations will not occur.

If we now consider the other extreme of R1, when it is at its minimum value, we see that its load line intercepts the device characteristic just below the holding values of V and I. The circuit will oscillate but, if there is any further reduction in the value of R1, operation will move up the curve into the highly conducting positive resistance region and oscillations will cease. The result will have been a single pulse output as the capacitor discharged but no further pulses since the capacitor is effectively shorted by the low resistance of the trigger device and is, thus, unable to charge up again.

Another important factor is the time taken for the switching operation, between the points 1 and 2, to take place. If this is slow compared with the discharge time of the capacitor, then point 2 will never be reached. This will limit the values of the pulse voltage and current amplitudes. When the value of the discharge time constant, R2xC, is much greater (≥10x) than the switching time of the device, the peak pulse output is $e_p$, as shown in the Figure 1b. If this discharge time constant is not significantly greater than the switching time of the device, then the pulse amplitude may be greatly reduced, with the possibility that the thyristor may not be triggered.

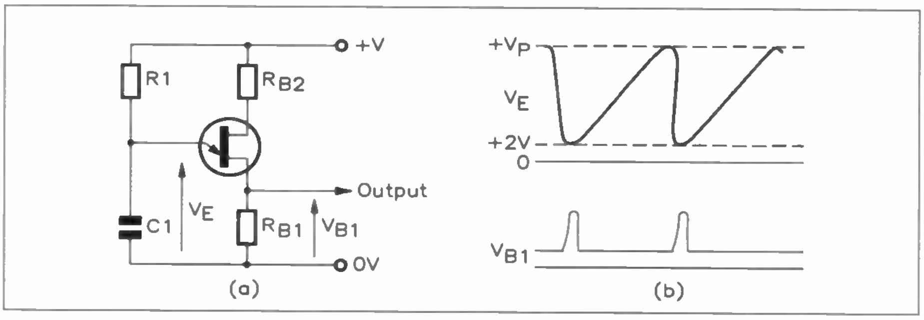


**Figure 3. Circuit for a UJT trigger pulse generator.**

## THE UNIJUNCTION TRANSISTOR

The UJT is a three-terminal switching device that satisfies the requirements for a relaxation pulse generator that can be used for triggering thyristors, as just discussed. Its circuit symbol and characteristics are shown in Figure 2. These characteristics do agree with those shown in Figure 1b; it is just a matter of proportion.

Regarding the device itself, the terminals are known as the emitter (E), Base 1 (B1) and Base 2 (B2). Between the two bases the device behaves as a resistor, this interbase resistance, as it is called, being denoted by $R_{BB}$. This has a value somewhere between 4k7Ω and 9k1Ω at 25°C. The biasing conditions for the UJT are shown in Figure 2, from which we see that voltages are applied between B2 & B1 ($V_{BB}$) and between B2 & E ($V_E$); as a result, currents $I_{B2}$ & $I_E$ flow in the relevant terminals of the device. The characteristics are a plot of emitter current against emitter voltage. Several characteristics are plotted, for different values of the voltage $V_{BB}$, in Figure 2; where each characteristic intercepts the vertical axis, the value of $V_E$ is known as the *peak point voltage* $V_P$. When the emitter voltage is less than the peak point voltage, the emitter is reverse biased and $I_E = I_{E0}$, a small leakage current only. When $V_E = V_P$ and the emitter current $I_E$ is greater than the peak point current $I_P$, the device then switches suddenly from a non-conducting to a conducting condition. When this happens, the resistance between the emitter and Base 1 falls to an extremely low value and the current flowing in this path is limited almost entirely by external resistance.

The peak point voltage $V_P$ can be determined from the following formula:

$$V_P = \eta V_{bb} + V_D \qquad (1)$$

The parameter η is known as the *intrinsic stand-off ratio* and has a value between 0·51 and 0·82; the term $V_D$ is the forward voltage of a diode in the emitter terminal and is about 0·5V, as a general rule. Since the device is temperature sensitive, it is usual to include a resistor in the B2 lead, known as $R_{B2}$. The value of this is quite easy to calculate from the following formula:

$$R_{B2} \approx \frac{10000}{\eta V_1} \qquad (2)$$

$V_1$ is the supply voltage to the circuit. These formulae should be useful with the well-known 2N2646 UJT.

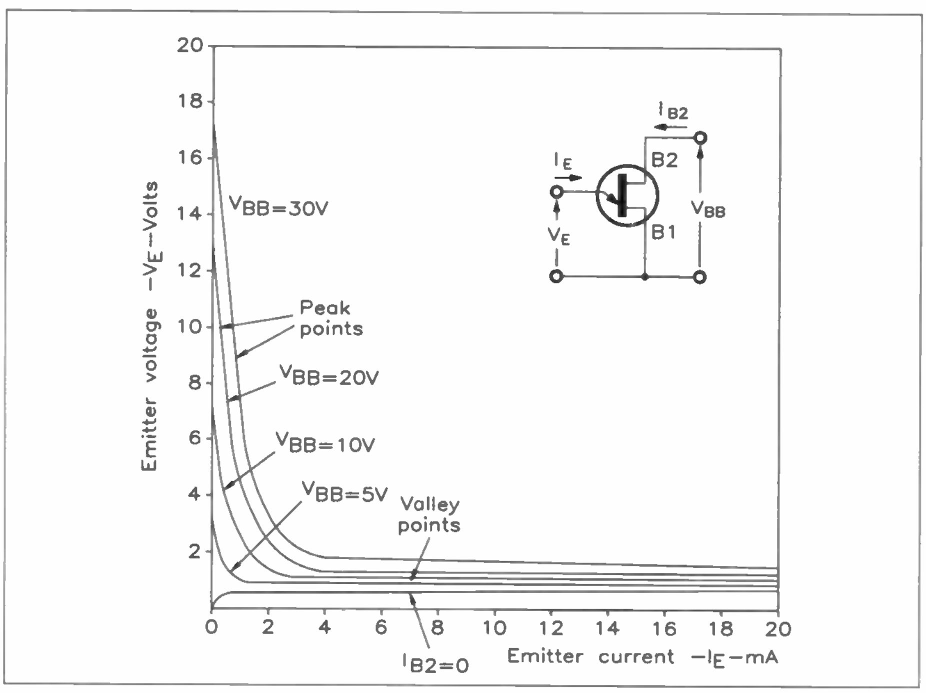


**Figure 2. Characteristics and circuit symbol for a UJT.**

## THE UNIJUNCTION TRIGGER GENERATOR

After all the theory, it may come as something of a relief to find that the UJT circuit itself is quite simple and easy to design. The basic circuit is shown in Figure 3. It comprises just four components in addition to the UJT itself. The functions of these are quite straightforward.

The resistor R1 and Capacitor C1 comprise a time constant for controlling the frequency of the pulses at the output. As capacitor C1 charges up through resistor R1, the emitter voltage rises until it eventually equals $V_P$; this we know is the point at which the device switches on and generates an output pulse. Since the switching action causes the region between emitter and Base 1 to become a low resistance, the capacitor will discharge through this path, and $R_{B1}$ in series, to ground. This short but heavy discharge current flowing in $R_{B1}$ generates the output pulse. $R_{B1}$ is, therefore, the output load. It doesn't have to be a resistor, and sometimes a pulse transformer is used in this position instead.

The resistor in the Base 2 lead, $R_{B2}$, is the one required for thermal stability.

The time period T (and, hence, frequency of oscillation $f$) is reasonably independent of both the supply voltage and temperature and can be estimated fairly accurately from the following formula:

$$T = \frac{1}{f} \approx R_1C_1\ln\left(\frac{1}{1-\eta}\right) \quad (3)$$
$$= 2{\cdot}3\ R_1C_1\log_{10}\left(\frac{1}{1-\eta}\right)$$

This formula assumes a nominal value for $\eta$ of 0·63.

## DESIGN OF UJT OSCILLATORS

The design of such circuits implies determining the values of the components, especially with regard to the frequency of operation, which means how often you want to generate pulses in order to trigger the following thyristor. Another, rather less tangible condition is the type of thyristor that is to be triggered and how much gate current it will need. This is getting into deep water and we shall have to limit our considerations to basic circuit design, with just one example on an actual case, which depends upon the availability of data for a given thyristor being available anyway. Bench testing could otherwise determine whether the output from a UJT oscillator circuit was sufficient to trigger a given thyristor.

The design criteria are quite broad and the design correspondingly easy. As is often the case, there is no magic formula; much of the approach is based on practical experience, what we call empirical data. For example, the value of $R_{B1}$ should usually be no greater than 100Ω; often you will find values of 47 to 100Ω used. The permissible range for the timing resistor R1 lies between 3kΩ and 3MΩ, a very useful and forgiving range. The normal range of supply voltage $V_1$ is about 10 to 35V.

