SECURITY · AUDIO · COMPUTERS · SATELLITE

No. 70

FULL SOR

ELECTRONICS

The Maplin Magazine

Britain's Best Selling Electronics Magazine

OCTOBER 1993 · £1.95

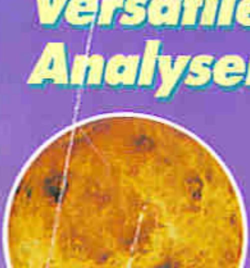
Printed in the United Kingdom

How to Build Your Own PC Weather Monitoring System

Protect Your Valuables With an Easy to Build Loop Alarm

Music to Your Ears – Top Quality 300W MOSFET Amplifier

Optimise Your Hi-Fi With a Versatile Spectrum Analyser

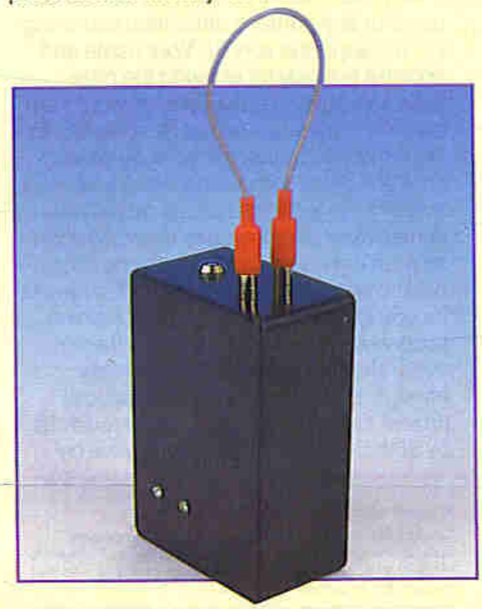


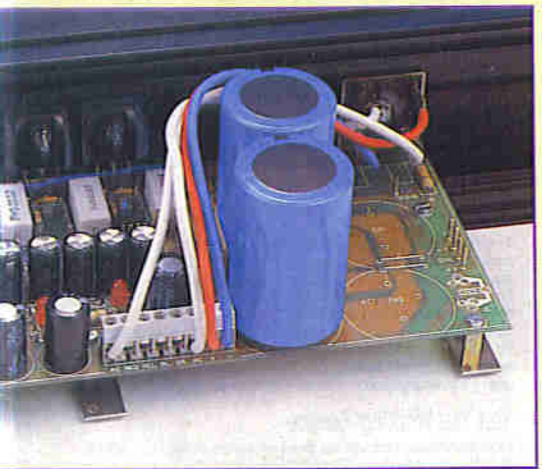
From Paradise to Hell – Science Reveals the Secrets of Venus!

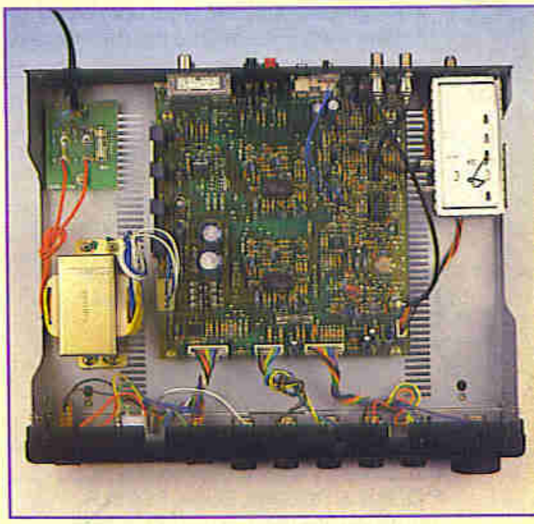
9 770957 545053 10

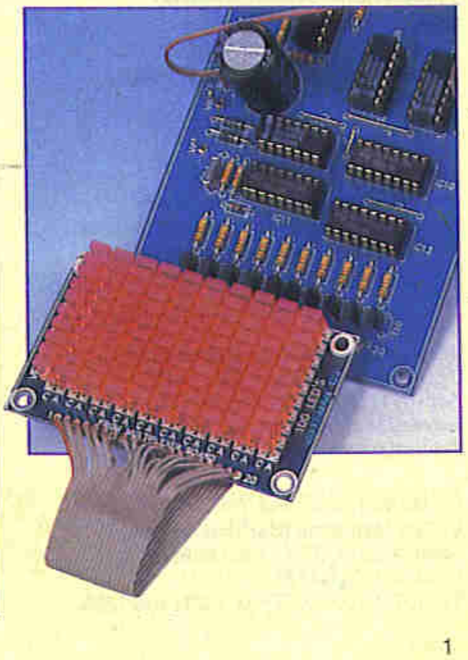
OCTOBER 1993
VOL. 12 No. 70

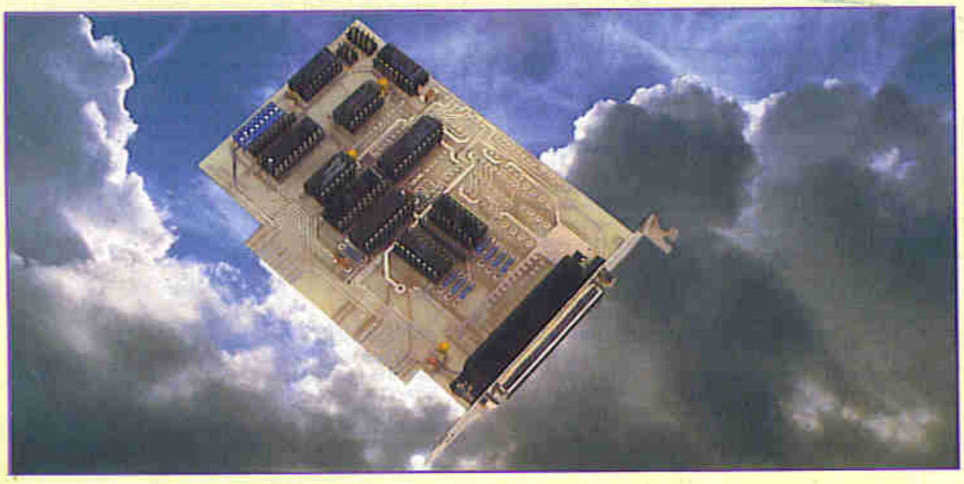
IN THIS ISSUE . . .











ABOUT THIS ISSUE...

For many years *Electronics – The Maplin Magazine* has been Britain's Best Selling Electronics Magazine – and it's still true today! The only reason that this magazine has continued to hold the number one slot is because of you, our valued readers! Each and everyone of you are very important to us; your opinion of *Electronics* is highly regarded – after all if you like what you find in the pages of *Electronics* each month, you'll continue to buy or subscribe; if you don't like what you find, you won't! – it's as simple as that!

Electronics is *your* magazine! For me, as the Editor, the rest of the Editorial team, the Design Engineers and the Authors to give you want *you* want, we actually need to know what *you* want to see in *Electronics* every month! A great many of you write in regularly with ideas, comments, suggestions, likes and dislikes, which has helped guide the content of *Electronics* over the years. So a big thank you to you all for writing in – please continue to do so in the future!

However, over the past few years, many changes have taken place in the world of electronics; electronics as a hobby, the components available, people's expectations of projects and electronics magazines, are all very different compared to a few years ago. So we all feel that now is the time to find out, as accurately and as thoroughly as possible, what our valued readers want. Please take the opportunity to complete the questionnaire in this issue as carefully and completely as you can, it'll be a few years before we conduct a survey of this magnitude again. When you have completed it simply fold it up as shown on page 4 of the questionnaire and pop it in the post – the postage is pre-paid so you don't even need to find a stamp!

As an added incentive for you to return the questionnaire, each questionnaire received will be entered into a prize draw! First Prize is a Superb 40MHz Dual Trace Oscilloscope worth £449.95, there are Ten Second Prizes of £10 Maplin Gift Tokens and Fifty Third Prizes of a copy of the *New Full Colour 1994 Maplin Catalogue* worth £2.95!

Any information you provide will not be used for any purpose other than compiling the results of the survey. Your name and address is solely for entering the prize draw and notifying you if you've won! Your name and address will not be entered into the survey computer nor will it be passed onto any other companies. I guarantee that all returned forms will be destroyed immediately after the prize draw. As soon as all of the questionnaires returned have been processed, we will publish the results for you to see. There's no catch, nothing to spend and nothing to loose! – there's every chance that you might be lucky enough to win one of over sixty special prizes! Your Questionnaire must reach us by 30th September 1993. Prizes will be drawn during October, all winners will be notified in writing soon afterwards. A list of prize winners will also be published in a future issue of *Electronics*.

Also included with this issue is a Free Booklet – A Guide to Making Your Own Printed Circuit Boards, written by Keith Brindley. The booklet was written in response to many of the commonly asked questions (and some not so common ones!) that readers have written in with. I don't suppose it will answer *every* question, but I'm sure you'll find it a handy reference to keep on the work bench.

Also well worth a mention is the publication of the New Full Colour 1994 Maplin Catalogue, available from Maplin, WHSMITH and wait for it Scottish readers!, selected branches of R S McColl in Scotland only. The Catalogue is on sale from 3rd September.

I hope that you enjoy reading this issue as much as the 'team' and I have enjoyed putting it together for you.

ABC CONSUMER PRESS

Front cover picture: © Copyright 1993 Science Photo Library. *False-colour satellite image of a severe storm in the Bering Sea, off the Kamchatka Peninsula, Russia.*

EDITORIAL

Editor Robert Ball AMIPRE
Technical Authors Martin Pipe BSc Hons, Mike Holmes
Print Co-ordinator John Craddock
News Compilation Stephen Waddington
Technical Illustrators Ross Nisbet, Lesley Foster, Paul Evans, Nicola Hull
Project Development Tony Bricknell, Chris Barlow, Dennis Butcher, Alan Williamson, Nigel Skeels

PRODUCTION

Art Director Peter Blackmore
Designer Jim Bowler
Published by Maplin Electronics PLC., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Tel: (0702) 554155. Fax: (0702) 553935.
Lithographic Reproduction by Stirling Graphics Ltd., 16-22 West Street, Southend-on-Sea, Essex, SS2 6HJ.
Printed in the United Kingdom by St. Ives (Caerphilly) Ltd., Mid-Glamorgan, CF8 3SU.

MANAGEMENT

Publications Manager Roy Smith
Development Manager David Goodman
Drawing Office Manager John Dudley
Marketing Manager Vic Sutton

ADVERTISING

Jackson-Rudd & Associates Ltd., 2 Luke Street, London, EC21 4NT. Tel: (071) 613 0717. Fax: (071) 613 1108.
Advertisement Director Colin Pegley
Advertisement Manager James Slater

UK NEWSTRADE DISTRIBUTION

United Magazine Distribution Ltd., Castle House, 37-45 Paul Street, London, EC2A 4PB. Tel: (071) 490 2020. Fax: (071) 490 1239.

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.

Ordering Information

Kits, components and products stocked by Maplin can be easily obtained in a number of ways:

Visit your local Maplin store, where you will find a wide range of electronic products. If you do not know where you nearest store is, refer to the advert is this issue or Tel: (0702) 552911. To avoid disappointment when intending to purchase products from a Maplin store, customers are advised to check availability before travelling any distance.

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.

Telephone your order, call the Maplin Electronics Credit Card Hotline on (0702) 554161.

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 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 3rd September 1993 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 editoral 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.

TECHNOLOGY WATCH!

with Keith Brindley

Changes are afoot in the common-or-garden British High Street. Alongside the traditional shopping arcades, supermarkets, building societies, banks and national retail stores which make most of our towns and cities all but indistinguishable apart from the order in which they appear, now comes the unforgettable sight of kids wired up to electronic money-gobbling machines emitting strange noises, and resultant queues of their clansfolk all eagerly awaiting their chance to mutate into hero frogs, at least for a short while, and throw away Dad's hard-earned money.

Yes, I'm talking about virtual reality, the latest in the never-ending line of electronic games machines – which started with pinball, but is now aided and abetted by computer processing power – where the only reality is a short dash through an interactive (though predefined) sequence of visual images with a large helmet over one's head, complete with internal liquid crystal displays – and that's virtually it! I'm being facetious, of course – aren't I? I mean, anyone who's experienced such a drugless trip knows what it's all about, and also knows that therein lies the future of entertainment. It's all in its early stages, mind you, but the feeling I have is that we'll end up in a world like Ray Bradbury's Fahrenheit 451, where reality is little else but virtual. Still, I've never been over-optimistic about the future of human suffering.

By the end of the year Sega plans to open around ten of these high-technology games centres in the UK, with a further 50 to follow at a later date. Games will be centred around large and expensive virtual reality machines costing around £30,000 each so, like it or lump it, it's a safe bet that the kids will want to hang out there whenever they can. Still, it's (maybe) safer than hallucinatory drugs, and probably only a little more expensive.

Sega plans other things too. At the Consumer Electronics Show in Chicago a few weeks ago, Sega provided details of a new television channel called, originally enough, Sega Channel, which is due to be launched early next year on cable networks in the United States. It might be a little while until it arrives here, I suppose, and when it gets across the Atlantic it will probably be distributed via satellite, since cable has made little penetration in the UK. The idea of the channel is to allow Sega users to be able to download games over the network into their consoles via a special tuner-cum-decoder, and store a game in a cartridge for later use. Games are carried in rotation, and so if you miss a game you want it's simply a matter of waiting for it next time around. The channel won't be free – naturally – but at its proposed cost, of around $20 a month, it will hardly break the bank.

Also shown at the Consumer Electronics Show was Sega's new Edge 16 device – a modem-type transmission adaptor for Sega consoles which lets two Sega players fight out a game over a single standard 'phone line while still in audio communication with each other. Parents, worn down by kids' persistent demands for new game cartridges, now have their phone bills to worry about as well!

Moving quickly onto another subject, our Government recently made it clear that some form of road pricing on motorways was probable in the future. Vehicle drivers wishing to use motorways will be charged for the privilege – the more the driver uses motorways, the more that is to be paid. Apart from the political minefield the whole episode lays down – and I can't say that I agree with the principle in the first place – there is a technical problem too. How on earth can an effective procedure be set up to control pricing? Mechanical toll-gates, for example, could never deal with the volume of traffic our motorways currently carry without causing traffic holdups – probably longer than the motorways themselves! Presumably the answer has to be electronic, in which individual vehicles are detected by a sensor, their motorway usage is totted up and then the users are billed accordingly.

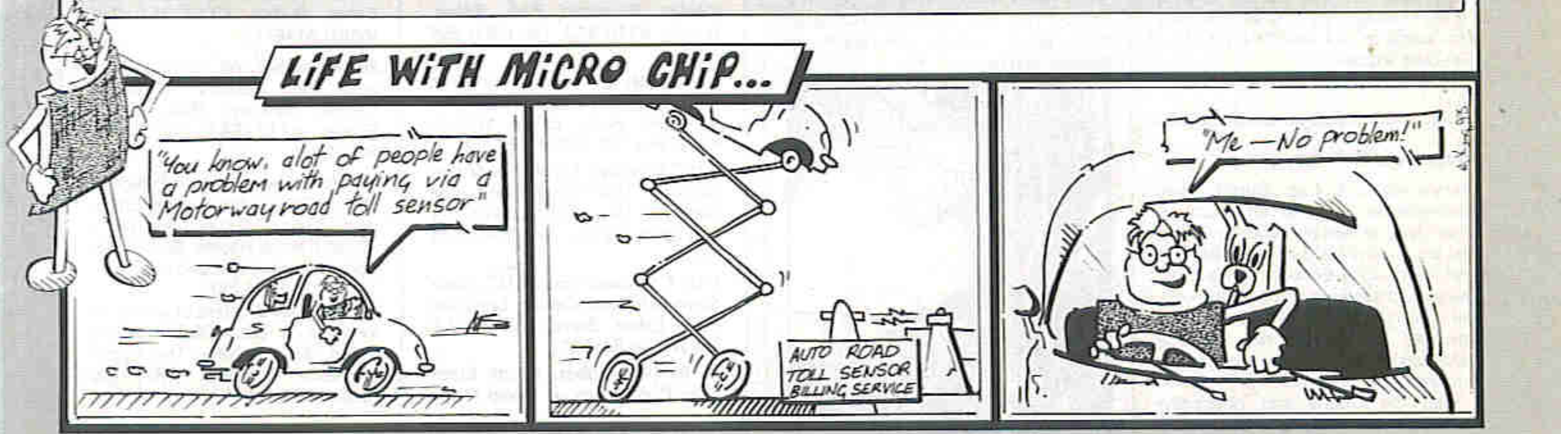
There are a few ways in which this could be achieved electronically. The most effective, in my mind, is a system where vehicles must be fitted with an electronic tag, which is detected by a roadside sensor. Tags are unique, such that a vehicle is immediately identified by the system and the motorist billed accordingly. In effect, this is an electronic licence plate system, which could have the added benefit of ensuring that a vehicle is actually the one it purports to be. If the tag becomes part of, say, an internal identification plate, the illegal repair and sale of unroadworthy vehicles would be a thing of the past.

This isn't a pipe-dream incidentally. Certain London bus routes already have been fitted with such systems to monitor bus positions, and provide passengers waiting at bus stops with details about how long the next bus will take to arrive. A similar system is planned for next year in Birmingham. So it can be done technically; the UK motorway network is simply a lot larger – geographically, and in terms of vehicle numbers.

Whatever system is chosen to allow road pricing, the benefits to the UK electronics and motor industry could be colossal. In a system where an electronic tag has to be installed in a car – every car in the UK – someone has to make the tags, and someone has to fit them. That means a lot of work, generating a lot of jobs. However, there are problems in how the task could be accomplished. Does the Government simply fix a start date, whereby every car must have a tag fitted, and after that date pricing will come into effect. By fixing the date at least three years in advance for already-registered cars, this could be accomplished pretty smoothly, as all cars over three year old must pass the annual Department of Transport test – commonly called the MOT – one component of which could be the tag. All new cars from the time of the announcement must have tags fitted by the manufacturer, and all MOT tests from then on must incorporate tag fitting, too. This means, though, that all drivers of already-registered cars would be charged for tag purchase and fitting – one of the biggest mines in the political minefield, I reckon. And what about cars who rarely (or never) use motorways?

Perhaps a more *ad hoc* arrangement, in which only new cars from a certain date are fitted with tags, might be better. This would be much like the recent legislation to make fitting of catalytic converters onto new cars a requirement for manufacturers. Older cars need not have catalytic converters, but after the cars' lifetime (say, around seven or eight years) all cars on the road (apart from the odd banger or vintage model) would have them. The same arrangement could apply with tags, but this plants another political mine. Cars bought prior to the date cannot be charged for motorway usage, so drivers will be tempted to drive older cars if they do considerable motorway driving. What's more owners of newer cars could remove the tags, fitting them back to the vehicle just before the MOT test; 'sorry Officer, it must have dropped off!', likely to be the driver's excuse if stopped.

Finally, as we've seen, the technicalities present little problem. Decently implemented, Governmental interference could be minimised, while jobs could be created. But how is the system (of whatever electronic form) to be policed? What happens to a motorist who refuses to pay the bill? Are motorway policepersons' lives to be spent hairing after 'can't pay, won't pay' motorists – maybe in convoy – up and down the M1? Is part of the roadside vehicle identification system to be a big hammer which descends on a car whose driver hasn't paid? What happens if – lordy, lordy, it can't surely be true – a computer 'error' defines a driver (who really did pay) a defaulter? After all, a significant number of drivers don't pay the existing road vehicle tax, so I don't suppose they'll pay a motorway 'tax' either!



NEWS Report

Better Bet for Casino Owners

Casino owners have to be constantly on their guard against unscrupulous, and inventive, gamblers – and they are looking to Philips Semiconductors to help them when the chips are down.

One trick that players use is to attach strings to gambling tokens in order to manipulate the tokens inside slot machines. With a little patience, gamblers can become quite adept at bouncing and pulling tokens backwards in order to trigger false credits inside the machine.

To prevent this type of cheating, fruit machines can be equipped with infra-red sensors and receivers to detect the direction of travel of a token. It is at this stage that Philips' 83C751 microcontroller comes into play – it actually monitors the direction of travel as the final step before accepting a token as valid.

It does this by checking the status of the infra-red LEDs to determine the direction of travel. The token has to move forward and pass the infra-red window within a short, specified period of time. If it stops or moves backwards, the microcontroller triggers a tilt indication to notify the casino management.

One reason the 83C751 was chosen for this application is its small size. The microcontroller comes in a 24-pin skinny DIP package and is also available in a 28-pin PLCC package for customers requiring surface-mount.

Economy was another important consideration. As little I/O is required, the low-cost 83C751 is ideal. ROM-coded, the device is less expensive than a customised part and lead-time is much shorter. Furthermore, the microcontroller is compatible with a crystal resonator, which is half the price of a crystal.

Contact Philips Semiconductors on (071) 436 4144.

Cartoon caption: Courtesy of Philips Semiconductors.

Mains LED

Internal limiting in an LED from Oxley Developments allows it to be connected directly to the mains. The hope is that the device will be used as an alternative to neon lamps in mains indicator applications.

You don't have to read the manufacturer's PR puff to see the benefits. The hard facts are that the new device will eliminate flicker, offer more light output, have a greater life expectancy, and will operate clearly at voltages below 50% of the rated voltage.

Constructed from a semiconductor cocktail of AlGaAs, the device is available in five colours with a peak wavelength of 500nm and operating voltage of both 110V and 240V AC.

Further details from Oxley Developments on (0229) 582621.

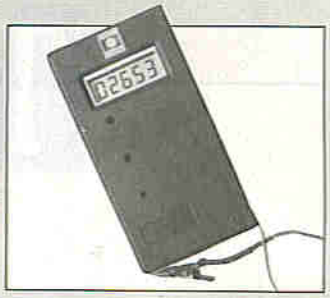
Virus Killer for the Archie

Most PC and Apple Macintosh users are aware of the danger of viruses, and are equipped with a suitable piece of software ready to identify and terminate any disruptive programs. Unfortunately, this is not always the case for other computer formats. Like all things, though, the sinister-minded have realised that what is applicable to one type of computer, can easily follow through to others.

New strains of virus have now evolved for the Archimedes and the Atari. Aware of these problems, a company called Digital Phenomena of Portsmouth have developed a public domain Virus Killer called Guardian, capable of destroying all known viruses on the Archimedes. What's more, Digital Phenomena promise to provide free upgrades and technical information to users for life. They also ask users to send them new viruses not recognised by Guardian, so that they might produce effective antidotes.

At a minimal cost of £9.95 for the professional version, take up has been good, with numerous schools opting to purchase the slightly more expensive site-licensed version.

Contact Digital Phenomena on (0705) 871530.



New Market Research Tool Uses Components from Maplin

Global Systems Ltd. have released advance details of their new SelectaCount, to be launched shortly. The movement detection systems was originally developed to trigger electronically stored promotional messages for point-of-sale displays. Adapted for SelectaCount, the system now provides a simple to use, low-cost sequential counter for numerous market research applications.

Incorporating a case and counter from Maplin, the system is currently undergoing final trials in the shops at Gatwick Airport before being made available to the retail market. When launched, the new product will allow companies to detect how people move about their shops, gauging how best to set out a shop floor. Uses are numerous and far-reaching. It is hoped that the product will demonstrate the effectiveness of shop window displays by indicating how many of the people passing stop to observe the contents.

Anthony Prior, Global Systems' Managing Director, says interest so far has been excellent, especially since it is likely that the units will be available for hire from as little as 75p per week. Details of how the system works are currently being protected until the design has been registered. It's a fair bet, though, that the SelectaCount works by measuring the minute changes in capacitance that a body creates.

Contact Global Systems Ltd. on (0273) 329880.

Computer Vision Screener

London's City University has launched a vision screener that will help users of VDUs at work to identify eyesight problems associated with their equipment. Providing a series of on-screen vision tests, the screener is used to assess if the user is experiencing any difficulties.

Under European Community regulations adopted by the UK this year, employers are obliged to provide regular eye tests for VDU users. There is, however, a clause allowing for vision screeners, which, with employee consent can act as a buffer and avoid costly visits to the opticians.

The product, developed by the University's Department of Optometry and Visual Science, will be sold by London-based City Visual Systems. The screener will sell for £495 for a 100-user licence.

Contact City University on (071) 628 5641.

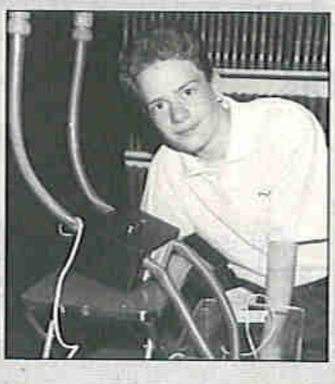
Duracell Winner

Fifteen-year-old Leo Currie, from Pollokshields, invented an automatic bath-filler that won his school a £1,000 first prize in the 1993 Duracell Science and Technology Schools competition. Duracell challenged students throughout the UK, to design a battery-powered device that has practical value and demonstrates imagination, creativity and innovation.

With the elderly and physically-handicapped in mind, Leo designed a device that will run bath water to a preset temperature and/or turn the water off as soon as it reaches a desired level. The taps are turned on using a simple push switch.

Leo sensibly chose inexpensive components, rather than using much simpler, but more expensive options. He used a bead thermistor to sense bath water temperature and, to detect when the water has reached the required level, he devised a sensor that makes use of the resistance of the water itself.

Leo's device solved not one but two quite complex problems – temperature sensing and level sensing. As a result, he proved to the competition judges that he has a good understanding of basic electronics and the ability to put it to practical use. Apart from the cash prize given to his school, Leo will shortly visit the Duracell Worldwide Technology Centre in Needham, Massachusetts.



Events Listings

8 and 9 September. Cabling World. Sandown Exhibition Centre, Sandown Park, Esher, Surrey, KT10 9AJ. Tel: (0932) 820100.

11 to 12 September. Hi-Fi Show. Heathrow Penta Hotel. Tel: (081) 686 2599.

18 September. The History of Crystal Palace by Ian Bevan of The Crystal Palace Foundation. 7.30p.m., All Saints Parish Church Rooms, Beulah Hill, Upper Norwood, London, SE19. Tel: (081) 699 5732.

29 to 30 September. Highways Roadshow. Sandown Exhibition Centre, Sandown Park, Esher, Surrey, KT10 9AJ. Tel: (081) 684 4082.

2 October. All Formats Computer Fair. Sandown Exhibition Centre, Sandown Park, Esher, Surrey, KT10 9AJ. Tel: (0608) 662212.

5 to 7 October. Electronics Manufacturing Technology Show and Electronic Design Show. Wembley Exhibition Centre. Tel: (081) 336 1282.

5 to 7 October. Euro-EMC. Sandown Exhibition Centre, Sandown Park, Esher, Surrey, KT10 9AJ. Tel: (0892) 544027.

11 to 14 October. Fourth European Conference on Radio Relay Systems, Edinburgh. Tel: IEE Conference Services (071) 344 5469.

16 October. Crystal Palace & District Radio Club Quiz Night. 7.30p.m., All Saints Parish Church Rooms, Beulah Hill, Upper Norwood, London, SE19. Tel: (081) 699 5732.

19 to 21 October. Comex '93. Mobile Communications Exhibition sponsored by the Federation of Communication Services, Wembley, London. Tel: FCS (081) 778 3343.

16 to 18 November. Electronic Information Display. Sandown Exhibition Centre, Sandown Park, Esher, Surrey, KT10 9AJ. Tel: (0822) 614671.

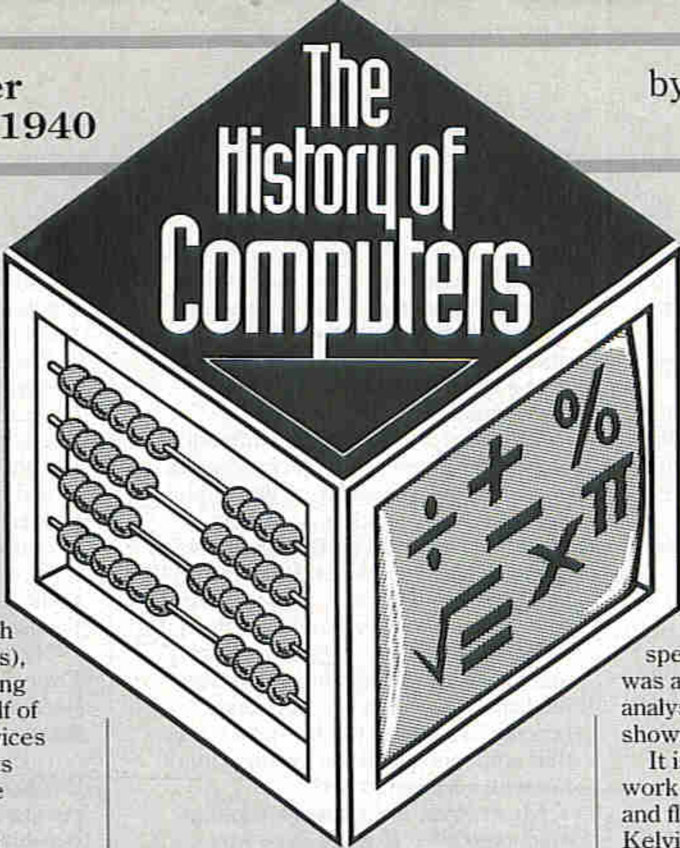
20 November. All Formats Computer Fair. Sandown Exhibition Centre, Sandown Park, Esher, Surrey, KT10 9AJ. Tel: (0608) 662212.

29 November. Crystal Palace & District Radio Club Surplus Equipment Sale. 7.30p.m., All Saints Parish Church Rooms, Beulah Hill, Upper Norwood, London, SE19. Tel: (081) 699 5732.

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

7. Other Men, Other Machines: 1870 to 1940

by Gregory M. R. Grant



In the seventy years covered by this part of the story, science and its acolyte, technology, made staggering advances – and as they did so, one factor continued as it had always done. Mathematical calculations became as complicated as the engineering problems that made use of them; in particular, differential equations got more and more complicated.

Now you can tackle such equations either numerically (with figures representing the variables), or graphically (the curves replacing the figures). During the latter half of the last century, quite clever devices were thought up to help scientists and engineers grapple with these problems. In the early 1860s, for example, the British scientist Professor James Thomson invented the mechanical integrator, which is shown in Figure 1.

As the sphere (b) rotates along the diameter of the disc (a), it transfers the disc's motion to the cylinder (c). The sphere's velocity depends on the disc's speed, and on the distance between its centre and the sphere's point of contact with it. So the sphere is a parameter, which 'integrates' the disc's rotary motion onto the cylinder. Thomson's younger brother William was also a scientist and mathematician, in fact the most famous British physicist of his day – better known as Lord Kelvin. In about 1870, he realised that his brother's integrator could help in his current work on tides.

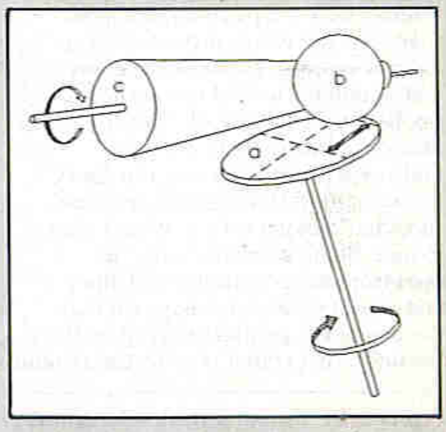
Consequently, he built three special machines – one of which was a tidal gauge, another an harmonic analyser, while the third was that shown in Photo 1.

It is a tide predictor which could work out the height and time of the ebb and flood tides for any day of the year. Kelvin later wrote that his analogue device replaced brain tissue with brass and saved a great deal of human energy in the process. He also realised that if someone took his device further, it could – quite possibly – solve complicated differential equations.

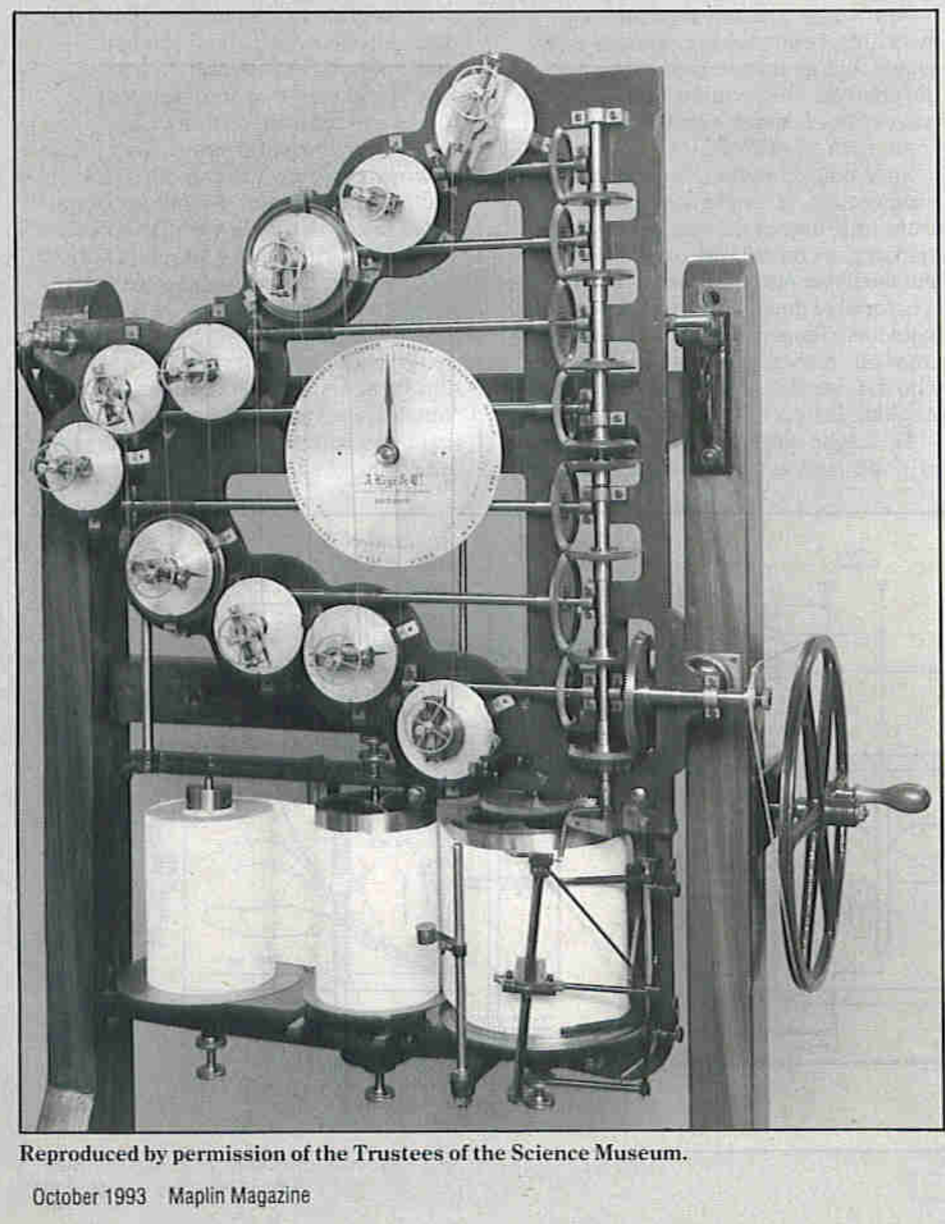
He even wrote a paper on the subject called 'On an Integrating Machine Having a New Kinetic Principle', which he presented to the Royal Society in 1876. In fact Figure 1 is taken from it.

Almost half a century would pass before someone would take Kelvin's idea further. And, like Kelvin, he too was plagued by the same problem – mathematical complexity.

Vannevar Bush's work on electrical power failures was stuttering to a halt because he and his team were



Above: Figure 1. Professor James Thomson's mechanical integrator, the underlying principle of Bush's 'Integraph' and Lord Kelvin's tide predictor.



Left: Photo 1. Lord Kelvin's tide predictor. Completed in 1873, it was the first automatic analogue calculator. It combined a maximum of ten simple waves into one wave, or tide prediction on the drums at the bottom.

drowning in differential equations of ever-increasing complexity. In fact he, and one of his electrical engineers, Ralph Booth, took months to crack just one problem on transmission line stability doing it the hard way, with graphs and diagrams. As Bush saw it there had to be a better way of handling this kind of problem. He decided that the way ahead lay with a machine.

Bush had joined the staff of the Massachusetts Institute of Technology (MIT) in 1919, after a period of research on submarine detection.

In the 1920s he devised what he called a 'Network Analyser' or 'Integraph', to mimic the behaviour of large electrical networks. In 1930, in a now-classic paper – from which Figure 2 is taken – two of Bush's engineers, W. V. Lyon and H. E. Edgerton, outlined how the Integraph worked, and the type of problems it could solve. This led, in turn, to the Differential Analyser, on which Bush and his team began work in 1927. Three years later, the first analyser was put to work.

It looked like nothing so much as a series of X – Y plotters strapped together, the whole driven by large electric motors, thermionic valves and a complex web of metal shafts. So, how well did it work? Was it efficient? Surprisingly well, and quite impressively so, are the short answers. It did have some problems, though. To begin with, it wasn't easy to use. Being semiautomatic, its operators were seated at the input and output tables to make sure that the machine's pointers stayed on track. Secondly, data input was via three input tables, and setting up frequently took a couple of days at least, due to the rearranging of gears and connecting shafts. No matter; what was two days and a mere 2% inaccuracy, compared to the months Bush and Booth had spent cracking one problem?

The Analyser became an influential device. It ended any lingering doubts about machine calculation, and copies of it were built in other countries, including Britain. The British physicist Douglas Hartree visited Bush in 1933, and used the Analyser. On his return to Manchester, Hartree and his colleague, Arthur Porter, spent £20 on Meccano and built a similar machine. Hartree explained later that his immediate reaction on seeing Bush's device was that someone had been having a lot of fun with a Meccano set!

Meanwhile, in Germany, a young engineer called Konrad Zuse was rapidly coming to the same conclusions that Kelvin and Bush had reached, namely that the maddeningly difficult equations of his profession had to be cracked in a swifter, more efficient way.

Knowing a great deal about mechanical engineering, he was well aware that gears and cogs were not the answer. His solution was to be a universal calculator – one that could crack ANY problem!

Zuse quickly settled on main components. It would have an arithmetic unit or central processor, a memory, a control unit or programmer, and finally an output attachment. Its creator also decided that his calculator would use binary, rather than decimal, notation. And this from an engineer who'd never even heard of Babbage, let alone Boole!

He began work on his first machine in 1936, completing it two years later. The Z1 wasn't a success, however, because the arithmetic unit didn't carry efficiently, and rarely functioned in tandem with the memory.

Zuse's next effort – the Z2 – was electromechanical and used the same 64-number memory store as the Z1, but its arithmetic unit used discarded telephone relays. Both machines would be regarded today as prototype research projects, for the development of concepts and practicalities. Whether Zuse intended them as such is a moot point, but they certainly helped him to finalise his ideas on a computer.

His employers, the German Experimental Aircraft Institute, had been impressed by Z2, and decided to finance a more advanced model, the Z3.

A small device, relatively speaking, it contained some 2,600 relays, a tape reader and a tiny memory which was capable of storing a mere sixty-four 22-bit numbers. However, from its operator's console, Zuse could find square roots as well as carry out the four basic mathematical manipulations. It was moderately fast, too.

In service by December 1941, this calculator – on which its originator had spent 6,500 US dollars – was the world's first general-purpose, program-controlled computer.

At this time, of course, World War Two was raging – and many of the most savage battles were fought far from the front lines, in a wide variety of research institutes. Both sides sought a variety of unholy grails from guided bombs, to all-penetrative radars, to atomic power. One laboratory, though, was looking into something completely different – shell trajectories. Next month, we'll look at what this outfit came up with, and how it has affected all our lives since.

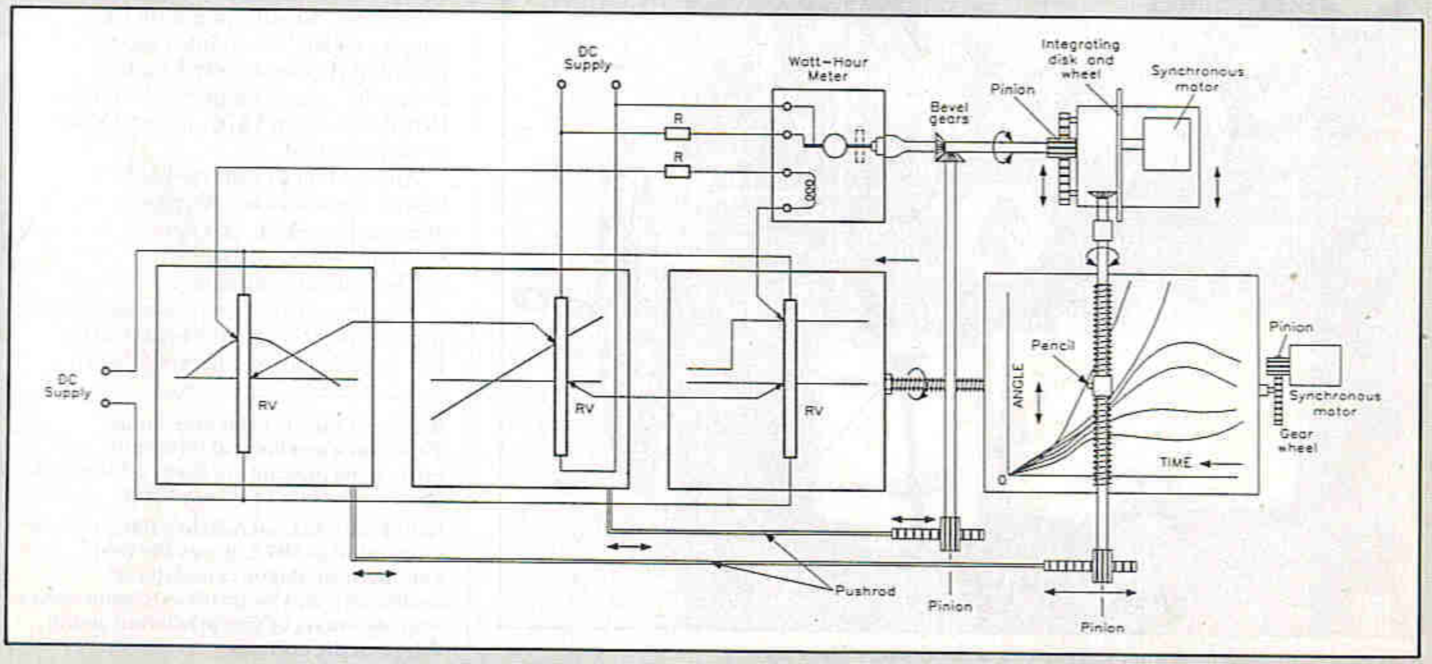


Figure 2. Dr. Vannevar Bush's 'Integraph', built to solve the complex equations involved in large electrical networks.

AIR YOUR VIEWS

More Valve Vagaries

Dear Sir,
Whilst it's nice to once again see articles on valves in electronics magazines, its a pity the information isn't correct. With reference to Mr. G. Dixey's Valve Technology article in the August issue, he states that:

$$VAF = g_m \times R_{eq}$$

This is only approximately correct and only then if $r_a = R_{eq}$, and therefore only used for pentode amplifiers due to their very high r_a. The correct formula is:

$$VAF = \frac{g_m \times r_a \times R_{eq}}{r_a + R_{eq}} = \frac{m \times R_{eq}}{r_a + R_{eq}}$$

Taking as an example the 12AX7/ECC83 with a 220K anode load:

$$VAF = \frac{100 \times 220}{80 + 220} = \frac{2200}{300} = 73{\cdot}3$$

using the formula given
$VAF = 1{\cdot}25 \times 220 = 275$!

In the case of a pentode such as the EF86 with an anode load of 50k. g_m = 2mA/V and r_a = 2,500K (2·5MΩ):

$$VAF = \frac{2 \times 2500 \times 50}{2500 + 50} = 98$$

and with the simplified formula $2 \times 50 = 100$ which is close to the correct value.
I'm quite interested in the 20W valve amplifier mentioned in the letter's page, but hope the circuit is better than the one in Velleman Kit reviewed in the March 1992 issue. The use of a concertina phase splitter was always thought to be 'iffy' in a Hi-Fi amp in the 60s due to the unequal impedances between the anode and cathode outputs. A twin triode 'long tailed pair' type was my personal preference with the anode loads adjusted for equal drive voltages.
The use of a transistor constant current source instead of the high value resistor in the cathodes may be an improvement and allow equal value loads.
Colin Eynon, Mid Glam.

Graham Dixey replies:
Thank you for the letter referring to one of my articles on valve technology. I try quite hard to ensure that errors, whether of fact, spelling or grammar, do not find their way into my articles but, being human, occasionally I let one slip by. It isn't actually that the formula for VAF is incorrect, but that I have not defined R_{eq} should itself include the value of r_a – then the formula becomes universal; the low value of r_a for triodes is taken into account and the high value of r_a for pentodes then has little effect on the calculations. I have included a more detailed explanation in Part 3 of the series.
How did the error occur in the first place? I think it is a matter of switching off my brain occasionally when I'm typing! I have been in the electronics business, in one guise or another, since 1950, so I have a fair degree of familiarity with valves, especially as I once used to teach the subject. Nonetheless, I accept that I made a mistake; thank you for taking the trouble to write in and point it out. I do, however, think that it is perhaps a little strong to condemn the entire article on the basis of this single error, which is what the wording of your letter seems to do.

Mike Holmes (designer of the 20W Valve Amp) replies:
You'll be pleased to know that Maplin's amplifier uses the double-triode long-tailed pair. While you may be right that there are differing anode and cathode impedances in the single triode version, the current is in fact the same and so, with identical value anode and cathode resistors, the antiphase signal voltage drops are also the same. However, too low a value for the following stage's grid leak bias resistors might upset the balance, e.g., a loaded cathode end causing higher output at the anode, but this is unlikely in practice as these are rarely less than 500kΩ. The main disadvantage though is that the stage has no voltage gain.
The twin-triode, push-pull long-tailed pair however, has inherent gain and equal output impedances. The disadvantage is that there may be a signal loss at the non-inverting output, but if the triodes are high-gain types (the ECC83 works well in this circuit) it is very small. It may be eradicated by a current generator as you suggest, but the simpler method is, as you say, to increase the anode resistor of the non-inverting output very slightly to restore the level. Experimenters take note, however; the DC drop across the common cathode resistor must equal (or nearly) that across each anode resistor, e.g., 80 to 100V. 2V is no good!
Each configuration has its pros and cons, and everyone has their personal favourite.

S·T·A·R L·E·T·T·E·R

This issue, J. S. Murray from Huddersfield, West Yorkshire, receives the Star Letter Award of a £5 Maplin Gift Token for describing his use of electronics in ornithology.

£5 Gift Token

Birdwatching with a 555 Timer

Dear Sir,
There was an article recently on the 555 timer IC and its many uses.
I use the device as a bird counter which clocks up the number of visits made to a tit-box in the garden. From this you can tell when the birds are building a nest, and gives a good estimate when the young birds are due to fly, and not missing out seeing their start in the world. When feeding their young, the parents will make over 800 visits a day at the busiest time.
Many people have bird boxes, and 'converting', them only involves putting a light sensitive resistor facing inwards on the circumference of the hole. This should be done well in advance of the nesting season, so the birds get used to their new electronically tagged home.

A very novel use, proving that the 555 Timer IC is a versatile little beastie. Perhaps you may consider sending in your circuit for publication – we could feature it as a 'Circuit Maker' design.

Spectrum Magazine! What Spectrum Magazine?

Dear Editor,
I refer to the letter from Mr M. R. Perry, Kidderminster, Worcs in the 'Air Your Views' column in Issue No. 69.
No doubt Malcolm will also be writing to you, because you were not 'of service to all of our Spectrum-equipped readers!' since you failed to give them the necessary information.
For the record, the disk-based magazine is OUTLET, it is published by Chezron Software, and their (recently changed) address is 34 Saltersgate Drive, Birstall, Leicester LE4 3FF.
Aland D. Cox, Dyfed.

Whoops! The address somehow ended up on the cutting room floor – excuses, excuses!

Charging Up Your Caravan

Dear Sir,
I am a keen caravanner who, like many others, enjoy getting away from it all into the countryside. This generally means weekend camps and holidays on temporary or unlisted sites where there is, of course, no mains electricity supply. The caravan battery then becomes the only source of electrical power, so ensuring that it is being properly charged by the 'split charge circuit' on the tow vehicle becomes important.
I would like to briefly relay two of the more extreme incidents that have happened to me whilst caravanning.
The first weekend camp of the season is always a bit of a rush, but eventually we got away on the Friday evening and towed for a few hours arriving at the site at dusk. We then found that we had no electrical power; indeed we did not even have the battery. It was still in winter storage in the garage.
On another occasion we were on a touring holiday when one evening the lights in the 'van suddenly dimmed as the battery announced that it was flat. This, of course, should not have been as the 'van was being towed daily. The following morning I found that the fuse was missing from the split charge circuit. It subsequently transpired that my son had 'borrowed' it to fit into his car, but had forgotten to mention it to anyone.
From the above it is clear that a project for a 'split charge current monitor' would be of considerable interest to myself and many others who tow caravans or charge auxiliary batteries for whatever purpose.
When the caravan is not coupled up there is no split charge current, but when it is connected even a fully charged battery draws some current. By detecting the presence of a definite split charge current and indicating it by illuminating a small LED on the dashboard the driver can be sure that the split charge circuit is operating properly. I suggest a small LED as it is virtually impossible to mount any other form of instrument inconspicuously on the cluttered and complex dashboard of a modern car. Perhaps a multi-coloured LED could be used to give some indication of the magnitude of the current as well as its presence.
In most vehicles the split charge relay is housed in the engine compartment at the front, and the 'S' socket is on the tow bar at the rear.
The two are joined by a (hopefully) stout cable which is several metres in length, and therefore exhibits a small but measurable voltage drop when current is being drawn. In my own vehicle the connection is made with about 4m of 4 sq mm wire which has a resistance of about 0·02Ω. By using the voltage drop between the ends of this cable the current can be measured without adding any additional resistance to the split charge circuit.
My expertise lies in the field of computer systems, so my design for the above monitor would involve A to D boards, pulse width modulation of the segments of the LED from a parallel port and a PC in the boot of the car! I am sure there is an easier way.
J. K. Richards, Chelmsford.

Thanks for your suggestion, it has been passed to the lab; the unexpected inconvenience of having no lighting (or television!) in your caravan can really put a damper on your holiday excitement. Hopefully, a suitable project will be forthcoming before the next holiday season!

PROJECT RATING 2

PC Weather Station

by Dennis Butcher

KIT AVAILABLE
LT28F
PRICE £29.95

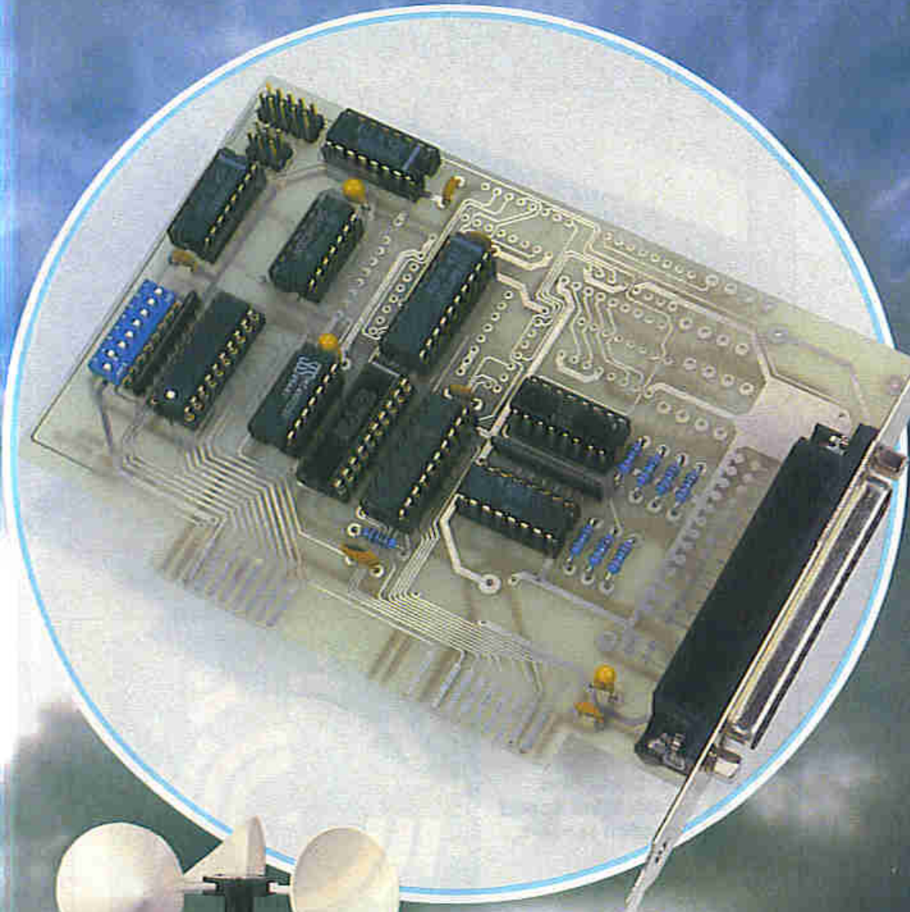
FEATURES

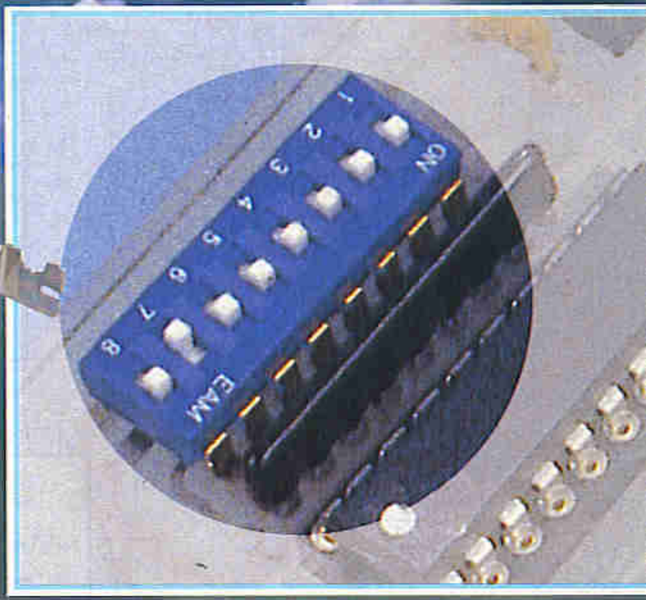
* Easy to build and set up
* Expandable – up to 8 extra sensors may be added (add-on boards to follow, using an inexpensive analogue-to-digital converter (ADC) chip)
* All signal inputs/outputs via optoisolators for minimum risk of ESD damage to the host computer
* Can be used on any IBM PC or compatible – minimum requirements: 8086, 512k RAM, monochrome display, single floppy drive.
* Accessible via easy-to-write BASIC routines (listings supplied)

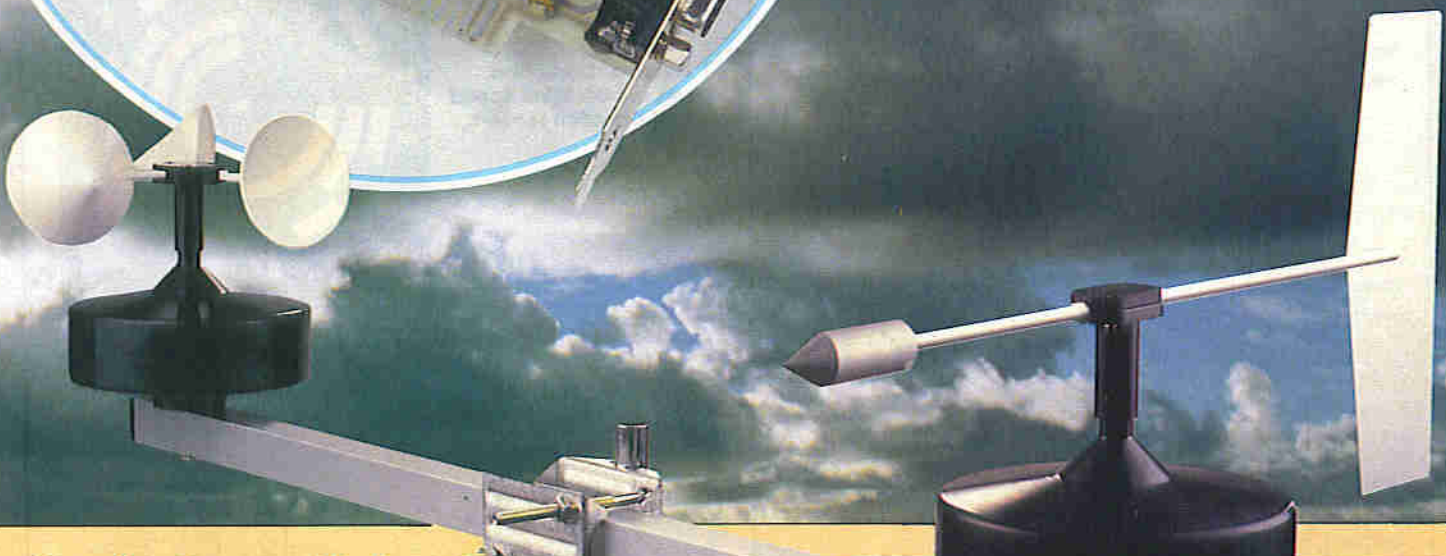
APPLICATIONS

* Intended for use with the Wind Speed and Direction Sensor outdoor units ('Electronics' Issue 31, April/May 1989)
* Upgrading the existing Weather Station project ('Electronics' Issue 33, August/September 1989); both systems can be run from the outdoor units.

Using the existing Wind Speed (LM87U) and Direction Sensor (LM88V) kits ('Electronics' Issue 31, April/May 1989), the PC Weather Station Card has been designed to either complement the Weather Station indoor unit (LM96E), which was covered in 'Electronics' Issue 33 (August/September 1989), or to present a computer-based alternative capable of monitoring, displaying and recording the wind speed and direction. The addition of the vast level of computing power that modern PCs provides allows data logging to be easily achieved with suitable software, enabling the information to be processed (e.g., trends in wind speed to be followed over a 24-hour period). The power of the PC will also be useful when other devices are connected (up to 8 additional analogue inputs will be included in a follow-up companion project); options on the PCB allow for this expansion. In addition, control systems can be implemented – these could operate 'gale' alarms, put out the laundry to dry (a dampness sensor connected to the follow-up ADC project could tell the computer to pull it back in again when rain is detected!) or move your amateur radio aerial array so that its minimum surface area points into the direction of the wind.







How the Sensors Work

To better understand how the PC Weather Station card works, we need to look at how the outdoor sensors themselves work (this is covered in greater detail in the 1989 article in which they originally appeared).

(i) Wind Direction Sensor

The wind direction sensor circuit diagram is shown in Figure 1. At the heart of the system are five diffuse scan opto-sensors (SN1 to 5). These work according to the reflectivity of markings on a rotating disc, which is coupled to the 'wind direction arrow'. Contained within each opto-sensor is an infra-red emitter and a phototransistor; the white markings on the disc reflect the infra-red energy from the emitter back into the phototransistor part of the device, turning it on. The black regions, of course, do not allow this to happen since they absorb the infra-red energy rather than reflecting it. The code disc, shown in Figure 2, has five rings printed in black-and-white sections, with the outer ring being a 'strobe' (more on this later), and the inner four rings coded in binary form. Sensors SN2 to 5 are placed around the PCB in such a way that a unique 4-bit binary code is produced for every 22·5° rotation of the code disc – this corresponds to 16 positions. Because all four sensors are required to produce an output signal (be it high or low) at *exactly* the same time (highly unlikely in the real world, thanks to the effects of manufacturing and construction tolerances, disc reflectivity and even device temperature), extra circuitry has to be provided. The analogue output of each sensor is 'squared up' by one of the Schmitt inverters of IC1, and then 'storing' the logic state in a quad 'D'-type latch (IC2). As the disc rotates, sensors SN2 to 5 produce their outputs first, and then the 'strobe' pulse from SN1 (which works with the previously-mentioned outer ring of the disc), causes the latch to output all four bits simultaneously. On the wind direction PCB, there is also a 5V voltage regulator circuit to power the active circuitry.

(ii) Anemometer (Wind Speed Sensor)

This circuit, shown in Figure 3, is much simpler than the wind direction indicator, but is built up on the same PCB. The same code disc is also used, but this is coupled onto a set of 'wind cups', rather than the 'wind direction arrow'. In this case, only one opto-sensor (SN1) is fitted, which aligns (as in the above system) with the outer ring of the code disc. Since there are sixteen white marks on the outer ring, it stands to reason that sixteen pulses are produced for each complete revolution of the wind cups, and thus the code disc. A faster wind speed will cause the wind cups to rotate faster, and so the number of pulses produced in a given period will be proportionally greater;

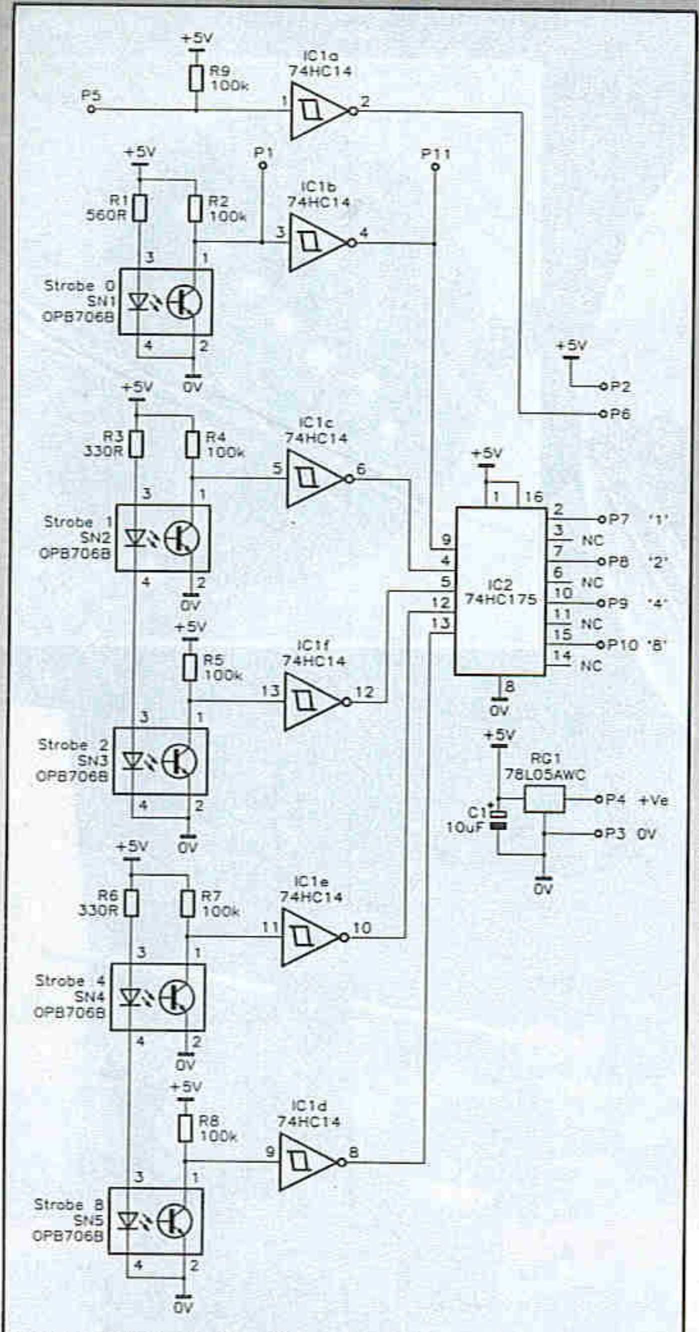
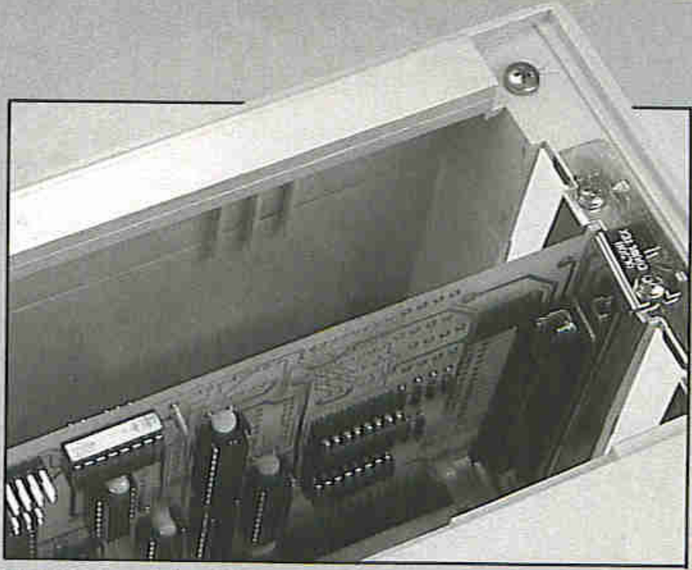


Figure 1. Wind Direction Sensor circuit diagram.



The Weather Station PC Card, shown installed inside a PC.

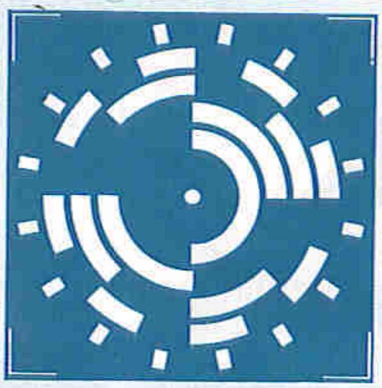


Figure 2. Code disc, use in both Wind Speed and Direction sensors.

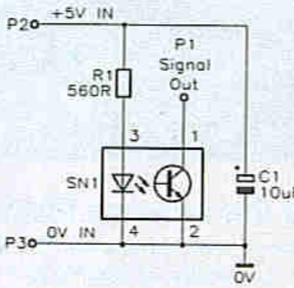


Figure 3. Wind Speed Sensor circuit diagram.

the converse applies when the wind speed reduces.

The PC Weather Station Card – Circuit Description

(i) Address Decoding

Referring to the block diagram (Figure 4) and the circuit diagram (Figure 5), you may see that part of the circuit looks vaguely familiar. No, it's not déjà vu; the address decoding (SW1 and IC1) and the Monitor Select (IC4) are basically the same as those used in the PC Opto Card. SW1 is used to select the I/O address. When the code set by the computer at A2 to A9 equals that set on SW1, pin 19 of IC1, an 8-bit logic comparator, will go low. When a program is run that recognises the preset address of the card, the computer will request either a read or a write cycle (depending on what the program requires) by pulling low either the IOR (I/O Read) or the IOW (I/O Write) lines, which are found on its expansion bus.

1. Requesting a Read. In this case, IC1's pin 19 line is used to latch data into the input buffers. It is fed into a NOR gate (¼ IC2) with the active-low IOR line to latch the 4-bit data, received from the Wind Direction Sensor, into a buffer (IC3). The line derived from IC1 Pin 19 is also used (with assistance from the IC4) to enable the output of IC6 (8-bit Wind Speed buffer), or IC9 (A/D converter latch and buffer).

2. Requesting a Write. In this case, IC1's pin 19 is fed into a NOR gate (¼ IC2) with the active-low IOW line, producing a positive write pulse for pin 11 of IC4 (an octal latch). This causes the information currently on data lines D0 to D7 of the PC's expansion bus to be simultaneously loaded into and held by IC4, and transferred to the outputs Q0 to Q7. The state of each bit here determines which sensor is monitored. Q0 enables the Wind Direction Sensor; Q1, the Wind Speed Sensor; and Q2 the output from the ADC (where used), converted from serial data into parallel by IC9. Outputs Q5, Q6 and Q7 select the serial data stream from one of the 8 ADCs, if this option is to be followed at a later date.

Figure 6 shows the pin-out of the plug-in card edge-connector, which may be useful for trouble-shooting and shows the PCs various buses and control lines.

(ii) Optoisolation

Another area which may look familiar, to builders of the PC Opto Card, is the use of optoisolators on all of the I/O signals applied via the 37-way D-type connector. These provide complete galvanic isolation of the computer's circuitry from the outside world, giving a high level of protection from possible damage by Electro-Static Discharge (ESD) – e.g., a nearby lightning strike! ILQ74 optoisolators (OP1 to OP4) are used, each of which contain four devices.

Such isolation is, of course, only present if an external power supply is used for any external electronics, including 0V returns; although provision is made on the PCB for supplying +5V and +12V via fused connectors on the PCB. This is only recommended for 'internal' connections (a room thermometer?) or for those who can afford to buy a new PC if things go wrong!

	Limits of Mean Speed			Specification of Beaufort Scale	
	Knots per hour	Miles per hour	Wind Conditions	Sea Conditions	Conditions on land based on observations made at Land Stations
0	Less than 1	Less than 1	Calm	Sea like a mirror.	Calm: smoke rises vertically.
1	1 to 3	1 to 3	Light air	Ripples with the appearance of scales are formed but without foam crests.	Direction of wind shown by smoke drift, but not by wind vanes.
2	4 to 6	4 to 7	Light breeze	Small wavelets, still short but more pronounced. Crests have a glassy appearance and do not break.	Wind felt on face; leaves rustle; ordinary vanes moved by wind.
3	7 to 10	8 to 12	Gentle breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses	Leaves and small twigs in constant motion; wind extends light flags.
4	11 to 16	13 to 18	Moderate breeze	Small waves becoming longer; fairly frequent white horses.	Raises dust and loose paper; small branches are moved.
5	17 to 21	19 to 24	Fresh breeze	Moderate waves, taking a more pronounced long form; many white horses are formed. Chances of some spray.	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	22 to 27	25 to 31	Strong breeze	Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray.)	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	28 to 33	32 to 38	Near gale	Sea heaps up and white foam breaking waves begin to blow in streaks along the direction of the wind.	Whole trees in motion; difficult to walk against the wind.
8	34 to 40	39 to 46	Gale	Moderately high waves of greater length; edges of crests begin to break into the spindrift. The foam is blown in well marked streaks along the direction of the wind.	Breaks twigs off trees; generally impedes progress.
9	41 to 47	47 to 54	Strong gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.	Slight structural damage occurs (chimney pots and slates removed).
10	48 to 55	55 to 63	Storm	Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole, the surface of the sea takes on a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected.	Seldom experienced inland; trees uprooted, considerable structural damage occurs.
11	56 to 63	64 to 72	Violent storm	Exceptionally high waves. (Small and medium sized ships might be for a time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.	Very rarely experienced; accompanied by widespread damage.
12	64 to 71	73 to 82	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	
13	71 to 80	83 to 92			
14	81 to 89	93 to 103			
15	90 to 99	104 to 114			
16	100 to 108	115 to 125			
17	109 to 118	126 to 136			

VISIBILITY

1 Nil	1 cable or less	4 Good	5 to 10 miles
2 Poor	1 mile or less	5 Very Good	10 to 30 miles
3 Fair	Up to 4 miles	6 Excellent	

STATE OF SEA

0 = Glassy calm	4 = Mod/Choppy	8 = Very high
1 = Calm	5 = Rough	9 = Phenomenal
2 = Smooth	6 = Very rough	
3 = Slight	7 = High	

Table 1. The Beaufort scale.

It is probably easier to understand the overall circuit as a group of three separate modules, so here goes! Firstly, we will make the assumption that all the I/O Addresses are set correctly in the software, since we shall cover this later.

(iii) Wind Direction

This is probably the easiest to understand, so a good place to start. As we saw earlier, the signal is a 4-bit binary code, giving 16 possible positions for the weather vane. This code is input via the 4 sections of OP3, a quad optoisolator. Each section is configured as an inverting amplifier, and will convert an input level of between +3V to +12V (high) to 0V, and an input of 0V (low) to a TTL-compatible level of approximately +5V. The code is presented to inputs D0 to D3 of IC3, D0 being the least significant bit (LSB). The inversion means that the code is now upside down ('low' becomes 'high', and vice versa), but this is easy to correct in the software. IC3 is a noninverting tri-state buffer. The data on the inputs is 'latched in' when LE (latch enable, pin 11) is high; when LE goes low, the latches store the data that was present a latch set up period before the low-to-high transition of LE. When $\overline{OE}$ is taken low, the

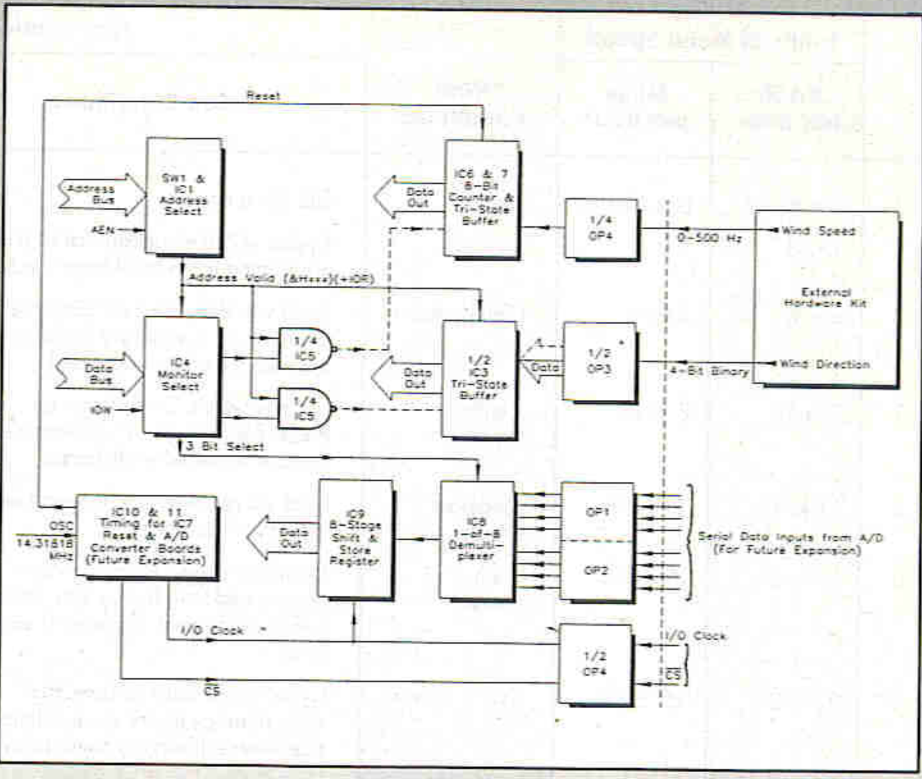


Figure 4. PC Weather Station Card block diagram.

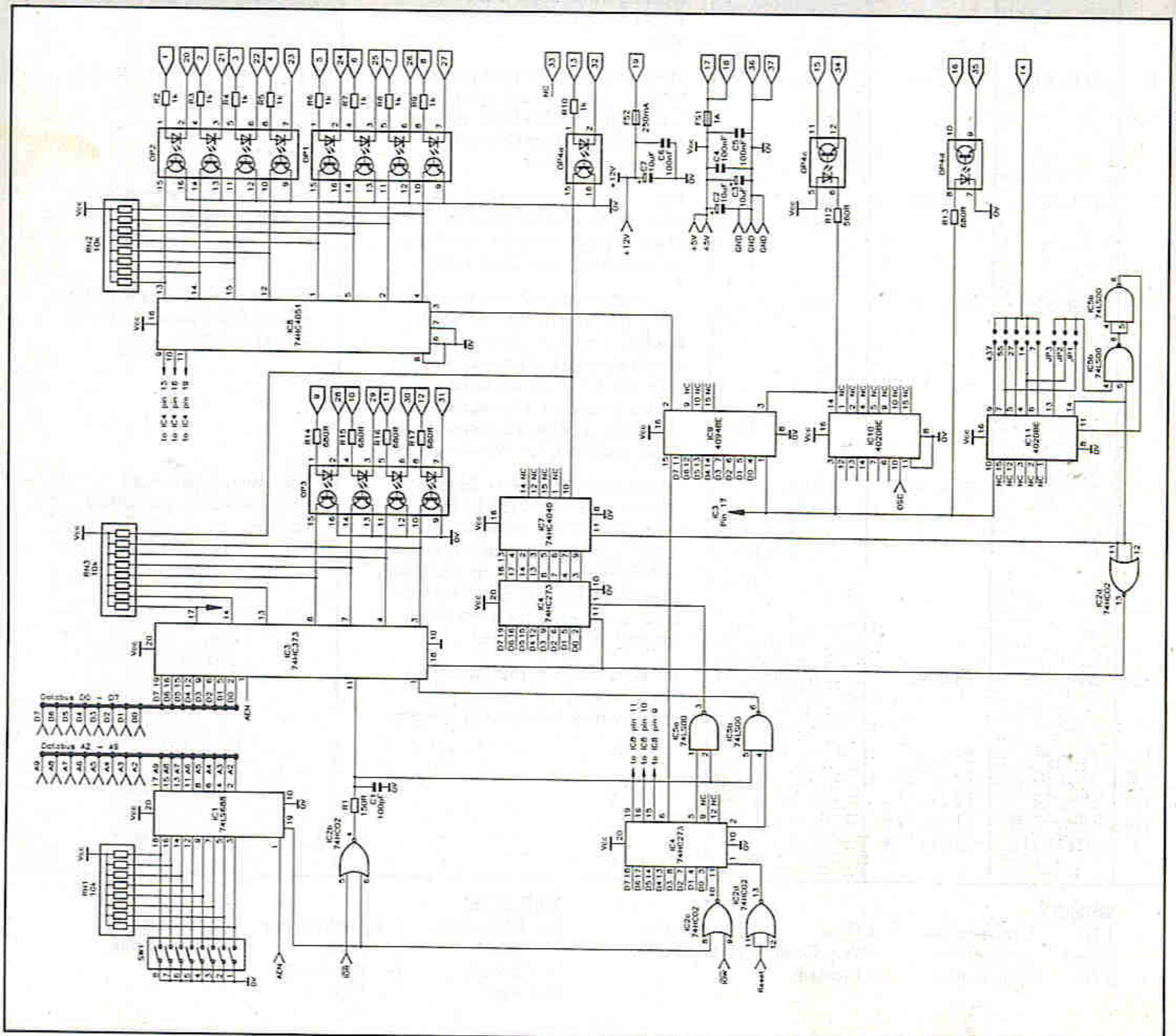


Figure 5. PC Weather Station Card circuit diagram.

contents of all 8 latches is available at the outputs (Q0 to Q7), and therefore on the computers data bus; when $\overline{OE}$ is high, the outputs have a high impedance, and are consequently 'transparent' to the computer.

As we have already discussed, the first 4 inputs/outputs of IC3 (D0 to D3) are used for Wind Direction. Of the other bits, D4 and D5 are not used, D6 allows the strobe pulse of the ADC option's serial-to-parallel converter (pin 1, IC9) to be monitored, and D7 allows the enable input (pin 11) of the Wind Speed latch (IC6) to be monitored. The relevant bits (no pun intended!) of data released by IC3 are extracted by software, which is covered later.

(iv) Wind Speed

The output from the anemometer is, as we found out earlier, a pulse train, the frequency of which is dependent on its speed of rotation. The input at pin 13 of SK1 will be a square wave of between 0Hz (0mph) and 500Hz (100mph), but our card will only read *directly* up to 87mph. This doesn't really matter too much in the UK; if you take a look at the Beaufort Scale in Table 1, anything above 82mph is classified as exceeding hurricane force anyway, and your weather station would probably be doing a fair impression of Concorde by now!

The strobe has been squared by the output stages of the Anemometer electronics and is transmitted at TTL levels (0 & +5V nominally), but according to the length and quality of the data cable used it will be reduced in amplitude and possibly rounded off slightly by now (the longer the cable, the worse the signal). Once again the input is via an inverting optoisolator (¼ of OP4) and this will restore the signal back to true TTL levels for us. The inversion doesn't matter in this instance, because the strobe is used to clock a 12-stage binary counter (IC7), and this only needs a negative-going 'edge' to advance the counter. In fact, we are only using the first 8 stages of this counter to give us a count of 0 to 255, corresponding to the frequency of the input.

We need to reset the counter to guarantee a 'clean' count for every sample period, and so a reset pulse is generated by IC10 and IC11 (refer to the Timing & A/D section). For a count of 255 to equal 500Hz (the approximate frequency at a wind speed of 100mph), we need a sample period of (count/frequency =) 255/500 = 0·51 seconds. However, the hardware gives us a sample rate of just over 0·588 seconds – which gives a single cycle count of up to 433Hz, equivalent to 86·6mph.

The count on IC7 is read by IC6 (a

Pin	Desig.	Remarks
1	ADC 1 IN+	
2	ADC 2 IN+	
3	ADC 3 IN+	
4	ADC 4 IN+	
5	ADC 5 IN+	
6	ADC 6 IN+	
7	ADC 7 IN+	
8	ADC 8 IN+	
9	DIR BIT 4	Wind Direction Input Bit 4
10	DIR BIT 3	Wind Direction Input Bit 3
11	DIR B BIT 2	Wind Direction Input Bit 2
12	DIR BIT 1	Wind Direction Input Bit 1
13	SPEED IN+	
14	TEST OUT	Wind Speed Calibration Output
15	I/O CLOCK	I/O Clock to ADC Modules (Future Expansion)
16	$\overline{CS}$	$\overline{CS}$ out to ADC Modules (Future Expansion)
17	+5V	+5V out from PC
18	+5V	Paralleled with P17
19	+12V	+12V out from PC
20	ADC 1 IN−	
21	ADC 2 IN−	
22	ADC 3 IN−	
23	ADC 4 IN−	
24	ADC 5 IN−	
25	ADC 6 IN−	
26	ADC 7 IN−	
27	ADC 8 IN−	
28	DIR BIT 4 0V	0V Return for Wind Direction Bit 4 – Common with 29 to 31
29	DIR BIT 3 0V	
30	DIR BIT 2 0V	
31	DIR BIT 1 0V	
32	SPEED 0V	0V Return for Wind Speed
33	N/C	
34	SI/O CLOCK 0V	
35	$\overline{CS}$ 0V	
36	SUPPLY 0V	+5V and +12V Supply Return – Common with 37
37	SUPPLY 0V	

Table 2. SK1 pin-outs.

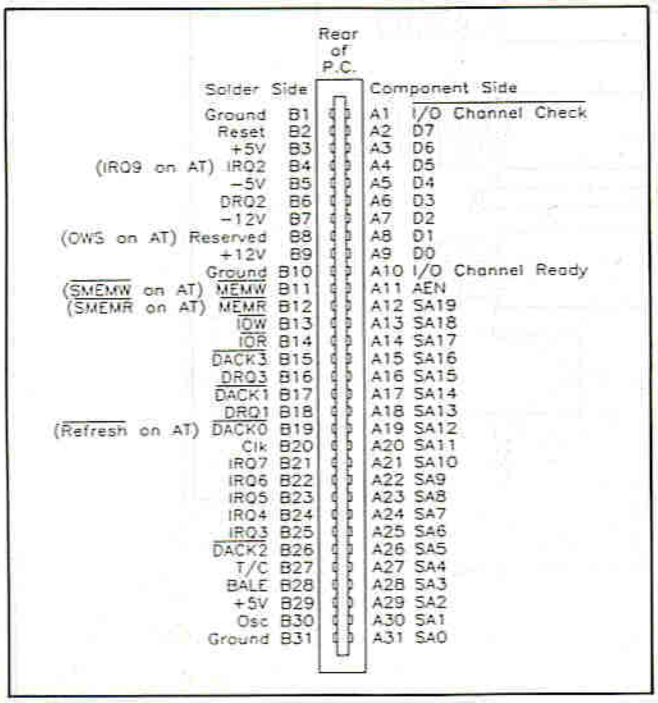


Figure 6. Edge connector pin-outs.

Description	Hex Address PC/XT	PC/AT	
Fixed disk	n/i	1F0-1F8	
Games adaptor	200-20F	200-207	
Expansion unit	210-217	n/i	
2nd Parallel printer port	n/i	278-27F	
Alternate EGA	2B0-2DF	2B0-2DF	*
GPIB (0)	2E1	2E1	*
Data acquisition (0)	2E2-2E3	2E2-2E3	
Prototype card	300-31F	300-31F	
Fixed disk	320-32F	n/i	
Network card	360-36F	360-36F	
1st Parallel printer port	378-37F	378-37F	
SDLC	380-38F	380-38F	
2nd Bisynchronous	n/i	380-38F	*
Cluster (0)	390-393	390-393	
1st Bisynchronous	n/i	3A0-3AF	
Monochrome adapter/printer	3B0-3BF	3B0-3BF	
Enhanced graphics adaptor	3C0-3CF	3C0-3CF	
Colour graphics adaptor	3D0-3DF	3D0-3DF	
Floppy diskette controller	3F0-3F7	3F0-3F7	

* Note: These devices decode the full 16 address bits, allowing further devices to be located in the same category above 3FF, for example GPIB (1) = 22E1, etc. n/i = not implemented

Table 3. Designated I/O Addresses.

tri-state buffer) whenever LE is high; during the reset period for IC7, LE is taken low and this 'holds' the data for when the computer reads it. $\overline{OE}$ is taken low to read the count when the software requests a read via IC4, and the information in the buffer is passed to the PC's data bus.

(v) Timing and ADC Interfacing

The OSC output on the PC's bus connector (B30) is always 14·31818MHz, irrespective of the system clock speed, and so this is used to generate all the timing pulses required. This means that the Card should run on any PC compatible, and that a separate on-board clock is not required. OSC is used to clock IC10, a 4020 14-stage ripple counter. Q9 (pin 14) is a ÷1024 output, giving a frequency of 13·9826kHz, which is used as the clock input for IC9, and the I/O clock for the optional off-board A/D converter(s), via one of the four optoisolators in OP4.

IC10 also offers a ÷16,384 output (Q13, pin 3), giving a frequency of 874Hz. This output is used in 3 ways. Firstly, it is used to strobe IC9. It is also used as the $\overline{CS}$ (chip select) line for the off-board A/D converter(s), via another of the four optoisolators in OP4. Finally, IC10's Q14 output is also used to clock IC11, another 4029 14-stage counter.