Example 1 – Suppose that we wish to design a UJT oscillator that will run at a frequency of 100Hz. As a starting point assume a 12V DC supply. We start the design by assigning a value for $R_{B1}$ of 47Ω, an arbitrary value within the permitted range. We then calculate the value of the other base resistor $R_{B2}$, using eq. (2) above. We assume an average value for $\eta$ of 0·63; what else could we do? From this data and using eq. (2), the value of $R_{B2}$ = 10000÷(0·63 x 12), which works out at 1322·8Ω. There is no need to be too academic about such a value, so we should probably plump for a 1k2Ω resistor instead.

At this point we must introduce a small complication in the form of another empirical formula. This formula has to be used whenever the calculated value of $R_{B2}$ exceeds 100Ω. The formula gives a revised value of supply voltage, known as $V_1'$, as follows:

$$V_1' = \frac{V_1\,(2200 + R_{B2})}{2300} \quad (4)$$

Thus, the new value of supply voltage $V_1'$ = 12 x (3400÷2300), which equals 17·73V, say 18V.

We then come to the matter of frequency, which depends upon the product of two components, R1 & C1. We always start this type of solution by assuming a possible (and certainly practical) value for one and then working out a value for the other. If the latter value turns out to be impracticable, we then adjust the first assumed value accordingly until we get sensible values for both components. The frequency of 100Hz is quite low so it is no good choosing a starting point for C1 that is too small, such as 100pF. Choose a moderately large value instead, such as 100nF. Using this value and eq. (3) we get:

$$T = \frac{1}{f} = \frac{1}{100} = 0{\cdot}01\text{s}$$

Thus, from equation (3):

$$0{\cdot}01 = 2{\cdot}3\ \text{R1} \times 10^{-7} \times \log_{10}\left(\frac{1}{1-0{\cdot}63}\right)$$

After transposing for R1 and calculating, the value obtained is very close to 100kΩ, and this value will be satisfactory. If we wished, we could change C1 to 1µF, in which case R1 would then be adjusted to 10kΩ, but there is little point in doing so.

Example 2 – A circuit is required that will trigger a C11 type of SCR (2N1773) at the lowest possible supply voltage using a 2N2646 UJT and a pulse transformer. The value of capacitance has already been determined, using operating frequency as a basis, as 100nF. Temperature compensation is desired and the value of $\eta$ may be assumed to be 0·66.

How do we start on a design of this sort? Well, it's not as difficult as it might seem. For a start, we don't have to bother about the value of $R_{B1}$, since a pulse transformer is going to be used instead. The value of C1 has been given and, by inference, the value of R1 is already known, since the frequency is not given. What we do need is some data on the SCR itself and the relevant curve is given in Figure 4. This is a plot of minimum supply

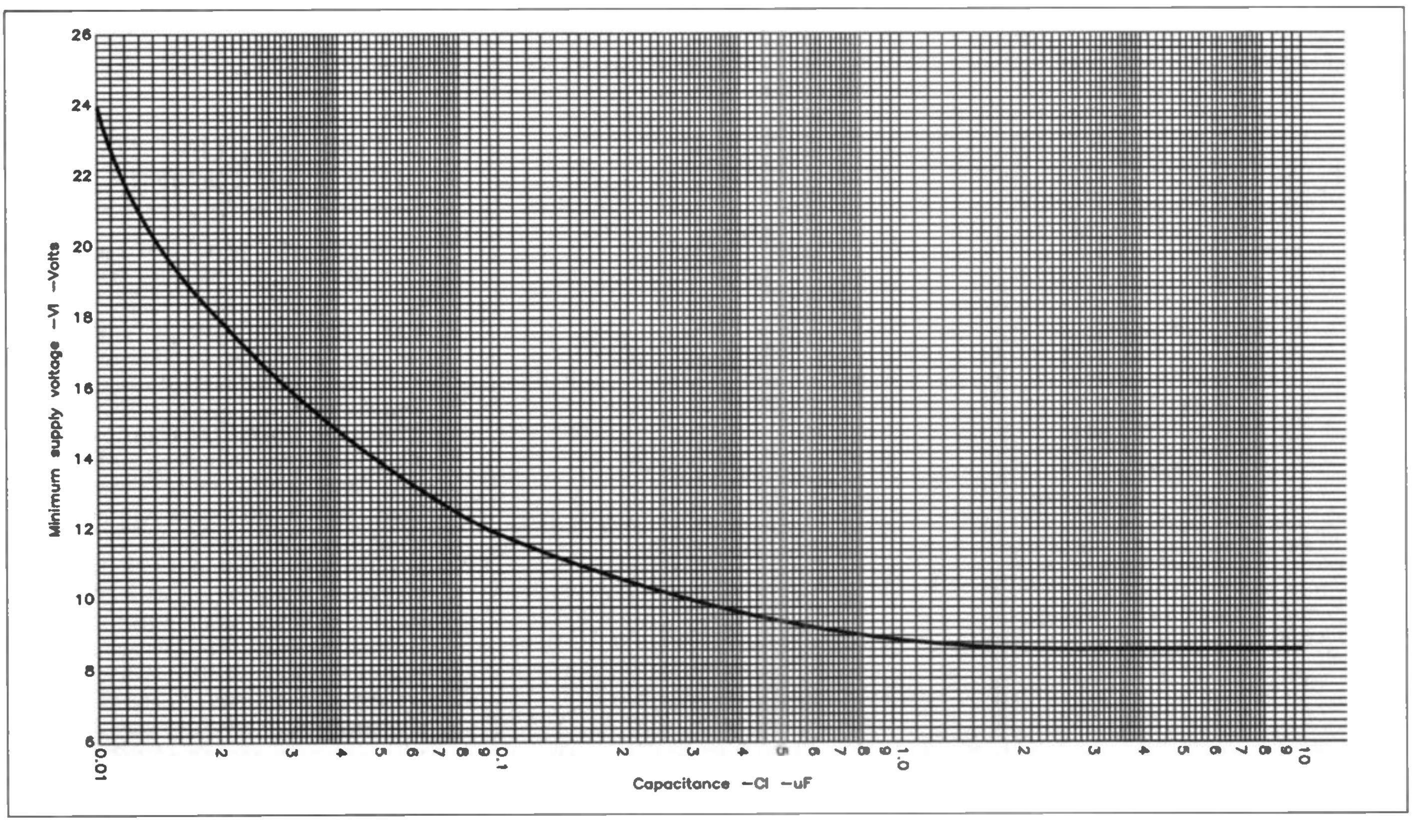


**Figure 4. UJT trigger circuit design curve for a C11 SCR.**

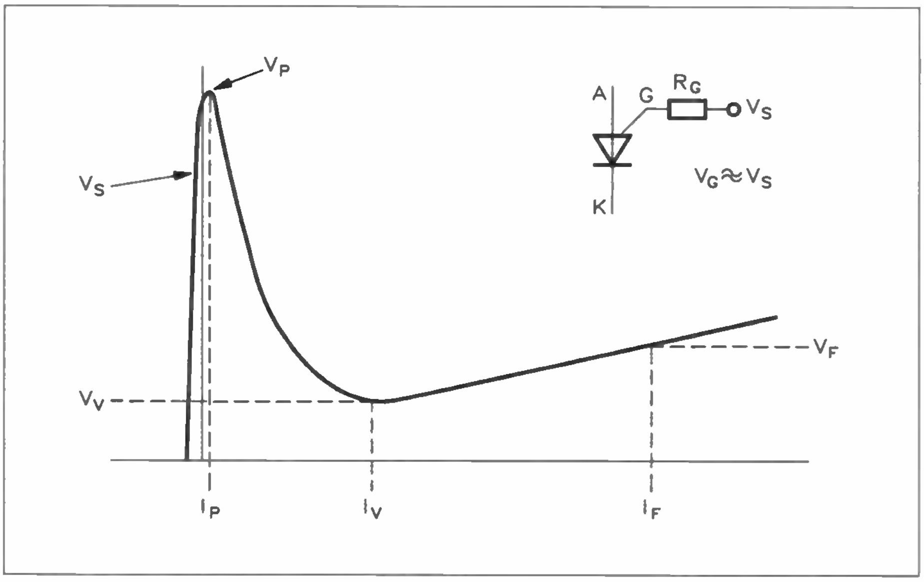


**Figure 5. Circuit symbol and characteristics for a PUT.**

voltage against capacitance C (this is the UJT's timing capacitor, C1). To use this graph, move along the horizontal axis until the value of capacitance is identified; this is given as 100nF (0·1μF). Move upwards from this point until the curve is intercepted and then across to the Y axis to read off the minimum value of $V_1$; this is 12V. This value is then used in the equation for the calculation of $R_{B2}$ given previously, eq. (2). We find from this that $R_{B2}$ is 10000÷(0·66 x 12), which is 1260Ω. We would use a 1k2Ω resistor in practice, which happens to be the same result as in the previous example. This means that the value of the supply voltage would have to be increased to 18V in order to ensure reliable operation.