Two of the outputs of IC11 (Q9, together with either Q3, Q5 or Q7) are combined via an AND gate via JP1 to JP3 to produce the reset period. The reason for this arrangement is that slower computers *may* require a slightly longer

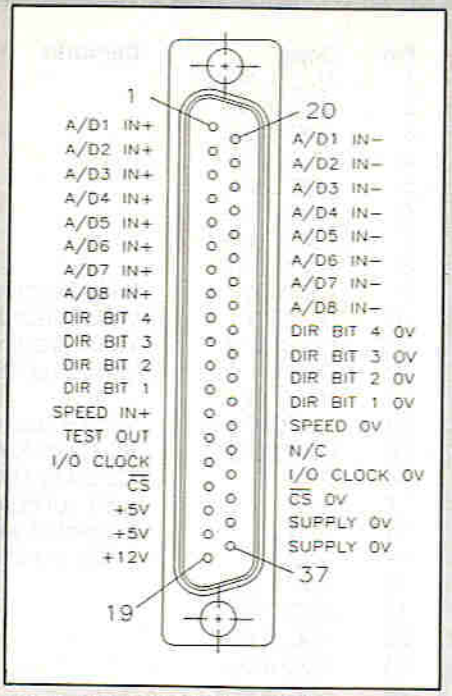


Figure 7. Pinout of 37-way D-type connector.

reset period for the software to work efficiently.

But that's not IC11's only task – its various division stages can be tapped off to provide a range test frequencies. The Q0, Q3, Q4, Q5 and Q6 outputs (pins 9, 7, 5, 4 and 6 respectively) can be selected, via JP4, and output to pin 14. The test frequencies are, in the correct order, 437Hz, 55Hz, 27Hz, 14Hz and 7Hz.

IC8 is an 4051 8-to-1 line demultiplexer, which selects the serial output from the required ADC. Each of the eight possible ADCs is connected via an optoisolator. Addressing is controlled by a 3-bit code sent to IC8 via latch IC4 (pins 15, 16 and 19). Since the ADC output is in serial format, IC9 (an 8-bit tri-state latch is used as a serial to parallel converter.

As with the Speed and Direction Indicators, all ADC connections to the PC Weather Station Card are made via SK1, a 37-way 'D' connector, the pin-out of which is shown in Figure 7 and Table 2. Note that the return connection from each ADC (A/Dx IN−) can be connected to PC ground – this course of action should only be taken if isolation ('floating' ground) is not required.

(vi) Power Supply Arrangements

The PC Weather Station Card is, of course, powered by its host computer. If isolation is not required, the PC can also be used to power the outdoor units – this option may dispose of the requirement for additional power supply, but this may prove to be a false economy! If power is to be derived from the computer, FS1 (1A, protecting the +5V rail) and FS2 (250mA, protecting the +12V rail) need to be fitted; there is provision for these components on the PCB. The capacitors associated with the power rails decouple them; C6 and C7 are required for the +12V rail which is only used by the outdoor units. These capacitors are therefore only required if the outdoor units are powered via the host PC.

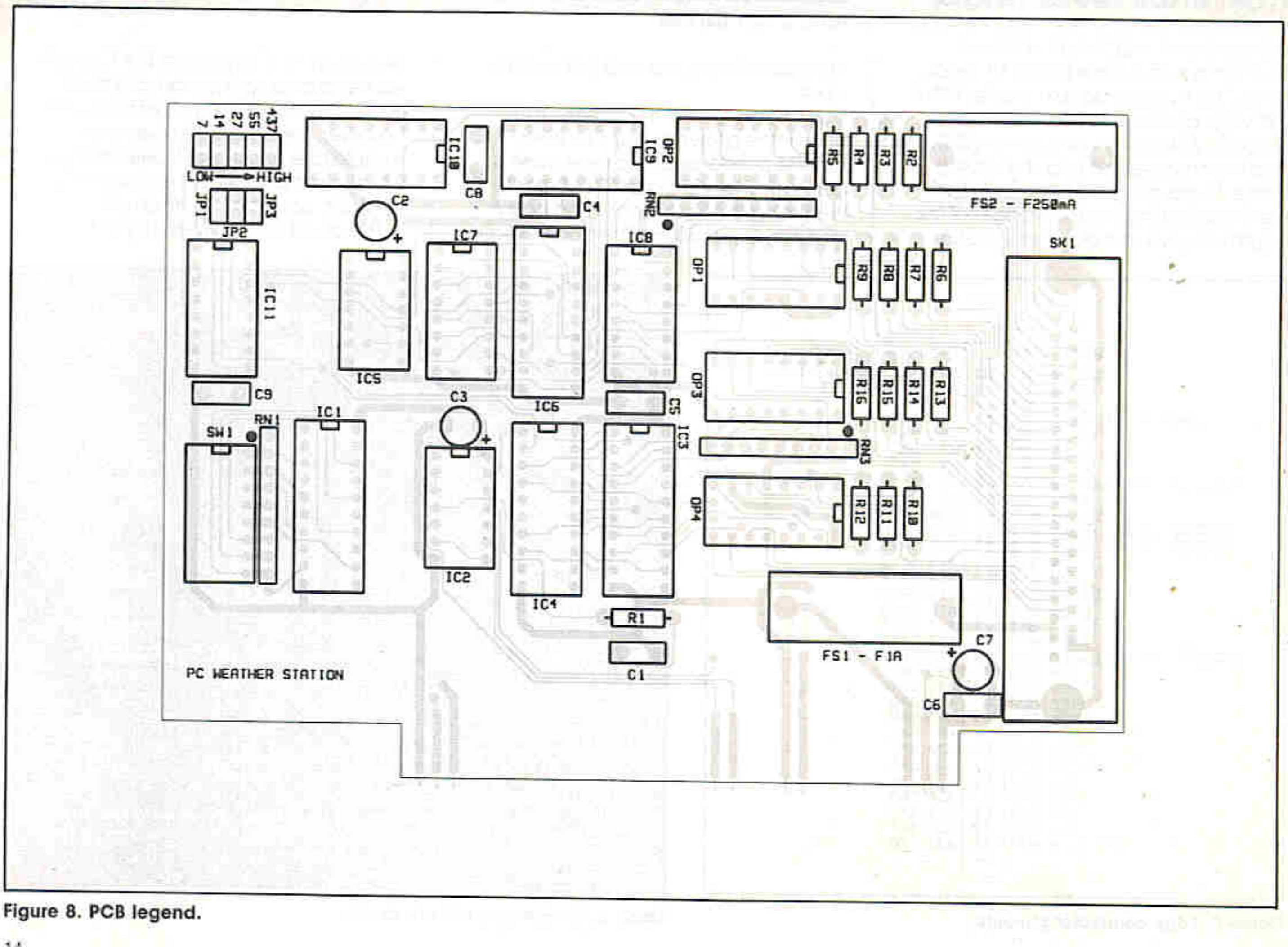


Figure 8. PCB legend.

There are two alternatives to using the PC as a power source and these are described later.

Construction

Construction, in those time-honoured words, is fairly straightforward. Assembly information for the Wind Speed and Direction Sensors (photocopies of the April 1989 article) is supplied with the kit of parts for each unit. Of course, if you are upgrading or augmenting the original Weather Station base unit, you can proceed with building the PC interface card itself straightaway.

The PCB is a double-sided, plated-through hole type, with a gold-plated edge-connector, chosen for maximum electrical reliability and mechanical stability. However, removal of a misplaced component is quite difficult with this type of board, so please double-check each component type, value, and its polarity where appropriate, before soldering! The PCB has a printed legend to aid you in correctly positioning each item, see Figure 8.

The order in which the components are fitted is not critical, however, the following instructions will make the assembly task as straightforward as possible. For general information on soldering and assembly techniques, please refer to the Constructors' Guide included with the Maplin kit. ***Note that the components highlighted in bold italics denote those only required if one or more ADCs are to be fitted at a later date ADC construction will be covered in a forthcoming article.***

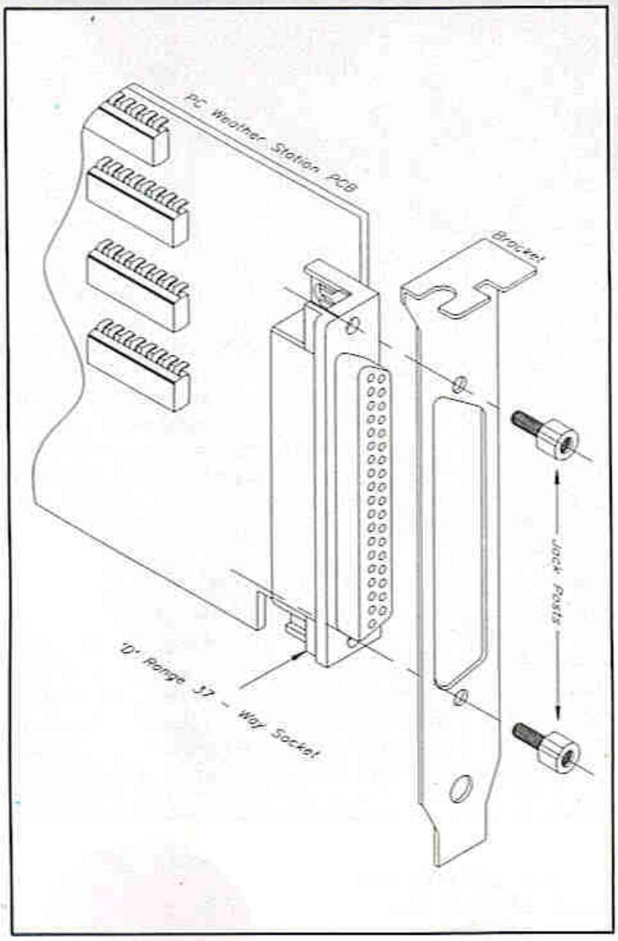
When building the PCB, be careful not to scratch the gold-plated edge connector or splash it with solder, as this is likely to affect operation of the card and/or computer.

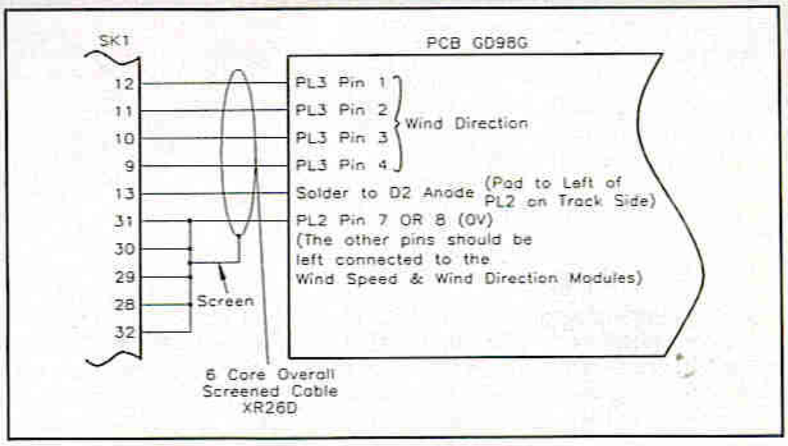
Referring to the parts list and PCB legend, insert and solder the resistor networks RN1, ***RN2*** and RN3. Note that the pin 1 marker aligns with the dot on the PCB in each case (this is the common terminal). This can be followed by the fitting of the discrete resistors (R1, ***R2 to R9,*** R10, ***R11, R12,*** R13 to R16). Insert and solder the three 10µF tantalum capacitors C2, C3 ***and C7,*** taking care that the lead nearest to the '+' mark on the body is inserted into the hole adjacent to the '+' mark on the PCB. Next, fit the remaining capacitors (C1, C4, C5, ***C6,*** and C8 to C9 – all 100nF ceramic, with the exception of C1 (100pF). Insert the slimline, 8-way DIL switch SW1, ensuring that the 'on' side is facing inwards on the PCB. Next, insert the DIL sockets for ICs 1 to 11, and ***12 to 15*** if required, ensuring that the notch on each socket is aligned with the corresponding marks on the PCB legend. Do not insert the optoisolators, or any ICs yet!

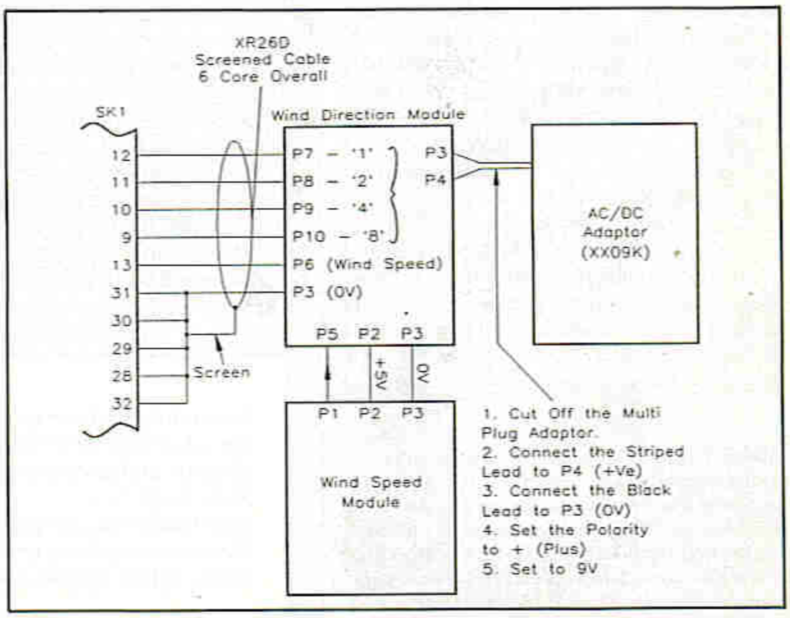
The remaining components can now be fitted, approximately in order of physical size. Fit the ***two fuse clips and fuses*** (FS1 is rated at T1A, and FS2 at T250mA) if required, followed by SK1 (the 37-way 'D' connector), into the board and make sure that it is butted-up close to the PCB *before* soldering. Next, fit the double-row pin strips; JP4 (wind speed test frequency) is a 5-way block, while JP1 to JP3 (reset period) are combined in a 3-way block. Please note that, if you are not building the project from a kit, that the smallest length of pin strip is 36 pins; you will need to cut off the required 3-pin and 5-pin segments, and discard the rest. The correct number of segments are supplied in the kit. It is suggested, for test purposes, that JP1 (reset period select) and JP4/55 (test frequently select) are both fitted with jumpers. When the pin strips have been fitted, insert the optoisolators ***OP1, OP2,*** OP3, OP4, and all ICs, into their sockets last, taking care to align the pin 1 designator on each package with the corresponding notch in its socket.

An end-plate is supplied in the kit, allowing the 37-way connector and the PCB, as a complete assembly, to be securely mounted to the back panel of your PC. This should now be fitted as shown in Figure 9.

Clean up the board by cutting off excess wires – no component lead should stand proud by more than 2mm – and with a PCB cleaner and a stiff paint brush, wash off any flux before inspecting the module. A close inspection of all tracks, joints and components is especially recommended on this board *before* you insert the card into your computer! Any mistakes and, well, you could find yourself making an unscheduled visit to your local computer repair shop!







Above: Figure 9. Connector mounting bracket assembly.

Top right: Figure 10. Using the PC Weather Station with an existing system.

Right: Figure 11. Deriving the power for the outdoor units from an AC mains adaptor.
Figure 8. PCB legend.

continued on page 21

by Douglas Clarkson

EXPLORING VENUS

The planet Venus has, at last, given up some of its most enduring secrets to the probing radar eye of the Magellan spacecraft. Scientists are now engaged in processing the wealth of data recovered to trace the development of the 'morning star' planet, and to discover why it has ended up looking so different from Earth. They are looking, no doubt, at processes which may offer some insights into the influence of global warming on our own world. Such information is surely most welcome as the Earth begins to feel the burden of carbon dioxide released into the atmosphere by human activity.

The Deceptive Twin

For many years prior to the launching of planetary probes, Venus was considered to be a 'twin' planet of the earth. Table 1 shows, however, that while some aspects such as size and gravitational acceleration are similar, others – such as atmospheric pressure and surface temperature – are significantly different. It is perhaps somewhat sad to realise that it is extremely unlikely that any form of life could exist upon its uninviting arid land surfaces. Scientists also are trying to piece together the chain of events which have produced such a climatic condition.

It was only with the launch of radar mapping probes that the true rate and direction of rotation of the planet could be determined. Venus rotates very slowly, and in the opposite direction to all other planets in the solar system. There is speculation that the capture of a retrograde moon in the early days of the planet may have changed its 'natural' rotational direction. If some massive body has impacted deep into the planet's structure, perhaps the present gravity mapping mission of Magellan will detect some abnormality in the planet's structure.

One unexplained fact is that Venus always presents the same face to Earth when the two planets are closest together. This is shown in Figure 1, where the lower drawing shows the relative positions of the planets when they are at one stage closest together. Venus rotates faster round the sun and catches up with Earth after about 584 days, which is also the time within which Venus will have completed two revolutions on its own axis. The upper drawing shows the relative positions of the planets in the solar system at the time they are again closest together.

It should be noted that when the two planets are closest, the sun is illuminating the side of Venus which cannot be seen from Earth – just like a new moon – and so the planet will hardly be visible. When the two planets are furthest apart, however, Venus is fully lit by the sun and will appear brightest – similar to a full moon.

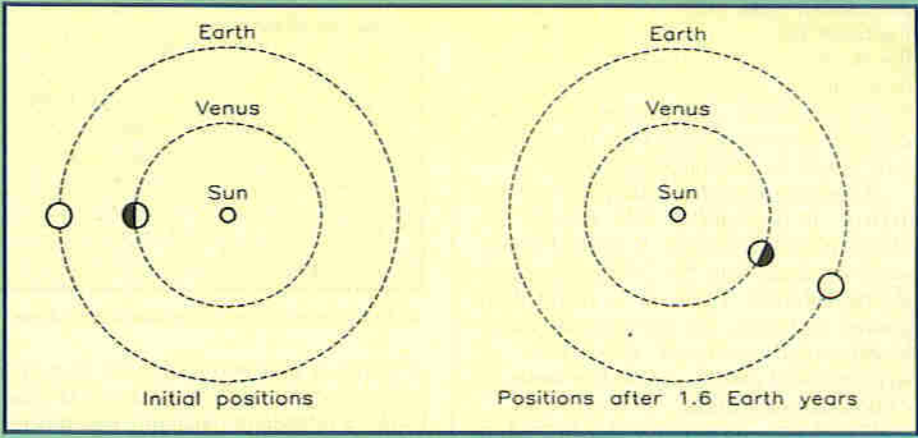
Early Observations

Venus was a natural object to investigate in the early days of the optical telescope. Christian Huygens was one of several who pondered over Venus's bright, even image and reflected '. . . is not all that Light we see reflected from an Atmosphere surrounding Venus?'. From observation of Venus as it

Mean distance from sun:	67,200,000 miles
Period of revolution (Venus year):	225 Earth days
Rotation period (Venus day):	243 Earth days
Mass (Earth = 1):	0·81
Acceleration due to gravity:	0·904
Surface atmospheric pressure:	94 bars (Earth = 1 bar)
Mean surface temperature:	462°C

Above: Photo 1. This picture was obtained by fusing together images from the first mapping session of the Magellan mission (September 1990 to May 1991). The main highland region of Venus, Aphrodite Terra, can be seen in the bright line region around the equator. This feature is as large as Africa and is some 10,000km long.
Right: Table 1. Venus's vital statistics

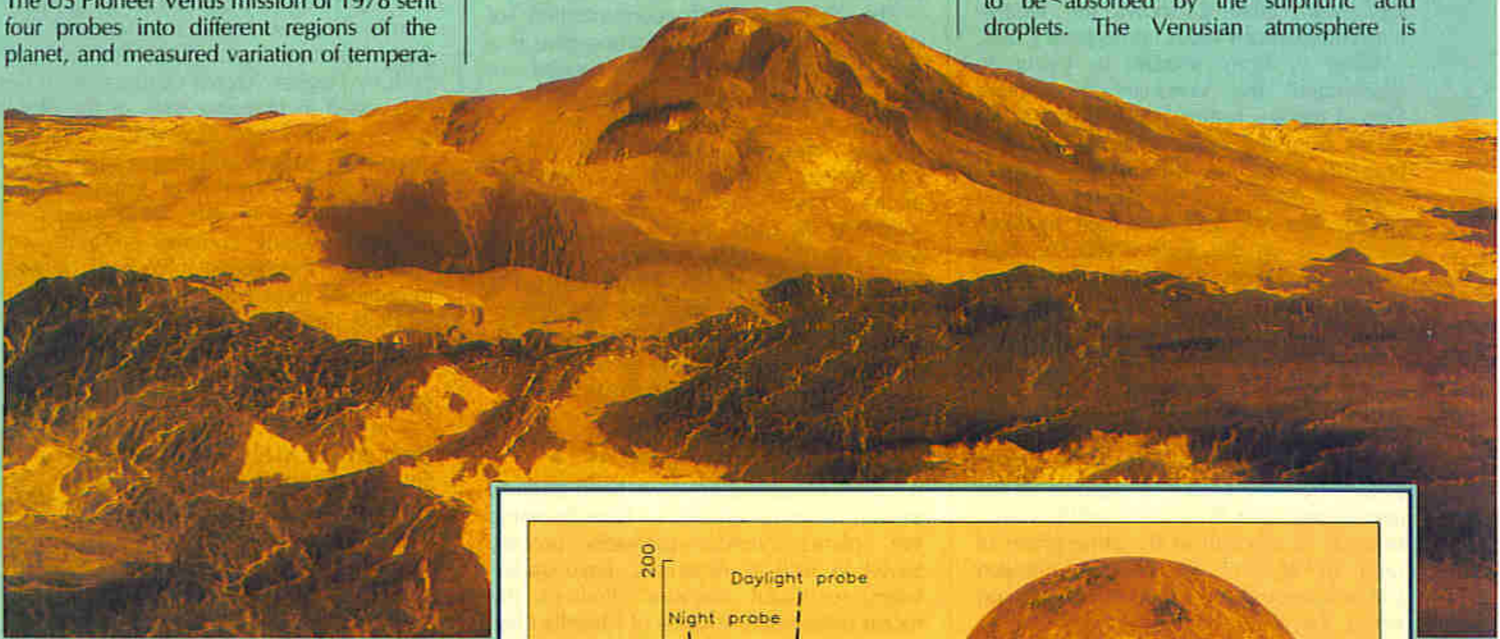
passed in transit across the sun in 1761, during which the planet appeared momentarily surrounded by a brilliant ring of light, the astronomer Lomonosov suggested that Venus had an atmosphere at least as dense as that of the Earth. This led to speculation that these clouds were of water vapour, and that Venus had a wet, swampy environment. This wishful thinking was dispelled in the 1920s, when researchers tried, and failed, to spectroscopically detect water vapour in the light emitted from Venus's upper cloud layer. Venus was then considered to be a dry desert planet, with clouds formed by dust carried aloft by turbulent winds.

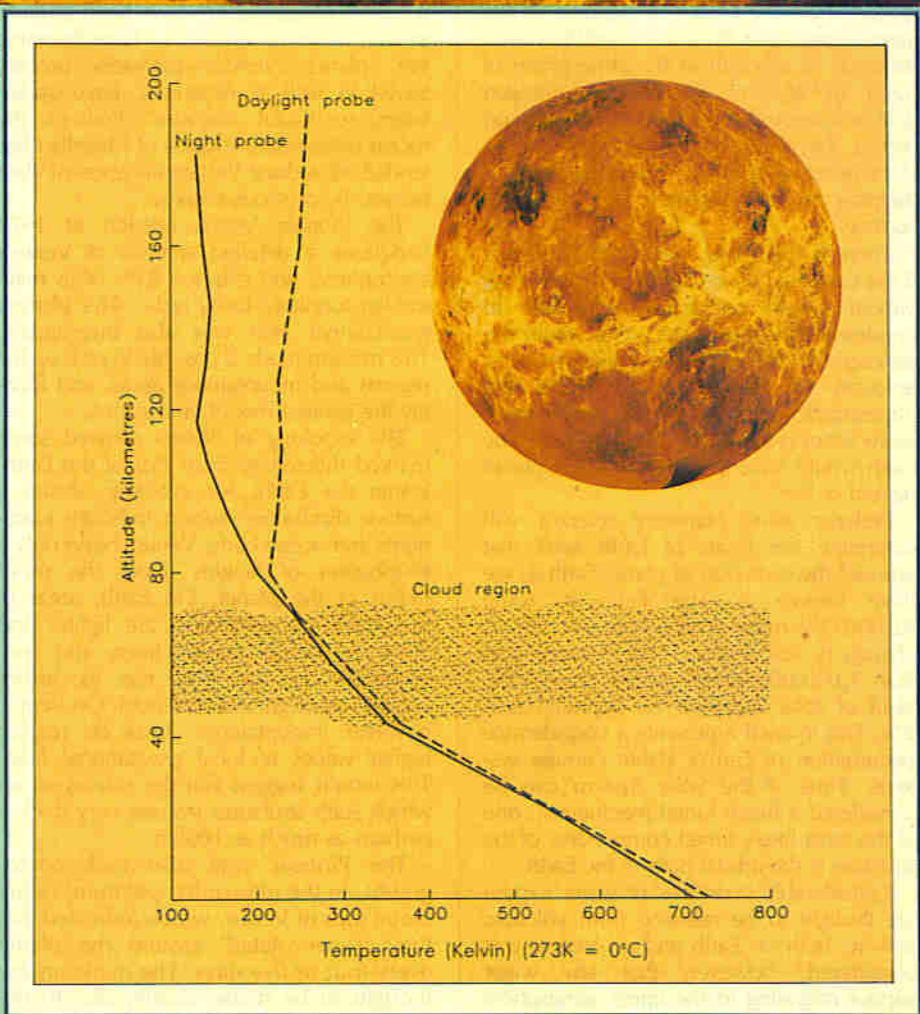


The Clouds of Venus

It was only during the 1970s, however, that a series of US and Soviet space probes revealed the secrets of Venus's atmosphere which had for so long remained elusive. The US Pioneer Venus mission of 1978 sent four probes into different regions of the planet, and measured variation of temperature and pressure with altitude. Figure 2 shows the variation of temperature with altitude encountered by one of the descent probes. The clouds of Venus are restricted to layers of the atmosphere between about 46 and 70km above the surface. The cloud cover allows, at most, only a few percent of the incident sunlight to reach ground level. There is, however, sufficient light for lander craft to take photographs of the Venusian surface, as proved by the Soviet Venera 9 and Venera 10 landers.

The dense clouds of Venus are largely made of small (representative diameter 0·008mm) droplets of sulphuric acid. Some larger particles are thought to consist of small solid crystals – possibly of a metallic chloride. Any water vapour which exists within the Venusian atmosphere is thought to be absorbed by the sulphuric acid droplets. The Venusian atmosphere is





Top right: Figure 1. The relative motion of the Earth and Venus round the sun is apparently synchronised to the rotation of Venus about its own axis. Each time the Earth and Venus are at their closest distance of approach, Venus presents the same face to the Earth.

Above: Photo 2. The picture depicts the main shield volcano of Venus – Maat Mons. The image is derived from extensive images of the region, and simulates the landscape as observed from a viewpoint 400 miles north at an elevation of two miles. Maat Mons is a feature on the eastern edge of the Aphrodite Terra. Sets of bright lines can be seen radiating from the area of volcanism. The topographic scale has been enhanced by a factor of about 10.

Right: Figure 2. Variation of temperature with altitude above Venus's surface, as determined by probes of the 1978 US Pioneer Venus probe. The dense clouds are found between 46 and 70km, with the atmosphere being 'clear' above and below these levels.

remarkably clear, both below and above the cloud layers. The clue to the nature of the clouds could have been obtained from their slightly yellow appearance. It is thought that the sulphur element of the cloud structure originated from the planet's long history of volcanic outgassing.

At higher levels in the atmosphere around 100km, it is probably cold enough for clouds of carbon dioxide to form. Pictures were sent back from the Galileo spacecraft during February 1990 on a planet hop journey to Venus; the short optical wavelengths used indicated dark areas of sulphuric acid clouds, and lighter areas of carbon dioxide clouds.

While Venus rotates very slowly (and in the direction opposite to the Earth), the upper layer of clouds is in rapid motion and has a so-called 'four-Earth-day' circulation.

The Atmosphere

Venus's atmosphere is very unlike that of the Earth. Table 2 shows the relative concentration of various component gases.

There is keen interest in trying to 'understand' the Venusian atmosphere. One of the key factors which distinguishes Venus from the Earth is that Venus has probably been too hot to allow water vapour to form, and consequently carbon dioxide has not been absorbed by large oceans, as on the Earth. With the high levels of carbon dioxide remaining in Venus's atmosphere, this has encouraged 'greenhouse effect' heating of the planet.

On Earth, by contrast, much of the carbon dioxide initially present in the atmosphere has been used in the formation of carbonate rocks. The presence of water thus acted as a catalyst in removing carbon dioxide from the Earth's atmosphere. It has been shown that there are roughly similar amounts of nitrogen in the atmosphere of Earth, and of Venus. On the Earth, nitrogen acts as a 'neutral' greenhouse gas, while on Venus the 96% composition of carbon dioxide acts as a very effective heat shield – keeping in heat captured by the planet surface.

There is, therefore, every indication that if the Earth had been slightly warmer, water vapour would not have been able to condense and form water. As a result, the atmosphere would have contained vast amounts of carbon dioxide, and the atmospheric pressure would have been many times greater than it is at present. The Earth would have been a hot desert planet devoid of life.

Perhaps some planetary scientist will determine the limits of Earth orbit that ensured the evolution of planet Earth as we have known it. The Earth is some 92,000,000 miles distant from the sun. A change of just 1% in orbit distance (less than 1,000,000 miles) would change the level of solar radiation by approximately 2%. This in itself represents a considerable perturbation of Earth's stable climate systems. Thus, if the Solar System can be considered a finely tuned mechanism, one of the most finely tuned components of the structure is the orbital path of the Earth.

Considerable quantities of water vapour are thought to be released from volcanic activity, both on Earth and on Venus. It is considered, however, that any water vapour migrating to the upper atmosphere

Gas	Level present
Carbon dioxide:	96%
Nitrogen:	3·5%
Water vapour:	less than 0·1%
Argon:	70ppm
Oxygen:	40ppm
Carbon monoxide:	20ppm
Helium:	10ppm
Neon:	10ppm

(ppm = parts per million)

Table 2. Composition of Venusian atmosphere.

of Venus is split into molecules of oxygen and hydrogen under the influence of strong levels of ultraviolet radiation. This process, occurring over periods of thousands of millions of years, is thought to be the reason why water vapour is present only in very low quantities within the 'clear' atmosphere. Oxygen present in the atmosphere would tend to react chemically with the hot surface rocks, to form numerous oxides.

The relatively high concentration of oxygen within the Earth's atmosphere is a result of photosynthesis over periods of hundreds of millions of years.

After touching upon some interesting thoughts about the evolution of Venus's atmosphere, some questions also arise about possible mechanisms which may influence the Earth. Are, for example, the levels of ultra-violet radiation sufficiently low at the Earth's orbit to ensure that water vapour is not broken up in this way? If more ultraviolet light is transmitted to lower levels in the atmosphere, will this have any effect on water molecules at such lower levels?

Early Venus Encounters

A variety of approaches have been taken to try and solve the mysteries of the 'morning star' planet. Various planetary probes, Soviet as well as American, have undertaken successful missions. Perhaps the recent outstanding success of Magellan has tended to reduce the significance of data relayed by previous probes.

The Pioneer Venus mission of 1978 undertook a detailed analysis of Venus's atmosphere, and mapped 83% of its main surface topology using radar. The planet's gravitational field was also investigated. This mission made it possible to pick up flat regions and mountainous areas, and identify the general mix of landscapes.

The topology of Venus showed some marked differences from that of the Earth. While the Earth, for example, shows a surface distribution which indicates continents and ocean beds, Venus shows only a distribution of heights about the mean radius of the planet. On Earth, areas of mountains on continents are lighter and 'float' on denser substructures, and consequently do not give rise to higher local levels of gravitational field. On Venus, however, mountainous areas do register higher values of local gravitational field. This would suggest that the sub-layers on which such structures rest are very thick – perhaps as much as 100km.

The Pioneer craft also took photographs, in the ultraviolet spectrum, of the cloud tops of Venus, which indicated that they 'super-rotated' around the planet every four or five days. The markings are thought to be made visible, due to the release of sulphur from the sulphuric acid clouds, under the influence of the sun's radiation.

Using radar, the two Soviet orbiters Venera 15 and 16 extensively mapped the northern hemisphere of Venus at a resolution sufficient to determine many new features of Venusian geology. Earth-based radio telescopes succeeded in producing radar maps of specific features of Venus in the early 1980s. The Arecibo radio telescope in Puerto Rico, for example, produced some useful images. Such a technique, however, could not be used to map the entire planet surface. Many of the conclusions drawn as a result of these probes and the limited investigation from ground-based radar were confirmed, with the eventual follow-up by the Magellan mission in 1990.

The Magellan Mission

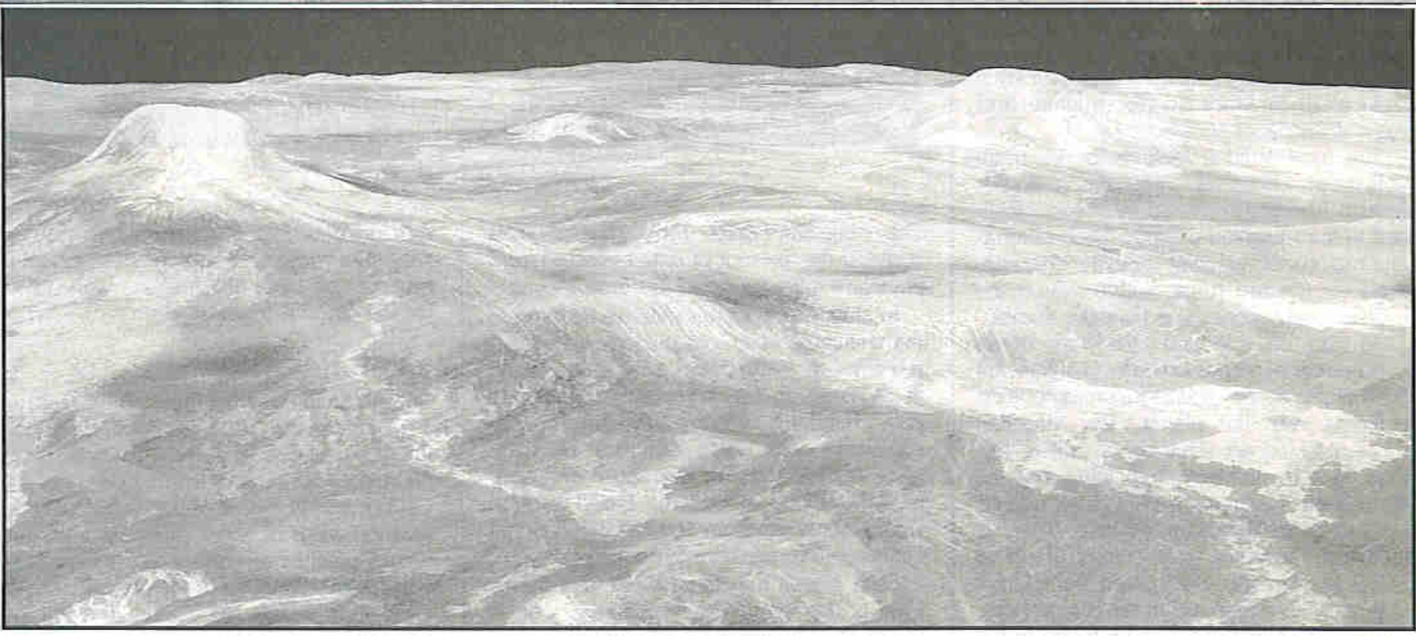
The Magellan mission has been, as it were, the crowning achievement of all previous Venus missions. Using a specialised Synthetic Aperture Radar (SAR) designed and built by Hughes Aircraft Corporation, it has succeeded in mapping 95% of the planet surface with a resolution that allows it to distinguish features 300 metres apart, and to determine the distance of features below the satellite with the same order of resolution. Using complex computer enhancement techniques, it has been possible to combine these two sets of information to produce simulated three-dimensional views of selected areas of the planet. Often, to enhance details, the vertical scaling of these studies has been increased.

The Magellan craft was launched from Earth on 4th May 1989, aboard the Space Shuttle Atlantis. It reached Venus after a 15 month cruise. The exploration of the planet surface is structured in 243-day cycles, which correspond to the planet's period of rotation. The first cycle began on 10th August 1990, while the second began on 15th May 1991. The third cycle began on 1st January 1992, and a fourth was begun on 15th September of the same year. This most recent cycle was to undertake a global gravity survey in order to provide clues about the planet's crustal structure.

The Magellan project has enabled around 97% of Venus's surface to be mapped. Around 20% has been mapped in $75m^2$ sectors, and the remaining area in $225m^2$ sections. Data is collected by scanning tracks across the planet's surface. Each orbit of the planet results in a strip of data 350 'spots' wide by 220,000 'spots' long. Several thousand of these orbital strips have been collected during the mission.

In the Magellan pictures, areas of high signal correspond to areas with high reflectivity. The darker areas correspond to areas, from which lower levels of signals were recorded. The areas of low reflectivity are thought to correspond to areas of smooth contour, with the bright areas indicating rough terrain. The colours simulate what would be observed by the human eye, and are based on the colour images recorded by the Soviet Venera 13 and 14 landers in the early 1980s.

In the first cycle of the mission, it is anticipated that an amount of data equivalent to that captured in all previous NASA missions will have been collected.



Top: Photo 3. The picture shows the simulated landscape looking east over the volcano Sapas Mons, with Maat Mons on the centre right horizon. Lava flows can be seen radiating from Sapas Mons, and extend out for many hundreds of kilometres. Sapas Mons is not particularly high, extending only about 1·5km above the surface of the region.
Above: Photo 4. This region of volcanism in the region of the Western Eistla Region simulates a view taken from an elevation of 7·5km. Gula Mons is shown just below the left horizon and is approximately 2 miles high. On the right horizon the volcano Sif Mons, some 1·2 miles high is also a prominent feature. The two volcanoes are approximately 730km apart. The topographic scale has been enhanced by a factor of about 10 for both images.

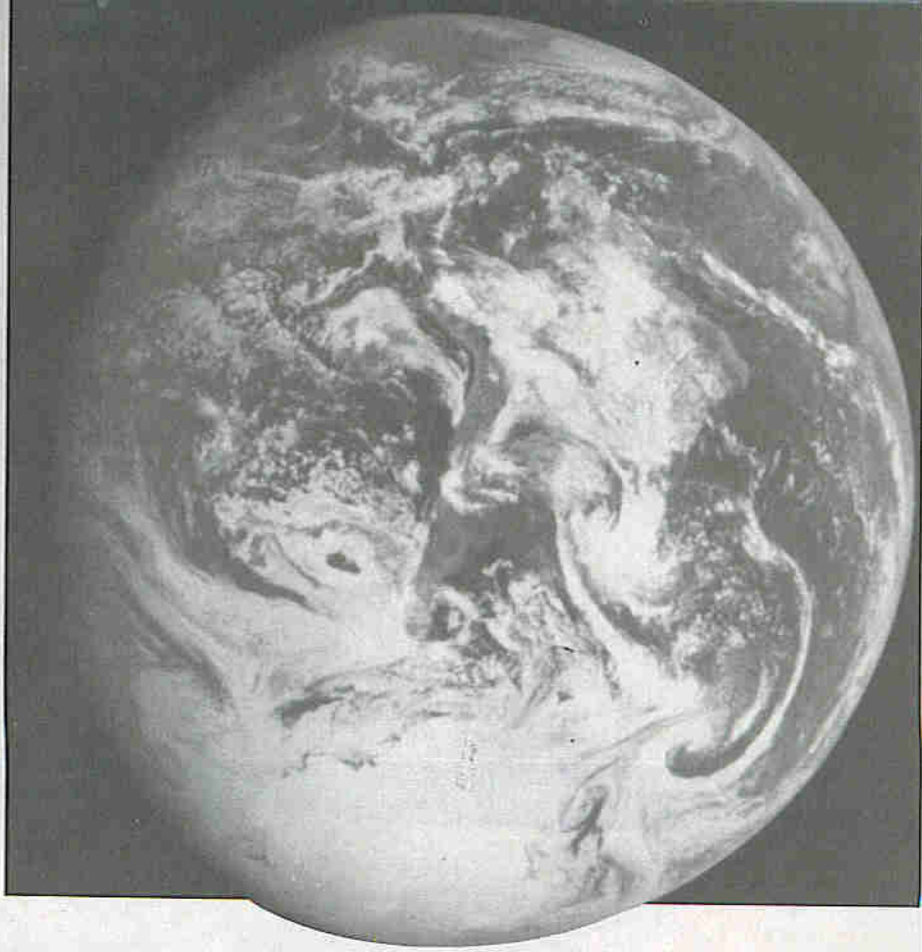
Surface Features

A striking feature that the pictures reveal is that there is very little weathering of surface features. The high temperature and pressure, however, might be expected to have the opposite effect and result in the crumbling of rock surfaces. It appears that the absence of water is a key factor in preserving such features. In contrast with Earth's surface geology, where the effect of the active weather can modify events such as volcanism and impact craters, the Venusian landscape preserves its scars and tears for much longer periods of time. A striking example of this phenomenon was the discovery of a lava channel some 2km wide and 6,800km long.

The high atmospheric pressure and high surface temperature, coupled with different crustal structures, give rise to different manifestations of volcanism compared to, for example, the Earth or Mars. Cinder cones, with evidence of plumes of material blown away from the cone by the prevailing wind, are in evidence. It is relevant to note, however, that the Magellan probe was essentially detecting ground structures. It was not able to observe smoke plumes in the atmosphere, which could well have been present. 'Pancake' domes, which resemble inverted cupcakes, are considered to be formed by eruption of viscous lavas.

Photo 1 shows a computer-simulated globe, which provides a hemispherical view of the surface of Venus from radar image mosaics of Magellan's first mapping cycle (September 1990 to May 1991). A prominent bright band, approximately the size of Africa, is visible on the equatorial zone. This feature is called Aphrodite Terra and is some 10,000km long. A large circular feature is visible slightly to the southwest. This is Artemis Chasma – a corona structure some 2,200km in diameter. These structures, considered to be unique to Venus, are sites where heat from deep mantle layers is transferred to the upper crustal layers. The large circular feature left of centre is the area around Maat Mons, the largest shield volcano on Venus.

Photo 2 shows Maat Mons in greater detail, from a computer simulated viewpoint 400 miles to the north, and at an elevation of 2 miles. The volcano, some 8km high, is considered similar in structure to the Earth's Mauna Loa shield volcano in Hawaii, and is built up from lava flows produced by a series of eruptions. Some of these flows can be observed stretching some hundreds of miles across the landscape. To enhance features, the vertical scale has been shown approximately ten times greater than that of the actual terrain.



Right: Photo 5. For comparison, this image shows the Earth as an oasis of moderate temperatures in comparison to the searing heat of Venus's barren land surfaces. The picture was taken by the Galileo spacecraft as it flew past Earth, as part of a planet hop process to propel it on its way to Jupiter.

Photo 3 shows the volcano Sapas Mons, which lies west of Maat Mons and can be observed on the horizon right of centre. Lava flows, extending for hundreds of kilometres, can be observed on the plains in the foreground. The topographic scale has been enhanced by a factor of 10.

Photo 4 shows another region of volcanism – this time in the Western Eistla Region. The volcano Gula Mons, a feature some 2 miles high, is shown just below the left horizon. Over to the right, the slightly smaller Sif Mons confirms that this is an area of active volcanism. Such regions are thought to be positioned over areas where hot material rises from deep within the planet. The Magellan scanners, however, have not been able to photograph vapour emissions from the volcanoes to determine their current level of activity. Lava flows, however, extend hundreds of kilometres out from the volcanoes. The vertical scale of the volcanoes is exaggerated, in this case by a factor of 20. Sif Mons is a vast structure, and has a diameter of 300km.