## THE PROGRAMMABLE UNIJUNCTION TRANSISTOR

The PUT is in fact a member of the thyristor family, being a four-layer device, with an anode gate. The circuit symbol and its characteristic are shown in Figure 5. The characteristic may look a little odd but it is in fact similar to that of the UJT, but rotated through 90° and reflected. It helps to establish the various voltages and currents applicable, as follows:

$V_A$ and $I_A$ are the anode voltage and current.

$V_V$ and $I_V$ are the valley voltage and current.

$V_P$ and $I_P$ are the peak voltage and current.

$V_S$ is the switching voltage applied to the gate.

One difference between the UJT and the PUT is the way in which it switches from the non-conducting to the conducting state. In the UJT it is by a change in conductance; in the PUT it is by a regenerative action that is characteristic of thyristors.

Figure 6 shows the PUT together with two resistors R1 & R2, these forming what we might describe as a PUT package; as for the UJT, there are two resistors $R_{B1}$ & $R_{B2}$, although there are no base terminals as such; however, it at least keeps the terminology consistent. The external timing components, R & C are also included, so it is quite easy to make a direct comparison between this circuit and that of the UJT. The two resistors R1 & R2 are used to *program* the device, this word program being used in a very flexible manner! It means nothing more than the ability to change the values of η and $V_P$ by varying the ratio of these two resistors. However, that is a useful function even if it is stretching the facts somewhat to refer to this as programming!

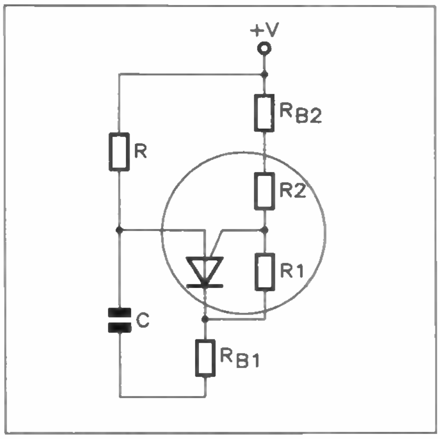


**Figure 6. Basic PUT circuit.**

## THE PUT OSCILLATOR

Figure 7 shows the basic PUT oscillator, together with the waveforms seen at the three terminals. When a voltage is applied to the circuit, capacitor $C_A$ charges up through $R_A$ exponentially (waveform C) until the capacitor voltage reaches the anode firing voltage, $V_P$. At this voltage, the anode-gate junction becomes forward biased and the anode enters the negative resistance region of the operating characteristic. The capacitor discharges through the anode-cathode path, generating a positive pulse at the cathode (waveform A); a negative pulse is also available at the gate (waveform B).

Once the capacitor has discharged, the PUT will turn off provided that resistor $R_A$ meets certain conditions. These conditions are illustrated by the load lines drawn on the characteristic of Figure 8. If the similar argument was followed regarding the UJT, this explanation shouldn't be too difficult to follow.

Figure 8 shows the PUT's anode characteristics in three different regions. Load lines for three different values of $R_A$ have been drawn on them, one for each region. Load Line 1 (LL1) intercepts the characteristic in the cut-off region; not enough current flows to trigger the PUT, because $R_A$ has too large a value. If the value of $R_A$ is too small, the load line (LL2) intercepts the characteristic in the positive resistance region and the PUT switches on, discharges the capacitor and stays on, this being a stable and indefinite state, hence no oscillations occur. If $R_A$ has the correct value, its load line (LL3) intercepts the characteristic in the negative resistance region and the circuit oscillates.

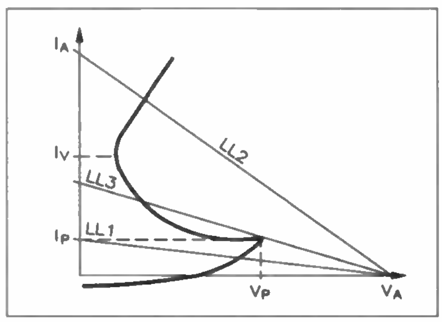


**Figure 8. Load lines for three different values of timing resistor drawn on PUT anode characteristic.**

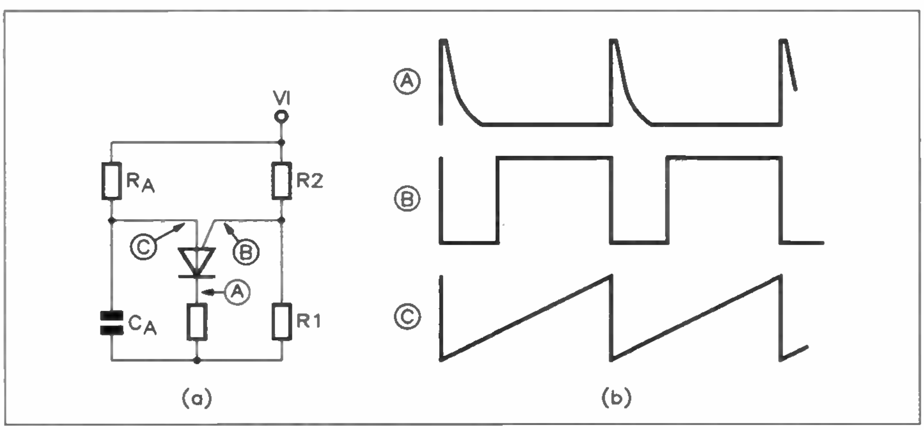


**Figure 7. PUT oscillator with waveforms.**

## FREQUENCY OF OSCILLATION

The formula for the frequency of oscillation is similar to that of the UJT, but with a useful and important difference. No longer do we have to assume a value for the intrinsic stand-off ratio $\eta$ because it is defined by the ratio of the resistors R1 & R2. Instead we can use these resistor values in the formula, as follows:

$$\frac{1}{f} = T = R_A C_A 2{\cdot}3\log_{10}\left(R_1 + \frac{R2}{R2}\right) \qquad (5)$$

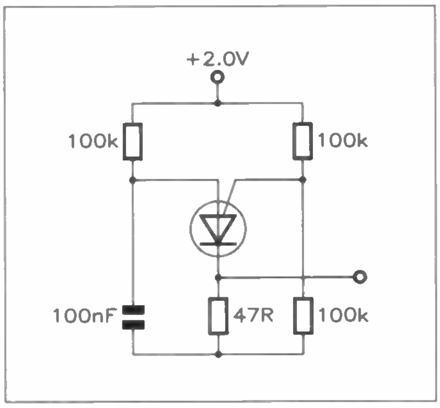


**Figure 9. Typical PUT oscillator circuit with component values.**

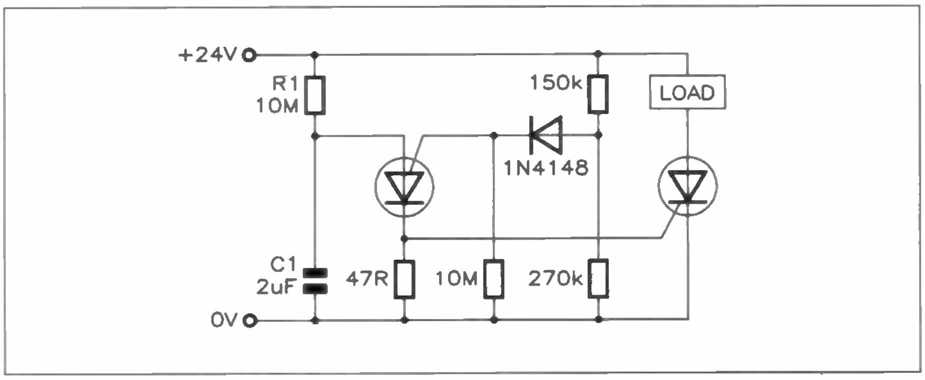


**Figure 10. A PUT timing circuit.**

## FEATURES OF THE PUT CIRCUIT

When fully conducting (saturated) the dynamic resistance of the PUT is only about 3Ω, which allows very large pulses of current to be generated, thus assisting in reliable thyristor triggering. The switching speed is very high and is typically between 65 to 80ns. Power dissipation in the off state is low, because only a leakage current is drawn in this state. This may be compared with the UJT, which draws a very much larger standing current even when not switching.

## APPLICATION CIRCUITS FOR THE PUT

There are, of course, many such circuits and in the next issue we shall be looking at more practical aspects of both the UJT and the PUT. Meanwhile, Figures 9 and 10 show a basic PUT oscillator and a PUT timing circuit switching an SCR and its load. Values are given for the components should anyone feel like a little experimenting in the meantime. For the record, a PUT type BRY39 is available from Maplin (Order Code QF31J) for £1·16. The UJT type 2N2646 is also available as QR14Q at £1·48. We shall see more of these devices next month!


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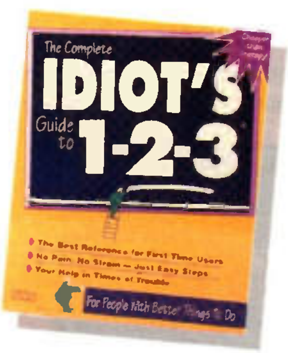
# NEW BOOKS

## The Complete Idiot's Guide to 1-2-3

*by Peter Aitken*

Lotus 1-2-3 is probably the most popular spreadsheet program ever written for the PC. However, it is not particularly obvious how to use Lotus 1-2-3, and the reference manuals can be very daunting. This book is not really for idiots, but for intelligent capable people, who know very little about computers and even less about Lotus 1-2-3, but do have a need to learn enough about 1-2-3 to get some useful work completed in the shortest possible time. The book adopts a very practical approach as to what topics to cover and those to skip - concentrating on those topics that are needed most often. It is not necessary to memorise information as techniques are easy to find and are described in plain English that is very enjoyable to read. Every term, instruction and task is fully explained – it is not necessary to be a computer genius before reading this book.




With this entertaining book you will be able to set up worksheets for various applications, create information-packed graphs, develop useful formulae, make and sort a database, master multiple worksheets, save and retrieve worksheets, and much more. The main text of the book applies to Release 3.4, but Release 2.4 is very similar or identical, and differences between the two versions are pointed out in specially marked sections.

This book is highly recommended for anyone embarking on Lotus 1-2-3 for the first time and comes with a convenient, colourful tear-out card with handy reminders and quick reference listings. This book will not necessarily make you an expert in 1-2-3, however, you should be able to easily use 1-2-3 for your daily work.

1993. 285 pages. 230 x 185mm, illustrated. American Book.

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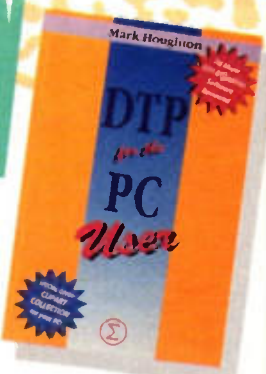


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*by Mark Houghton*

It was the early 1980s that saw the introduction of the Apple Macintosh computer with its user friendly graphical user interface (GUI). It was this advantage over the PC that saw the Apple Mac become the dominant machine for desk top publishing (DTP). However, with the drop in price and the rapid advance in microprocessors, PCs are now in a comparable position especially with the introduction of modem software such as Windows.

This book concentrates exclusively on PC based desktop publishing, for a cheap-and-cheerful PC can be equally as effective for DTP as the Mac. But how do you find out what additional hardware and software you will require? This is where this book will be of great assistance, recommending the type of PC to buy for serious DTP work, together with the essential printers and scanners to complete your system. A wide range of software packages are reviewed from the low-cost PagePlus to QuarkXPress for Windows, as well as graphics packages from GST's Designworks to Corel Draw! Finally, a comprehensive list of hardware and software suppliers in the UK are listed.

If you are planning to set up your own DTP system, or are hoping to expand an existing system, then this book is for you.

It will provide you with information needed to assess what are the best possible combinations of hardware and software for your requirements and budget.

1993. 240 pages. 229 x 152mm, illustrated.

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## Teach Yourself Electricity and Electronics

*by Stan Gibilisco*

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Each chapter ends with a 20 question multi-choice quiz, which should be answered with the aid of the chapter text – answers are provided at the back of the book. The book is divided into three major sections: direct current, alternating current, and basic electronics. At the end of each section is a 50 question multiple choice test, with answers at the rear of the book. Finally, at the end of the book there are three 100 question, multiple-choice exams.

Standard symbols and notations for circuits are gradually introduced, so that by the time the reader finishes the book, he/she should be fully conversant with most of the symbols used in electronics schematics.


It is not necessary to have a mathematical or scientific background to make use of the book, as secondary school level mathematics and physical science should suffice. The style of the book does require a certain amount of self-discipline on the part of the reader, but the book is easy to read and follow, and the reader can set his/her own pace. A highly recommended book.

1993. 678 pages. 234 x 188mm, illustrated. American Book.

***Order As AA24B***
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## A Concise Introduction to Word for Windows

*by N. Kantaris & P. R. M. Oliver*

Microsoft's Word for Windows is the best selling Windows wordprocessor, and is naturally fully integrated with Microsoft's Windows environment. In all the Windows versions Word has been biased towards desk top publishing (DTP), featuring a WYSIWYG mode with full edit capability. Additionally, the package features the ability to manipulate full colour graphics, making this a powerful wordprocessing package. Although, Version 2.0 and above have been designed to make full use of the improved features of Windows 3.1, they are equally at home with Windows 3.0.

The text is written with an emphasis on what the authors consider to be the most important aspects of the program, such as page layout, paragraph styles and the use of frames etc.

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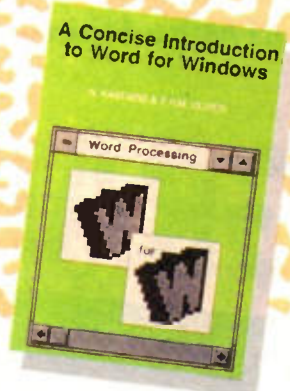


all that is really needed to be known can be covered in a selected fewer number of pages. It is hoped that with this book you can be efficient and productive in the shortest possible time. No previous knowledge of the software is required, and the presentation of the facts is based on what you need to know first is presented first. Each chapter is self-contained, and does not require an earlier chapter to have been read first to be understood.

1993. 160 pages. 198 x 130mm, illustrated.

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## A Beginners Guide to CMOS Digital ICs

*by R. A. Penfold*

CMOS logic integrated circuits have remained virtually unchanged since they were first introduced over twenty years ago, and have been very popular with the electronics enthusiast since their introduction. One reason for this popularity is their modest power supply requirements – being able to work over a wide voltage range and drawing very little current, they are well suited to battery powered circuits. However, getting started with logic circuits can be daunting, and off-putting, since many of the fundamental concepts of digital design appear rather abstract, and remote from practical applications.


This handy, inexpensive little book introduces the reader to the basics of simple logic circuits and then progresses to specific CMOS logic integrated circuits. No previous knowledge of logic circuits is assumed, but an understanding of general electronics is necessary. The circuits described in the book are practical applications of CMOS logic, and cover such applications as oscillators, monostables, flip/flops, binary counters, binary dividers, decade counters and display drivers.

1993. 130 pages. 178 x 111mm, illustrated.

***Order As AA22Y***
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**Text by Alan Williamson and Mike Holmes**

PROJECT RATING 3

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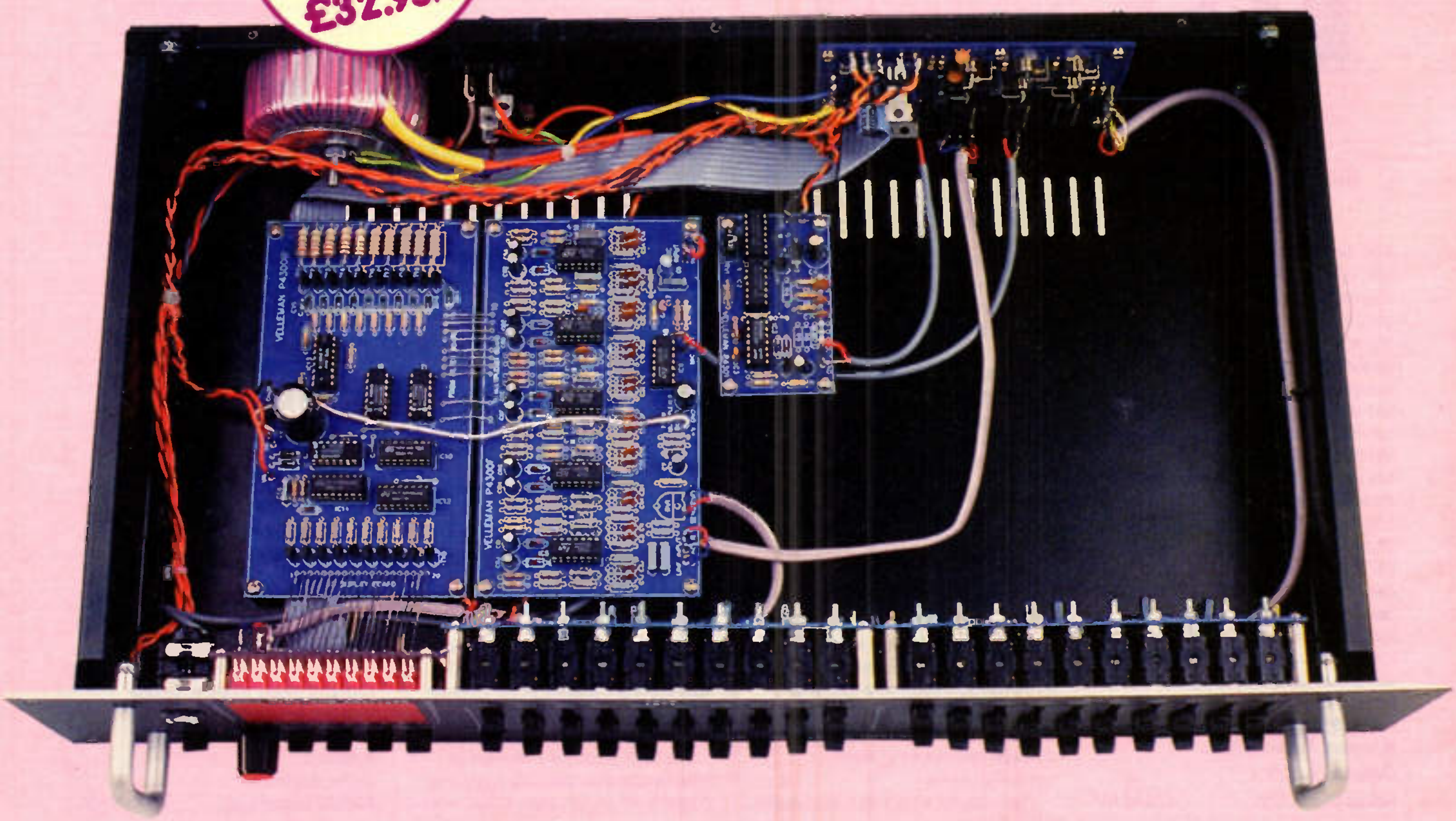
1 x VX18U Slider Knobs (20 required)