The most striking features of Venusian volcanism, however, are the coronas. Several hundred have, so far, been identified in the Magellan pictures. Such coronas are regions of volcanic activity characterised by fracture rings, within which are located cinder cones and pancake domes.

As can be expected, the very dense atmosphere of Venus provides a significant level of protection against incoming objects colliding with the planet. The Magellan mission found an absence of craters less than 3km in diameter, indicating that the atmosphere was able to burn small objects up within the dense atmosphere. There is evidence, however, that craters of up to 15km in diameter are formed from larger objects which break-up in the atmosphere. Clusters of craters can thus be found in the region where the object fragments impact on the planet surface. Often the shapes of the impact craters are asymmetrical – suggesting that the incoming fragments tended to skim the planet surface rather than impact directly.

Models of the atmospheric circulation on Venus indicate that winds of a few metres per second are probably present on the planet surface. This will probably result in the creation of some aspects of wind erosion and accumulation of wind blown debris. Detailed examination of the Magellan data does in fact indicate features such as 'sand dunes' and 'sand deposits' in the sheltered sides of prominent land features.

While the data from the Magellan mission has helped provide many answers, new sets of data have also introduced new puzzles. Teams of planetary scientists from around the world will be studying data from the Magellan mission well into the next century.

Problems of Data Handling

Prior to the Magellan mission, around 1 million megabytes of data has been collected from existing NASA space missions. The Magellan space probe has at least doubled the amount of data collected from planetary missions up to this time.

In anticipation of this massive addition to the available data on planetary systems, scientists at Washington University, based at St. Louis in the USA, have developed data handling systems to cope more effectively with such volumes of data. A team, led by Dr Raymond Arvidson, has developed a system, based around CompuServe's System 1032 4GL/Relational Database Management System.

Data is split into three main data bases. One is the map image catalogue, one is the original image data, and the other contains high-level data information about the spacecraft, the mission and associated sensor technical data. This latter resource is described as the 'high-level catalogue'.

Dr Arvidson's team has developed the data handling and analysis system for the planetary geology and geophysics programmes within NASA. At present, there are around 150 investigators associated with this project. Access to improved data retrieval systems will, no doubt, very significantly improve both the quality and the quantity of work undertaken by this group of scientists.

Once a specific image or series of images has been identified, the original data can be accessed, usually from CD-ROM, and loaded into memory where specific software can access and manipulate the original image data. The key role of the System 1032 is therefore as a catalogue of image data which allows retrieval and processing of a much larger set of raw image data.

It is intended that the bulk of the raw image data be made available on CD-ROM. A recent two and a half year initiative has succeeded in storing the Mars Viking mission data in this form. In terms of the Magellan project, it is planned to save the raw data on tape, but publish mapped data for Venus on a set of 50 discs.

Earth Revisited

The Earth fly-past by the Galileo craft on 11th December 1990 provided an opportunity to take a sequence of frames in a flight path running across Europe and the Caribbean. Photo 5 shows blue oceans, swirling wisps of water vapour clouds, and brown patches of continents. It is perhaps good to be reminded of the unique climatic conditions which we enjoy on Earth, in contrast to the baking, lifeless conditions which are present on Venus.

Summary

The Magellan mission has provided many answers to the present topology and evolution of Venus in general. The simulated three-dimensional pictures of the planet's surface are an amazing achievement of image processing technology, and bring the planet to 'life' in a remarkable way.

It is unlikely that manned missions to Venus would be considered – conditions are just too extreme. There is already keen interest, however, in sending further scientific missions to investigate details of the planet's crustal structure. This would require placing seismology instruments at key areas on the planetary surface. Such instrument systems, however, would be required to withstand the very high surface temperatures, and also operate without the benefit of useful levels of solar radiation to power solar panels.

Even as we develop (or at least think we do!) an understanding of the Earth's climatic and geological systems, Venus has many more secrets to yield.

PC Weather Station continued from page 15

```
10 REM ******* GW BASIC WIND SPEED PROGRAM *******
20 CLS
30 PRINT "Maplin PC Weather Station - Wind Speed Checking & Calibration Program."
40 PRINT "Copyright (C) 1993, Maplin Electronics PLC., All Rights Reserved."
50 BASEADD%=&H300                    'Set to the required base address in Hex
60 LOCATE 10,9:PRINT "The current value being returned from IC6 is: ";
70 LOCATE 12,1:PRINT "The approximate frequency at the Wind Speed input is: ";
80 LOCATE 14,26:PRINT "The simulated Wind Speed is: ";
100 REM START:
110 OUT BASEADD%,1                   'Enable IC3
120 A%=INP(BASEADD%)                 'Read IC3
130 A%=A% AND 128                    'Extract Bit 8 state (Bit 8 high = RESET)
140 IF A%=128 THEN GOTO 100          'If Bit 8 is LOW, wait
150 OUT BASEADD%,2                   'Enable IC6 Output
160 S%=INP(BASEADD%)                 'Read IC6
170 OUT BASEADD%,0                   'Reset all Data Outputs to Hi-Z
200 REM Check LE                      This routine checks that the data has been
210 OUT BASEADD%,1                   'read during the RESET period only; if not,
220 A%=INP(BASEADD%):A%=A% AND 128    'it returns the routine to the start without
230 IF A%=128 THEN GOTO 100          'updating the value of A%
300 FREQ%=S%*.855                    'Calculate approximate frequency
310 MPH%=FREQ%/5
320 LOCATE 10,55:PRINT USING "###";S%
330 LOCATE 12,55:PRINT USING "###";FREQ%;
340 PRINT " Hz"
350 LOCATE 14,55:PRINT USING "###";MPH%;
360 PRINT " MPH"
370 GOTO 100
```

Listing 1a. GWBASIC wind speed program.

```
REM ******* QUICK BASIC/QBASIC WIND SPEED PROGRAM *******
CLS
PRINT "Maplin PC Weather Station - Wind Speed Checking & Calibration Program."
PRINT "Copyright (C) 1993, Maplin Electronics PLC., All Rights Reserved."
BASEADD%=&H300                       'Set to the required base address in Hex
LOCATE 10,9:PRINT "The current value being returned from IC6 is: ";
LOCATE 12,1:PRINT "The approximate frequency at the Wind Speed input is: ";
LOCATE 14,26:PRINT "The simulated Wind Speed is: ";
start:
OUT BASEADD%,1                       'Enable IC3
A%=INP(BASEADD%)                     'Read IC3
A%=A% AND 128                        'Extract Bit 8 state (Bit 8 high = RESET)
IF A%=128 THEN GOTO start:           'If Bit 8 is LOW, wait
OUT BASEADD%,2                       'Enable IC6 Output
S%=INP(BASEADD%)                     'Read IC6
OUT BASEADD%,0                       'Reset all Data Outputs to Hi-Z
'Check LE                             This routine checks that the data has been
OUT BASEADD%,1                       'read during the RESET period only; if not,
A%=INP(BASEADD%):A%=A% AND 128        'it returns the routine to the start without
IF A%=128 THEN GOTO start:           'updating the value of A%
FREQ%=S%*0.855                       'Calculate approximate frequency
MPH%=FREQ%/5
LOCATE 10,55:PRINT using "###";S%
LOCATE 12,55:PRINT using "###";FREQ%;
PRINT " Hz"
LOCATE 14,55:PRINT USING "###";MPH%;
PRINT " MPH"
GOTO start:
```

Listing 1b. QuickBASIC/QBASIC wind speed program.

Installation

Installation of the PC Weather Station Card can be broken down into a number of steps.

1. Selecting an appropriate base address:

The I/O address area of an 8086/80286 machine is limited to 64k. The design of PCs reserves I/O addresses up to &H00FF for use on the motherboard, and makes available I/O addresses &H0100 to &H03FF for use on expansion cards.

When selecting an I/O base address, it is important to avoid those already in use by existing cards. If you have two or more cards both addressed at, say &H0300, 'bus contention' is likely to cause problems (the microprocessor is accessing two devices at the same time). For example, one card could be pulling the data lines high while another card is trying to hold them low, so that the data itself is meaningless.

Addresses already in use can be determined by consulting the installation instructions for the existing cards. In addition, Table 3 gives a helpful list of designated I/O addresses. It is suggested that address &H0300 is used, as this is designated for prototyping cards.

The base address of the PC Weather Station Card is set up as follows. The settings of SW1-1 to 8 can be determined by converting the required address into binary, and taking the eight most significant bits (A9 to A2) as the settings for the switches. SW1-1 corresponds to bit A2 and SW1-8 corresponds to bit A9, a logic 1 = switch 'off' and a logic 0 = switch 'on'. An example of how to determine the switch settings is shown in Table 4. The switch settings on the prototype corresponded to a base address of &H0300. Note that even though the card only uses one address (its base address), the least significant two bits, A1 and A0, are not actually implemented. This results in the card's single equivalent address actually occupying four of the machine's address locations. This may seem rather odd, but is done in order that the card is given maximum versatility in the high-order bits, allowing the address range of expansion cards to cover &H0300 to &H03FC.

2. Turn off the computer and disconnect it from the mains supply. Lethal voltages reside inside computers, and installation of the card with the computer switched on may result in permanent damage to your computer and/or the card.

3. Remove the cover of your computer to expose the expansion card area.

4. Locate a suitable empty expansion slot and remove the metal blanking plate cover screw, and cover (if fitted). Store the cover in a safe place for later replacement, should you wish to remove the PC Weather Station Card from your computer.

5. Carefully insert the card into the empty slot, pushing it fully home without forcing it. Using the cover screw removed in step 4, fix the end-plate to the back of your computer.

6. Replace the cover.

Testing

With all fingers, etc. crossed, switch on the computer – it should boot in the normal way. If it does not, turn it off immediately, remove the expansion card and check for solder whiskers shorting out adjacent tracks.

The next stage is to test the card, prior to plugging in the outdoor sensors themselves. As we discovered in the Circuit Description, a Wind Speed test signal is available on-board; one of five pulse trains of different frequency can be selected via JP4, and output to pin 14 of SK1. This should be temporarily linked to the Wind Speed input (pin 13 of SK1). A simple program written in BASIC can be used to test the card – refer to Listings 1a (GWBASIC) and 1b (QuickBASIC/QBASIC). It displays the approximate frequency of the pulse train

Required base address = 0300 hex 0300 hex = 11000000xx

x = don't care – as the PC Weather Station Card does not decode the last two bits A1 and A0, their setting is irrelevant. Thus the DIL switch settings equate to address lines A2 to A9, as shown below:

Switch number:	SW1-8	SW1-7	SW1-6	SW1-5	SW1-4	SW1-3	SW1-2	SW1-1
Address line:	A9	A8	A7	A6	A5	A4	A3	A2
Binary value:	1	1	0	0	0	0	0	0
Switch setting:	OFF	OFF	ON	ON	ON	ON	ON	ON

Table 4. I/O Selection.

```
10 REM  ******* GW BASIC WIND DIRECTION PROGRAM *******
20 CLS
30 PRINT "Maplin PC Weather Station - Wind Direction Checking & Calibration Program."
40 PRINT "Copyright (C) 1993, Maplin Electronics PLC., All Rights Reserved."
50 BASEADD%=&H300                    'Set the required base addres in Hex
60 LOCATE 10,1:PRINT "The current position of the Weather Vane is: ";
70 LOCATE 12,1:PRINT "(0 is North, the returned number should increase CLOCKWISE)"
100 REM start:
110 OUT BASEADD%,1                   'Enable IC3
120 D%=INP(BASEADD%)                 'Read IC3
130 D%=D% AND 15                     'Extract Bits 1 to 4
140 D%=15-D%                         'Inverts the result (due to the input opto's)
150 FOR N=0 TO D%
160 READ D$
170 NEXT N
180 RESTORE
190 LOCATE 10,45:PRINT D%
200 LOCATE 10,50:PRINT D$
210 GOTO 100
220 DATA "N  ",NNE," NE",ENE," E ",ESE," SE",SSE," S ",SSW," SW",WSW," W ",WNW," NW",NWN
```

Listing 2a. GWBASIC wind direction program.

```
REM  ******* QUICK BASIC/QBASIC WIND DIRECTION PROGRAM *******
CLS
PRINT "Maplin PC Weather Station - Wind Direction Checking & Calibration Program."
PRINT "Copyright (C) 1993, Maplin Electronics PLC., All Rights Reserved."
BASEADD%=&H300                    'Set the required base addres in Hex
LOCATE 10,1:PRINT "The current position of the Weather Vane is: ";
LOCATE 12,1:PRINT "(0 is North, the returned number should increase CLOCKWISE)"
start:
OUT BASEADD%,1                    'Enable IC3
D%=INP(BASEADD%)                  'Read IC3
D%=D% AND 15                      'Extract Bits 1 to 4
D%=15-D%                          'Inverts the result (due to the input opto's)
FOR N=0 TO D%
READ D$
NEXT N
RESTORE
LOCATE 10,45:PRINT D%
LOCATE 10,50:PRINT D$
GOTO start:
DATA "N  ",NNE," NE",ENE," E ",ESE," SE",SSE," S ",SSW," SW",WSW," W ",WNW," NW",NWN
```

Listing 2b. QuickBASIC/QBASIC wind direction program.

(which should correspond with the test frequency), the 8-bit binary count from IC6, and the simulated wind speed (in mph).

You can test the Wind Direction section by applying a TTL level voltage (i.e. 0 or 5V DC) to each of the four inputs (pins 9, 10, 11 and 12 of SK1). It is important to tie pins 28, 29, 30 and 31 to ground. There are sixteen possible combinations of 'high' and 'low', each of which correspond to a possible output from the Wind Direction Sensor. When the program of Listing 2a (GWBASIC) or Listing 2b (QuickBASIC/QBASIC) is run, the 4-bit simulated input value should be displayed, together with the corresponding compass bearing.

Apart from the ADC part of the circuit, which will be covered (together with the ADC circuit) in a future issue, testing is now complete – the outdoor units can now be wired up to SK1. There are two methods of connecting the sensors to the card. The first, shown in Figure 10, shows how the PC Weather Station Card can be wired into an existing system which is based around the Weather Station Main Unit. Apart from allowing wind speed and direction to be monitored when the PC is being used for other tasks, this unit will provide the outdoor sensors with power. The other option is to use a low-cost AC mains adaptor (XX09K) to power the sensors, as shown in Figure 11. If you are building the units from scratch, constructional and alignment information is given in the original article, which is supplied with the kit. The test programs could, if you wish, be developed into 'user-friendly' software; additional features (such as data logging and graphical output) could be built in.

PC WEATHER STATION CARD PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1	150Ω	1	(M150R)
R10,R13-R16	1k	5	(M1K)
RN1, 3	10k SIL Resistor	2	(RA30H)
CAPACITORS			
C1	100pF Ceramic	1	(WX56L)
C2, C3	10μF 16V Tantalum	3	(WW68Y)
C4,C5,C8,C9	100nF 16V Minidisc	4	(YR75S)
SEMICONDUCTORS			
IC1	74LS688	1	(KP49D)
IC2	74HC02	1	(UB01B)
IC3,IC6	74HC373	2	(UB80B)
IC4	74HC273	1	(UB72P)
IC5	74HC00	1	(UB00A)
IC10,IC11	74HC4020	1	(UF00A)
OP3,4	ILQ74 Quad Optoisolator	2	(YY63T)
MISCELLANEOUS			
SW1	DIL Switch SPST Octal	1	(XX27E)
SK1	RA Socket 37-Way 'D' Type	1	(JB38R)
	14-Pin DIL Socket	2	(BL18U)
	16-Pin DIL Socket	5	(BL19V)
	20-Pin DIL Socket	4	(HQ77J)
	Pin Strip 2 × 36 ST	1	(JW62S)
	PC Bracket 37-Way 'D' Type	1	(CR45Y)
	Mini Pin Jumper	2	(UL71N)
	PCB	1	(GH53H)
	Instruction Leaflet	1	(XU31J)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)			
R2-R9	1k	8	(M1K)
R11,R12	560Ω	2	(M560R)
RN2	10k	1	(RA30H)
C6	100nF 16V Minidisc	4	(YR75S)
C7	10μF 16V Tantalum	3	(WW68Y)
IC8	74HC4051	1	(UF06G)
IC9	4094BE	1	(QW54J)
OP1,2	ILQ74 Quad Optoisolator	2	(YY63T)
FS1	Fuse 20mm 1A	1	(WR19V)
FS2	Fuse 20mm 250mA	1	(RA06G)
	20mm Fuseholder with Cover	2	(KU29G)
	6-Core Screened Cable	As req.	(XR26D)
	37-Way 'D' Plug	1	(FV71N)
	37-Way 'D' Hood	1	(JB66W)
	16-Pin DIL Socket	4	(BL19V)
	Maplin Magazine Issue 31	1	(XA31J)

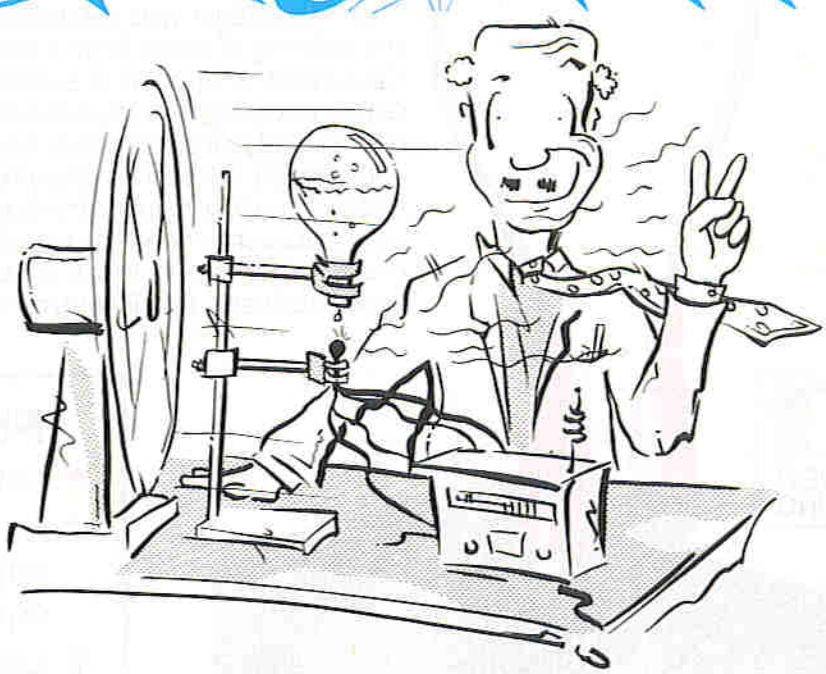
The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding optional) are available as a kit, which offers a saving over buying the parts separately.
Order As LT28F (PC Weather Station Card)
Price £29.95.

The following new items (which are included in the kit) are also available separately, and are also shown in the 1994 Maplin Catalogue.
PC Bracket 37-Way D-Type **Order As Price CR45Y £2.25.**
PCB **Order As GH53H Price £12.95.**

Stray Signals

by Point Contact



In case you are wondering (following my last month's jottings) how it was possible to get 5W of RF power at 130MHz from a small-signal germanium transistor, the answer is 'with the aid of extreme measures'! The device, an EW43 (I think that was the type number, EW indicating an 'experimental crystal' device, predating the GET series) had an f_T of not much more than 130MHz and a collector-emitter punch-through voltage of less than 10V, so you can see that it was being pushed very hard indeed. To prevent it melting under the strain, the people in the Transistor Applications Lab next door to the Solid-State Physics Lab, where PC was a student assistant at the time, had come up with a scheme which was as barmily impractical as it was effective. This particular transistor was bare, never having had its top cover cold-welded to the base. It was mounted on a retort stand, immediately below the nozzle of a burette full of ether. When the burette's tap was open, a continuous stream of ether came into contact with the germanium chip, and so the stated RF power was obtained, the latent heat of evaporation of ether keeping the chip cool. The whole caboodle was placed on a window sill, with a fan supposedly wafting the fumes away, but a breeze blowing on that side of the building defeated this part of the strategy – it was the smell that brought the experiment to the notice of all in the SSP Lab! I think that it was another six or seven years before silicon devices enabling such RF power levels to be raised in a practical, engineerable way, finally arrived.

Last year, Mr and Mrs PC visited the Military Aviation Museum near Chichester in East Sussex. It is situated at Tangmere on the edge of the famous but long-gone RAF fighter station, and housed in an H block of prefabricated construction. Wandering around the exhibits, it dawned upon me that this was in fact the 'new' combined radio workshop where I worked briefly as a Junior Technician (Radar), towards the end of my time as a National Serviceman in the mid-fifties. It replaced the old Radar Section where I had worked previously (and which was situated miles from the main camp away around the peri-track), bringing it together with the old Wireless Section in a new purpose-built workshop. It lacked the informal 'laissez faire' ambience of the old Radar Section, so Tony, Woody, Pip, Tony "Dubious" and the rest were rather more subdued – when they weren't in trouble. In fact, only months (perhaps a year or so) after the new workshops were opened, the station was closed – but that's the way it goes in the forces! You have to spend the money allocated to you this year, or your budget for the next year will be cut on the grounds that you obviously don't need that much! (Nothing like the Civil Service, eh? – Ed) Now, the building houses not only electronic gear from the war years and after, but some of the enormous internal combustion engines that powered the fighters and bombers of that era. Together with the photographs and other mementos of the period on show, it all added up to a fascinating trip down Memory Lane for an oldy like myself! On a visit to the Farnborough Air Show in the eighties, PC had purchased an A3 print of a Hawker Hunter, which was in service in the fifties. It was purchased because the plane was shown in 34 Squadron colours, with the wolf's head emblem surrounded by the Squadron motto *Lupus volit, Lupus tollit* (what the wolf wants the wolf takes) on the fuselage. 34 Squadron was stationed at Tangmere whilst I was there, or rather when they weren't swanning off to Cyprus or wherever. The museum seemed a good home for it – so there it is, together with some photos of the hangars, the station Anson and the like.

Following my disparaging comments about those BS-standard plastic lampholders whose shade-retaining rings jam, two readers wrote in offering the same solution – 'apply a little silicone oil to the thread when new – a useful tip which I am happy to pass on to 'Electronics' readers. But the fact remains that this shouldn't be necessary in a well-designed lampholder, and in any case it won't help Granny Smith (who has undoubtedly never heard of silicone oil!) as she stands on a rickety chair to put up a new shade. No, I reckon you should make sure that Granny's house has brass lampholders, properly earthed to an ECC in the lighting circuit.

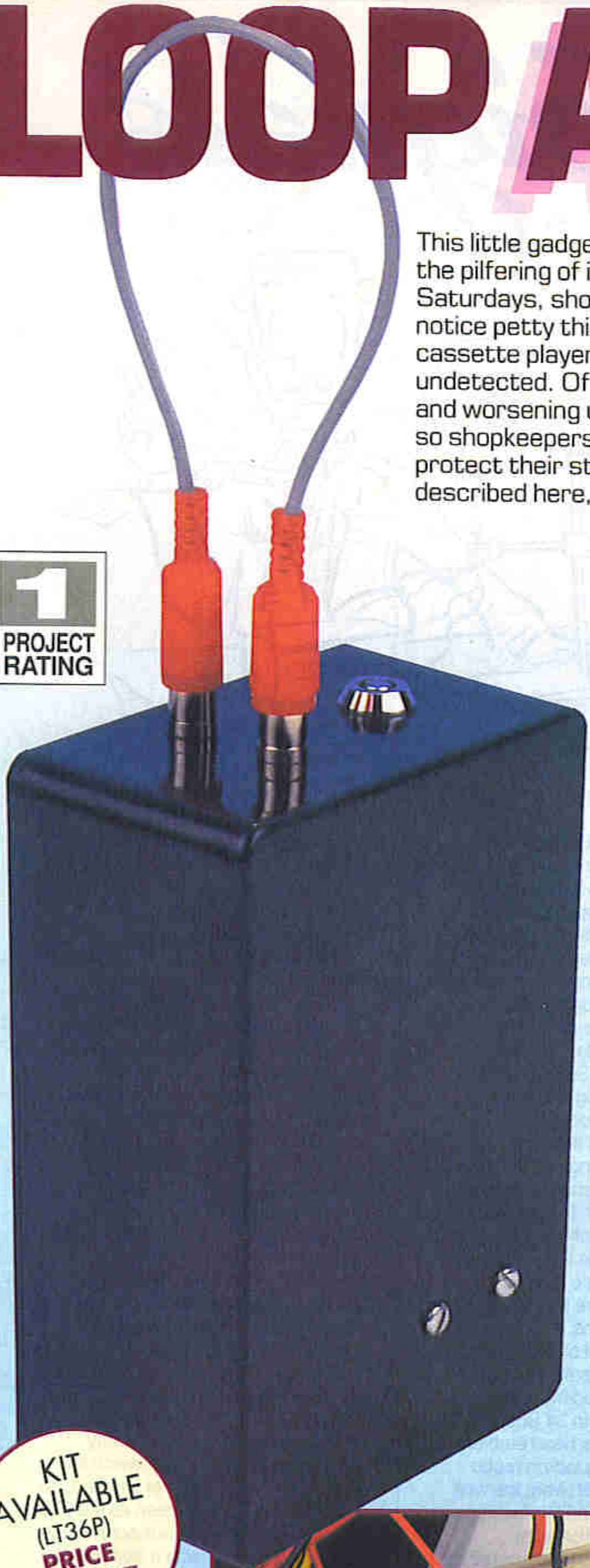
Mind you, silicones have some interesting properties which can cause problems. I remember a colleague being troubled by a persistent water leak, at the bottom of his car's windscreen. He tried all sorts of compounds to seal it, but the leak always returned after a few months exposure to sun and rain. He then tried some MS4 silicone grease, which did the job permanently. Success? No – this grease has the awkward property of gradually spreading over any optically-flat surface with which it is in contact! So, whenever it rained, he had a smeary windscreen as the water could not wet it. Vigorous scrubbing of the windscreen with a little paraffin effected only a temporary cure, until in desperation he tried removing the grease sealing the leak. After that, he had a leak *and* a smeary windscreen. Eventually he sold the car!

Yours sincerely,

Point Contact

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

LOOP ALARM



This little gadget was developed in response to a real problem – the pilfering of items from a shop. During peak shopping periods like Saturdays, shop staff are usually too pre-occupied with customers to notice petty thieves lift items of often quite significant value (personal cassette players and cameras, for example), and then disappear undetected. Of course, this problem – thanks to a severe recession and worsening unemployment situation – is increasing steadily and so shopkeepers need to invest in some kind of security system, to protect their stock. In the case of the simple but effective Loop Alarm described here, this investment need not be too great.

1
PROJECT RATING

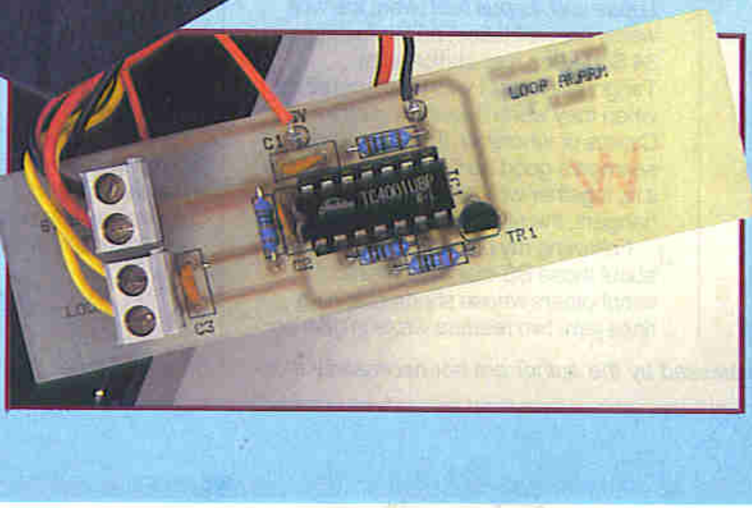
FEATURES

* Low-cost * Easy to build
* Does not need complicated adjustment, or test equipment to set up
* Long standby life from one set of alkaline batteries – typically three years or more

APPLICATIONS

* Shop loop alarm – protect display items
* Office/school loop alarm – protect computers etc.
* Home loop alarm – protect ladders, garden tools, bicycles, etc. when left in the garden
* Could be adapted for use with a garden gate or garden shed

KIT AVAILABLE (LT36P) PRICE £16.45



Design by Dennis Butcher
Text by Martin Pipe and Dennis Butcher

Above left: The assembled Loop Alarm, complete with loop.
Left: The assembled Loop Alarm PCB.

Householders are also vulnerable – leaving aside obvious targets like bicycles, surprisingly large objects like ladders (and in one case, a satellite dish with a diameter of six feet!), have been known to go missing. This situation has developed to the point that some insurers will not provide cover for such items; even where cover is provided, in some cases (garden tools, for example) it is simply not economically viable to pursue claims – but the annoyance and expense of replacement are still there. Again, the Loop Alarm will help considerably at home – it can be used to protect a garden shed, and/or even alarm a back gate – and is priced at a fraction of the cost of a new set of 40ft. aluminium ladders!

Circuit Description

Power is a nominal 6V DC (though it will work with supplies of between 4 and 12V), supplied from four AA alkaline cells. The unit draws a maximum of 70μA when armed, giving up to 1,190 days on standby from a fresh set of batteries! The current consumption increases to approximately 56mA when triggered. Of course, this reduces the standby life according to how long the unit had previously been left sounding – it pays to check the batteries at least twice a year! Theoretical battery life for a unit when triggered, and left to sound away, is over 35 hours.

As you can see from the circuit diagram of Figure 1, the circuit is built around IC1, a 4001UBE quad unbuffered NOR gate, of which two sections (b and d) are used. When power is applied, the loop is closed (the loop must present a resistance of less than 90kΩ to the circuit, which should not pose too many problems unless your loop encircles the planet!). Under normal non-criminal circumstances, one of the inputs of IC1a (pin 1) is held low by the low resistance of the loop (pull-up resistor R4 has a value of 100k, and thus has negligible effect). Also held low (this time by the pull-down resistor R3) are the output (pin 11) of IC1c, and the other input (pin 2) of IC1a.

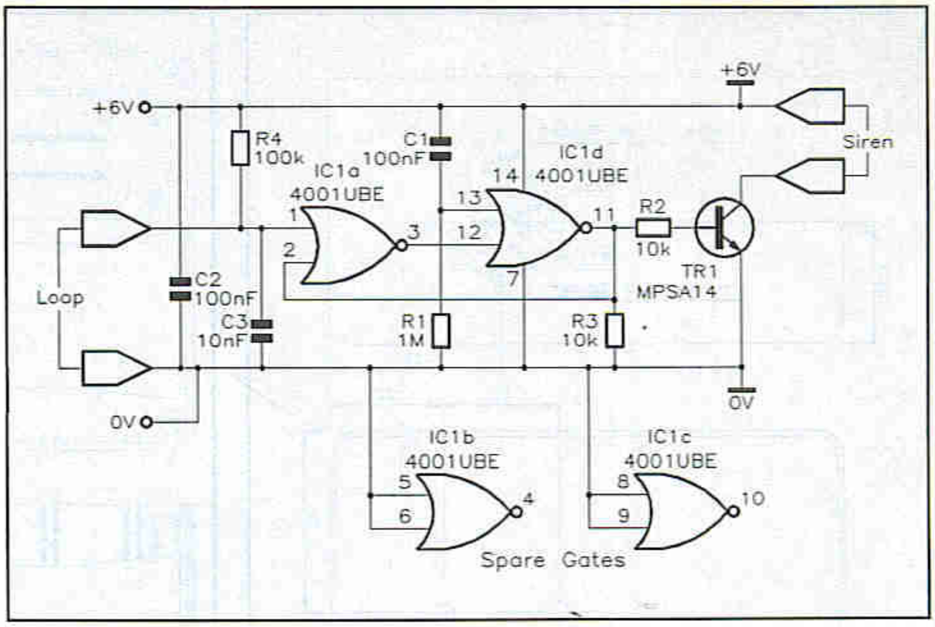


Figure 1. Loop Alarm circuit diagram.

Since both inputs of IC1a are low during normal operation, its output (pin 3) – and therefore the input (pin 12) of IC1c – will be high. After less than 100ms, C1 will be charged, and IC1c pin 13 will be held low; these components are present to ensure a power-on reset of IC1. Since both inputs to IC1c are low, its output, and consequently the base of TR1 will also be low. TR1 is therefore switched off, and so the siren does not sound.

When the loop is 'broken' – in other words, when the resistance across P3 and P4 is greater than the value of R4 i.e. 100kΩ – the alarm condition is triggered. IC1a pin 1 will be pulled high by R4, and so IC1a's output (pin 3) – and therefore pin 12 of IC1c – will go high. The output of IC1c (pin 11) will now go high. TR1 (MPSA14) is a Darlington device, and will conduct, therefore, applying power to the siren connected across P5 (red, +V) and P6 (black, 0V).

Since the output of IC1c (pin 11) is also connected to the other input of IC1a (pin 2), the output of IC1a will be held low, irrespective of any change to IC1a's other input (i.e. pin 1). Due to this innovative use of a NOR gate, the alarm is therefore latched 'on', and the only way to reset it is to remove power (via the keyswitch).

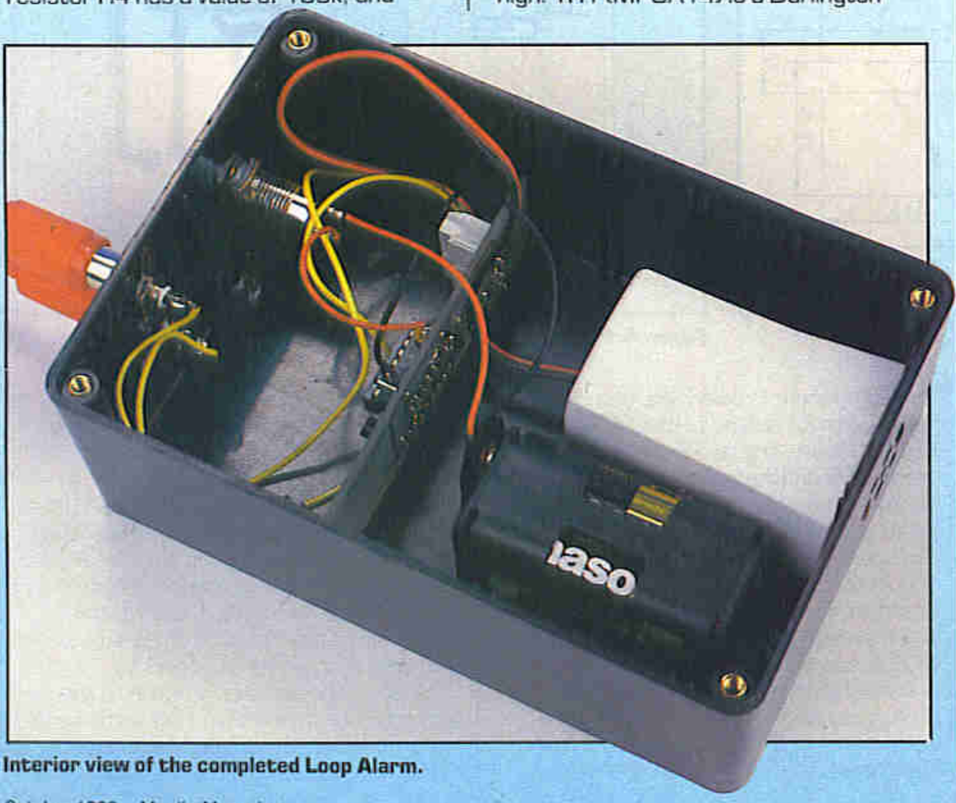
C3 is a decoupling capacitor, which has been incorporated to prevent any stray RF from taxi transmitters, CB sets and the like from triggering the alarm. Note that all connections to the unused gates have been grounded.

Construction

The Loop Alarm is, by virtue of its simplicity, easy to construct. To make things even easier, the PCB is designed to fit into one of the slots within a MB5 box – refer to Figure 2.

First, the box should be drilled – the required dimensions are given in Figure 3. A number of holes have to be drilled on the base and sides of the box for the siren, keyswitch, and the two phono sockets which connect to the loop itself. Once the drilling is complete, all items bar the PCB, of course, can be fitted – refer once again to Figure 2. The siren should be attached to its mounting bracket; the assembly can be held to the base of the box using two No. 6 × ⅜in. self-tapping screws. Of course, the mouth of the siren should point towards the outlet grille drilled in the side of the box. The keyswitch and chassis-mounting phono sockets can then be passed through their respective mounting holes, and secured into position with the nuts supplied. Finally, provision needs to be made for the battery holder. Self-adhesive Velcromounts should be applied to the area of the case next to the siren (see Figure 2), the mating surfaces being attached to suitable positions to the 4 × AA battery holder.

Having drilled and 'kitted out' the



Interior view of the completed Loop Alarm.

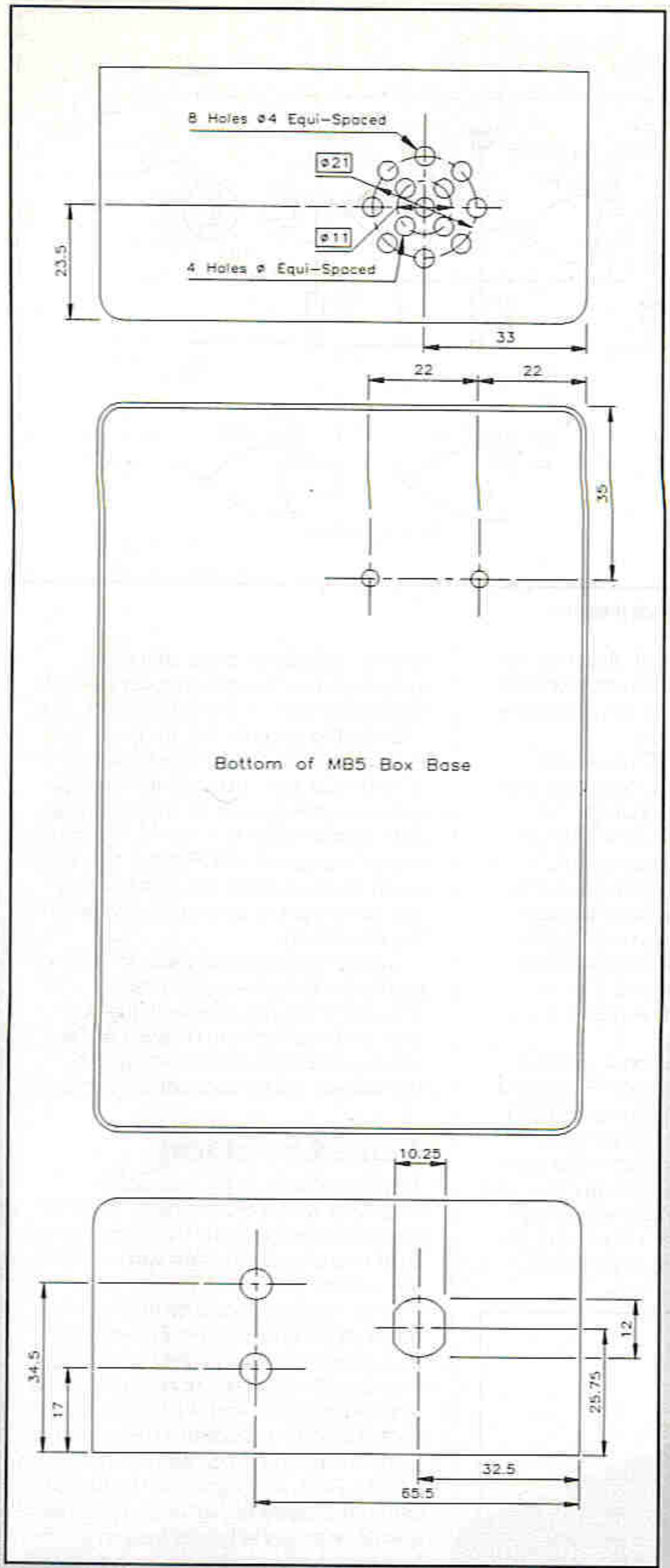


Figure 2. Physical assembly and wiring.

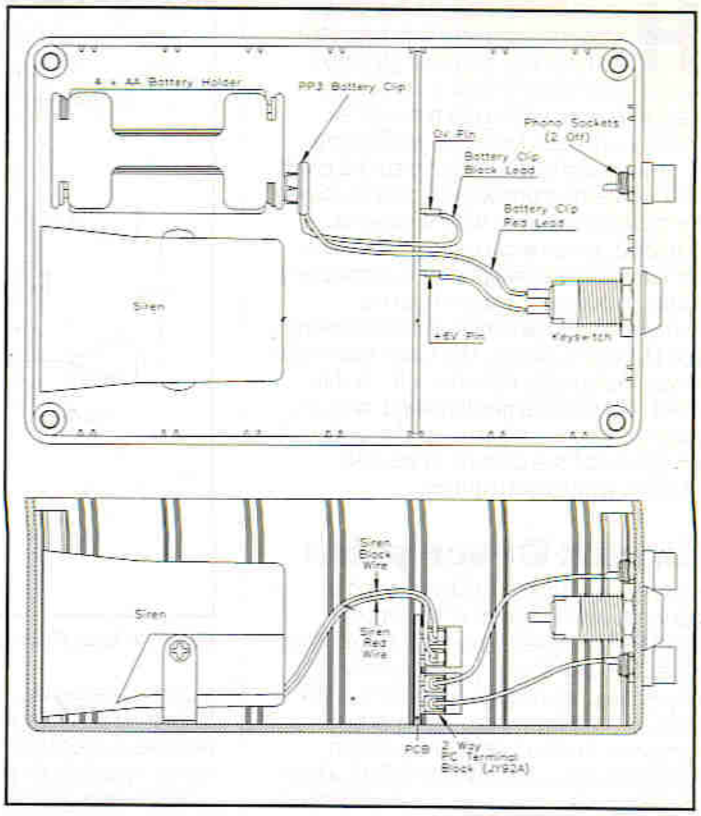


Figure 3. MB5 box drilling details.

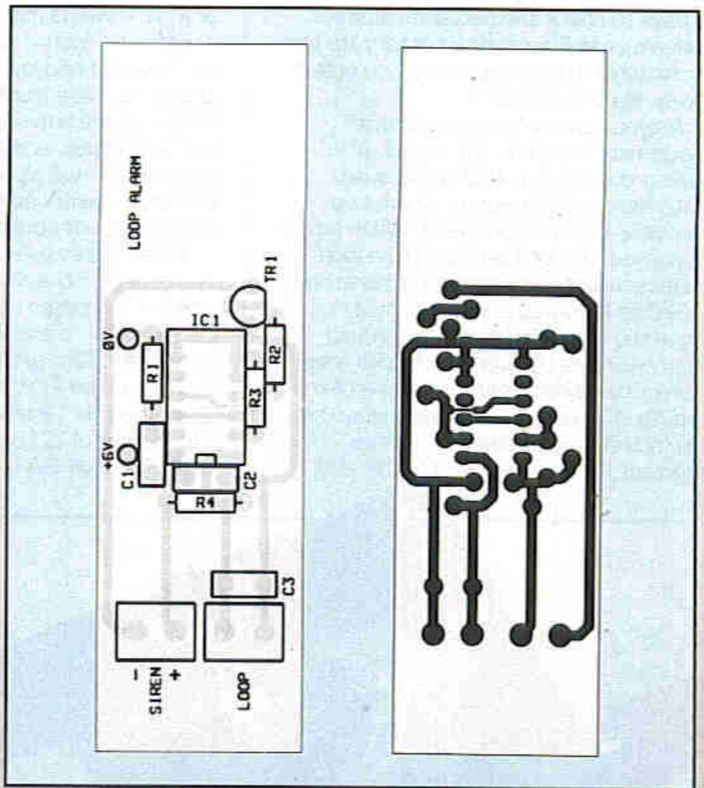


Figure 4. PCB legend and track.

box, it's now time to put together the PCB – a simple task, thanks to the low component count. If you are not experienced in electronic construction, please refer to the Constructors' Guide supplied in the kit – a goldmine of helpful practical advice.

Referring to the component legend of Figure 4, insert and solder all resistors, capacitors and the two PCB pins. Next, IC1's 14-pin DIL socket – the notch in its body should line up with that of the socket's symbol on the PCB legend. Do not fit IC1 at this stage. TR1 should follow next – please note that, like IC1, this component is polarised, and should line up with its outline on the PCB legend. Finally, the two 2-way screw terminal connectors now need to be fitted – push the connectors into position until they are flush against the board (the receptacles for the wires should point to the nearest edge of the board, to facilitate their easy insertion) and then solder them into position. PCB assembly is now complete, but it is advisable to check your work before continuing any further.

Now that the PCB is complete, wiring can commence; reference should again be made to Figure 2. Solder the black lead of the PP3 battery clip to the '0V' PCB pin, and the red lead to one of the terminals of the keyswitch. Solder a 120mm length of red wire (supplied in the kit) between the keyswitches other terminal, and the '+6V' pin on the PCB.

Cut the cable attached to the siren in half, since it is far too long for this application; do not discard the excess, though, as it will be used shortly. The siren should be connected to the appropriate screw terminals – the red wire goes to the '+ SIREN' connection. The siren's excess wire, put to one side

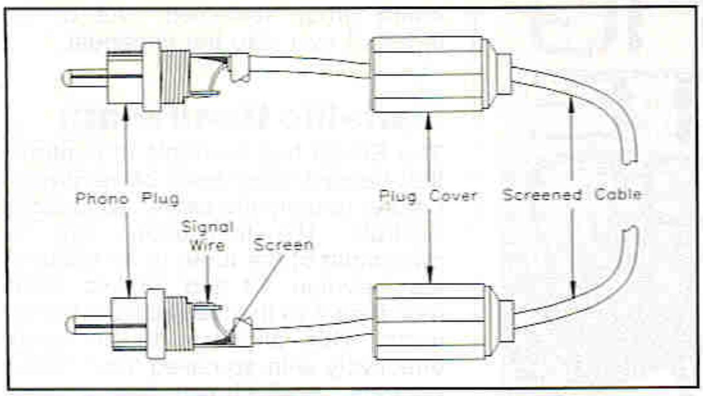
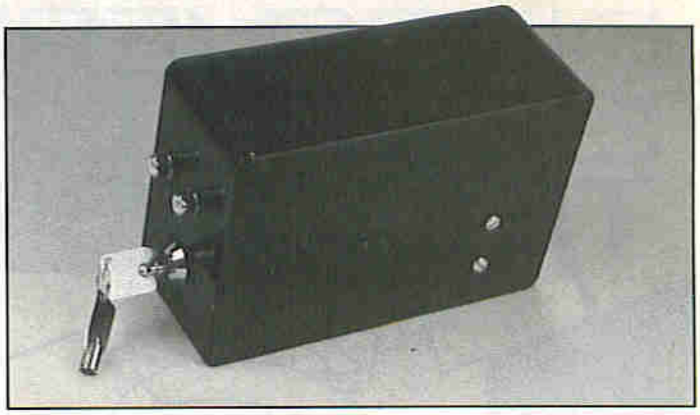


Figure 5. Making up the loop cables.



The finished Loop Alarm.

earlier, should now be used to connect the centre terminals of the two phono sockets to the screw terminals marked 'LOOP' (the outer terminals of the sockets are not used). After inserting IC1 (ensuring correct polarity) the board can now be fitted into the second or third slot of the box (from the keyswitch end), with the track side of the PCB facing the siren.

Fit four AA alkaline cells into the battery holder (watch the polarity!) and clip the battery clip into place (check that the key switch is off first!). Secure the battery holder in place, mating the two Velcromounted surfaces together, and finally screw the box lid on.

Having warned anybody within a radius of 100m of an impending loud noise, check that the siren sounds by turning the keyswitch to its 'on' position – if you hear a loud noise reminiscent of a wailing banshee, then switch off and continue; if no noise is apparent, you have a fault and should check your work.

Connect a suitable lead between the two phono sockets (the only requirement here is that there is a connection between the two centre conductors). One could be temporarily borrowed from your Hi-Fi system for the purpose of this test; alternatively, such a lead could be made up from a spare piece of wire and a couple of phono plugs.

With the lead in place, switch the alarm on. The alarm should not operate at this point, but as soon as the the phono lead is disconnected at either end, the siren should sound. Reconnecting the lead should not have any effect – the only way to silence it is to switch it off!

Installation

Now that the unit has been tested, you can now proceed to install it. The loop, terminated with phono plugs at either end, and of suitable length must now be made, capable of reaching all of the items for which protection is intended; a suitable cable is the single-core lapped audio variety (XR13P). Cable wiring is illustrated in Figure 5. Since the resistance can be as high as 90kΩ, the loop can effectively be as long as you like! The alarm itself should be hidden out of view (e.g., under a desk) preferably somewhere near the cashier, supervisor or manager's working area. Of course, the unit must be installed somewhere dry – this comment is particularly valid when the unit is being used to protect items outside the home or shop. Nevertheless, the fact that the loop length is restricted by practical considerations, rather than by any limitations of the design, may be of assistance here.

When installing the loop, pass it through the main body of the item to be protected. For example, when protecting a bicycle, pass it through the frame and the wheels. When protecting a ladder, pass it through several rungs. Cameras and the like could be protected by passing the loop through a permanently-attached carrying strap. If the item to be protected does not have any suitable apertures through which to pass items (e.g., TV set), a suitable one could be glued on, or a more elegant situation could be devised. For example, a computer could have an unused connector, or one with at least two unused pins, and these could be used to form a loop. Again, only your imagination is the limit here. The golden rule to remember is that if a thief thinks he is going to receive hassle when trying to steal something, he is likely to reconsider and move elsewhere.

If at a later stage you need a longer loop, you could make a second lead to cover the extra distance, and connect them 'in the middle' using 'barrel' connectors (HH05F).

LOOP ALARM PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1	1M	1	(M1M)
R2,3	10k	2	(M10K)
R4	100k	1	(M100K)

CAPACITORS

C1,2	100nF 16V Minidisc	2	(YR75S)
C3	10nF 50V Disc	1	(BX00A)

SEMICONDUCTORS

IC1	4001UBE	1	(QL03D)
TR1	MPSA14	1	(QH60Q)

MISCELLANEOUS

Micro Piezo Siren	1	(JK42V)
ABS Box MB5	1	(YN40T)
Min Key Switch	1	(FE44X)
DIL Socket 14-Pin	1	(BL18U)
PP3 Clip	1	(HF28F)
PCB Terminal Block 2-Way 5mm	2	(JY92A)
4AA Batt Box	1	(HF29G)
Velcromount	1 Pkt	(FE45Y)
Self-Tapping Screw No. 6 × 3/8in.	1 Pkt	(LR67X)
7/0·2 Wire 10m Red	1 Reel	(BL07H)
Chassis Phono Socket	2	(YW06G)
PCB	1	(GH46A)
Instruction Leaflet	1	(XU32K)
Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

Alkaline AA	4	(FK64U)
Screw-Cap Phono Black	2	(HQ54J)
Cable Single Grey	As Req.	(XR13P)
Phono Adaptor Male	As Req.	(HH05F)

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 LT36P (Loop Alarm) Price £16.45.

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.

Loop Alarm PCB **Order As GH46A Price £1.98.**

DISCOVERING SATELLITE TELEVISION

Part Eight For the Enthusiast...

by Martin Pipe

Cast your mind back to the last issue, in which we reviewed the TechniSat ST-60025, a comprehensive and versatile micro-processor-controller multi-satellite receiver. This month, we delve into the world of the Echostar SR-50 another enthusiast's receiver but at the other extreme when it comes to complexity.

Echostar SR-50

The SR-50, from one of the oldest names in domestic satellite television, is a very basic but well-made 'no-frills' receiver – but that's a huge 'plus' point in its favour. Once upon a time, all satellite receivers seemed to share this design philosophy. No microprocessors, no remote control, no kitchen sink – oh, how things have changed! What the SR-50 is equipped with, though, is variable IF bandwidth – something that DX-TV'ers have long considered essential to screw the last ounce out of a weak signal – a 70MHz loop, and tuning via a single-turn pot, amongst other things. The rear panel is also well-equipped with socketry. There's no positioner built in – but a unit like the superb Pace one featured last month would suit it well functionally, although not aesthetically.

For the purpose of this review, the Threshold Assistance Device (TAD) from Echostar's UK distributor, Eurosat, was installed. This small PCB, which can be fitted to any receiver with a 70MHz loop, can yield considerable improvements with the weakest signals (i.e. those normally 'below threshold').

Compared to most receivers currently on the market, the design of this receiver seems positively in the Dark Ages. Yet, in terms of features, it is a considerable advance on other receivers of its type – stereo sound and variable IF bandwidth, for example. Each parameter is controlled by a panel-mounted potentiometer, and not a D-to-A converter hanging off one of the I/O ports of a microprocessor. On the receivers utterly unpretentious front-panel are the large tuning knob, two audio tuning controls (the SR-50 can resolve stereo or bilingual audio), transponder and audio IF controls, a skew knob, a polarity select push-button and a decent-quality analogue signal strength meter (all multi-satellite receivers should have one of these!) which is back-lit in a tasteful green. And I loved it; the SR-50 was by far the easiest-to-use receiver of the entire group reviewed. Out of interest, it was also the cheapest.

Variable Bandwidth

The SR-50 has a couple of controls that haven't been seen on receivers before, namely the two IF bandwidth controls. The first allows the IF bandwidth of the tuner to be controlled between 12 and 26MHz, thus matching it to the transponder bandwidth. This allows it to be used effectively with so-called 'half transponders', in which two channels are transmitted via a single transponder for economy reasons; such instances are common with newsfeeds, for example. In addition, reducing the IF bandwidth helps to clean up a weak signal; the less-important higher-order sidebands, together with the noise that accompanies them, can be filtered out. IF bandwidth control can also be useful when problems are encountered with strong adjacent channels or transponders. These two facts are well-known to amateur radio enthusiasts and DX-TV'ers. The latter group, by the way, are people (usually radio amateurs as well!) with imposing Yagi aerial arrays mounted on rotators atop impressively tall towers, who seek out TV pictures – in any form – from distant countries; whenever the conditions are right. Needless to say, this group took to satellite television extremely quickly – a good few years before Astra came on the scene!

The second IF bandwidth control allows the bandwidth of the left ('A') audio channel to be varied between 150kHz (for the narrow bandwidth Wegener subcarriers) and 350kHz (for the primary subcarriers). Note that the bandwidth of the right channel, 'B', is fixed at 180kHz. This control allows the audio bandwidth to be optimised to that of the desired audio channel; in theory, reducing the audio bandwidth may help improve the audio performance with channels that are perceived weaker and are close to the threshold figure of the receiver's baseband demodulator. In the case of the SR-50, this weak signal threshold is 7dB C/N (carrier to noise ratio).

The Echostar SR-50. A masterpiece of simplicity.

Audio Matters

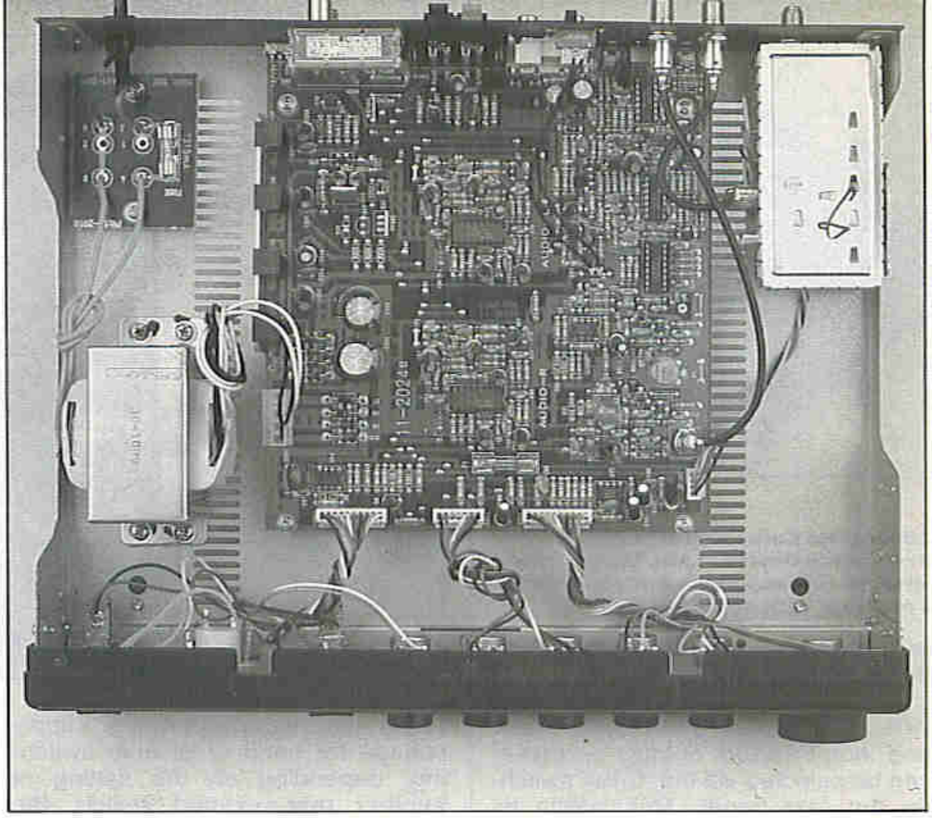
The audio de-emphasis time-constant of the SR-50 is fixed at 50μs. Although the receiver doesn't offer such niceties as J17 or Panda-1 de-emphasis, it must be borne in mind that the DX-TV and weak-signal enthusiasts are happy with any signal at all! In any case, leaving out such features keeps the cost down, while allowing features like the adjustable IF filter to be incorporated. The audio subcarrier tuning range is specified as being between 5 and 8·5MHz, in practice the range was a little wider – the higher frequency subcarriers on Telecom 2B (5°W) could be accessed. Talking of Telecom, the fact that the sound demodulators are independently tunable is a boon when it comes to dealing with non-standard subcarrier spacings, such as those encountered with Telecom radio stations. These, as you may recall from a previous review, showed up a major short-coming of the Mimtec Premiere 2 and the Pace MRD950, both of which had their audio channels fixed 180kHz apart.

Polarising Stuff

The SR-50 is intended for use with servo-controlled mechanical polarity selectors (known as 'polarisers'), rather than the more reliable magnetic (current-driven) 'wavetwister' types that are becoming the norm these days (the former tend to 'seize up' occasionally, particularly in cold weather, resulting in the loss of one polarity). Mechanical polarisers are, however, less lossy and are generally very popular at the enthusiast end of the market, with Chaparral and Echostar both producing excellent quality units. Mechanical polarisers (also known as 'polarotors'), together with other types, will be looked at in greater detail in a subsequent instalment, but suffice to say that the heart of a mechanical polariser is a resonant probe that can be rotated so that it 'lines up' with the vertically or horizontally polarised wavefront of the incoming signal. The probe is then coaxially coupled to the one in the LNB aperture. The amount of rotation is controlled by the mark/space ratio of a TTL-level square wave applied to the 'control' input of the device – the 'servos' used by model racing enthusiasts work on the same principle. There are three spring-loaded terminal blocks at the rear of the SR-50 for this purpose; control signal apart, there are ground and +5V connections.

Nuts and Bolts

The mark-space ratio, as you've gathered, is controlled using the 'H-V' switch and the 'skew' knob on the front panel of the receiver. Looking inside the receiver, I find the ubiquitous NE555 timer at the heart of the circuit. The H-V switch on the front panel switches another resistor into the timer circuit; this allows two different ranges of pulse width to be obtained – corresponding to vertical and horizontal channels, where the angles of probe rotation will differ by 90°. The 'skew' knob allows the polarity to be 'fine-tuned'.

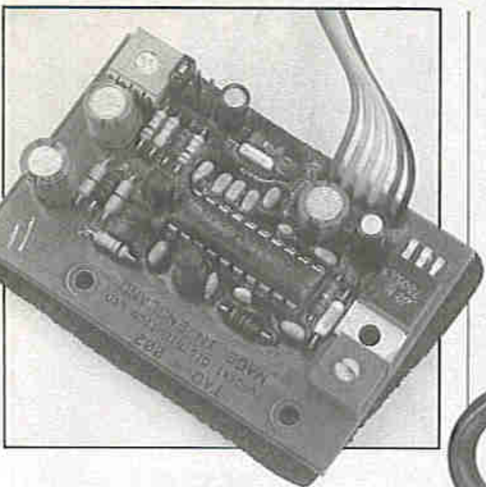


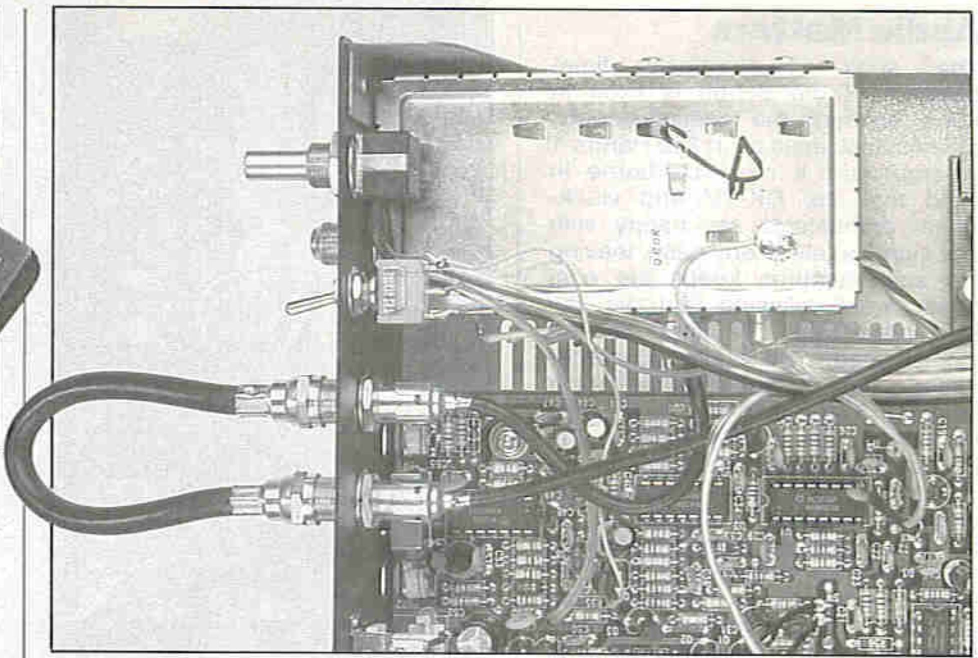
Inside the SR-50. Read 'Nuts and Bolts' to find out what it all does.

Because the receiver is so simple, much of the circuitry becomes identifiable – and we can go into some detail, which we cannot with other receivers as most of the circuitry is either in custom ICs or sealed screened boxes! In the SR50, audio tuning and demodulation is controlled by two Exar XR-215 chips (one for each channel) – a device which is quite ubiquitous in this application. Baseband demodulation is accomplished using a MC1496 in a double-balanced demodulator configuration.

The tuner and first IF stage (if you don't count the LNB, which is a down-conversion stage in its own right) is in a large metal can. Here, the first IF (i.e. 950MHz to 1750MHz) is down-converted to a second IF frequency of 70MHz, which is brought out to the rear panel – the so-called '70MHz loop' This frequency of 70MHz, by the way, is an industry standard (for example, it is used for IF signal distribution at satellite earth stations). Unfortunately, though, the 70MHz loop is disappearing from most domestic receivers, which is a pity since there are various accessories that are designed for use with it – such as a bandwidth controller (admittedly superfluous in the case of the SR-50). The return path of the loop goes into the adjustable bandpass filter, which is varicap-tuned; some amplification then follows, which compensates for the significant insertion losses incurred by the final IF filter (a SAW type) that comes next. After the SAW filter is a MC10116 three-stage wideband amp/limiter, and finally the baseband demodulator mentioned earlier. The signal from this is fed to the two sound demodulator circuits, and in a separate path to the vision de-emphasis filter. After de-emphasis, the video signal is clamped (to remove dispersal) and amplified (using the well-known NE592 de-

The rear panel of the Echostar SR-50, with 70MHz loop.





Above: The Eurosat Threshold Assistance Device (TAD). Watch those sparklies disapppear – but you'll need a receiver with a 70MHz IF.

Right: The Eurosat TAD, seen fitted inside the Echostar SR-50.

vice). The NE592 provides inverted and non-inverted outputs – these can be selected via the 'C/Ku' switch on the rear panel. This switch is so-called since 'C' band channels are transmitted with positive-going video, while 'Ku' band channels commonly use negative-going video. The common pole of the switch is fed via a buffer stage to the video output socket, and to the RF modulator. Out of interest, the UHF modulator can be switched for use with both the UK's 6MHz intercarrier sound system, and the Continental 5·5MHz standard. It can be adjusted between channel 30 and 38 – which is not a particularly wide range and may cause compatibility problems in some areas. Another reason for using a direct video connection! Talking of which, the gain of the LM392 is adjustable via the 'video level' preset on the rear panel. There is another video socket ('BB/MAC') on the back; this is the 'baseband' output socket for a decoder (MAC transcoder, Videocrypt, etc.). A switch enables this output to be derived from before (MAC – flat response) or after (filtered baseband) the de-emphasis filter. This arrangement allows for a certain amount of flexibility when it comes to using the SR-50 with other equipment.

Other circuitry on the well-crafted double-sided PCB is associated with the receivers automatic gain control (AGC) circuitry (another preset allows you to adjust this from the rear panel) and tuning meter, and also the power supply. One of the power supply's regulators (the 12V one) did run hot in operation – a clip-on heatsink was conspicuous in its absence! The mains transformer is a substantial affair; a point to note is that the 'power' switch on the front-panel switches its secondary winding – current always flows through the transformer's primary while the unit is plugged in.

The SR-50 can also be used with LNBs that depend on the supply voltage for band or polarity switching; depending on the setting of another rear-mounted switch, the 'H-V' control will select the voltage sent up the LNB feed cable; in the 'horizontal' position 18V will be sent to the cable, while 14V will be supplied when the switch is in its 'vertical' position. This brings us to a problem when the receiver is being used with a triple-band LNB – each time you change bands, you'll have to keep tweaking the skew control for best results.

There is, would you believe, yet another option related to polarity switching. A fourth spring-loaded terminal supplies 12V (at 100mA) when the H-V switch is in the 'vertical' position; in the other position, the output is 0V. This option would be used in a SMATV (satellite master antenna television) system for switching between the outputs of two LNBs – one for each polarity. SMATV systems will be looked at in greater detail in a subsequent article.

Performance

Performance-wise, the SR-50 was fairly disappointing in some respects – bearing in mind the promising specification offered. The first problem was that of overloading, which produced chronic sparklies with Astra using an 80cm dish fitted with a 1·2dB Marconi LNB (it was considerably worse using a 1·2m dish!). Careful adjustment of the AGC preset (and it is a critical adjustment!) minimises the problem – but it doesn't get rid of it! Feeding the SR-50's 70MHz input (the 70MHz loop is certainly a handy thing!) with the 70MHz output from an elderly Multipoint receiver gave much better results – and proved that the SR-50 was potentially capable of excellent picture quality. With weaker signals the SR-50 did perform well – after all, the SR-50 is primarily designed for use in countries where the satellite footprint is weak – but the fact remains, the SR-50's AGC circuit appears to be poorly designed, resulting in limited dynamic range. A pity!

The second problem is that of imaging. A strong transponder on a satellite causes weaker images to appear elsewhere in the receiver's tuning range. This is related to the above problem and, once again, careful AGC adjustment helps.

The MAC output caused compatibility problems, when used with the Ferguson/Trac transcoder (refer to 'Electronics', Issue 63), I could not get any of the MAC channels to lock satisfactorily – regardless of video level. The transcoder has not presented any problems with other receivers – the SR-50 was the first one that wouldn't work properly. MAC decoder circuits are extremely fussy about such parameters as frequency response and channel bandwidth – perhaps the IF filtering is having an effect on, this, or unwanted image frequencies were causing interference (remember the comments made earlier, and that the DBS satellites are extremely powerful – the images will thus also be stronger).

The action of the SR-50's tuning control can be construed as being both a benefit and a nuisance. On the positive side, a single twist of the large knob (there's no reduction gear) takes you from one end of the IF band to the other. This is great when you are moving your dish, since it enables you to scan for new channels or satellites by quickly turning the tuning knob in alternate directions. The disadvantage is that it is easy to knock the receiver inadvertently off-tune! A 'stiffer' action would certainly have helped. Out of interest, the receiver can be tuned between around 900MHz (great for the so-called 'cable-only' channel that the Germans plan for Astra), and just above 1750MHz. The tuning range is thus greater than that of a conventional receiver with a 950MHz to 1750MHz IF, but not as wide as a receiver equipped with a 2GHz tuner.

Adjustable IF-bandwidth proved to be very useful, when it came to resolving those weaker transponders. Bearing in mind that an adjustable 70MHz IF filter unit, for use with suitably-equipped receivers, costs around £100, the value of the £180 SR-50 is put into perspective. In fact, if you already have a receiver (particularly an older one) equipped with a 70MHz IF loop, using it as a 'front end' with the SR-50 may give better results – and adjustable IF bandwidth and stereo sound are 'thrown into the bargain'!

The Eurosat Threshold Assistance Device (TAD)

At around the time the SR-50 was made available in the UK, Eurosat's TAD came onto the scene. Its job in life is to enable better quality pictures to be extracted from weak signals – in fact, the TAD was developed for use in areas like Saudi Arabia and Africa, where signals are weak and dishes have to be large. There is clearly a large market in countries which are outside the footprint of popular satellites such as Astra – MTV, and Sky News are as good reasons as any! Bearing in mind the target market for the SR-50, we thought that reviewing this module at the same time as the receiver would be a good idea. The somewhat expensive (over £100) TAD can be fitted to any receiver equipped with a 70MHz loop, which of course includes the SR-50. Other such receivers include the Echostar SR-4500, Chaparral Monterey, Drake ESR-324 and TechniSat ST-6000, to name but a few; speak to your dealer if you are not certain whether your particular receiver fits into this category. As we have discussed earlier, it is a shame that receiver manufacturers are doing away with the 70MHz IF loop (preferring a single-conversion design based around a 480MHz IF); as a result, flexibility suffers. Eurosat are, it is rumoured, working on a TAD for receivers with a 480MHz IF.

It is important to note that fitting the TAD will invalidate the original receiver manufacturer's guarantee. We would therefore recommend that the dealer who sold you the receiver fits the module, if the unit is still under guarantee. Since Eurosat are a distributor rather than a dealer they do not, unfortunately, deal direct to the public, and so you will have to order your TAD via your dealer in any case. Another option is to purchase a SR-50 already fitted with a TAD by Eurosat; these are also available via your dealer.

The TAD effectively acts as a replacement demodulator – a far superior and efficient one than that in the host receiver – and, in theory at least, enables pictures to be resolved from signals with a C/N ratio of 4dB (most normal receivers stop working at 7dB or so). A TAD-equipped receiver shouuld therefore give better weak-signal performance than the same one unmodified. We shall, in due course, find out if this is actually the case.

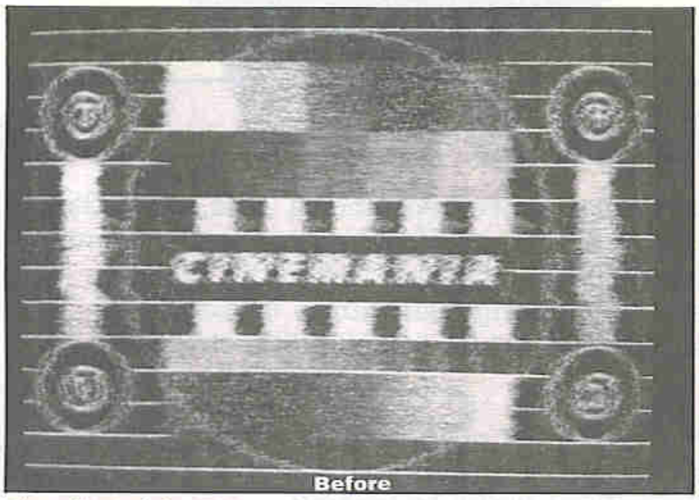
The fairly small PCB (70 × 50 × 15mm) is dominated by a 20-pin DIL IC, which carries out the duties of IF amplification and limiting, demodulation and video processing. The review sample – including the socketed IC – was encapsulated in a resinous substance – this would not do much for the long-term reliability of the unit. Eurosat say that this was so that the module did not yield its secrets to over-inquisitive people; apparently the module was a 'demonstration' one, and had travelled extensively before being despatched here. Eurosat assure me that this treatment does not extend to commercially-available units!

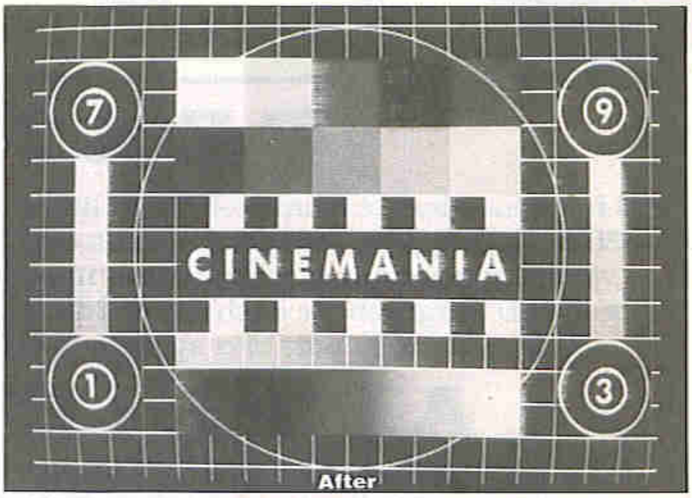
Connection to the receiver is via a six-wire ribbon cable; two wires are for power (12V DC) and ground (0V), one is the 70MHz input, another is the video output, while the remaining two are for a rear-mounting 100Ω variable resistor – the so-called 'tuning pot'. Fitting is very easy, and Eurosat provide paperwork with the kit which gives fitting details for your specific receiver. The instruction sheets for the SR-50, which seem to have been produced using Microsoft Windows Draw, are easy to follow – they have to be, since the TAD is normally fitted by dealers – who often, in the experience of this author at least, sadly have little knowledge of the product they are selling.

Fitting the TAD

Modification of the SR-50 is easy. Eurosat do, however, recommend that an isolated soldering iron (i.e. one fed from the mains via an isolating transformer, or a battery/gas-powered iron) is used; the demodulator IC is, apparently, extremely static-sensitive – as well as expensive to replace. The video output from the TAD is fed into the receiver's de-emphasis filter by lifting one end of a resistor from its main PCB and soldering the TAD's output lead to it. Eurosat recommend fitting a toggle switch, so that the SR-50's original demodulator can be switched in if required; the output from this is obtained from where the resistor's lifted leg used to be. Eurosat supply a suitable single-pole changeover toggle switch for this purpose. Note, however, that the original demodulator is used to drive the two audio circuits. The IF input is tapped from the input to the MC10116; a 10nF ceramic capacitor in series with the TAD input lead provides AC coupling. Power and ground are obtained from strategic points on the SR-50's PCB. The 'tuning pot' is then fitted to the rear panel of the receiver (a hole has to be drilled here!); the module can then be bolted to the ventilation slots at the base of the receiver.

Setting up is fairly straightforward; there are two presets (video level and preset tuning) that need to be adjusted; the simple procedures are given in the instructions.





The effect of the TAD on the Spanish Cinemania test card on Astra, before and after it is switched into circuit. The 'weak signal' effect was obtained by misaligning the skew and moving the dish slightly off the optimum position. Screen images © Cinemania 1993.

Continued on page 39

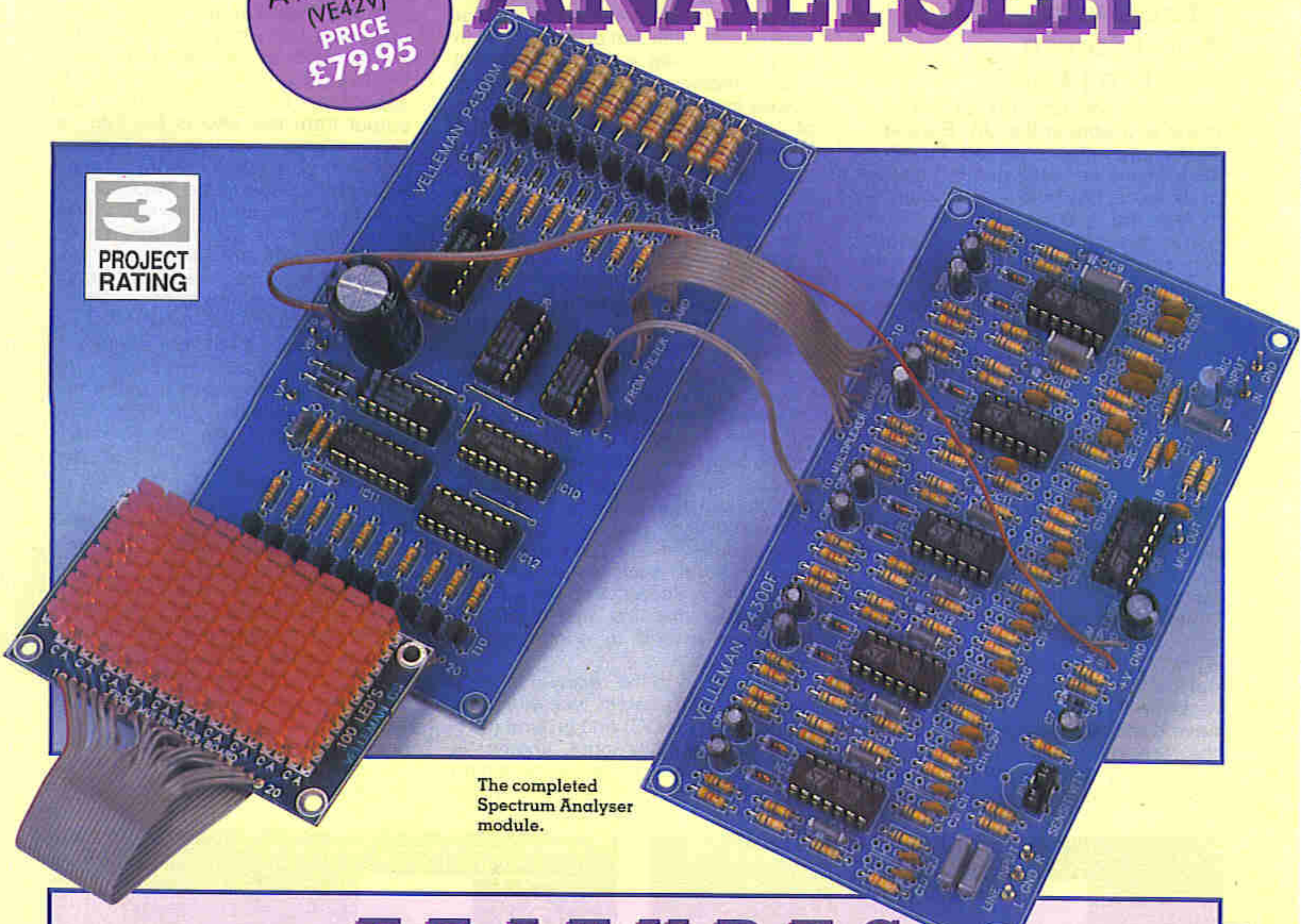
Text by Martin Pipe

To some people – generally 'Hi-Fi snobs' – spectrum analysers and other displays are seen as mere gimmicks, and of no real value. They say that the money spent on such equipment would be better utilised in improving the rest of the system, through purchasing platinum-plated mains plugs, pieces of tin-foil to be placed strategically under your turntable's mains lead, and other such nonsense!

AUDIO SPECTRUM ANALYSER

KIT AVAILABLE (VE42V) PRICE £79.95

3 PROJECT RATING



The completed Spectrum Analyser module.

FEATURES

★10 frequency bands monitored on 10 linear bargraphs; centre frequencies 32Hz, 64Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz and 16kHz. ★Single +12V DC power requirement ★Microphone input ★High input impedance (100kΩ) – will not load audio system ★10 LED bargraph for each band; 2dB for each LED, giving 20dB range ★Used in its own right, or as part of a system, to be described in future issues of 'Electronics'

APPLICATIONS

★Setting up speaker systems ★Checking adjustment of graphic equaliser ★Assuring a flat frequency response ★Something pretty to look at!

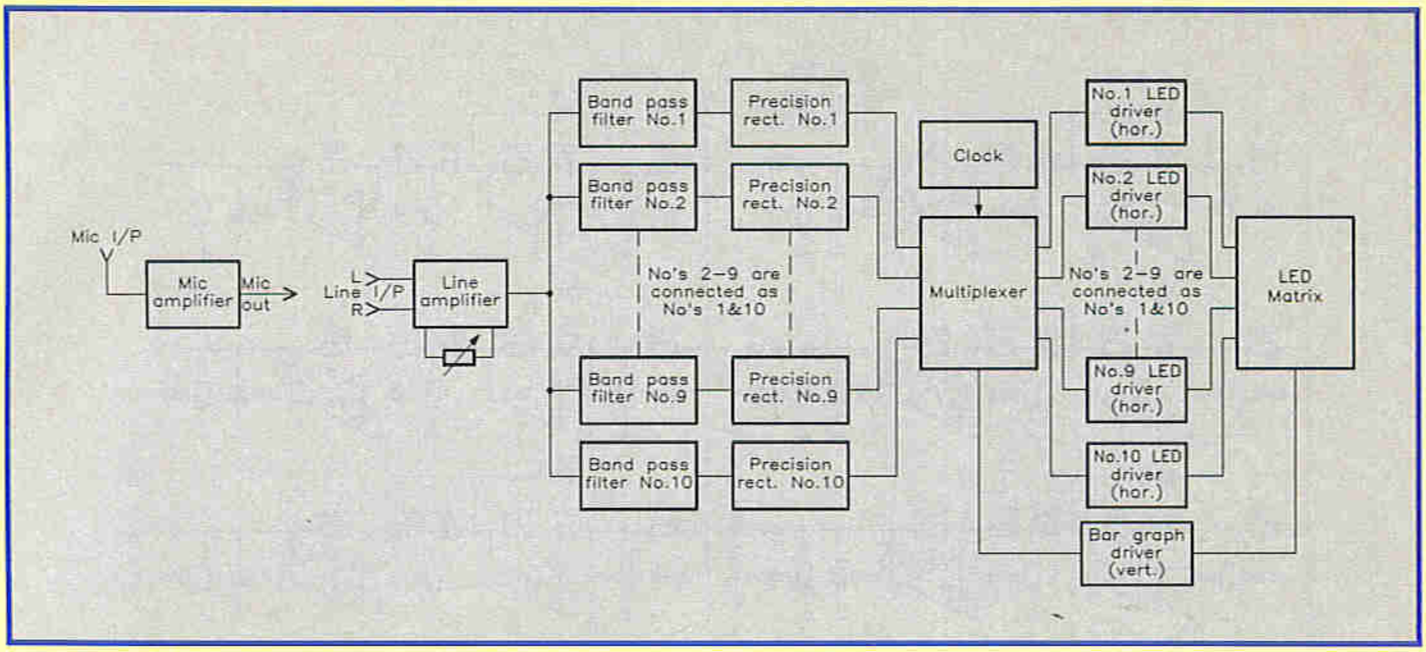


Figure 1. Spectrum Analyser block diagram.

Whereas it certainly is foolish to buy a piece of equipment without identifying a definite need for it, a spectrum analyser is a useful tool when used with that other bane of the Hi-Fi snob's sultry existence – yes, I'm talking about the graphic liquidiser – whoops – equaliser! These act as very comprehensive tone controls (gosh, tone controls – I'd better not push the Hi-Fi snobs *too* far!) – instead of the standard 'bass' and 'treble' controls, graphic equalisers offer 'boost' and 'cut' over multiple frequency ranges, and so fairly precise control can be maintained across the spectrum. Apart from compensating for deficiencies in the equipment or listening environment (they are virtually standard practice in high-end in-car audio systems), they can be used to 'doctor' tape recordings for use in particular applications (e.g., reggae music, in-car, personal stereo, the dilapidated workshop ghetto-blaster), or to compensate for any deficiencies encountered when making tape recordings (a slight loss of high-frequency 'sparkle' can be compensated with a slight boost of the 8kHz and 16kHz ranges) – or, for that matter, the recording engineer's somewhat depraved sonic preferences! Yes, a graphic equaliser, when used properly, can be an asset to any Hi-Fi system – but a spectrum analyser will help you to use it properly in the first place! If you haven't got a graphic equaliser, don't fret, as one will be featured in a forthcoming issue of 'Electronics'. This, together with the Spectrum Analyser, Pink Noise Generator and a purpose-designed front panel, will form a complete high-quality graphic equaliser system that rivals the best.

A spectrum analyser simultaneously displays the levels across a number of specially-chosen frequency ranges within the audio band – generally those adjustable by the graphic equaliser itself – thus allowing you to monitor the effects of adjustment. The unit presented here incorporates a microphone preamplifier, which increases the versatility of the unit still further. If you feed pink noise into your graphic equaliser-equipped audio system, it will be picked up acoustically from the speakers by the microphone. The equaliser can now be adjusted so that the spectrum analyser displays a 'flat' response. This system, typically used in a domestic environment, allows you to compensate for speaker frequency response, soft furnishings and hard walls, and other sources of colouration. A pink noise generator, by the way, will also be featured soon in 'Electronics'. Spectrum analysers' look good too – something to take your mind off the dirge that passes for 'music' these days… (Perhaps the Hi-Fi snobs have now given me a temporary reprieve!)

Specification

Supply current:	0·75A (DC).
Power supply:	2 × 9V AC, or 12 to 15V DC.
Range:	20dB (10 LEDs, 2dB per LED).
10 Bands:	32Hz, 64Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz, 16kHz.
Line Input Level:	Adjustable, 100mV to 2V rms.
Line Input Impedance:	100kΩ
Microphone Preamplifier Gain:	40dB.
Microphone Input Impedance:	10kΩ.

Circuit Description

The circuit is built up on three separate PCBs: one contains the filtering circuitry to drive each of the ten bargraphs, and the microphone preamplifier; the second contains the display multiplexer (which saves on expensive bargraph drivers); while the third contains the LEDs themselves – there are ten LEDs for each of the bargraphs, giving a total of 100. The overall scheme of things is shown in Figure 1.

(i) The Filtering Circuit

This section of the Spectrum Analyser, the circuit of which is reproduced in Figure 2, consists of ten separate active bandpass filters, with centre frequencies ranging from 32Hz to 16KHz. Each filter uses two op amps, and so a total of five LM324 quad op amps are used – i.e. twenty in all. Therefore each LM324 will encompass two separate filters.