A block diagram of the Graphic Equaliser System is shown in Figure 1.



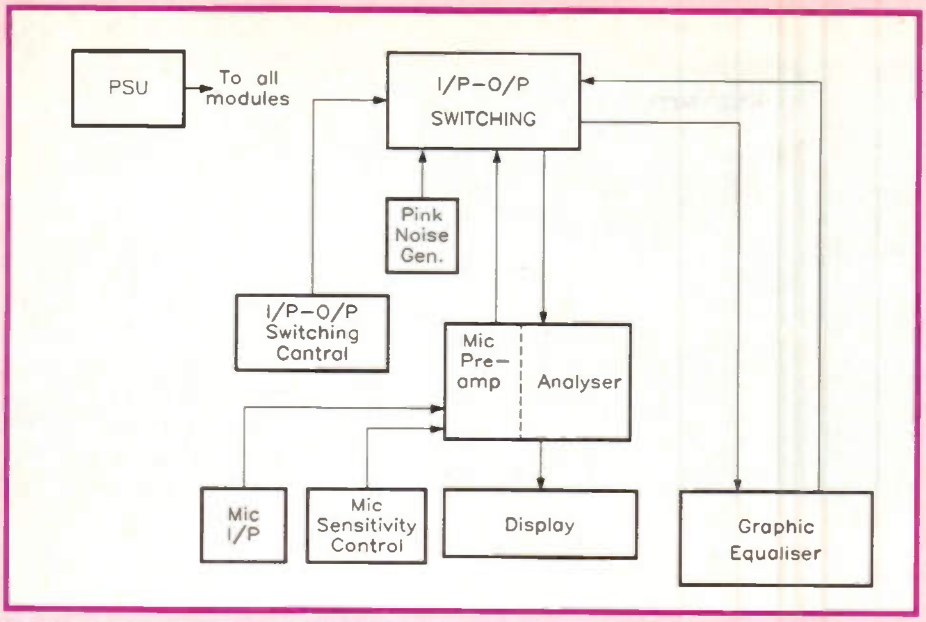



**Figure 1. Block diagram of complete unit.**

## Fitting the Modules into an Enclosure

There are two 2U rack cases available from Maplin, XM68Y and XJ24B, the first is completely unsuitable, whilst the second can be used with a few minor adjustments.

Case XM68Y is unsuitable because of its construction, and internal height dimension which is 2mm too small. The lip on the front and bottom parts of the case will foul the modules mounted on the front panel. Also, the case handles are too far out of alignment with the Equaliser Front Panel.

The internal height of the XJ24B case is also 2mm to small, so with the modules fitted, the lid will slightly bow outwards. This problem can be alleviated by shaving a little of the edges of the PCBs by using a fine flat file. The handles of the case are also out of alignment, but again it is possible to file a little of the front panel to allow the handles to align correctly. The left-hand side panel front lip would also require modification to accept the mains switch.

## Fitting the Hardware to the Front Panel

Before you start the front panel assembly, it is necessary to decide which type of ¼in. jack socket is to be used for the microphone input. If either HF90X or BW78K is used, then the front panel hole will require opening up to a diameter of 11mm.

For each of the countersunk hole positions in the front panel, fit a 6BA x ¼in. countersunk screw, followed by a 6BA shakeproof washer to each of the screws and secure using 6BA ¼in. hex threaded spacers. For the spectrum display, round 6BA ¼in. threaded spacers are used instead of the hex spacers – see Figure 2.

At this stage, it is advisable to temporarily fit the appropriate modules to the front panel so as to check that their positions are correct. The switch module will need slight modification as switches SW2 & SW3 require the mounting lugs, next to the fixing hole, to be bent through 90° towards the PCB. It is important to ensure that the switches do not touch the front panel, and that the potentiometer is in the middle of the hole. The spectrum display LEDs should be flush (or slightly recessed) with the front of the panel, if not, then adjust as necessary. When you are happy with the position of all the modules then remove the modules and store them in a safe place.

Once all the front panel hardware is fitted and in the correct position, double-check that all the hardware is secure. To ensure the finished system looks 'professional', make sure that all the screw heads are below the surface of the front panel and that there are no burrs which could damage the front panel foil – or you!

It may be prudent at this stage of construction to paint the edges of the panel and the fixing holes in the corners of the panel, plus the switch and slider apertures. Remember to allow plenty of time for the paint to dry, otherwise the solvent in the paint will affect the front panel foil glue and legend.

## Fitting the Front Panel Foil

*Please note that when the panel foil has been rubbed down into position, it will be impossible to remove without totally destroying it!*

Clean the front panel with a suitable solvent (DM90X) to remove dust and greasy finger marks. Remove all the debris from the front panel foil cut-outs, then carefully, and accurately, align the foil over the front panel. Once in position, apply a little sticky tape to the left-hand end of the foil to keep it in position. Remove the protective backing from the right-hand side of the foil – *do not tear off*, fold back at right angles, and rub down the right-hand side of the panel foil with a soft cloth working from the centre to the edge – be careful not to trap any air bubbles. Finally, remove the sticky tape from the left-hand side and repeat the procedure for the right-hand side. This procedure is shown in Figures 3a, 3b and 3c.

Using a sharp knife, trim the holes for the sensitivity control pot, microphone socket, front panel handles and fixing holes for a 19in. rack tower enclosure.

The switching unit and both equaliser modules can now be permanently fixed into position with 6BA ¼in. screws and 6BA shakeproof washers. After these parts are in place, the optional ¼in. jack socket can be fitted. The slider knobs (VX18U) can be fitted along with the optional 10mm collet knob (JZ45Y) and cap (JZ61R) to the display level sensitivity control.

## Fitting the Remaining Modules

Drilling details of the rear panel are shown in Figure 4. The exact positions of the pink noise generator, the spectrum analyser filter