Both of the op amps in each filter are arranged as inverting amplifiers (and thus the filtered output is of the correct phase). The audio signal is input through resistor R1 which, along with R2, determines the static gain of the first op amp. As the frequency rises, the impedance of C1 & C2 decrease causing the gain to fall. This arrangement forms a high-pass filter. C3 acts as an AC coupling capacitor and, along with R4 and R7, acts as a low-pass filter. The second op amp forms a precision rectifier; C8 is used as a storage capacitor with a slow discharge through R5, and this acts as a 'peak picker' which allows the signal peaks to be registered more clearly by the human eye (i.e. fast attack and slow decay).

There is another LM324 quad op amp on the Filter PCB, which is not directly associated with the filter circuitry – this is used in several ways, as can be seen from Figure 3. One of the op amps is used as a half supply voltage reference

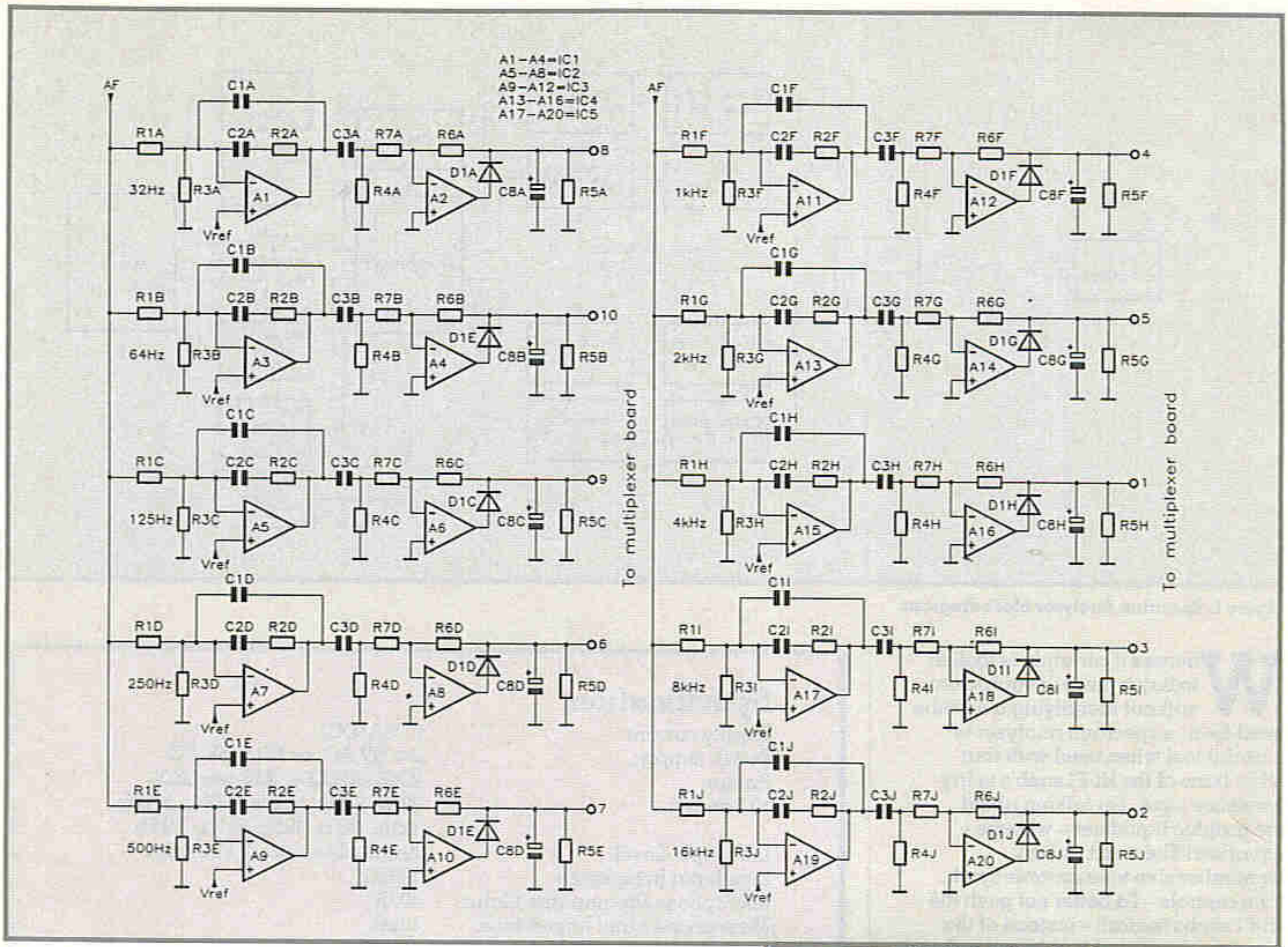


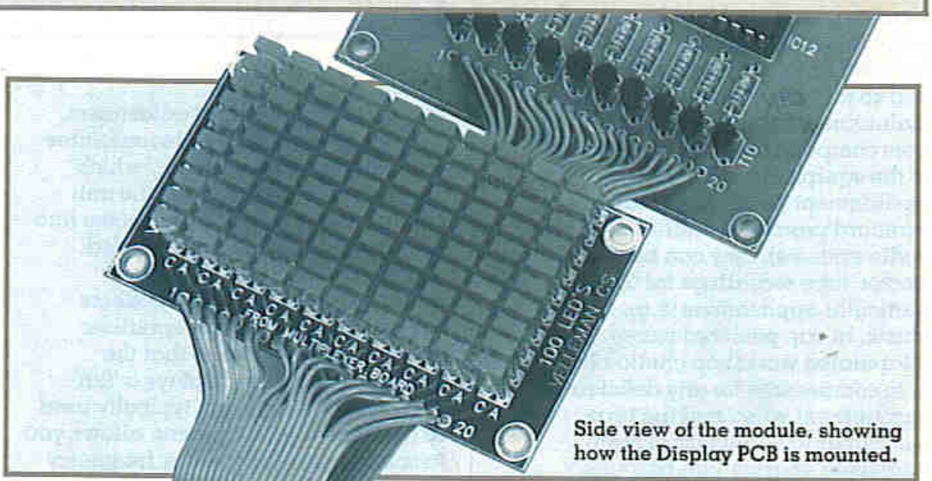
Figure 2. Filter circuit diagram.

for the the rest of the op amps, and is referenced by ZD1. A half-supply generator allows the circuit to run from a single 12V DC supply; if it were not present, then split power rails would be required. The remaining three op amps are used in the input section.

Two are used for the equalised microphone input, which has a gain of 40dB (100) and an input impedance of 10kΩ. The line-level input, based around the remaining op amp, sums together the left and right channels, and its gain can be adjusted via preset RV1. An alternative to summing the left and right channels could be to use an (optional) switch, so that the left, right or summed channels could be monitored. If this circuit is to be implemented, note that C4L/R and R8L/R are not mounted on the PCB, and the output from the switch is fed straight to the junction of RV1 and the inverting input of A24.

Since the microphone preamplifier brings up the microphone input up to line level, it can be applied to either the 'left' or 'right' line input. Alternatively, a switch could used to select between either the microphone or line inputs.

The circuit has a high input impedance (100kΩ), and consequently it will present a negligible load to an audio system. The Spectrum Analyser can be inserted in a loop (e.g., preamplifier/power amplifier) or tape loop if required.



Side view of the module, showing how the Display PCB is mounted.

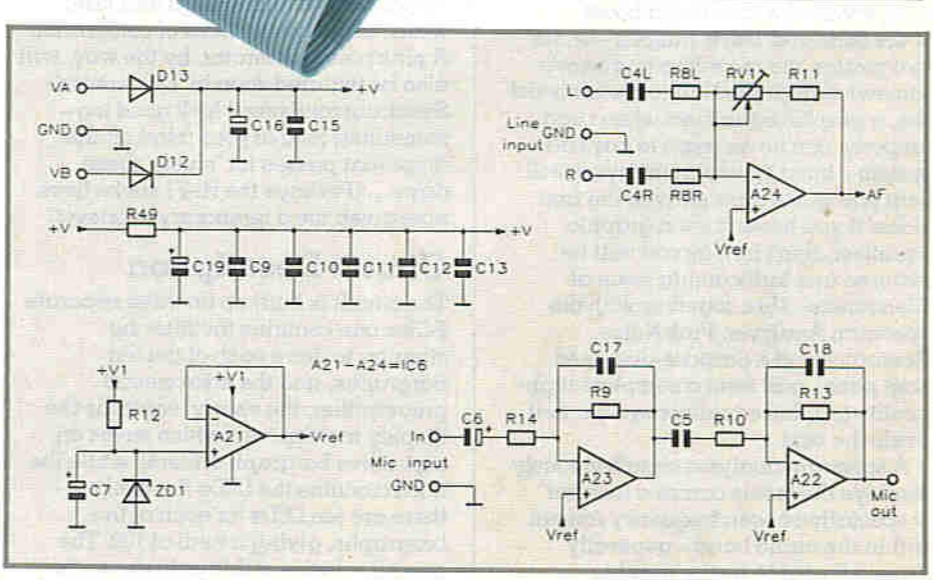


Figure 3. Preamplifier and power supply circuit diagrams.

(ii) The Multiplexer

The outputs from the active filters are connected to the multiplexer, the circuit of which is shown in Figure 4. This is based around a 4017 decade counter (IC10), which is controlled by a high-speed clock (built around two of the hex inverters of IC11). Each of the ten outputs of the counter controls a analogue on/off switch (IC7, 8 and 9, which are quad 4066BE devices). The input to each of the ten analogue switches is connected to one of the outputs from the filters, and the outputs from the switches are summed together; since only one of the outputs of IC10 is on at any one time, only one of the filter outputs will be present on this common rail. Referring to Figure 5, the signal derived so far is passed to IC13, which is also on the multiplexer PCB. This is the LED bargraph driver (U2067), which determines how many of the LEDs on the display board are to be illuminated, in this case vertically – note that the scale is linearly calibrated, rather than logarithmically.

The outputs from the counter also determine which row of LEDs is switched on (via T1 to T10 and the associated inverters); the row selected is, of course, the one corresponding to the filter currently being fed to the bargraph. Since the clock runs at very high-speed, the display is perceived as being continuous by the user – in other words, the switching between channels happens too quickly to be noticed. The advantage of using this multiplexer system is that only one expensive bargraph driver is required, instead of ten – this keeps the cost down. Apart from this, the wiring is a lot simpler, and power consumption is lower.

The Multiplexer PCB also contains the power supply circuitry. D12 and D13 form, when used in conjunction with an external (not supplied) centre-tapped transformer, a bi-phase full-wave rectifier. C16 provides smoothing, while C15 provides high-frequency decoupling. Additional decoupling is also provided, where necessary, at other points within the circuit. DC may be applied directly to the anode side of D12 or D13, if an existing power supply capable of sourcing 12V to 15V DC at a current of at least 750mA, is available.

(iii) The Display PCB

The final PCB contains the LEDs, which are arranged in a matrix as shown in Figure 6.

PCB Construction

Construction of the three PCBs used in this project is straightforward, and is dealt with in greater detail in the leaflet supplied with the kit. Novices should consult the Constructors' Guide (XH79L) for practical guidance. Generally, it is best to fit the physically smallest components (the wire links) first, followed by the larger devices. The diodes, electrolytic capacitors and transistors are all polarised devices, and care should be exercised when

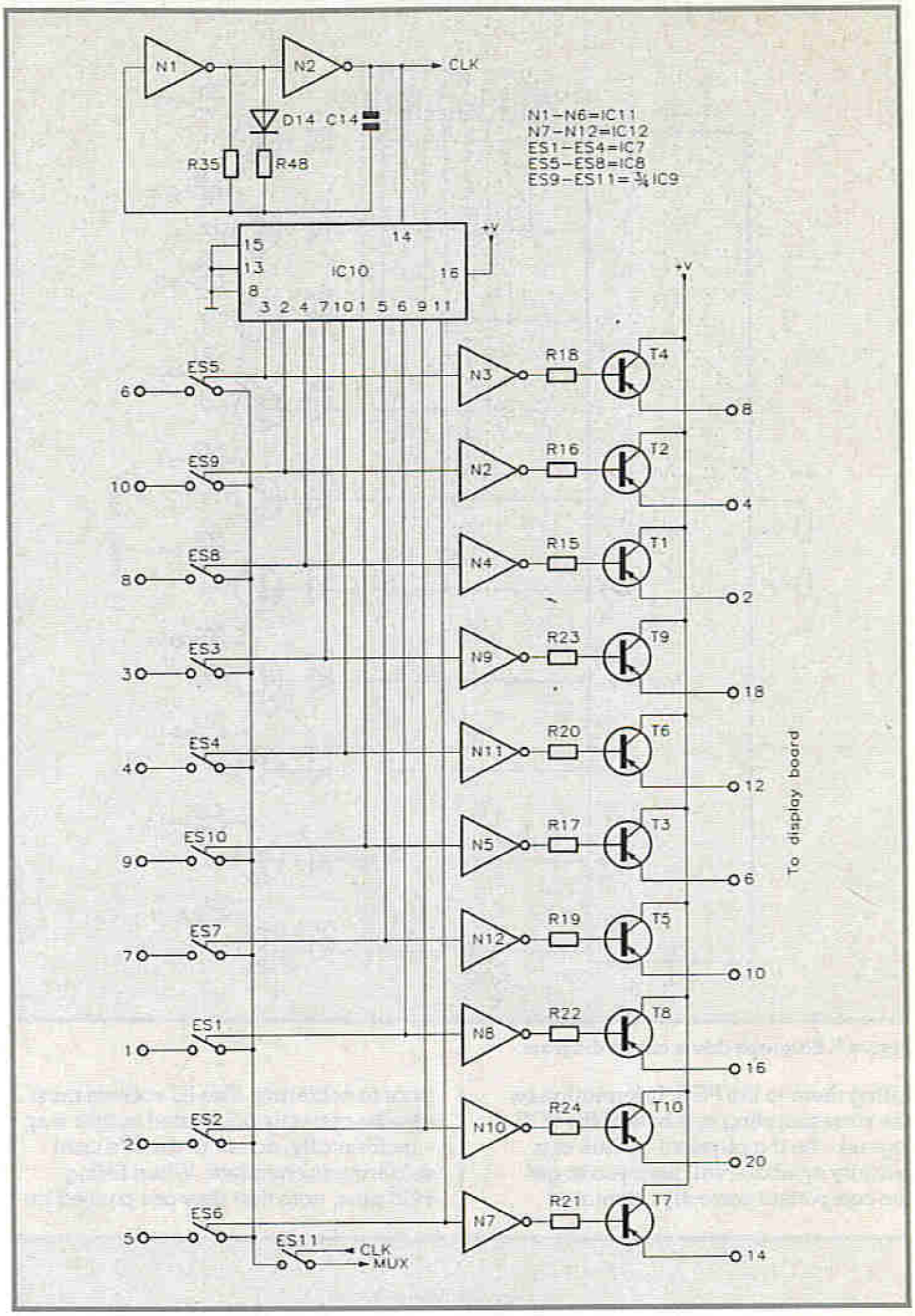
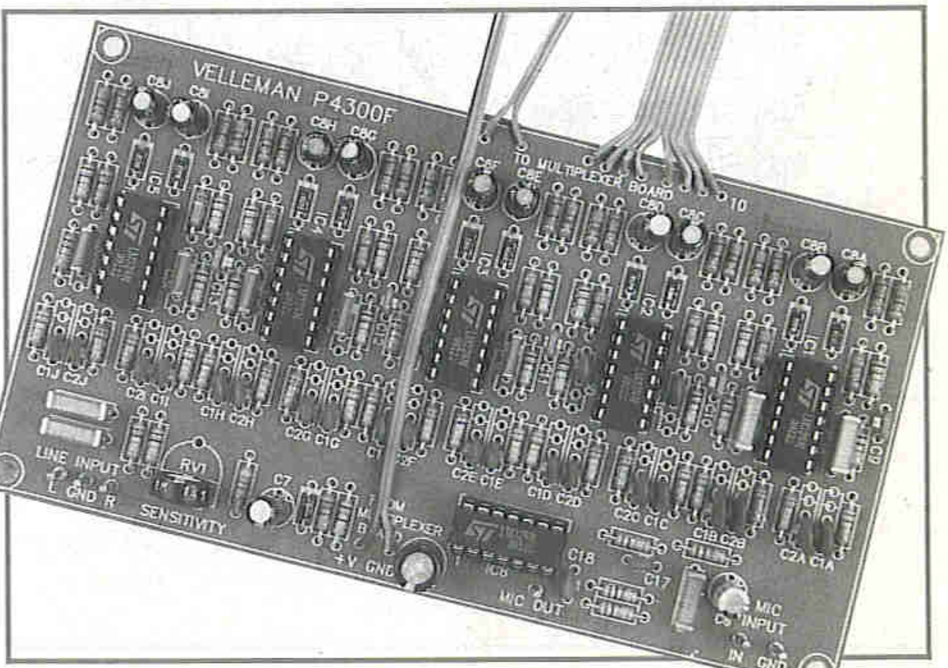


Figure 4. Display multiplexer circuit diagram.



The completed Filter PCB.

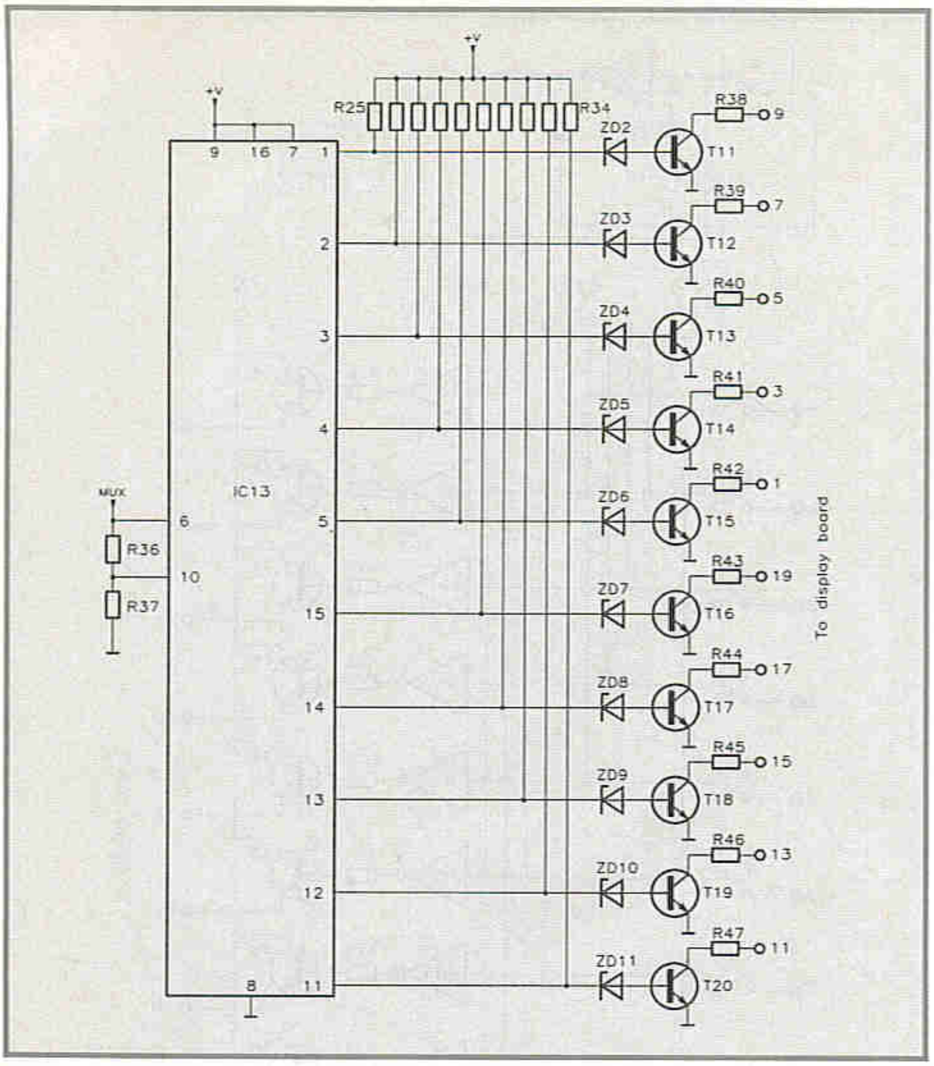


Figure 5. Bargraph driver circuit diagram.

fitting them to the PCB. Information on the corresponding symbols of the PCB legend – be it a physical outline or a polarity symbol – will help you to get the component correctly orientated prior to soldering. The IC sockets must also be correctly orientated in this way – incidentally, do not fit the ICs until soldering is complete. When fitting PCB pins, note that they are pushed in

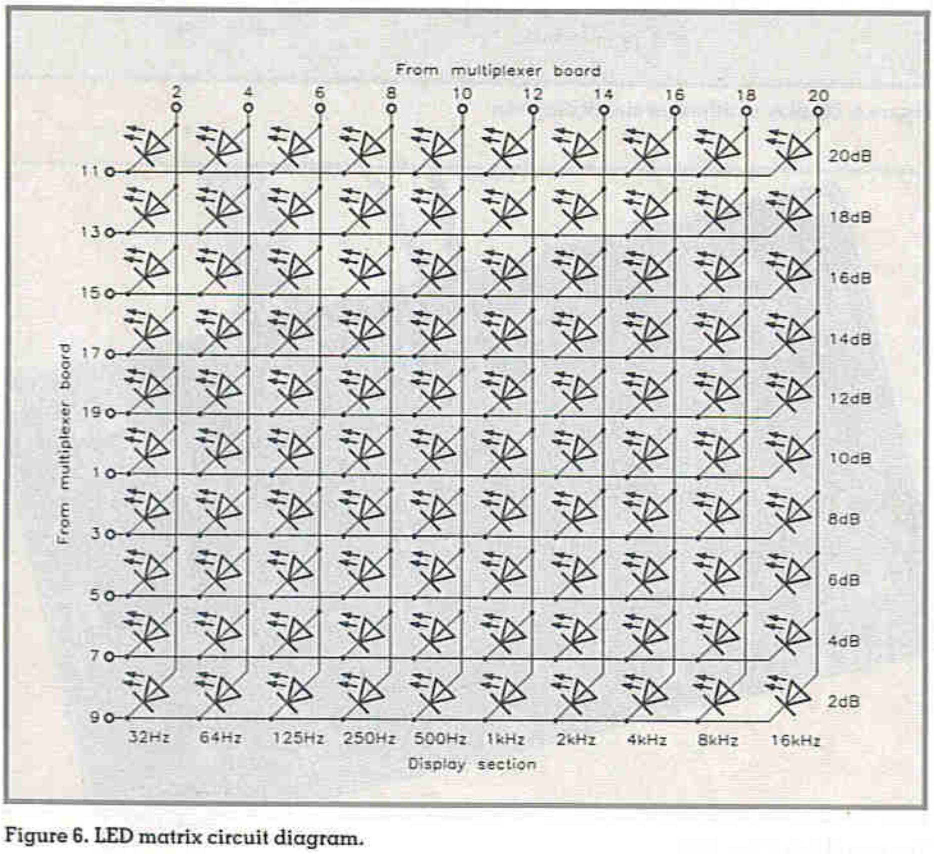


Figure 6. LED matrix circuit diagram.

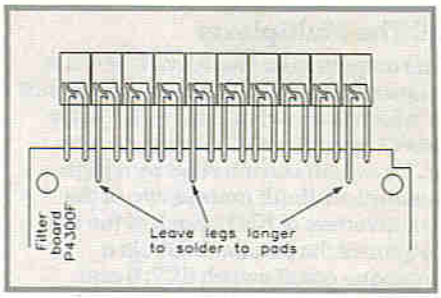


Figure 7. LEDs 1, 6 & 9 should have anode leads left uncut.

from the component side of the board – the tip of your hot soldering iron may help to force the pin into position.

While building the Filter PCB is simple enough, a couple of points need to be raised with respect to the Multiplexer and Display PCBs. Since resistors R38 to R47 on the multiplexer board have to dissipate a significant amount of power, they should be mounted so that there is a clearance of 5mm between the resistor body and the PCB. On the Display PCB front, it is important to make sure that all the LEDs are mounted at the same height – failing to do this will spoil the appearance of the finished unit – and it *won't* look pretty! The longest lead is the anode lead, and is identified by the letter 'A' on the PCB legend. After insertion, the LED is pushed towards the board so that the little tabs on each lead are flush against the PCB, at which point the device can be soldered in place. This way, you can ensure that all of the LEDs are at the same height. It is advisable to complete successive rows of LEDs – as each row is completed, you can then check that each LED is at exactly the same height, and make any slight alterations where necessary. The excess leads can now be trimmed; note that, if the Spectrum Analyser is to be built as a module (refer to the Assembly section), LEDs 1, 6 and 9 in the top row should have their anodes left uncut. This is so that they can be soldered to the pads on the multiplexer board, thus holding the display in place at the end of the two boards, see Figure 7.

Assembly

There are two main methods of assembling the PCBs together:

(i) All Out in the Open'

The first option is to mount all the PCBs separately in the case – the Filter and Multiplexer PCBs are connected via wire links (component lead offcuts), and the Display PCB is connected to the Multiplexer via a length of 20-way ribbon cable. This method may be preferable if the Spectrum Analyser is to be built in a low-profile case – in addition, access for servicing will be easier. However, it does mean that a lot of base area in the enclosure is required. Note that spacers should be used to provide at least 5mm clearance between the underside of the PCB and the metalwork of the case (you are using a metal case, aren't you?).

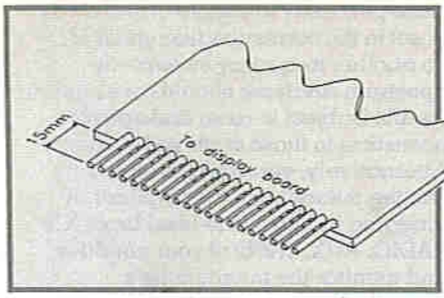


Figure 8. Preparing the multiplexer links.

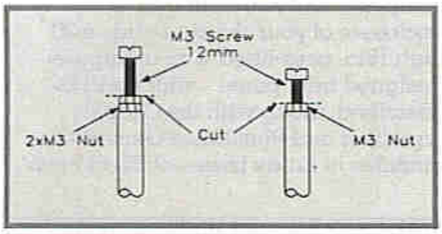


Figure 9. Preparing the upper and lower 20mm spacers.

(ii) As a Module

The alternative option is to assemble the Spectrum Analyser in 'module' form. In this instance, the Display (top) and the Multiplexer (bottom) PCBs are stacked on top of each other, being held apart by 40mm spacers at each corner. The two boards are then linked together with tinned copper wire. The display board is held to the assembly, by its connection leads to the multiplexer at the bottom end, and by the three LED anode leads (refer back to the PCB Construction section) at the top end.

Referring to Figure 8, it can be seen that the multiplexer connections to the display take the form of 20 wire links, which should protrude by 15mm from the edge of the board. These links can either be component offcuts, or some of the bandoliered links supplied with the kit. These should be fitted before the rest of the module is assembled.

Next, the spacers need to be prepared, as shown in Figure 9; as you can see, each of the four 40mm spacers is formed from two 20mm insulated threaded spacers, which are fastened together. Obtain a 12mm M3 screw and fit a nut, turning the nut until it is flush against the head. Insert the screw into one of the spacers and turn it as far as it will go (4mm or so). Turn the previously-fitted nut the other way until

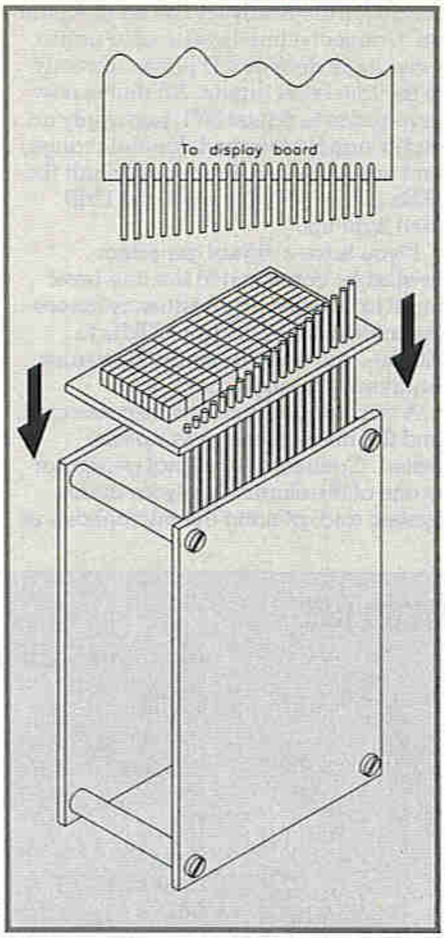


Figure 11. Fitting the Display PCB.

it is flush against the spacer (rather than against the head of the screw). At this point, cut off the excess screw with a hacksaw, as shown in Figure 9. The nut can now be undone (with pliers if necessary) and removed; its purpose is to clear the screw's thread from swarf produced when using the hacksaw. Another 20mm spacer can now be threaded onto the screw.

Another M3 thread needs to be added to each of the four newly-prepared 40mm spacers, using the methods as outlined above, to accommodate a third (10mm) spacer – refer to the assembly drawing of Figure 10. In this case, two spacer nuts (refer to Figure 9) will be required, since a PCB will be sandwiched between the two spacers – the thickness of which needs to be allowed for. The third spacer will be located underneath the multiplexer, and will provide a standoff so that the module can be mounted on a flat surface – particularly important if the case is a metal one.

After all four 40mm spacers have been prepared in this way, they can be fitted on the component side of the Filter PCB using the short screws originally supplied – refer once again to Figure 10. Ten links of suitable length (use the spacers as a suitable reference) can now be made, and soldered in at the Filter PCB end (again, the links should be on the component side of the board). The Multiplexer PCB can now be fitted over the previously-added threads of the 40mm spacers; note that the board's component side should face that of the Filter PCB. The Filter PCB's

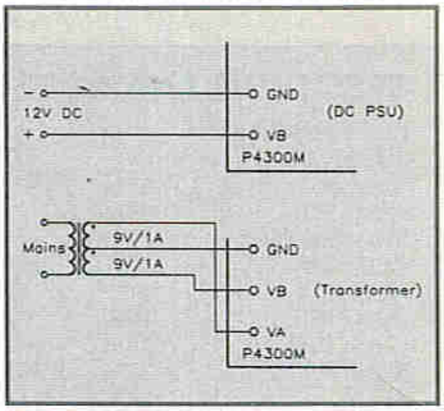


Figure 12. Power supply wiring diagram.

wire links can now be passed through the appropriate positions on the Multiplexer PCB and, after securing the assembly together with the 10mm spacers, the wires can be soldered.

The 20 wires from the Multiplexer PCB prepared earlier can now be lined up and passed through the correct positions of the Display Board as shown in Figure 11. Once the Display PCB has been aligned to your satisfaction, the connections can be soldered. You may find this job easier to do if the front two pillars are temporarily removed. The remaining solder joints are not really connections *per se*; they are the three uncropped anode leads which should be soldered to the isolated pads provided on the Filter PCB – these provide a secure fixing for the top of the Display Board. Assembly of the Spectrum Analyser, as a module, is now complete.

Setting Up and Testing

Once you have thoroughly checked your assembly work for any obvious errors, the Spectrum Analyser should be connected up as shown in Figure 12. Since rectification and smoothing is provided on-board, the unit can be powered by a 9V-0V-9V centre-tapped transformer, which must be capable of sourcing at least 750mA per winding. The two output leads should be connected to the 'VA' and 'VB' terminals, while the centre tap (0V) lead should be connected to the adjacent 'GND' pin. Alternatively, a 12V DC supply can be used (existing DC power supply, car's electrical

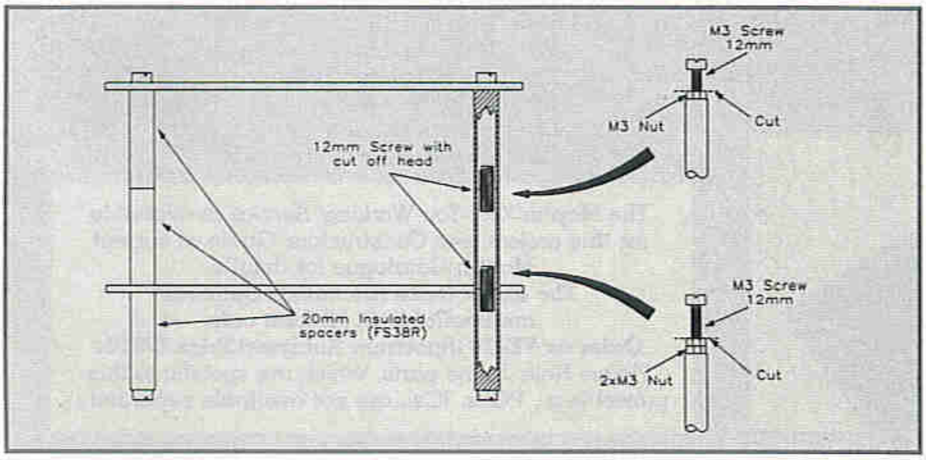


Figure 10. Assembling the Filter and Multiplexer PCBs together.

system, etc.); in this case, the positive output is applied to either the 'VA' or the 'VB' terminal (in this case, the relevant diode will provide reverse-polarity protection), and the ground line to the 'GND' terminal.

You can use the connectors of your choice for the audio channels. Generally, though, phono sockets will be ideal for the line-level inputs, and a 6·3mm mono jack for the microphone input. Using a balanced-line input circuit (e.g., the SSM 2017-based circuit featured), professional microphones could be used with this unit. The SSM 2017 circuit, out of interest, features a line-level output, thus rendering the Spectrum Analyser's internal microphone preamplifier redundant.

Once the connections are in place, the Spectrum Analyser can be powered up. Connect a line-level source (radio tuner, tape deck or CD player) directly to the line-level inputs. All that is now required is to adjust RV1; just apply an audio signal of limited dynamic range, and adjust RV1 so that roughly half the LEDs of the 1kHz (i.e. up to the 12dB row) light up.

If you have a signal generator available, connect it to the line-level input and sweep the frequency across the audio range (i.e. from 20kHz to 20kHz) – you should see the Spectrum Analyser respond accordingly.

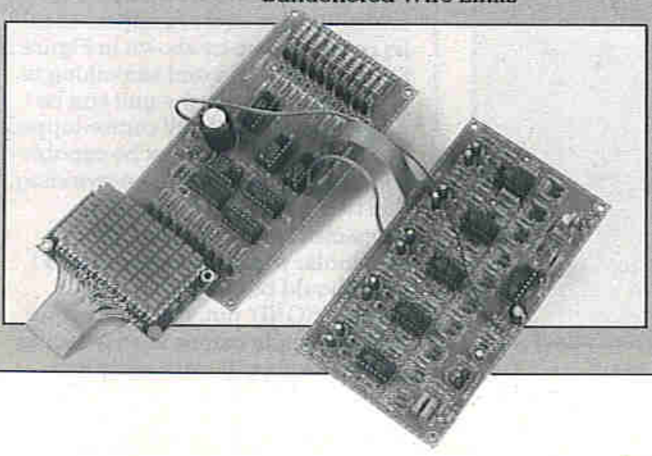
A microphone can now be connected, and the microphone preamplifier tested. Connect your signal generator to one of the channels of your audio system and, placing the microphone in close proximity (a couple of feet away or so) to the corresponding speaker, do another frequency sweep – the Spectrum Analyser should give similar results (subject to room and speaker acoustics) to those achieved earlier. Alternatively, you could subjectively test the microphone preamplifier by plugging in into a line-level input (CD, RADIO, AUX, TAPE) of your amplifier, and monitor the microphone's amplified output using headphones.

The Spectrum Analyser is now complete, and can built into an enclosure of your choice, or into a 2U high 19in. case fitted with a purpose-designed front panel – which will be described, along with the Graphic Equaliser and Pink Noise Generator modules in future issues of 'Electronics'.

SPECTRUM ANALYSER PARTS LIST

FILTER BOARD

RESISTORS		
R1A to R1J	330k	10
R2A to R2J	680k	10
R3A to R3J, R14	10k	11
R4A to R4J	56k	10
R5A to R5J	4k7	10
R6A to R6J	1M8	10
R7A to R7G	470k	7
R7H, R7I	390k	2
R7J	270k	1
R12	1k5	1
R13	1M	1
R49	180Ω	1
	1M Preset	1
CAPACITORS		
C1A, C2A	56nF Ceramic	2
C1B, C2B	33nF Ceramic	2
C1C, C2C	18nF Ceramic	2
C1D, C2D	8n2F Ceramic	2
C1E, C2E	3n9F Ceramic	2
C1F, C2F	1n8F Ceramic	2
C1G, C2G	1nF Ceramic	2
C1H, C2H	470pF Ceramic	2
C1I, C2I	220pF Ceramic	2
C1J, C2J	120pF Ceramic	2
C3A, C3B, C4R, C4L, C5	100nF Ceramic	5
C3C, C3D	47nF Ceramic	2
C3E to C3J	10nF Ceramic	6
C6	1µF Electrolytic	1
C7, C8A to C8J	100µF Electrolytic	11
C9 to C13	100nF Epoxy	4
C17	39pF Ceramic	1
C18	4pF Ceramic	1
C19	220µF Electrolytic	1
SEMICONDUCTORS		
IC1 to IC6	(A1 to A24) LM324	6
D1 to D10	1N4148	10
MISCELLANEOUS		
	Filter PCB	
	Bandoliered Wire Links	



MULTIPLEXER BOARD

RESISTORS		
R15 to R24	1k5	10
R25 to R34	10k	10
R35, R36	82k	2
R37	39k	1
R48	4k7	1
R38 to R47	270Ω 1W	11
CAPACITORS		
C14	10nF Ceramic	1
C15	100nF Mono	1
C16	2200µF Electrolytic	1
SEMICONDUCTORS		
D12, D13	1N4000 Series Diodes	2
D14	1N914 or 1N4148 Diode	1
ZD1 to ZD11	3V3 Zener	10
T1 to T10	BC327	10
T11 to T20	BC547 or equiv.	10
IC7, IC8	4066	2
IC10	4017	1
IC11, IC12	4009	2
IC13	U2067B	1
MISCELLANEOUS		
	Multiplexer PCB	

DISPLAY BOARD

	LEDs Red Square	100
	Plastic Front Panel	1

OPTIONAL (Not in Kit)

Insulated Spacer M3 × 20mm	2 Pkts	(FS38R)
Insulated Spacer M3 × 10mm	1 Pkt	(FS36P)
Screw M3 × 12mm	1 Pkt	(BF52G)
Steel Nut M3	1 Pkt	(JD61R)
Rotary Switch SW4B	1	(FF75S)
Phono Socket	4	(YW06G)
Open Chassis Socket 6·3mm	1	(HF91Y)
Wire 7/0·2 10m Black	1	(BL00A)
Wire 7/0·2 10m Red	1	(BL07H)
Single Core Lapped Screen	1	(XR12N)
Ribbon Cable 20-Way	As req	(XR07H)
Constructors' Guide	1	(XH79L)
Case As per user requirements		

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 in kit form only.

Order as VE42V (Spectrum Analyser) Price £79.95.

Please Note: Some parts, which are specific to this project (e.g., PCBs, ICs), are not available separately.

Satellite TV continued from page 31

What Difference Does It Make?

So that's how it was fitted. Now for the performance! In a word, incredible! The SR-50 became considerably better when the TAD was switched into circuit, resolving pictures from practically non-existent signals. The module seemed to deliver its best results whenever the IF bandwidth control was set to maximum, regardless of how weak the signals, to be resolved, were.

To best demonstrate the TAD's performance, the Cinemania test card on Astra was chosen, and the skew (polarity control) deliberately misadjusted so that minimal signal reached the LNB. In addition, the dish was moved away from its 'peak' position. These two measures allow a weak signal to be 'simulated' (how the channel would appear in an 'out of footprint' area). After the TAD is switched in, the rear-panel tuning control is simply advanced (it is normally set almost fully clockwise) for best results (the sparklies literally disappear!); if it is advanced too far, however, the picture starts to smear.

When the tuning control is optimally set, though, the results, which can be seen in the 'compare and contrast' photographs, speak for themselves! Although the pictures are hardly of broadcast quality, they are certainly watchable – and it is almost a miracle bearing in mind that nothing could be seen before the TAD was called out to bat. Even better results were obtained on full-transponder (36MHz) channels. The TAD therefore has a sterling role to play amongst the DX-TV fraternity – those most likely to be interested in the SR-50, or already in possession of a large motorised dish and 70MHz IF receiver (together with a bandwidth controller, no doubt!). The TAD would appear to be the answer to the TV-DXer's prayers! Apart from Ku-band, the TAD has considerable advantages with the lower-frequency (4GHz) C-band transmissions; normally, much larger dishes are required for these much weaker signals, which in Western Europe can be found on several Intelsat and Russian Gorizont satellites.

It was a shame that the sound could not be resolved as well as the video; this would appear to be because the audio circuits are fed from the SR-50's original demodulator circuitry. It can still be heard though, but only just; it helps to take the audio IF bandwidth right down to 150kHz. Thankfully, though, Eurosat have also developed a TAD for the audio side – hopefully, this will give similar results as the video one reviewed here.

In summary, if you're into weak signals and have a receiver with 70MHz IF (the loopthrough sockets on the rear panel will normally give away such a receiver), the TAD will prove a worthwhile investment. At over £100, it may appear expensive, Eurosat-modified SR-50 available, which may kill two birds with one but it has no equal. There is also a stone if you are interested in this particular receiver; the added advantage is that a guarantee on the modified receiver will be honoured by Eurosat. It must be reiterated, however, that all TAD purchases will have to be made through your local dealer, since Eurosat do not sell directly to the public. The company can deal with queries, such as those relating to receiver compatibility, via its Nationwide Service Centre (tel: (081) 450 5152).

The Verdict

The Echostar SR-50 was used very well for satellite searching and newsfeed-spotting (the TAD certainly helped with some of the weaker feeds); at one point, a home-made splitter fed both this receiver and the TechniSat, which was used as the dish positioner. The easy movement of the SR-50's tuning knob allowed me to find channels and satellites which would have taken ages had the ST-6002S been used on its own. It is just a pity that two receivers had to be used to provide the 'best of both worlds'!

Recommended Retail Prices (inclusive of VAT @ 17·5%)

Echostar SR-50: £180.

Echostar SR-50 WITH Eurosat TAD (Eurosat dealer only): £300.

Eurosat TAD (Eurosat dealer only): £120.

Prices correct at time of writing.