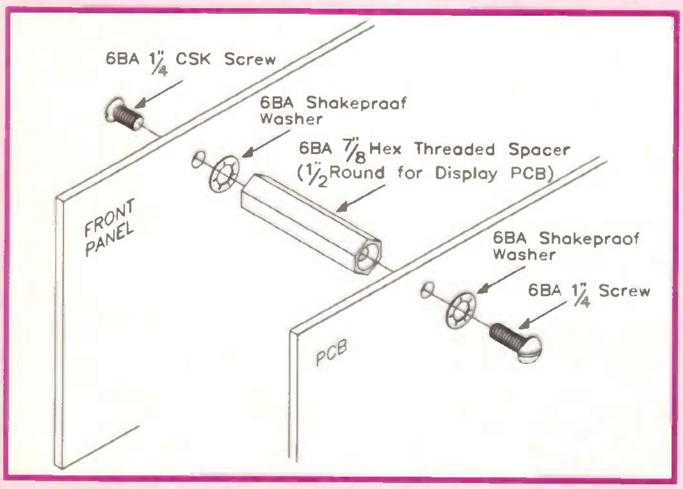



**Figure 2. Fitting the front panel hardware.**

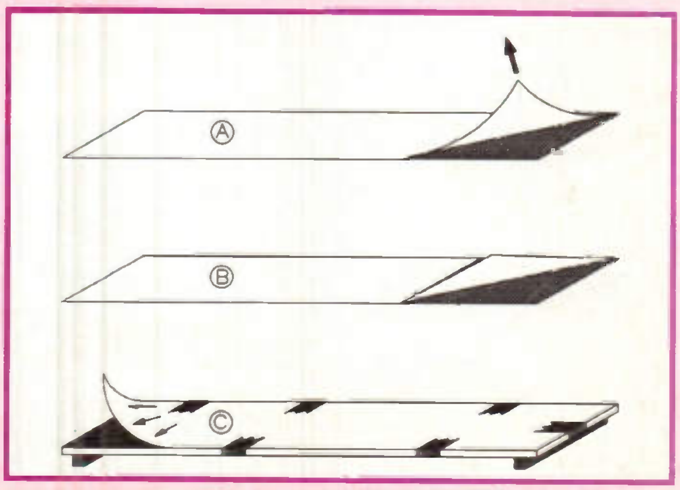
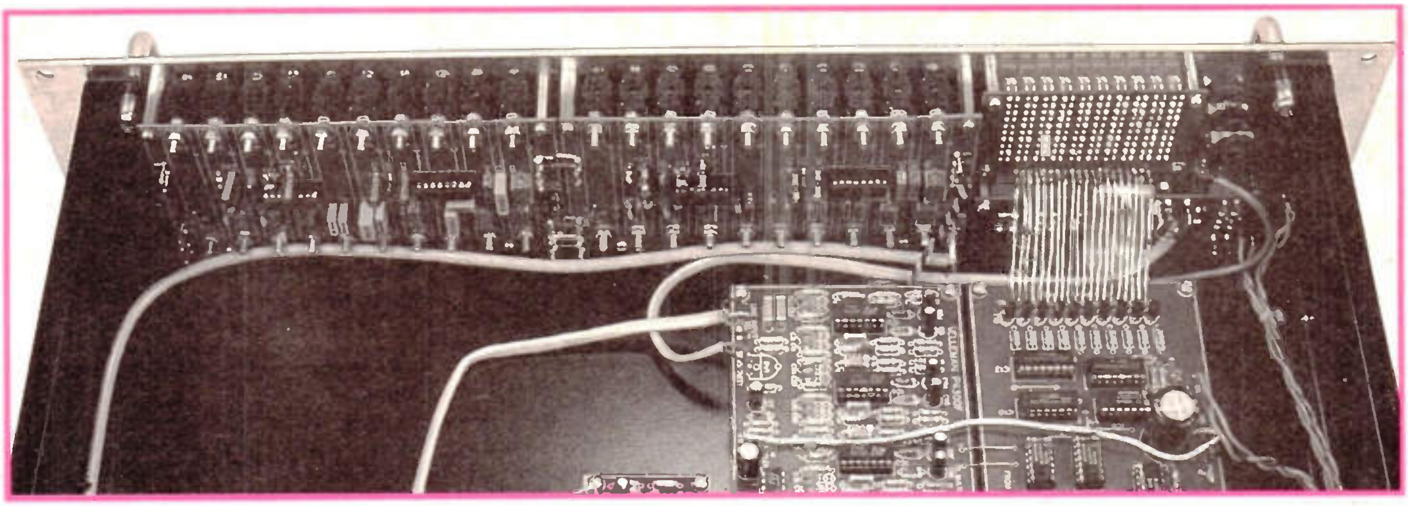



**Figure 3. Fitting the front panel (foil).**



Close-up of front panel from inside.

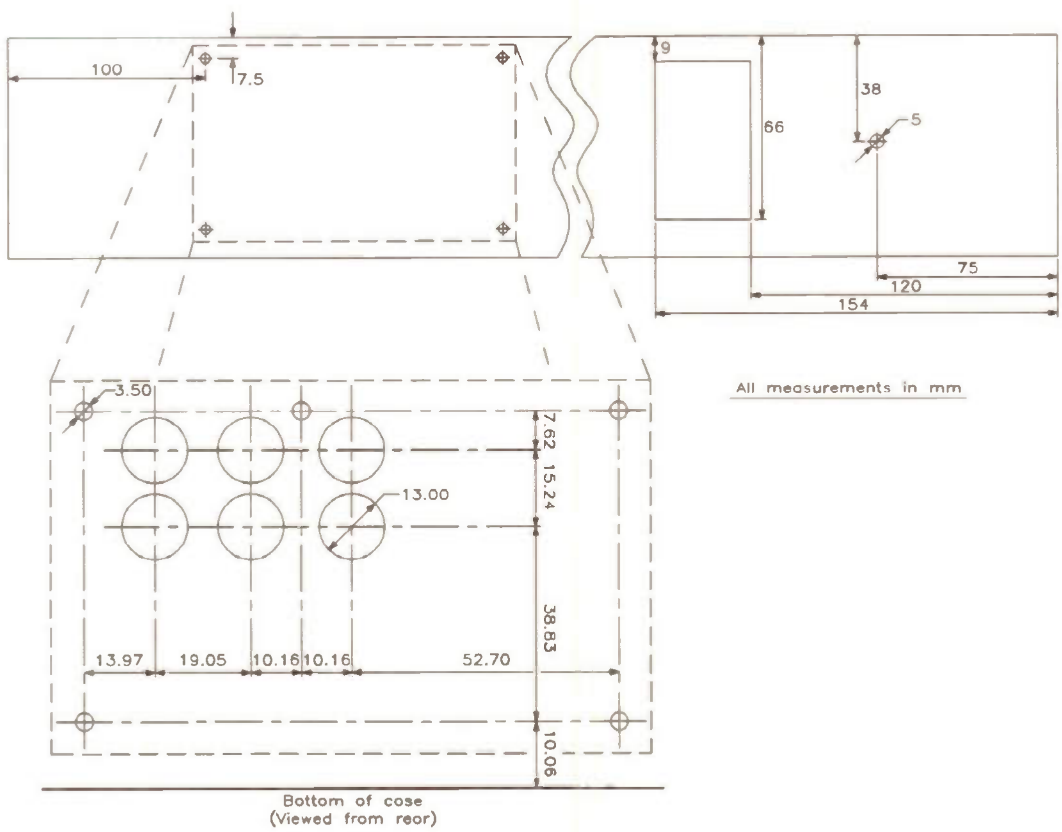
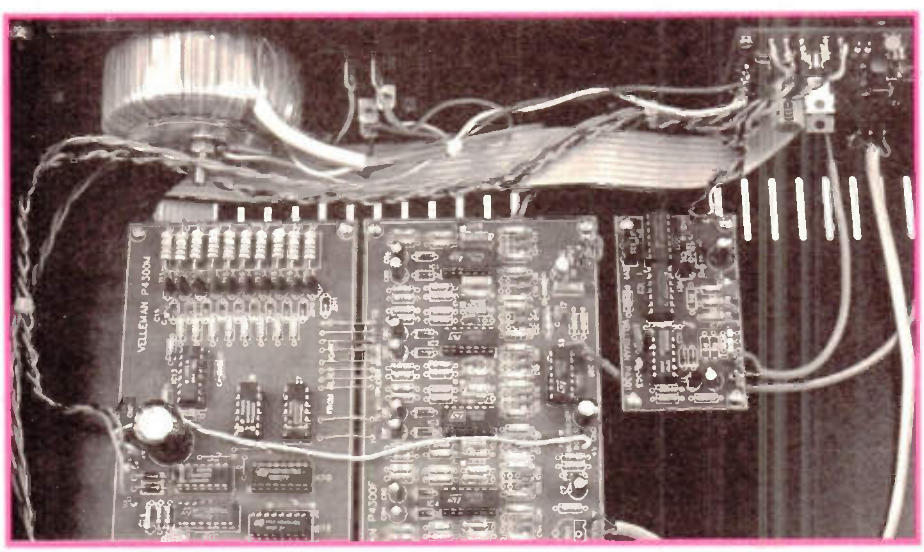



Figure 4. Back panel drilling details.



Close-up of mains wiring.

and multiplexer PCBs within the case is not too important. A suggested plan view of the inside of the enclosure is shown in Figure 5. A short length (approx 70mm) of 20-way ribbon cable should be fitted to the analyser multiplexer PCB before being permanently fixed into position.

For obvious reasons, allow plenty of clearance (at least 5mm) around *all* of the 240V AC mains connections in the enclosure. It is *strongly* advised that *all* connections should be insulated. The PCBs mounted on the bottom of the case should be fitted using 10mm insulated spacers (FS36P).

## Assembling the Case

Once the spectrum analyser filter, multiplexer modules, the pink noise generator and the rear panel mounting

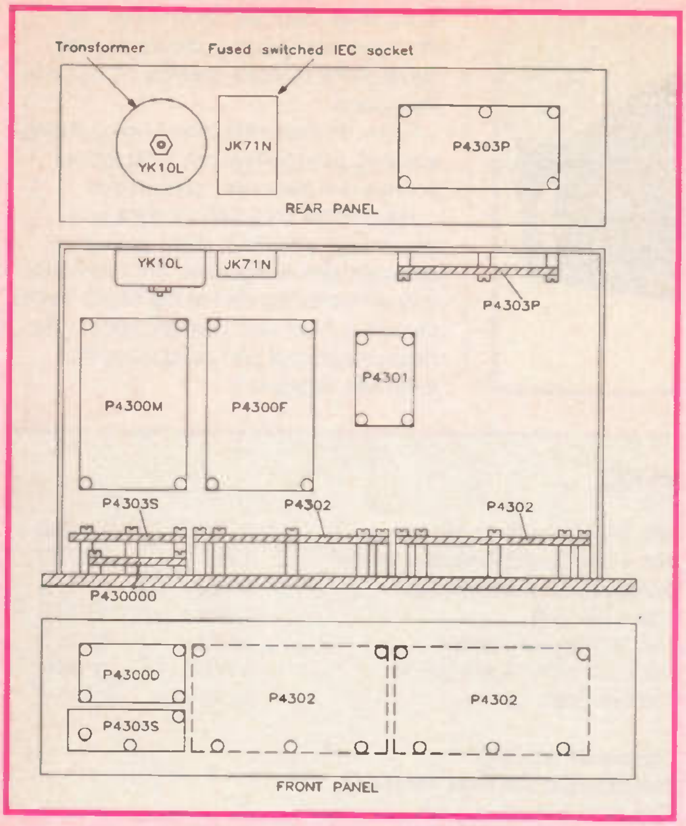



**Figure 5. Layout of modules with transformer, fuse, IEC socket, etc.**

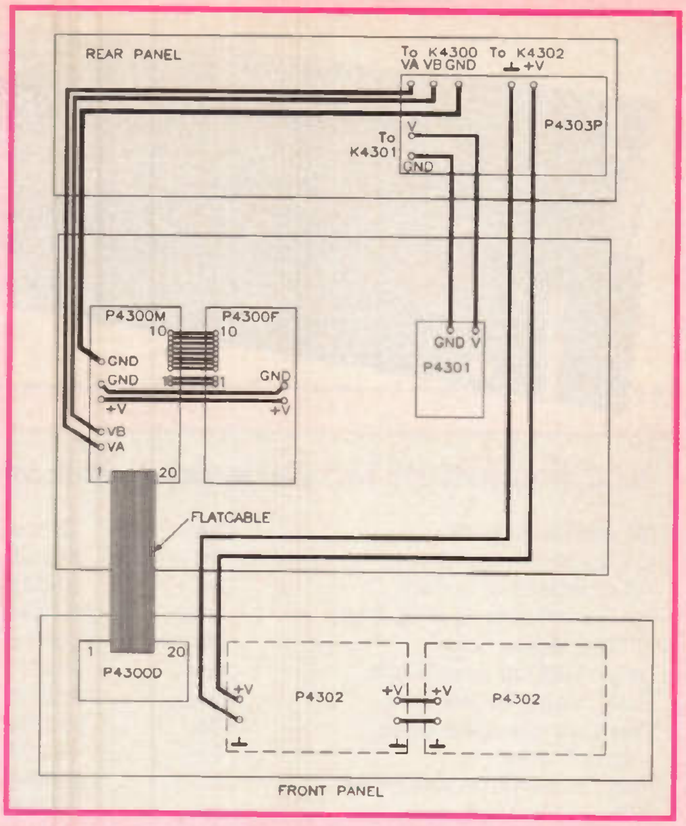



**Figure 6a. Switching PSU to remaining modules wiring.**

power supply module and components have been fitted to the appropriate panels, the front and rear panels can be bolted to the side panels.

Once all the modules, except the spectrum display, have been fitted, check using a multimeter set on the highest resistance range, that there is no electrical connection between the 0V rail of the modules and the case. When you are sure there are no short circuits, the spectrum display can now be permanently fitted.

It is easiest to complete some of the wiring between the modules while the case is in this partially assembled state. The suggested wiring layout is shown in Figures 6a, 6b and 6c, which is discussed in the next section. After completing as much of this wiring as possible, the base panel should then be fitted – the rest of the wiring can then be completed

## Wiring the Modules

Figure 6a shows the connections between the K4303 switch and the PSU modules and the low voltage supply connections to each

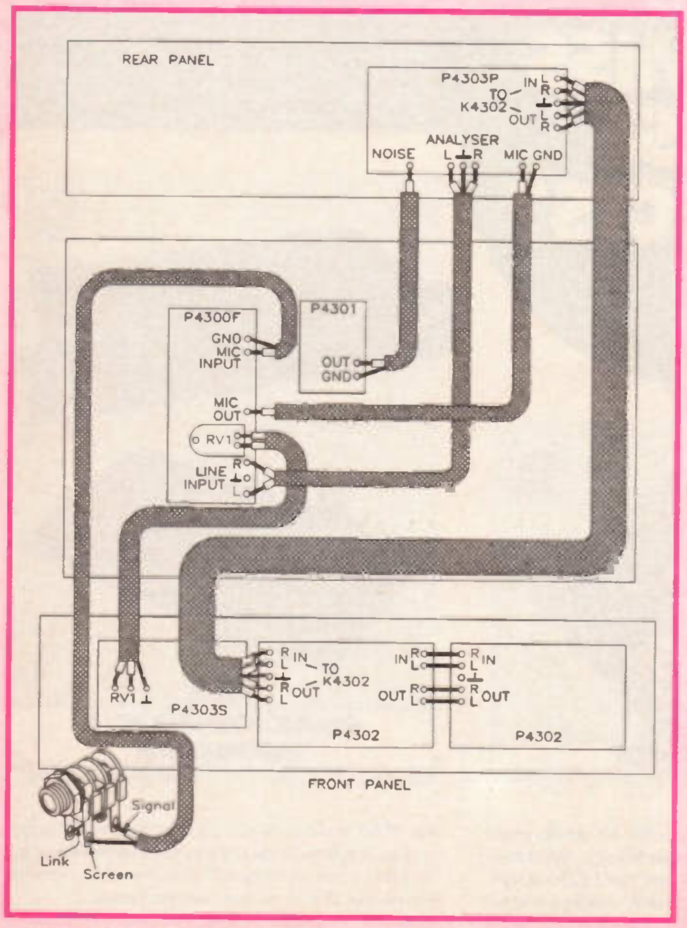



**Figure 6b. Signal wiring.**

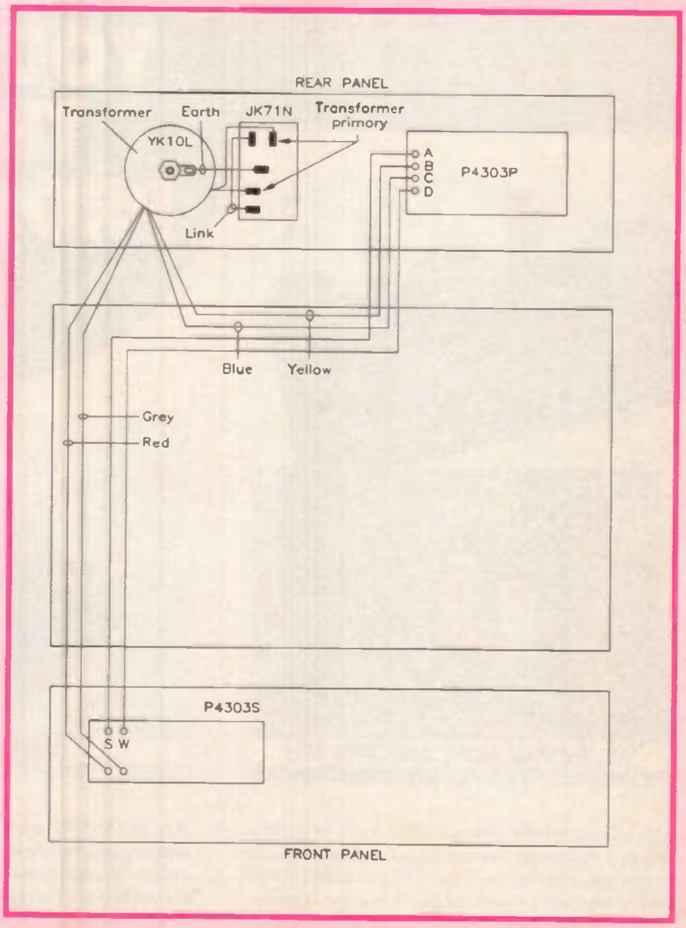



**Figure 6c. Transformer primary, secondary and earthing wiring.**

of the other modules. Figure 6b shows the signal wiring (using screened cable) between the modules and the microphone jack socket.

Figure 6c shows the mains wiring, fusing, earthing arrangement and transformer primary and secondary connections.

Please note; for safety reasons, you are strongly advised to follow the wiring arrangements of Figure 6c. Any alternative way of connecting SW1 to the K4303 switch module is *NOT* recommended due to the close proximity of SW1 pin spacing the enclosure metalwork.