Contact Information

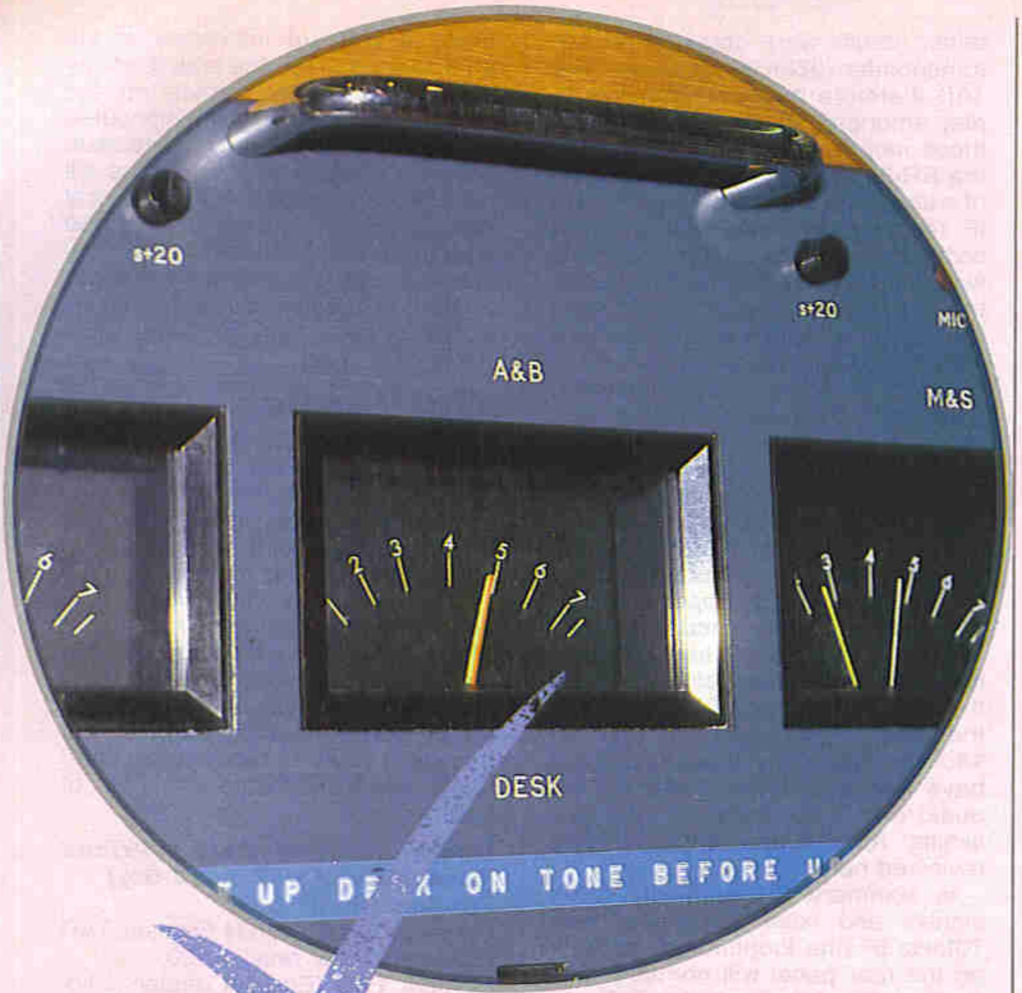
Eurosat Nationwide Service Centre
Tel: (081) 450 5152.

MAPLIN'S TOP TWENTY KITS

POSITION			DESCRIPTION OF KIT	ORDER AS	PRICE	DETAILS IN		
1.	(1)		L200 Data File	LP69A	£ 4.75	Magazine	46	(XA46A)
2.	(2)		TDA7052 1W Amplifier	LP16S	£ 4.95	Magazine	37	(XA37S)
3.	(5)		Live Wire Detector	LK63T	£ 4.75	Magazine	48	(XA48C)
4.	(12)		Remote Power Switch	LP07H	£ 5.25	Magazine	34	(XA34M)
5.	(3)		MOSFET Amplifier	LP56L	£20.95	Magazine	41	(XA41U)
6.	(4)		1/300 Timer	LP30H	£ 4.95	Magazine	38	(XA38R)
7.	(6)		Lights On Reminder	LP77J	£ 4.75	Magazine	50	(XA50E)
8.	(8)		Stroboscope Kit	VE52G	£14.95	Catalogue	'94	(CA11M)
9.	(–)	NEW ENTRY	Electronic Ignition	VE00A	£12.95	Catalogue	'94	(CA11M)
10.	(9)		Car Battery Monitor	LK42V	£ 9.25	Magazine	37	(XA37S)
11.	(11)		SL6270 AGC Mic Amplifier	LP98G	£ 8.75	Magazine	51	(XA51F)
12.	(13)		IBM Expansion System	LP12N	£21.95	Magazine	43	(XA43W)
13.	(7)		Courtesy Light Extender	LP66W	£ 2.95	Magazine	44	(XA44X)
14.	(14)		UA3730 Code Lock	LP92A	£11.45	Magazine	56	(XA56L)
15.	(10)		LM386 Amplifier	LM76H	£ 4.60	Magazine	29	(XA29G)
16.	(16)		Mini Metal Detector	LM35Q	£ 7.25	Magazine	48	(XA48C)
17.	(15)		LM383 8W Amplifier	LW36P	£ 7.95	Catalogue	'94	(CA11M)
18.	(18)		Universal Mono Preamp	VE21X	£ 5.95	Catalogue	'94	(CA11M)
19.	(17)		TDA2822 Stereo Amplifier	LP03D	£ 7.95	Magazine	34	(XA34M)
20.	(–)	NEW ENTRY	8-bit I/O + RS232	LP85G	£19.95	Magazine	49	(XA49D)

Over 150 other kits also available. All kits supplied with instructions.

The descriptions are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate project book, magazine or catalogue mentioned in the list above.



A GUIDE TO PROFESSIONAL AUDIO PART SEVEN

by T. A. Wilkinson

Analogue Tape Recording

For the next three parts in this series, we concentrate on all aspects of tape recording systems, from analogue through to the latest digital techniques. This month, by way of introduction, we take a look at recording media and the basics of analogue recording systems.

The concept of audio tape recording is something that has fascinated me for the greater part of my life, and I have to admit that it still does. There is something very magical about being able to capture a sound by some mechanical means, store it indefinitely on a small medium, and yet be able to refer and listen, again and again, to any part of it at any time.

Since the first methods of magnetic recording were patented in the early 20th century there have been massive steps forward and great development in this area of the audio industry. Today, we have reached the peak of analogue magnetic recording methods, which are making way for other recording media such as optical and digital storage systems.

Analogue systems include all types of tape recording which rely directly on the conversion of the audio signal into a series of magnetic 'waves' on a carrying medium, tape. As we know, many formats of analogue tape media exist – open reel, cassette, cartridge or whatever.

Today we have already developed the physics of analogue recording systems and tape as far as is likely and practical; indeed modern professional systems are as near-perfect as this technology allows, and recorder manufacturers now tend to put resources into improvements in system control and tape transport, rather than the actual signal-to-tape and tape-to-output areas.

Now, considering the significant difficulties involved in getting an audio signal onto and off the tape in an analogue system, its a miracle that it works at all, but it does work – and as we all know, it can work very well. However, analogue tape recording is really a series of well constructed, well utilized compromises, as will soon become apparent.

A number of factors determine how good the final quality of an analogue recording will be – these include the medium itself, various mechanical and electronic aspects of the recorder, and the setting up of the system as a whole. Above all, the original audio signal must be of good quality (technically anyway!), and at a level with which the recorder is happy. With too little signal, there will be (almost) more noise than audio – and at the other end of the scale, too great a signal level will simply saturate the tape – causing serious distortion. It must be remembered that no tape recorder can improve on a poor quality input, and garbage in certainly does mean garbage out!

Firstly, let's examine the medium itself, the magnetic tape.

Size is Everything!

Standard analogue audio tape comes in various formats and widths to suit our applications (and thus machines). From smallest to largest these are:

1. Compact Cassette 3·8mm (0·15in.)
2. Broadcast Cartridge 6·25mm (0·25in.). Arranged as an endless loop of tape of predetermined length and packed as a cartridge, similar in appearance to those awful 8-track cartridge systems of the early seventies.
3. Open Reel 6·25mm (0·25in.). Full track, twin track, four-track and stereo work.
4. Open Reel 12·5mm (0·5in.). Used for serious stereo mastering, also for semi-professional multitrack work. Eight and now even sixteen tracks can be squeezed onto ½in. tape.
5. Open Reel 25mm (1in.). Up to 16 track.
6. Open Reel 50mm (2in.). 16 track and above.

In addition to reel/spool size or package format, our tape will also be identified as standard play, long play, double play or triple play length.

Standard play tape is the stuff in everyday broadcast use, and a 10½in. reel of this (2,400ft) gives 30 minutes recording time at 38cm/s (15in./sec), or 1 hour at 19cm/s (7½in./sec). A 7in. reel (1,200ft), meanwhile, gives 15 minutes at 38cm/s, and 30 minutes at 19cm/s. A long-play spool crams in one-and-a-half times as much tape as the equivalent-sized standard-play reel, i.e. 22½ minutes at 38cm/s, or 45 minutes at 19cm/s. Logically, a 7in. double-play reel gives twice the playing time, allowing 30 mins at 15in./sec, or 1 hour at 38cm/s, and triple play an amazing 45 minutes at 15in./sec, or 1½ hours at 19cm/s.

But there is a price to pay; obviously to force two or three times the effective length of tape onto a reel of the same diameter, the tape thickness must be reduced by a significant amount. This leads to serious tape handling difficulties (remember C120 cassettes?). Triple-play tape, in particular, needs the utmost respect as far as handling is concerned, and may well not present a cost-effective solution for the professional user. It does have its place, though – certain professional tape recorders (e.g., the 'reporter' type recorders made by Uher) can only accommodate a small-sized (5in.) reel so that the machine is small enough to be portable. Using extra-play tapes means that the user can get on with interviewing (or whatever), rather than worrying about the tape running out!

Tape Speed

Although tape speeds range from 1⅞in./sec to 30in./sec, the three most used in professional applications are 19cm/s (7½in./sec) for broadcasting mono speech, 38cm/s (15in./sec) for stereo and multitrack music, and 76cm/s (30in./sec) for very high quality music applications. As we shall discover later, increasing the relative tape to head speed produces a proportional increase in quality, but this starts to become expensive, at 30in./sec a 10in., 2,400ft reel of tape lasts just 15 minutes! There is also a very slow speed, 15⁄16in./sec, which is used for logging the output of radio stations. Out of interest, this is the 'standard play' (SP) speed of a VHS video recorder – this is why Hi-Fi performance can never be achieved from the longitudinal soundtracks of a VHS cassette, and why the sound is generally appalling when the machine is used in 'long-play' (LP) mode, which runs at half the SP speed.

Magnetic tape consists of a three-layer laminate of different materials, as illustrated in Figure 1.

The thickest layer of material is the central layer, which is known as the 'base'. This is a plastic polyester material around 40μm thick. Bonded to one side of the base is a layer of 'backing' material. This thin (around 2μm) rough textured layer is applied in order to assist tape handling characteristics, and helps to overcome tape 'print-through'. Print-through is the unintentional transfer of audio (normally occurring during storage) from one layer of wound tape to an adjacent layer on the same reel. Backing material with conductive properties will help to reduce static electricity friction problems during high-speed spooling operations ('fast forward' and 'fast rewind')

8-track head block, showing (L to R) erase, record and playback heads. This is actually a fairly worn 8-track head block removed from the machine for maintenance.

On the other side of the base is the surface which comes into contact with the tape heads – the 'coating'. This is normally 10 to 15μm thick, and consists of many tiny needle-shaped particles of a magnetic material, such as ferric oxide, chromium dioxide, or cobalt-doped iron oxide, depending on the formulation specification of the tape. The particles can be thought of as long thin bar magnets, and during the recording process these are re-arranged to form magnetic 'waves' representing the cycles of audio signal.

It would appear that more signal information can be recovered from the tape if the major axis, of the magnetic particles in the coating, is more or less parallel with the tape tracks. Thus, during the manufacturing process, the particles are forcibly aligned along the length of the tape, using a powerful magnetic field. If left to their own devices, the particles would distribute themselves in a rather random and haphazard manner, and this would not benefit tape performance.

An abrasive tape with a rough textured coating will have adverse effects on the heads, and will therefore cause rapid wear to take place, and so it is imperative to use quality tape in order to prolong head life. As with most things in life, the quality of tape is proportional to price; it would be prudent to always select the best quality tape within your budget.

Most branded tape today is actually of very good quality, with a possible frequency response that exceeds far beyond the 20kHz audio spectrum. For example, a good ferric tape with an average magnetic particle size of 2μm (2 micron), and running at a speed of 38cm/s (15in./sec), would typically be able to resolve signals of up to 190kHz in frequency. This theoretical response can be calculated in the following way:

$$\text{Frequency } f = \frac{\text{tape speed}}{\text{particle size}}$$

where the tape speed is assumed to be 38cm/s (15in./sec) and the particle size is 2μm (2 micron).

However, whilst the tape itself appears to have very good frequency response, the recording system as a whole does not work nearly so well, and at best will achieve a 'flat' frequency response extending to around 18 to 20kHz. By flat response I mean a variation of not more than ±0·5dB at any frequency.

Tape specification, type and formulation tells us several things about the performance ability of a particular tape. Important parameters to consider when choosing tape are frequency response, dynamic range and maximum, or peak flux, level. The first two are really self-explanatory but 'peak flux level' may be less familiar. Peak flux level really describes how hard we can drive a signal into the tape before we completely saturate the tape, causing distortion elements to become obvious. This will be discussed in some detail next month.

Additionally, as bias requirements will vary from brand to brand, we will need to know just how much 'HF bias' to apply when using a particular brand of tape. Tape manufacturers are actually very good at supplying all the data necessary, and go to some lengths in providing sometimes very detailed specification sheets. Biasing will be looked at in more detail later.

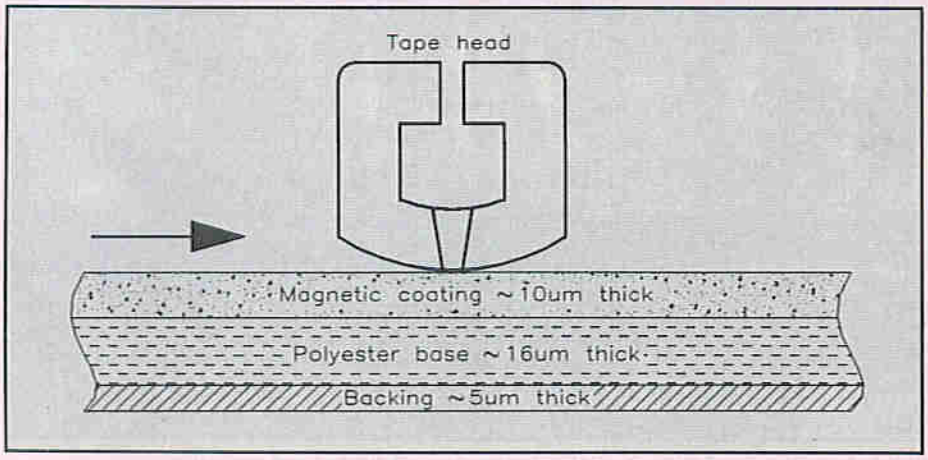


Figure 1. Magnetic tape with a three-layer laminate coating, base and backing materials.

Three Heads are Better than Two!

Any professional studio recorder, and most professional portable units, will use a three-head system. From left to right in the direction of tape travel, these are:

1. **Erase head** for removing any previously recorded material, thus ensuring clean tape.
2. **Record (or record/sync) head** for

recording audio onto the tape. A record/sync head allows the record head to be used as a replay head for synchronisation purposes, but with degraded performance.

3. Replay head, used to reproduce recorded audio.

The separate replay head is often referred to as a 'confidence head', and allows genuine 'off tape' monitoring of the material you have just recorded, in order to be absolutely certain that what you think you have recorded is, without doubt, stuck to the tape. Hence the term confidence head.

However, there is one minor drawback. As the replay head is some distance away from the record head, a small delay (which varies with tape running speed, and the spacing of the heads) occurs between the source material and the replayed off-tape audio. In some instances this delay may prove difficult to work with and the user would actually monitor the source signal for most of the time with periodic blasts of monitoring the confidence replay just to be sure all is well. On the positive side, this delay does differentiate between the 'live' signal and the recorded one.

The heads themselves are likely to be very high specification hard-wearing types manufactured to close tolerances, and will represent, in replacement cost terms, a serious percentage of the machine's value. Any tape head, be it professional or domestic, should be treated with the utmost care and respect, and lavished with regular (correct) cleaning and demagnetising. It is important to use an appropriate cleaning agent, such as isopropyl alcohol applied with a soft cotton bud. The heads should be cleaned vigorously but not violently, and should be free of all traces of oxide and the like when the task is complete.

Frequency of cleaning will of course depend on the level of machine usage – possibly more than once a day if a machine is in constant use.

All three heads are precision-made inductors, similar in appearance and construction to that of Figure 2. In some two-track machines, however, the erase head will be a 'full track' type, with a single set of windings, and not divided into two separate inductors.

You will notice that where the two pole-pieces almost meet at the front of the head, there is an area known as the 'head gap', which is filled with a wedge of non-ferrous material. The head gap is where the audio signal is transferred to the tape during the recording, and vice versa during replay.

Head gap size is critically important, and each of the three heads have differing head gaps which are tailored to their specific application.

The erase head gap is by far the largest being around 100μm, the size of this permits a large amount of magnetic flux to saturate the tape, leaving the tape effectively demagnetised. Next in size is the record gap at 15 to 20μm, which is large enough to emit copious amounts of magnetic flux during the recording process. The smallest gap is that of the replay head at 5 to 10μm; as we shall soon see, too large a gap here would limit the high-frequency response.

In order to better understand how the

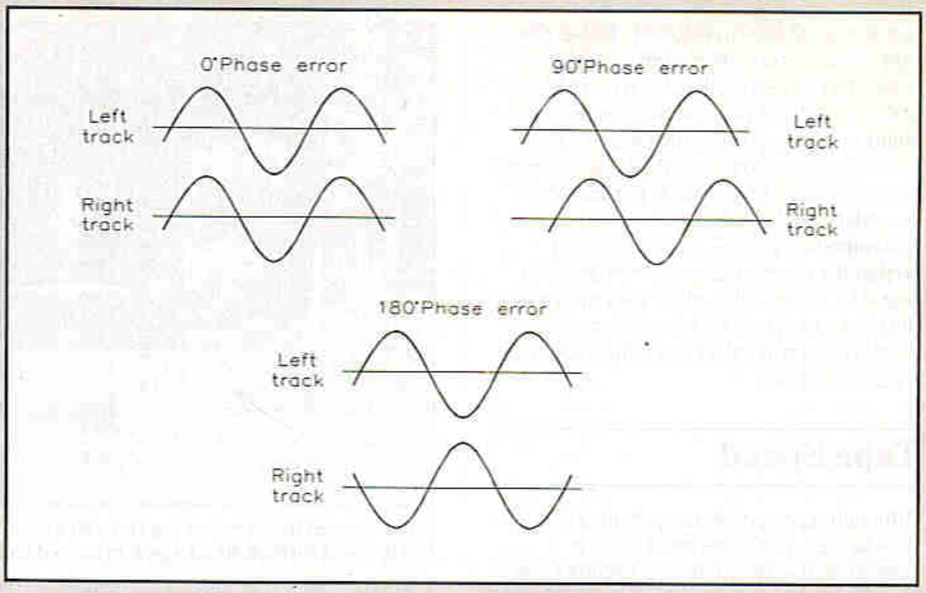


Figure 2. Typical construction of a two-track tape head. Note front head gap.

whole recording process works, it helps to examine the replay side of things first. As already mentioned, during the recording process, audio signals are converted to magnetic waves made up of the tiny magnetic particles of the tape coating. Now, each of these waves has a North and a South pole, and the distance between any two North or South poles is referred to as the 'recorded wavelength'. If a signal with frequency 'f' is impressed by the recording system on a tape travelling at 'S' metres per second, the resulting magnetic flux pattern on the tape has a wavelength 'λ'.

This wavelength can be determined by the expression:

$$\lambda = \frac{S}{f}$$

Thus a signal with a frequency of 15kHz contained on a tape travelling at 38cm/s (15in./sec) would have a wavelength of 25·3μm, and at 19cm/s (7½in./sec) the wavelength would be 12·6μm.

The replay head responds to these magnetic waves passing the head gap, this is referred to as the 'rate of change of magnetic flux'. The changing magnetic flux is induced in the coils of the head and produces a very small AC signal as a result. If the tape had no signal recorded on it, then the replay head would not have a rate of change of flux to respond to, thus producing no substantial output signal.

In a similar way, if the head gap was such that its distance was equal to the distance between two similar poles of the magnetic wavelength, then once again there would be no change of flux and no signal is produced. This is referred to as the 'frequency cut-off point' or 'extinction frequency', and can be calculated as follows:

$$\text{Cut-off frequency, } f_{extinction} = \frac{\text{Tape Speed}}{\text{Head Gap}}$$

Assuming the tape was traversing the heads at a speed of 38cm/s and the gap of the replay head was say 8μm, then the extinction frequency would be equal to:

$$f_{extinction} = \frac{0{\cdot}38\text{m/s}}{8\mu\text{m}} = 45\text{kHz}$$

Now, reducing the tape speed to half also reduces the extinction frequency by half, thus a tape running at 19cm/s has an extinction frequency of 22·5kHz.

From this, it would seem that even with tape running at the relatively slow speed of 19cm/s, it can still handle our full 20kHz audio bandwidth. Well, as usual, that would be too good to be true, and as can be seen from the graph of Figure 3, the usable frequency range only extends to just about half of the extinction frequency. Below this point the frequency response is a familiar 6dB per octave slope, rising with increased frequency, and thus is fairly easy to correct,

Figure 3. Replay head characteristic, showing cut-off due to head gap size.

but above the turnover point the response becomes much more difficult to deal with.

So going back to the extinction frequency figure for tape running at 38cm/s, frequencies above 22kHz or so have a rapid fall off in level, and in reality, we would be more than happy to achieve any response at all above 20kHz.

From this examination it is quite easy to understand why professionals like to use the highest practical tape speed possible. Quite simply, increasing tape speed produces a corresponding increase in frequency response.

Head Alignment

No matter how good the rest of the system, it will only perform well if the head-to-tape transfer is optimised; this includes the physical orientation of the tape heads. Correct orientation involves the four distinct settings of vertical (height), horizontal (tape wrap), zenith and azimuth (head 'tilt' and 'lean') positional adjustments.

However, of these only the azimuth adjustment requires regular, routine checking and setting. The remaining adjustments are carried out during assembly and alignment of a new machine, or following the replacement of one or all of the heads, and would not normally warrant regular setting, but should there be a suspicion that any head adjustment other than azimuth is wrong, it may be necessary to carry out the complete head alignment procedure.

Head azimuth, when incorrect (i.e. when the head is not perpendicular to the tape) causes several problems. The most noticeable to an average listener would probably be the apparent loss of high frequencies on one or other or both tracks of a stereo tape, resulting in dull muffled replay.

We all experience this from time to time on our car cassette machines. The constant vibration of the cassette mechanism soon leads to the azimuth setting drifting, resulting in a very noticeable deterioration in reproduction quality. Whilst this may be a minor irritation when listening to Meatloaf's 'Bat Out of Hell' for the umpteenth time on the M1, (although having to poke your finger in the cassette slot to move the tape over for better treble is not ideal!), the azimuth situation has far more serious implications for the professional tape user.

Apart from the problems mentioned above, should the azimuth be incorrect, signal timing or 'phase' errors will occur, and this leads to potentially disastrous consequences.

Let us consider a stereo recording. There will be periods where the information on both left and right recorded tracks is identical – for example, where a vocal passage is at the centre of the stereo sound stage. Now if the azimuth adjustment was such that the phase error was 180°, (easier to achieve than you might think), then the replayed signals from the tape would, in effect be exactly opposite. Listening to this in stereo gives a strange effect, but in mono the result is no signal output. This is because the left and right signals are exactly opposite in phase and so, when added together for mono, they have the effect of

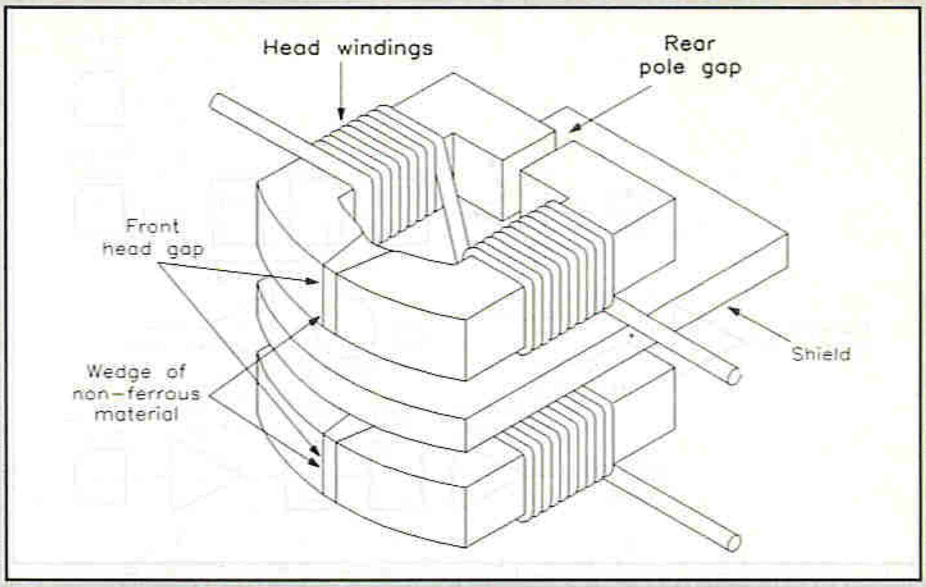


Figure 4. Comparison of the two channels of a stereo tape recorder. The test tape playing has an identical sine wave (in both frequency and phase) recorded on it. Azimuth errors on the tape recorder will introduce phase errors between the two channels, as can be seen in two of the instances shown.

cancelling each other out, the result being zero output! Of course, phase errors exist at any point between 0° and 360° with varying effects, but commonly we deal with, and correct, azimuth errors of only a few degrees.

In practice the azimuth of both the record and replay heads is set for maximum signal output with minimum (ideally zero) phase error. The azimuth adjustments are normally done as part of a full recorder line-up procedure which is not discussed in detail here, but will hopefully be included as part of a later feature of this series.

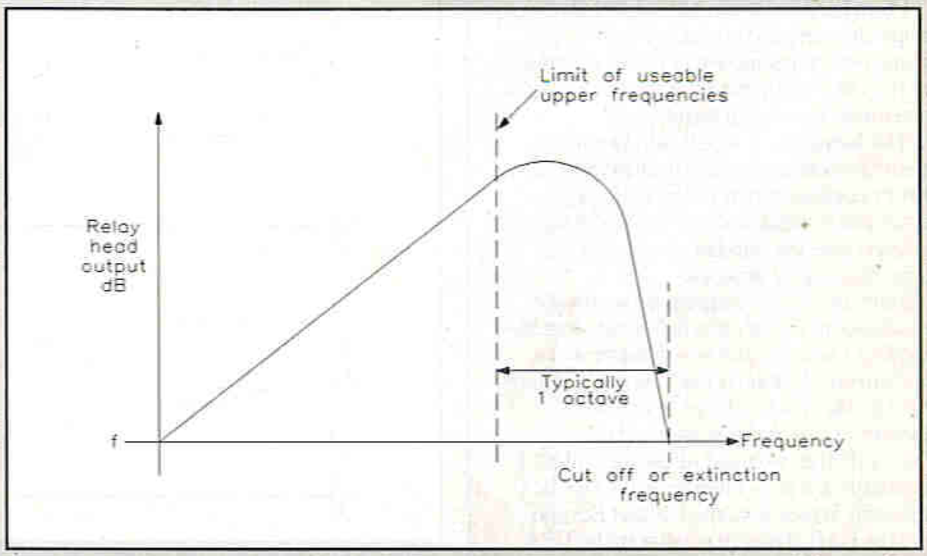
To establish a starting point, replay head is adjusted first. This can be done using a dual-trace oscilloscope to observe replay head output signal, whilst replaying the azimuth section of a calibration tape. This is usually a sinewave, of frequency between 10 and 12kHz, accurately recorded across the full width of the tape.

Both tape recorder outputs are fed independently into the inputs of the oscilloscope, which is then adjusted so that one or two full cycles of the replayed signal are visible. The azimuth can now be correctly set by turning the adjuster screw slightly both clockwise and anti-clockwise until the two traces show minimum (ideally zero degrees) phase error. Figure 4 shows how the two traces compare with 0° (a), 90° (b), and 180° (c) phase errors.

When the replay head azimuth adjustment is complete, the record azimuth can be set. Again, an oscilloscope is used to display the replay head outputs, but now clean tape is loaded onto the recorder and a signal, of frequency between 10 and 12kHz, is applied to the recorder inputs, and the machine set to 'record'.

Because we have already set the replay azimuth to be correct, any phase error now displayed on the scope must be attributable to incorrect record head azimuth – well, almost. In fact the record bias current also has a bearing on the relative phase of the two tracks. This being so, it means that at this stage of a line-up operation only a rough setting of record azimuth can be done; when the record bias has been accurately set, a fine tweaking of the azimuth screw may be required.

Having now gained an insight into some of the basics of replaying a previously-recorded tape, much of the recording process can be understood by looking at a typical complete tape recording system.



Head-block view of the Nagra portable tape recorder, which is extensively used for outside work, particularly 16mm film soundtracks.

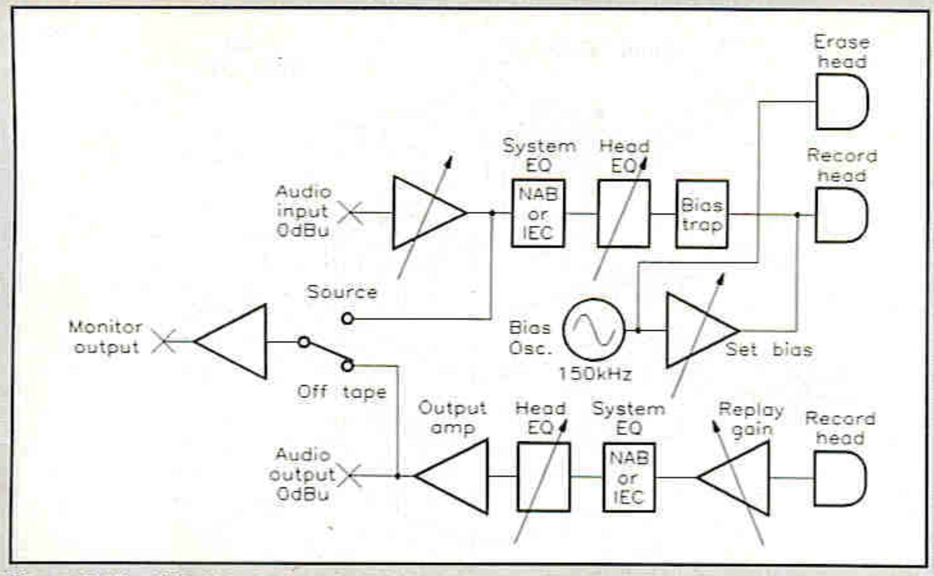


Figure 5. Simplified block diagram of a typical tape recorder – only one channel shown. Note unity gain from input to unity.

A Trip Inside your Tape Recorder

Figure 5 shows a typical tape recorder block diagram. Although the various stages appear here as separate blocks, two or more of these stages may well, in reality, be combined as a single block. For the purposes of inspection, it is important to consider each stage as a self-contained unit.

The various stages of recording and replay can be followed by referring to the audio blocks in Figure 5, and also the eight graphs in Figure 6. The graphs roughly represent the shape of the signal from recorder input, right through to recorder output. It should be noted that these graphs areee intended as a graphical illustration only, and are not presented here as detailed technical data.

Graph 1 shows the signal at the recorder input which has, basically, a flat frequency response. Audio is passed directly to an input amplifier with an adjustable gain control, which is used to set the record level of the machine. Immediately following the input amp will be a 'source', or input monitoring point; most machines allow the user to switch between monitoring the input and the confidence replay, for the purposes of quality comparison.

From here on, the input signal undergoes many changes, and is equalised or frequency-compensated in such a way that by the time it gets onto the tape, it barely resembles its original form.

The frequency compensation elements, generally referred to as 'equalisation', are a very necessary part of any analogue recording system, and are used primarily to overcome the non-linear action of the recording/replay process.

Stage two of the diagram is the system equalisation, intended to help overcome the nonlinear action of the recording process. System equalisation is not adjustable, being fixed by the manufacturer to one of a number of well-defined standards. Currently the two most often encountered standards are IEC-1 (equivalent to CCIR), generally favoured in the UK and Europe, and the NAB standard popular in the USA. Both of these are commonplace in the UK, but large tape recorder users, such as the BBC and Independent broadcasters, will adopt one standard of correction equalisation throughout, with all machines being specified and aligned as such.

The difference between the equalisation standards can be seen in the replay equalisation characteristic graphs of Figure 7. This shows the differing frequency turnover points for the IEC and NAB equalisation standards. These are normally referred to in time constant form, rather than as a frequency. The IEC characteristic has a time constant of 70μs (microseconds) at 19cm/s, and 35μs at 38cm/s, and thus makes an allowance for frequency/speed factors. The NAB standard uses a time constant of 50μs at all speeds.

It is worth noting that because of the difference in IEC and NAB equalisation characteristics, the two are not really compatible. That is to say that a tape recorded to the NAB standard should not be replayed on a machine with IEC replay characteristics, and vice versa. The result of mixing these two standards would be a far-from-flat frequency response.

Graph 2 shows the audio signal after system equalisation to the IEC standard has been applied. The most noticeable effect is the boost at high frequencies. Now follows the head equalisation stage, whose task it is to overcome record head losses. Head equalisation is most definitely adjustable via a range of presets. A professional recorder would have separate presets for both HF and LF adjustment at each of the machine's running speeds. On a two-channel machine with three speed ranges, there will be a total of twelve record equalisation presets – six for each channel.

The now well-mangled audio signal is passed through a 'bias trap' (more on this shortly) and mixed with the bias oscillator signal, before finally arriving at the record head. Graph 3 shows how the signal now appears in terms of record head flux, and Graph 4 represents the flux in the tape. In order to achieve the best possible

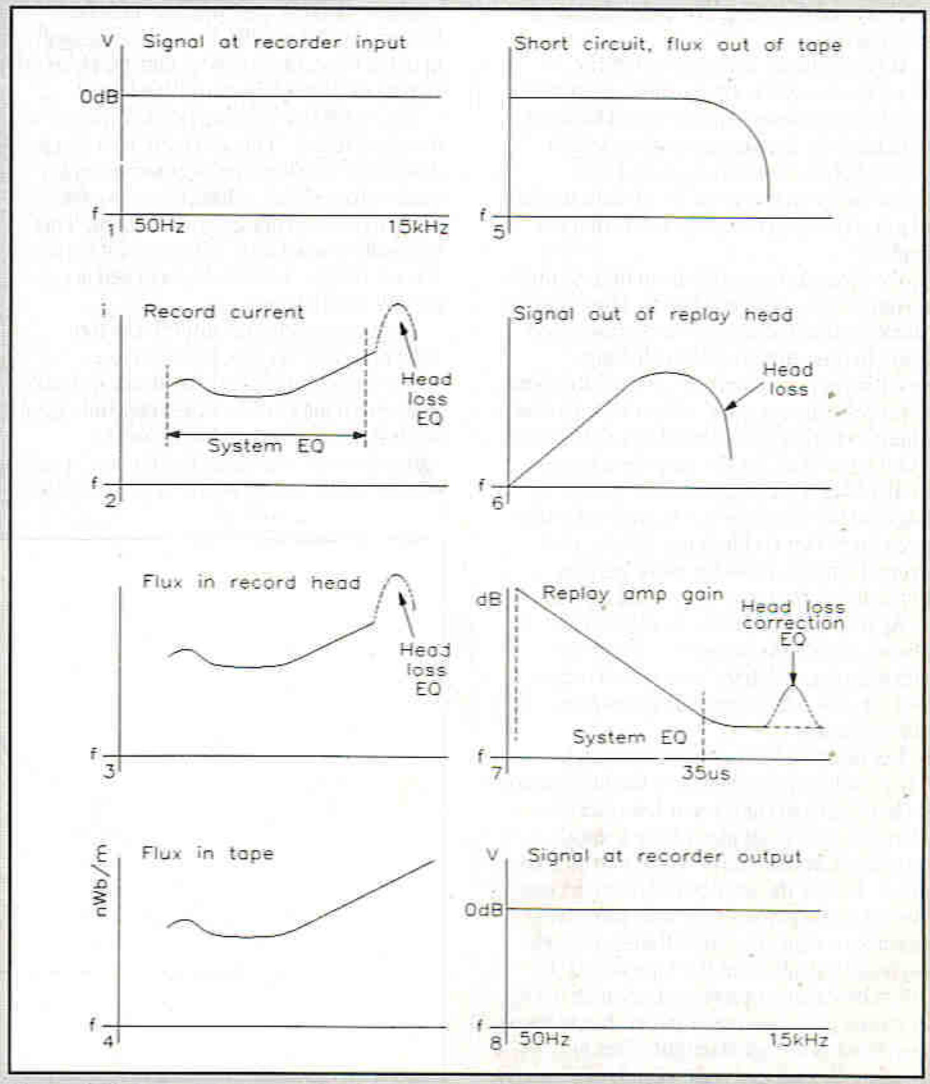


Figure 6. Frequency response graphs, corresponding to the various stages of tape recording (See text).

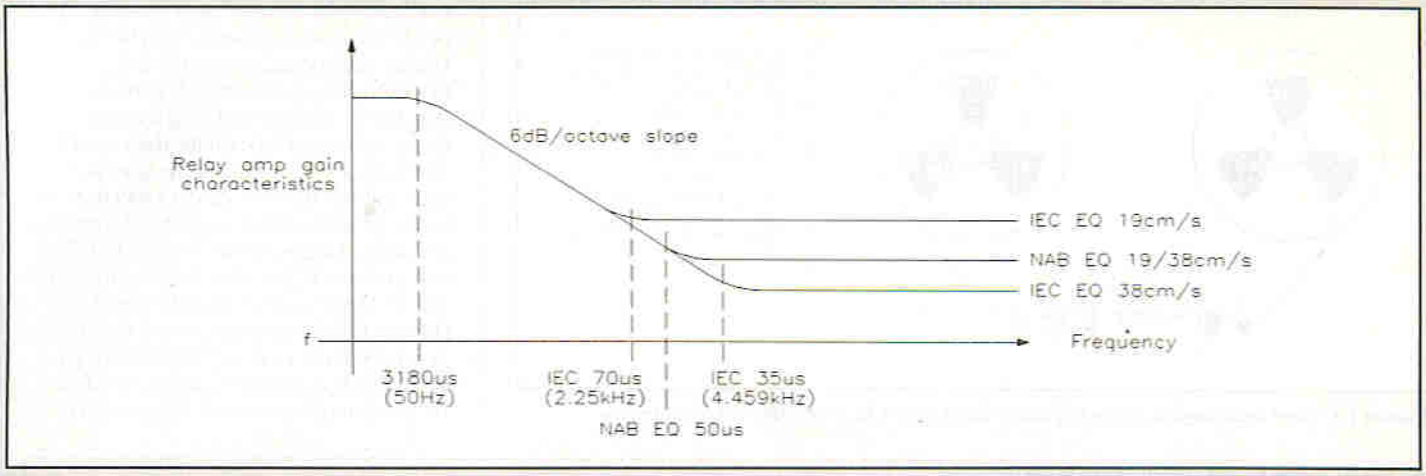


Figure 7. Comparison of IEC and NAB replay characteristics. Note frequency turnover points.

performance from any analogue tape recording system, it is necessary to use a high frequency 'bias' signal. There is no easy explanation of why bias works but, in short, adding a bias signal to the audio signal greatly reduces distortion and unwanted noise by helping to linearise the way in which the signal to head to tape transfer is carried out.

Correctly set up, bias current will have a positive effect on the whole record process, and in particular will influence the areas of distortion, noise and frequency response. Correctly-set bias current reduces distortion elements, improves the signal to noise ratio and optimises the record process frequency response.

Curiously, optimum bias current is not 'maximum bias current', but at a figure several dB lower than maximum. This point is referred to as 'overbias', and is expressed in dB. Optimum bias is achieved by adjusting the 'bias trimmer pot', whilst recording a low-level high-frequency (10kHz or so) onto the tape. Monitoring is achieved 'off tape' via the replay head, using a metering device calibrated in dB.

A point will be found where the output peaks, as indicated by the meter. Having established this point, the bias level is increased so that the recorded output is reduced in level by the specified amount (the overbias level). The exact level of overbias depends on tape type, machine type and tape speed.

As can be seen in Figure 8, optimum bias current is at a point where the recorder's distortion figure has passed minimum and has just begun to rise again. At this point, the noise level is at absolute minimum.

As you may have gathered, setting of the bias current is a critical matter. In order to optimise tape-to-machine performance, the bias must be spot on – anything less than perfect will severely degrade quality. Some cassette machines (particularly 3-head models) offer a manual bias adjuster exposed on the front panel; using this to 'tweak' the machine could result in impaired performance (e.g., incorrect frequency response and/or increased distortion). Bias setting is a job for the professional with the correct test gear, adjustment information and an understanding of exactly what is required to bias a particular tape to a particular machine. Without all of these, leave well alone and refer to a suitably qualified person!

Typically the bias oscillator produces a high-frequency sine wave (typically 100 to 200kHz), at several times the level of the record head current. Now, at typical bias oscillator frequency, the record head impedance is quite high, and the bias current can develop fairly high voltage levels at the head – in some cases this may be up to 100V! To prevent this potentially damaging voltage from finding its way back down the signal path, a bias 'trap' is added to the circuitry, as shown in Figure 9. The bias trap itself is simply a filter tuned to be most efficient at the bias signal frequency, and effectively removes any stray bias.

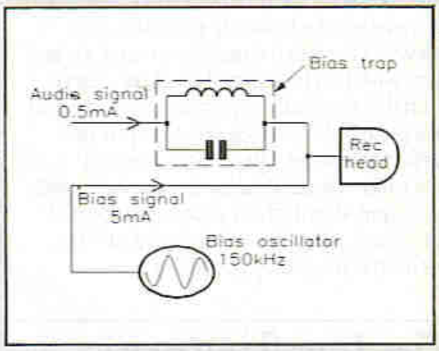


Figure 9. Typical 'bias trap' arrangement, used to prevent the HF bias signal from finding its way back down the audio path.

More often than not, the bias oscillator also supplies the signal used by the erase head to remove previously-recorded material from the tape. An audio signal being replayed off-tape is the product of the magnetic properties of the replay head responding to the 'rate of change' of the magnetic flux pattern on the tape. It follows that if the rate of change was zero, then the replay head would have nothing to respond to and would therefore produce no output – a blank tape!

So, in order to make a tape blank, or erase it, it is necessary to comply with the above. In practice, this is achieved by using a very high- frequency, relatively-large AC field which uses brute force and literally saturates the tape, leaving it with near-zero magnetism. The erase signal is provided, in most cases, by the bias oscillator, with the addition of a power stage producing the extra welly required for successful erasing.

The replay section of the recorder block diagram of Figure 5, looks and is, essentially, very similar to the record section. The replay amplifiers and equalisers must now correct the actions of the various systems used to get the audio onto the tape in the recording process. Again, fixed system equalisation is used, and the replay head equalisation is adjustable to combat head losses.

Graphs 4 and 5 represent the flux in the tape, while Graph 6 shows the corresponding signal output from the replay head.