## Additional Parts List (Not included with Front Panel Kit)

| | | |
|---|---|---|
| 3A Red Hook-Up Wire | 1m | (FA33L) |
| 3A Black Hook-Up Wire | 1m | (FA26D) |
| 3A Orange Hook-Up Wire | 2m | (FA31J) |
| 6A Green/Yellow Hook-Up Wire | 1m | (XR38R) |
| 20-Way Ribbon Cable | 1m | (XR07J) |
| Single Core Lap Screen Cable | 1m | (XR13P) |
| Two Core Lap Screen Cable | 1m | (XS23A) |
| Four Core Lap Screen Cable | 1m | (XR92A) |
| 24swg TC Wire | 1 | (BL15R) |
| ¼in. Chassis Mono Jack Socket | 1 | (BW78K) |
| 10mm Collet Knob | 1 | (JZ45Y) |
| Red Collet Knob Cap | 1 | (JZ61R) |
| Fused Mains Inlet Chassis Plug with Switch | 1 | (JK71N) |
| 20mm T200mA Fuse | 1 | (WJ94C) |
| 30VA 2 x 12V Toroidal Transformer | 1 | (YK10L) |
| M5 Solder Tag | 1 Pkt | (LR62S) |
| 6BA x ⅞in. Hex Threaded Spacer | 2 Pkts | (JG20W) |
| 6BA x ¼in. Round Threaded Spacer | 1 Pkt | (LR72P) |
| 6BA x ¼in. Countersunk Screw | 2 Pkts | (LR56L) |
| 6BA x ¼in. Bolt | 2 Pkts | (BF05F) |
| 6BA Shakeproof Washer | 4 Pkts | (BF26D) |
| M3 x 10mm Insulated Spacer | 5 Pkts | (FS36P) |
| 102mm Cable Tie | As Req. | (BF91Y) |

**Optional Parts List**
(Not included with Front Panel Kit)

| | | |
|---|---|---|
| 19in. Rack Mounting Case | 1 | (XJ24B) |

**Order As VE41U (Graphic Equaliser Front Panel) Price £32.95 A1**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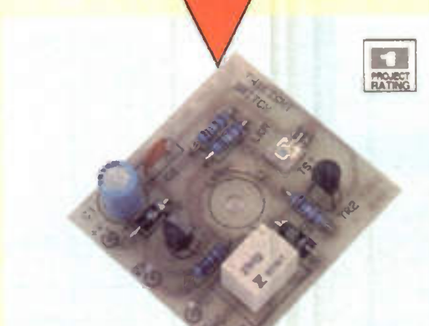


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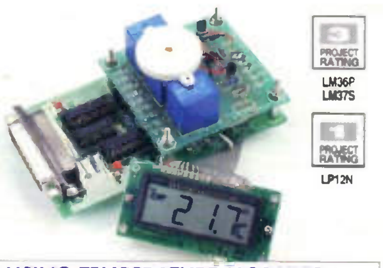


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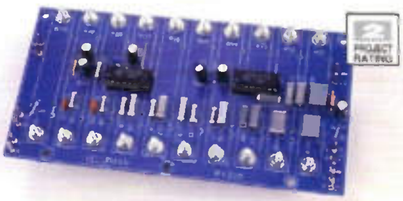

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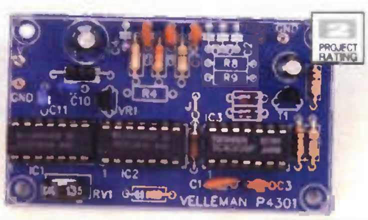


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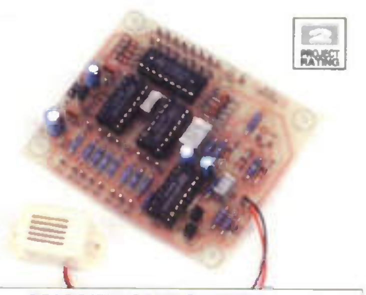

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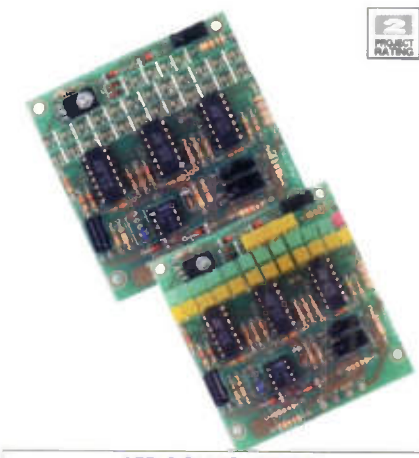

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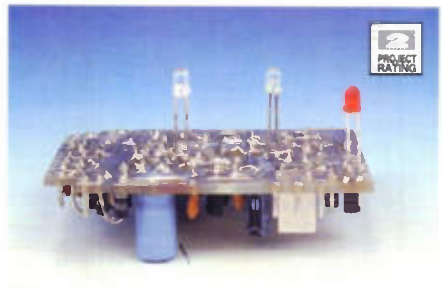

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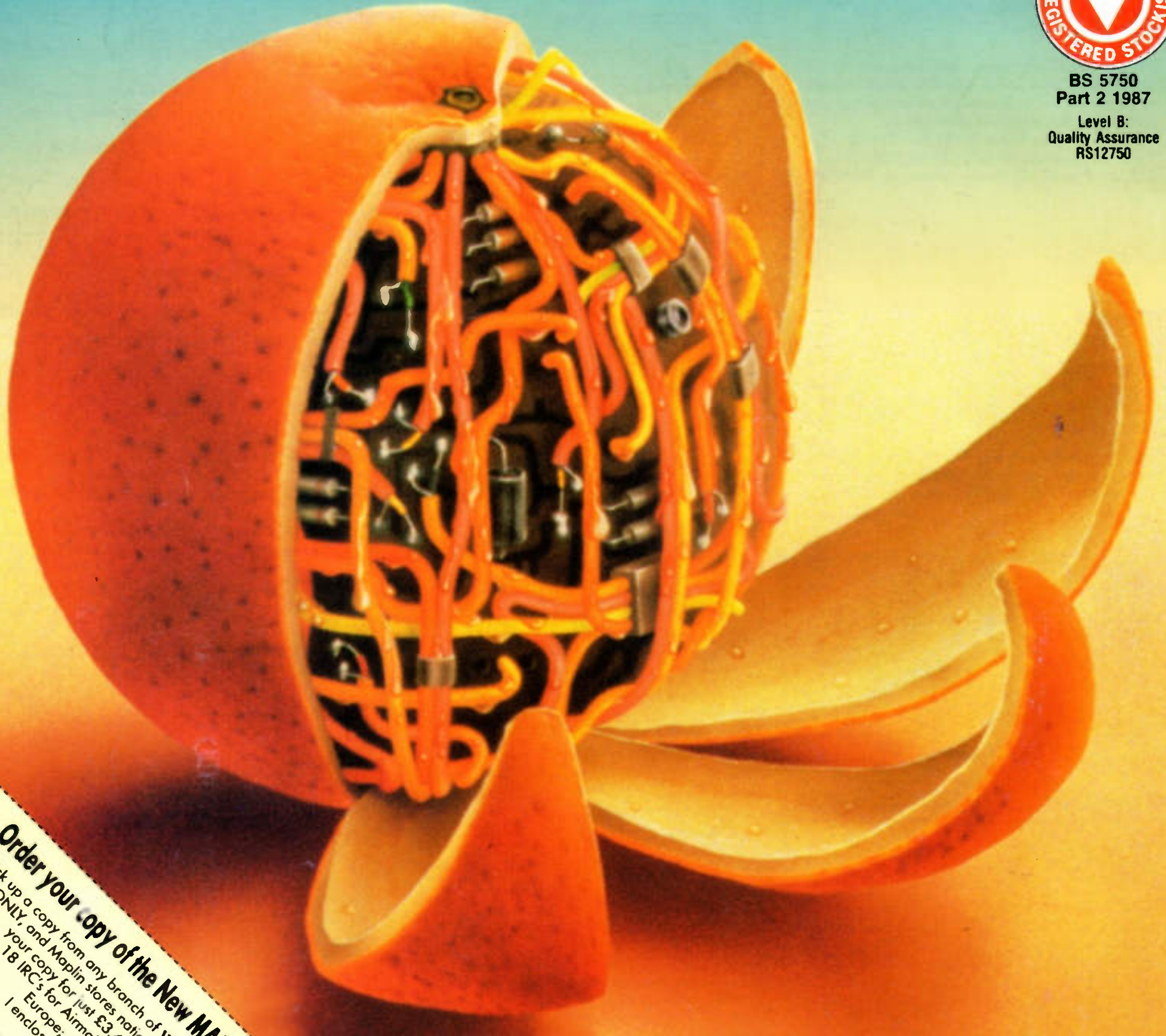

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