Arguably, the most useful is Graph 7, which shows the gain and equalisation

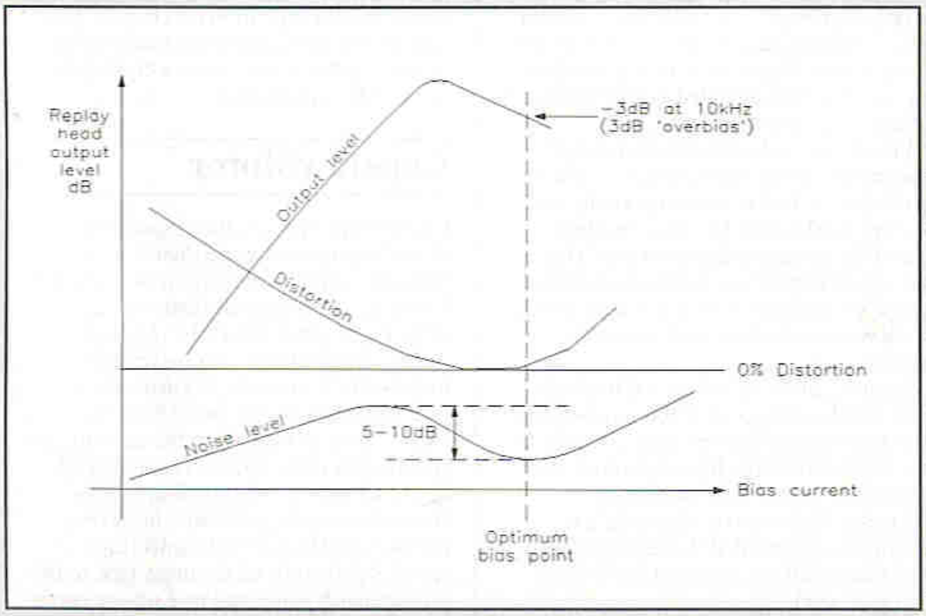


Figure 8. Effect of adjusting bias current. Note changes to distortion and noise levels, and the optimum bias point. The input signal has a frequency of 10kHz.

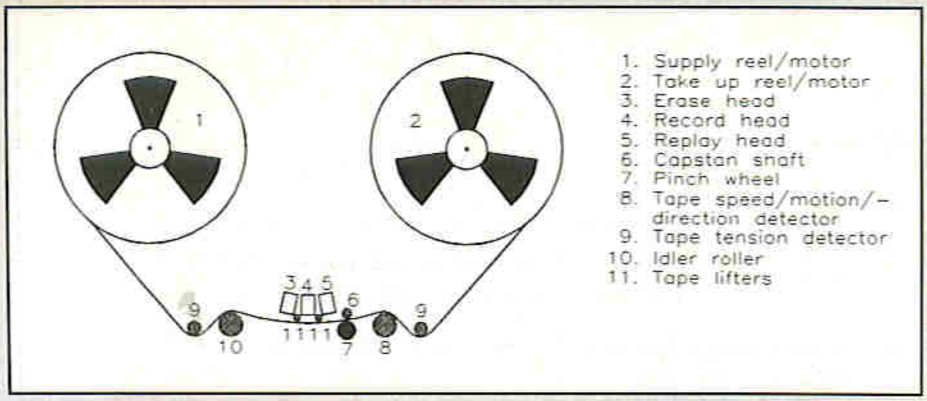


Figure 10. Tape deck layout, showing location of major tape transport components.

necessary in the replay amplifier sections to resolve all of the previous processes. All tape recorders posses replay amp gain/ responses which closely resemble this curve. It has been suggested that if we are aware of the characteristics of this curve, then it is not really important to know what has gone before, since we can draw our own conclusions – decide for yourself!

Finally, Graph 8 takes us full circle, with an output signal which should look pretty much as it did at the recorder input – i.e. with a flat frequency response.

The Tape Transport

Whilst current tape recorder audio circuits are undoubtedly very good, they will only produce best quality results when partnered with mechanical tape transport systems of a similar high standard.

Tape transport systems are made up of a number of electromechanical (and often electronic) elements, working together to provide smooth traversing of tape from reel to reel, accurate speed control in 'record' and 'play' modes and general safe, gentle and damage-free handling of tape. These elements comprise:

1. Tape transport control system.
2. Supply spool motor.
3. Take-up spool motor.
4. Capstan motor and speed control.
5. Tape tension control system.
6. Reel braking system.

At the very heart of the tape transport is the control system, which is responsible for the actions of the various motors, solenoids and such. Older systems used complicated mechanics or a series of relays for system control; modern recorders, however, rely upon microprocessors and logic control to provide easy and non-destructive transport commands. By this I mean that, with modern control, it is possible to switch from any mode to any other mode without affecting the tape in any adverse way. For example, punching the 'record' buttons whilst in 'fast rewind' mode would produce no more dramatic an effect than a gentle slowing of the tape to a halt, followed by an almost instant change into record. No fuss, no bother, and no stretched or tangled tape!

The transport control will undoubtedly feature a tape counter or timer. The most useful are those that indicate, in hours, minutes and seconds, the elapsed time, rather than a simple and rather limited numeric counter. The more comprehensive timers include a search and autolocate facility, which can seek out specific points on the tape and either 'stop' or drop into 'play' mode. Another useful feature is a 'Return To Zero' (RTZ) function, which will find the zero datum of the tape and follows commands as programmed by the user.

All of the counter and timer functions require information relating to the tape's relative position, speed and direction of travel. This is provided by pulses produced (as the tape moves) from a tacho arrangement driven by a rotating tape guide roller.

All tape recorders have a number of tape guide pins and rollers along the tape path, as shown in Figure 10. Some are fixed, and others either rotate or move in a horizontal lateral plane. These serve several purposes and are generally provided as a steadying, guiding influence on the tape.

Fixed tape guides assist in keeping the tape in the correct vertical plane in relation to the heads. This is most important, since the tape tracks must line up accurately with their corresponding head gap. This is critically important on multitrack machines, where any misalignment in this area would cause serious track-to-track crosstalk problems.

Rotating guides or rollers will be used to drive a tacho arrangement for assessing the tape speed and relative position, be used to give a measure of the tape tension or may serve as to reduce wow and flutter elements. Whatever the situation, it is essential to ensure that these rotate freely at all times, and are kept spotlessly clean and degaussed.

Some of the machine's fixed guide pins will move (by solenoid operation) in an horizontal plane to and away from the head block; these are known as 'tape lifters'. During record, playback and editing functions the tape lifters will allow the tape to come into full contact with the heads, but during fast spooling motions the tape lifter solenoids are activated by the transport logic and 'lift' the tape gently away from the heads. If tape was left in full head contact in all modes, two problems are created. The first problem is that allowing the tape to rub against the heads at very high speed is likely to result in rapid head and tape wear. Secondly, the extremely high frequency audio that is reproduced during spooling is very uncomfortable to listen to, and may damage both hearing and monitoring loudspeakers, even if only replayed at moderately high level!

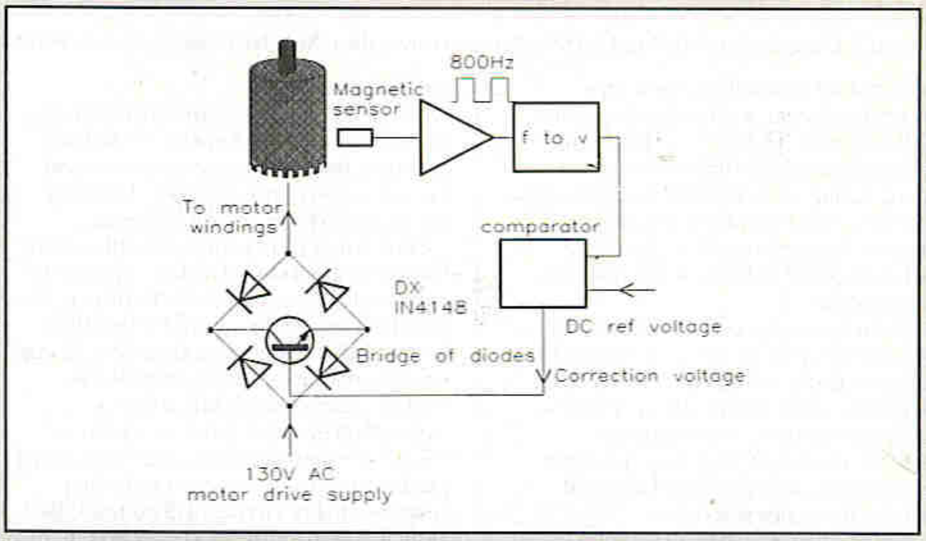


Figure 11. One method of controlling capstan speed. Similar arrangements are used by the respected Austrian firm Studer Revox.

For these reasons, all professional recorders (and most domestic/semi-professional machines) employ a tape lifter system of one sort or another.

High-speed passage of tape in either direction, known as 'spooling' ('fast forward' and 'fast rewind') is carried out by two spooling motors, usually mounted directly below the left and right reel turntables. These motors are high quality, smooth running 'no fuss' types. In addition to simply traversing the tape from reel to reel, these motors also form part of the tape tension system, and may also act as a braking force to slow the tape to a halt.

Capstan Motor

Correct tape speed is the responsibility of the 'capstan motor' and 'pinch wheel'. The tape runs between a precision ground hardened steel shaft (the capstan), and a rubber type pinch wheel. In 'play' and 'record' modes these two are brought together by a solenoid, and drive the tape (sandwiched between them) from the supply spool on the left, to the take-up spool on the right. In a correctly aligned transport system, the spooling motors should have no responsibility for driving the tape, and thus do not control tape speed, but merely act to supply tape to the capstan/pinch wheel and take up any excess from the capstan.

During tape spooling operations, and

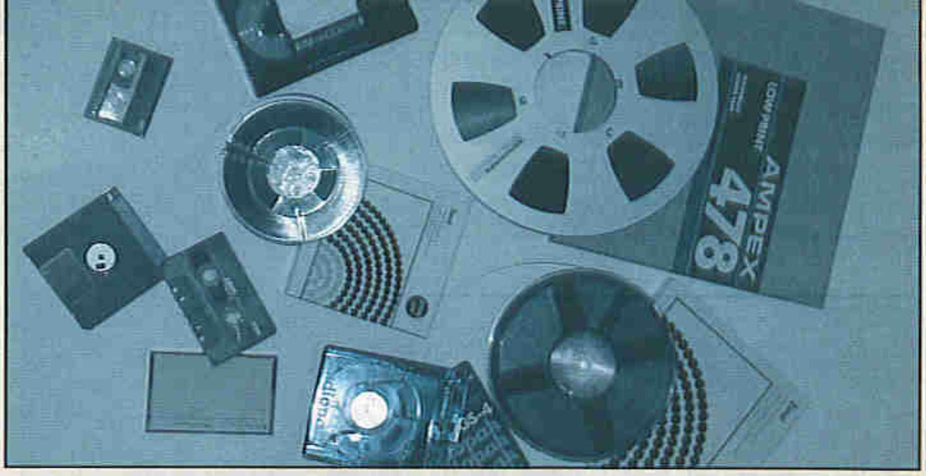
when the machine is in its 'stop' mode, the capstan and pinch wheel are separated and the tape is distanced from the heads by the solenoid-driven 'tape lifter' system.

The capstan shaft usually forms an integral part of the capstan motor and is thus directly driven. Other systems, such as belt drive, do exist but the direct-drive method probably gives less room for speed error and instability. The capstan motor is normally an AC induction motor or brushless type DC unit, both of which benefit from low noise, interference-free smooth running operation. Whatever the motor type, its speed will be accurately monitored and controlled electronically.

Several systems of capstan speed control are in use. Figure 11 gives an example of one such arrangement. The capstan shaft is supported by high- quality bearings, and is attached to a heavy steel drum (the motor housing), which rotates around the motor windings. One end of the steel drum has accurately machined slots or indentations cut into the steel surface. Placed in close proximity to the slots are small magnetic sensors, similar in design to a tape head, which detect (as the motor rotates) the passing of the slots or indentations, and thus sense a changing magnetic field. These minute signals are amplified and 'cleaned up', to appear as a square wave pulse train, the frequency of which relates precisely to the capstan speed. This signal undergoes frequency-to-voltage conversion producing a steady DC level, which can now be used as a usable measure of capstan speed. A comparator is fed with both the capstan speed voltage and a stable DC reference level. The resulting error correction voltage ultimately controls capstan speed.

The AC voltage to the capstan motor is not applied directly, but via a bridge of diodes. The collector and emitter of a transistor, together with a loading network are wired across the diode bridge, and the comparator correction voltage is applied to the base of the transistor.

As the correction voltage varies, with fluctuations of capstan speed, the transistor behaves as a variable load across the bridge, and thus adjusts the supply level to the motor. Although simplified here, this control system does produce very accurate motor control, and is widely used in professional recorders.



A selection of magnetic media – 10½in., 7in. and 5in. tape spools, a cartridge, a compact cassette, a Betamax video cassette, a 3½in. computer diskette and a DAT cassette.

Tape Tension

Correct tape tension is necessary to keep the tape in intimate contact with the heads, whenever the recorder is in 'record' or 'playback' mode. This is achieved by sensing and measuring tape tension, and then applying a braking force – either electrical or mechanical – on one of the spooling motors, whilst an opposing driving force is applied to the other spooling motor.

A tape machine running with incorrect tape tension will suffer several problems. Firstly, the tape will not remain in proper contact with the heads, and as a result signal information will be lost and poor quality recording will obviously occur. Similarly, replaying a good tape on a machine with poor tension will produce muffled replay and low signal levels.

Other, potentially more damaging, problems exist if the supply tension is too great. Physical destruction of the tape itself, and increased head wear, are possible; in 'play' or 'record', the capstan will still try very hard to drive the tape to the take-up spool – tape stretch is therefore a possibility. On the other hand, if take-up tension is insufficient, tape will still flow past the capstan at the same rate, but as it is not being collected by the take-up spool it will simply distribute itself wherever it can, maybe even on the floor!

It is also necessary to maintain a certain amount of tape tension when the machine is at rest, in its 'stop' mode, so that the tape remains seated in its guides. Commonly, this is done by applying a mechanical braking force to the spool or reel turntables.

Braking

All professional recorders include some method of gently slowing and stopping a moving tape – this is referred to as the braking system. To avoid tape damage, it is important to apply very controlled braking; this is normally done by exerting a mechanical force on the hubs of the spooling motors. In some cases a combination of electrical and mechanical braking is used, the use of such allows (by the nature of controlled electrical energy applied to the motors) greater braking accuracy over a purely mechanical arrangement.

Typically, braking is normally in a 'fail safe' arrangement, with the brakes being normally 'on' in 'stop' mode and whilst the machine is unpowered. In this way, even if the supply to a machine is unintentionally disconnected, no tape damage will occur, and the tape will be held firm until the power has been restored, thus saving from scrap the last six years you have just spent making a potentially award-winning documentary! On the other hand, there is always the backup safety copy you made earlier as a matter of course!

Figure 12 shows a common braking system using 'brake bands'. These are long strips of thin flexible stainless steel wrapped around the hubs of the spooling motors to act as mechanical brakes. Clamped firmly around the hub in braking mode, they are, however, actuated by the electrical operation of a solenoid. As with all other tape recorder components, brake bands must be kept clean (and to be effective, free of any traces of grease), and in good operational order with regular inspection and replacement.

Problems resulting from poor maintenance of the braking system range from unbearable high-pitched screeching noises caused by dirty bands dragging on the motor hubs, to far more serious tape damage problems, all of which can be prevented by regular servicing.

Next month, we will take a practical look at all types of professional tape recorders, and delve into the uncertain world of location recording.

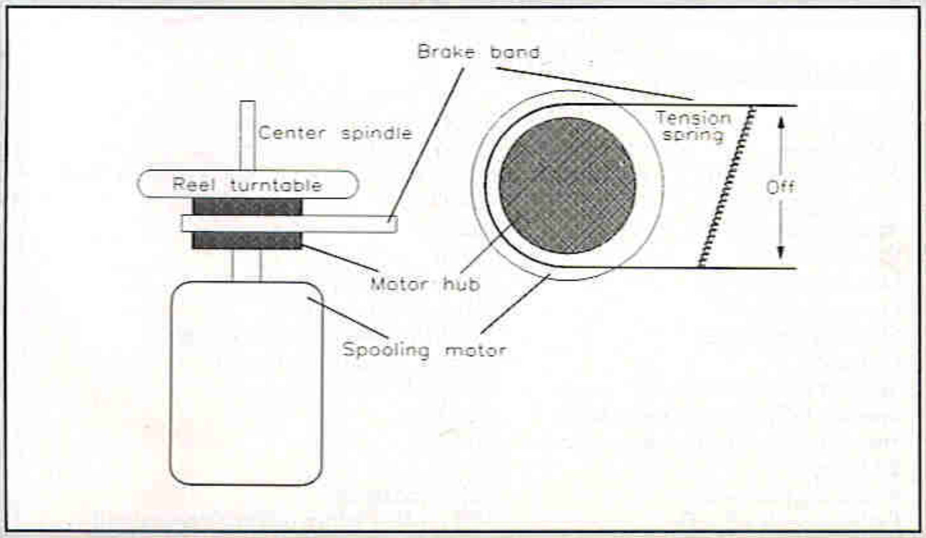


Figure 12. Spooling motor braking system. Stainless steel breakbands are applied to the motor hubs, and thus slow the motors gently to a halt.

WARNING: It is imperative that every possible precaution is taken to prevent electric shock. 240V AC mains can *kill*. Do not use this module without a suitable case.

KIT AVAILABLE VF19V PRICE £129.95

Text by Martin Pipe

300W MONO MOSFET POWER AMPLIFIER

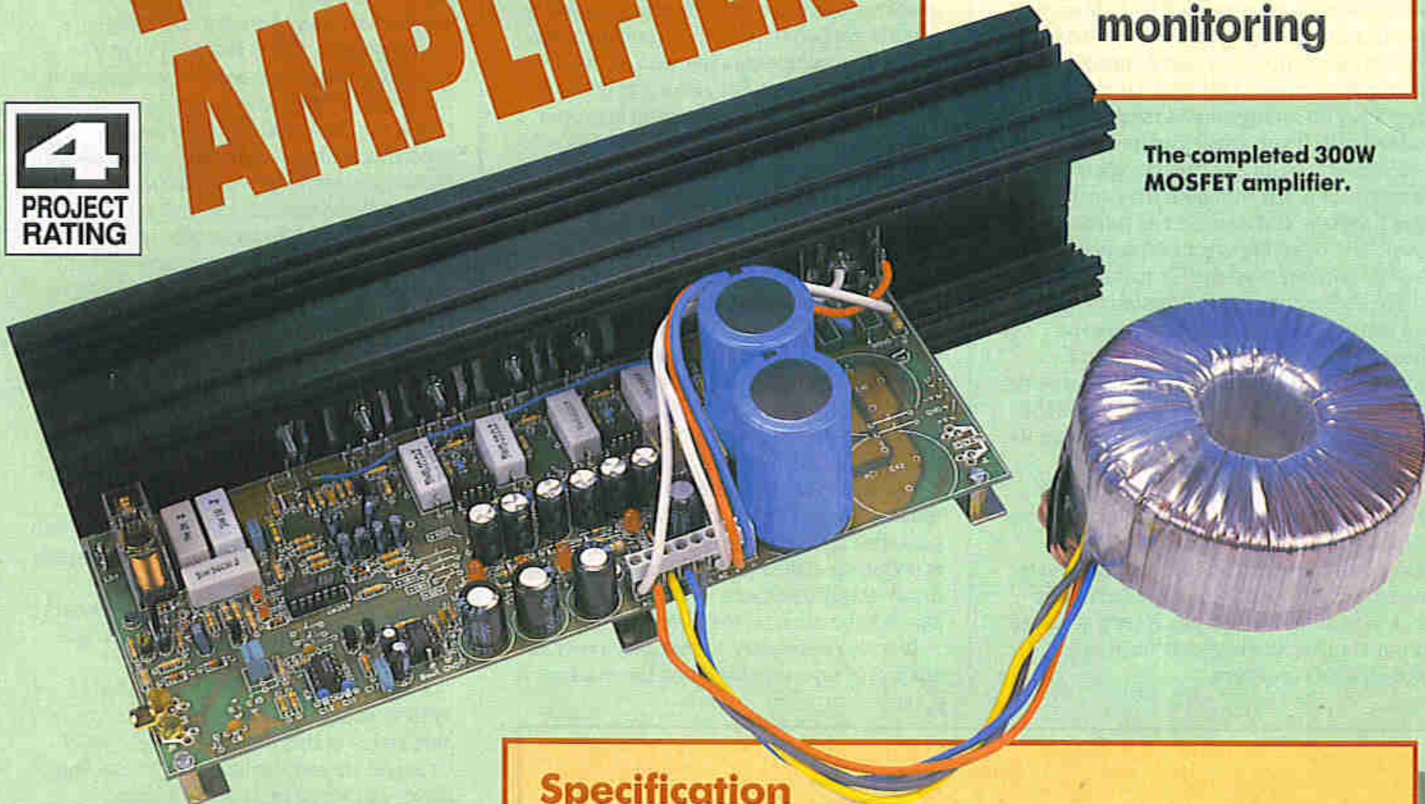
FEATURES

* High power
* Low distortion
* Highly efficient
* Comprehensive protection circuitry

APPLICATIONS

* Hi-fi systems
* Disco applications
* Laboratories
* Studio monitoring

4 PROJECT RATING



The completed 300W MOSFET amplifier.

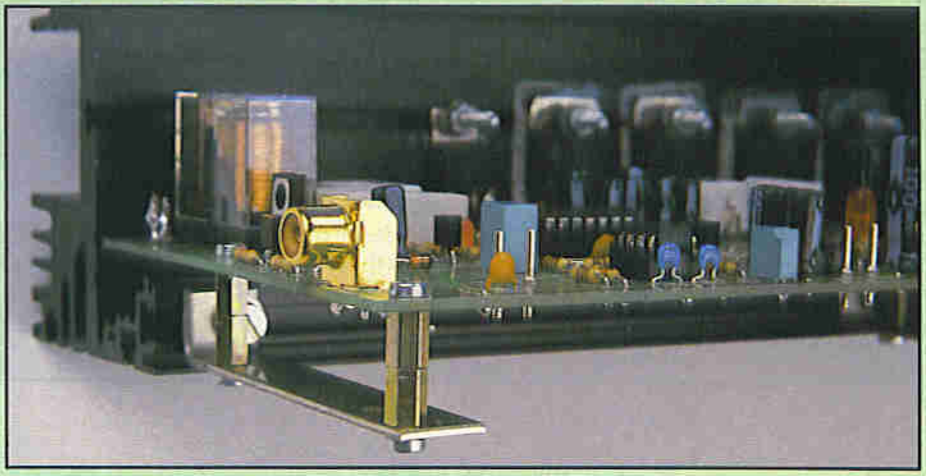
Some audio applications demand high power levels – disco equipment, public address systems, laboratory experiments, and very large living rooms! The amplifier featured in this article, an 'efficient' Class A design, will provide 150W RMS into 4Ω. "That's as may be (I hear you cry), but what *do* you mean by the term efficient?"

Specification

Music power:	300W into 4Ω, 200W into 8Ω
RMS power:	150W into 4Ω, 100W into 8Ω
Harmonic distortion:	0·008% @ 1W 1kHz, 0·04% @ 90W 1kHz
Damping factor:	>300
Input impedance:	47kΩ
Input sensitivity:	1Vrms
Frequency response:	3Hz to 120kHz (−3dB)
Power bandwidth:	5Hz to 50kHz (−1dB)
Signal-to-noise ratio:	112dB (A weighted at full power)
Protection:	Thermal, DC and short circuit
Speaker switch-on delay:	2 seconds
Speaker DC protection trip voltage:	>±1V
Thermal protection trip temperature:	90°C
Efficiency:	>70%
Power consumption:	220W maximum
Dimensions W x H x D:	350 x 140 x 90mm (without transformer)

Well, a standard fixed-bias class A amplifier has an efficiency of between 20 and 30% – in other words, as much as 80% is wasted in the form of waste products – e.g., heat. A Class A amplifier without any other losses in the output stage (not including the low power driver circuit, which itself is normally Class A) would have a maximum theoretical efficiency of 50%, since the output devices are always conducting and consuming energy, regardless of the presence of an input signal.

The amplifier described here gets around this inefficiency problem by clever design – making use of a 'dynamic' (sometimes known as sliding) biasing technique. As a result, an efficiency of more than 70% – much more in keeping with its Class B



End view of the heatsink, showing how the PCB is mounted.

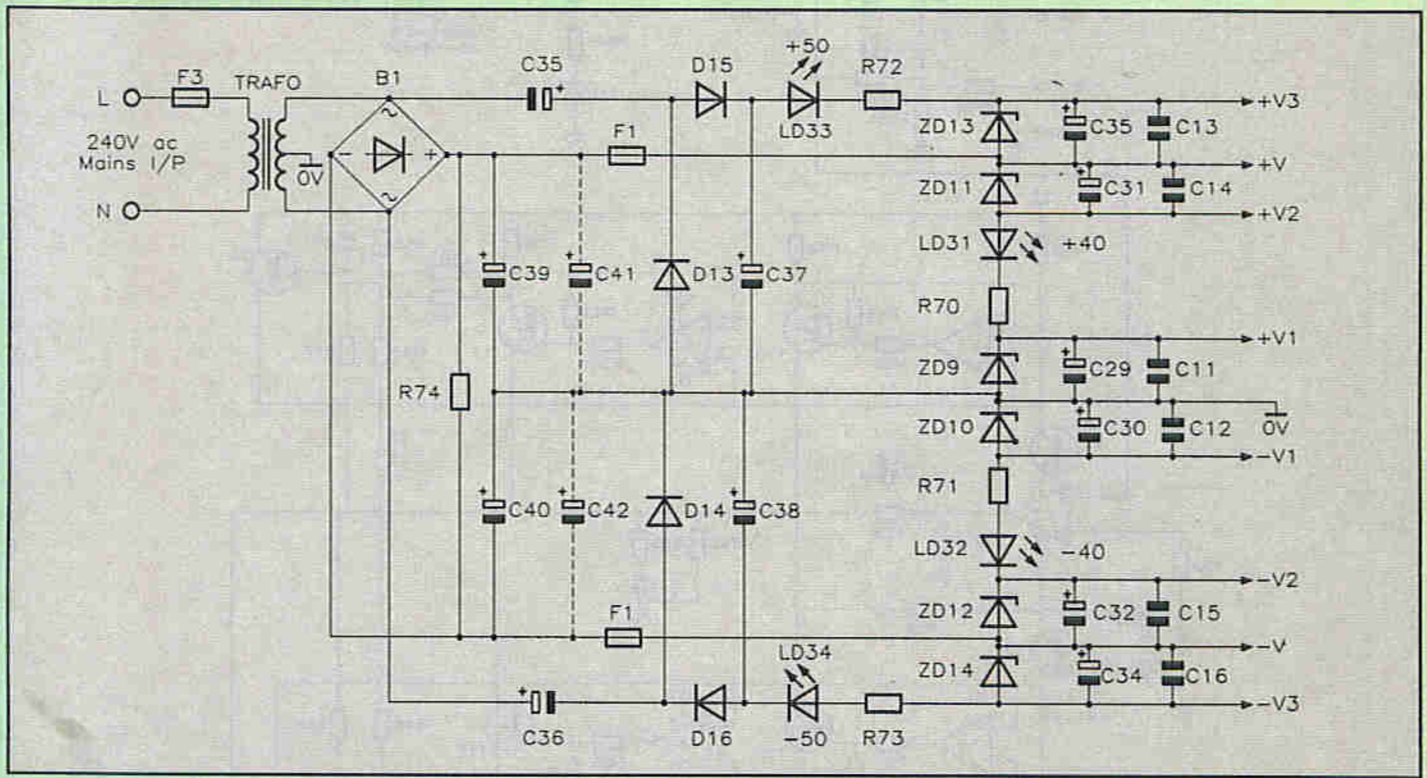


Figure 1. Power supply circuit diagram.

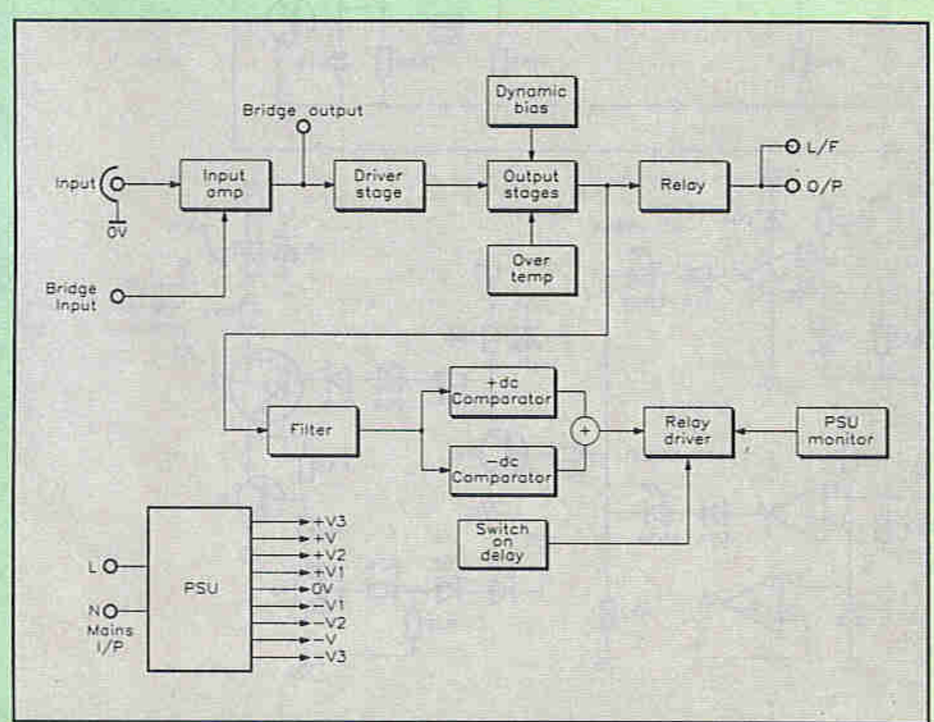


Figure 2. Amplifier block diagram.

and AB cousins, but without the problem of crossover distortion. The kit, out of interest, is complete – even including the large toroidal power transformer and heatsink.

Circuit Description

(i) Power Supply

The power supply, shown in Figure 1, is a fairly interesting arrangement. At first glance, there may only appear to be three split rail supplies – in actual fact, there are four. They are: +V1/0V/–V1, which are used to power IC6 and A5 to 7, and to provide a voltage reference for T5 & T7; + V2/+V/+V3, which are used to power A1 & A2; –V2/–V/–V3 to power A3 & A4; and finally +V/0V/–V, which is the high current supply to power T6, T8 & T10 to T13.

The high current supply (+V) is derived from the transformer and rectified by B1, before being smoothed by the two 10,000μF capacitors C39 & 40 (or four 4700μF capacitors – C39 to C42).

Diodes D13 & D15, together with C35, form a diode pump. The voltage produced is smoothed by C37, and regulated by R72 and Zener diode ZD13, which are stacked on top of the +V (40V) rail. This arrangement allows a higher voltage (the 50V +V3 rail) to be generated than that expected from a simple bridge rectifier circuit. The +V2 (30V) rail is derived from the +V rail via ZD11 to R70 limits the current through ZD11, and provides the required voltage-dropping component. The current passed through ZD11 is also passed through ZD9 to obtain the +V1 (18V) supply. LEDs LD33 & LD31 are used to show that current is flowing, and hence that voltage is present on the supply rails.

The negative supply-generating circuits (−V, −V1, −V2, −V3) work along exactly the same principles as those given above.

(ii) Amplifier

The design of the amplifier, shown as a block diagram in Figure 2, is also interesting and will be discussed in some depth. The amplifier's circuit diagram, which shows the workings in greater detail, can be seen in Figure 3. Starting with the input, as good a place as any, C6 is used for RF decoupling, while R46 sets the input impedance of the amplifier. C19 AC-couples the signal to input amplifier IC6, the gain of which is determined by dividing the value of R47 by that of R45A. Resistor R45B is the inverting input resistor, and is only used when the amplifier is connected in bridge mode (two amplifiers are required – this will be discussed in a future article). C7 is present to reduce the gain of IC6 above audio frequencies.

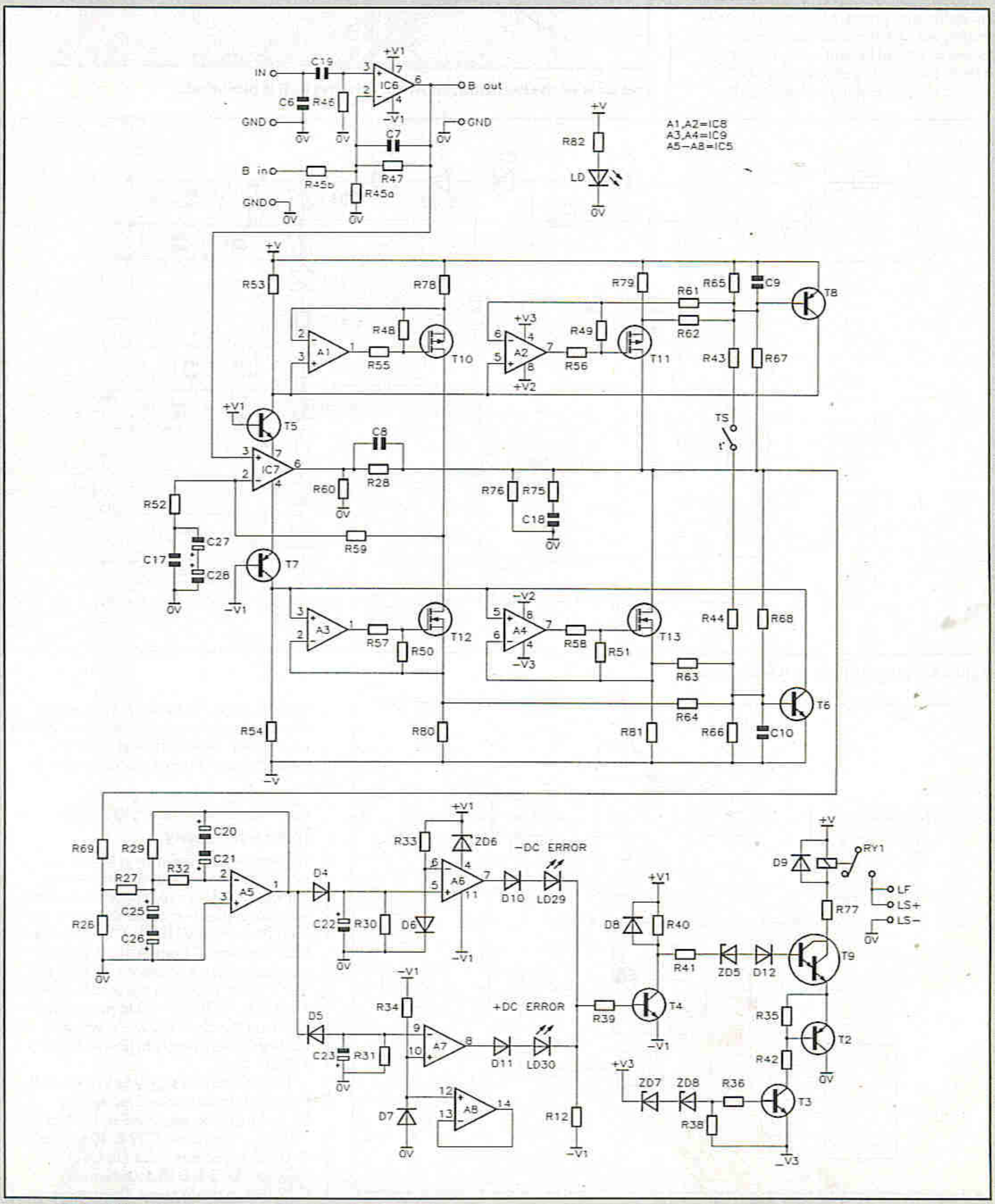
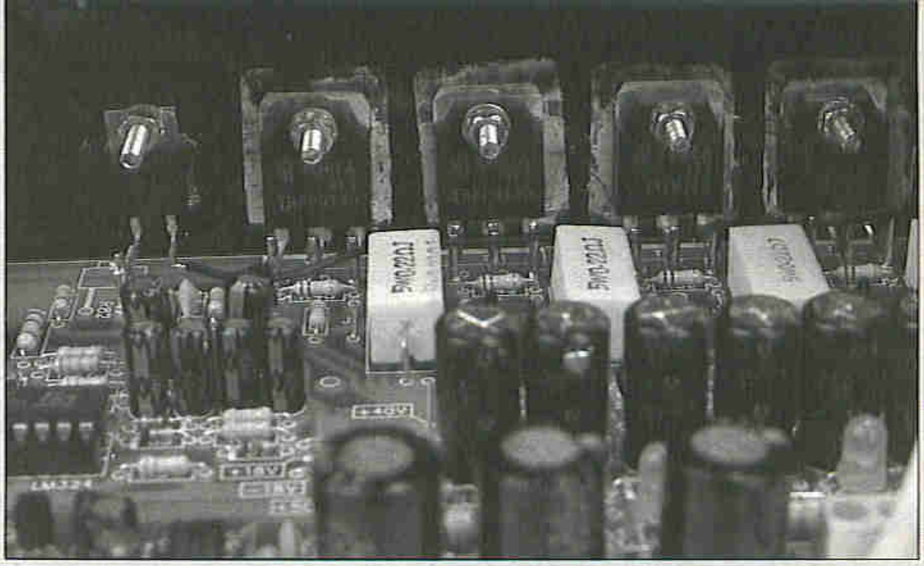


Figure 3. Amplifier circuit diagram.

The output of IC6 is then fed into IC7. Transistors T5 & T7 are used as pass transistor regulators to power IC7; R60 is the constant load for IC7. With no signal present, the voltage at the collectors of T5 & T7 set the quiescent current in the output stage, which is based around power MOSFETs T10 & T11 (negative half-cycle), and T12 & T13 (positive half-cycle). Applying a signal to the circuit will cause IC7 to draw more current; in doing so, a voltage drop proportional to the signal will appear across R53 (positive half-cycle) and R54 (negative half-cycle) – i.e. modulating the –V and +V supply rails. This modulation is applied to the non-inverting inputs of A1 & A2 (negative half-cycle), and A3 & A4 (positive half-cycle). This has the effect of turning on one pair of the output FETs, while turning off the other. Normally, this would lead to Class B operation, and hence crossover distortion – in this amplifier's dynamic biasing system, though, the modulated –V and +V supplies present at R78 & R79 and R80 & R81 are summed together at the bases of transistors T8 & T6, by R61 & R62 and R63 & R64 respectively. The supply fluctuations caused by modulation alter the currents flowing through T8 & T6, cancelling the modulation voltage at the collectors of T5 & T7 and turning the non-inverting inputs of A1 to A4 into current inputs – hence no input resistors. Because the voltages at the collectors of T5 & T7 are now constant, the bias current applied to the non-inverting inputs of A1 to A4 is always present, and so neither pair of FETs is turned off. As a result, the amplifier remains always in Class A, and crossover distortion is therefore avoided.

There are several feedback networks in the amplifier, apart from the current-operated dynamic bias already mentioned. These are: R28 & R60, which sets the overall DC gain of the amplifier; C8, which reduces the gain above audio frequencies; R59 & R52, which determines the AC gain of the amplifier; and C17, C27 & C28, which are required to reduce the gain of IC7 to unity at DC, to prevent upsetting the DC gain network. Each of the FET drivers (A1 to A4) also has its own local feedback network – for amplifier A1, these components are R55, R48 & R78; the gain of each amplifier is determined by (R55 + R48) / R78.

The resistor R76 is used to provide a minimum load for the amplifier while the speaker is disconnected, allowing the amplifier to stabilise and the protection circuit to time out. R75 & C18 form a 'Zobel network', which is a low-pass filter and has two functions. The first is relevant when driving the amplifier at or near full power into a speaker. In such instances, the inductance of the voice coil may generate a high voltage when the signal falls, possibly damaging the output stage. The Zobel network helps to cancel the reactive element of the speaker, so the amplifier is presented with a resistive load. The network's second function comes into effect should there be any stray RF (instabilities, stray coupling) on the amplifier's output. The Zobel will filter out these unwanted signals, preventing burn-out of delicate drive units (particularly tweeters).



Close-up view of MOSFETs and thermal switch (As you can see, this is an early version with a trailing lead on one of the terminals of the thermal switch).

(iii) Excessive Temperature Shutdown

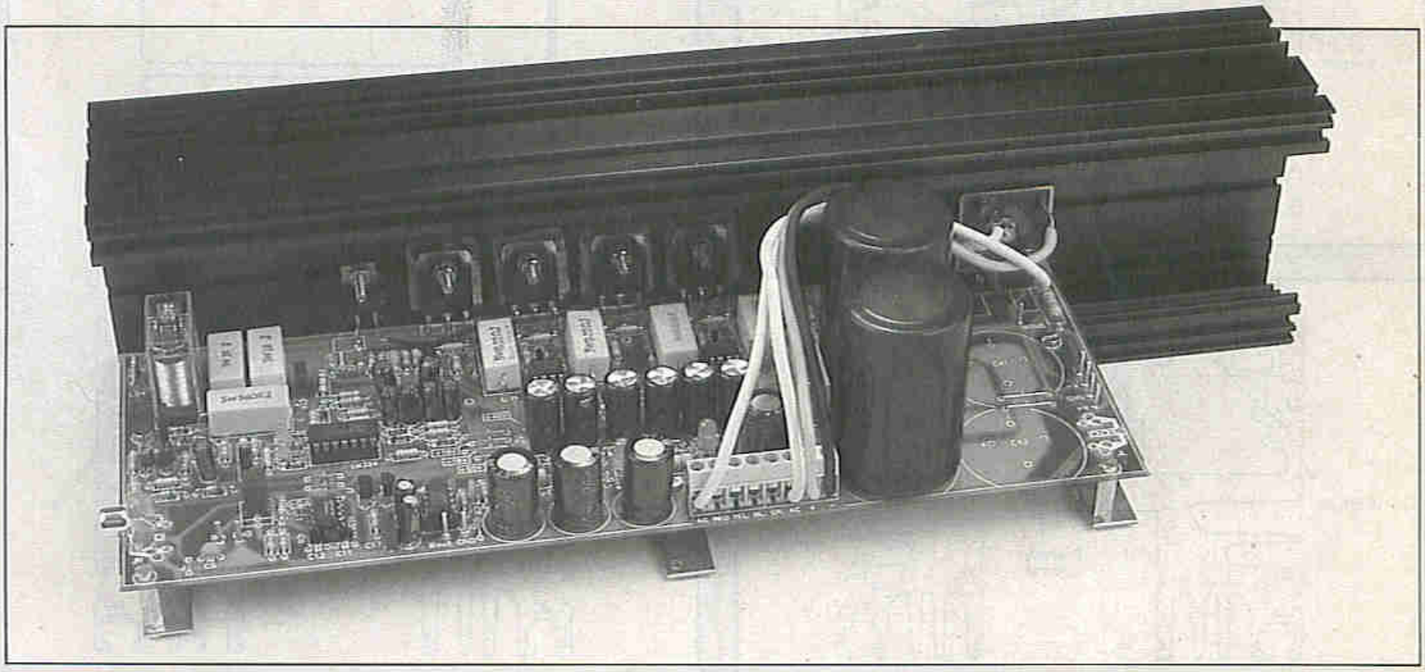
In the event of the amplifier overheating, the thermoswitch (TS) will shut down the output stages in the following way. TS will become short circuit at a temperature of approximately 90°C. R43 & R44 will then be connected together, forcing T8 & T6 to switch hard on. This will cause the outputs of A1 & A2 to swing high, shutting down T10 & T11, and the outputs of A3 & A4 to swing low, shutting down T12 & T13.

(iv) Output Protection Circuit

R69 & R26 form a potential divider, limiting the input voltage to the multiple-feedback low-pass filter. A DC offset would cause the output of A5 to swing high or low, depending upon its polarity. A negative offset will charge C22 via D4, while a positive offset will charge C23 via D5.

Op amps A6 & A7 are used as comparators. If the input voltages to A6 or A7 exceed the reference voltage set by D6 & D7 respectively, the output of one of the comparators will swing high. This will illuminate one of the DC error LEDs and turn on transistor T4, which in turn will switch off the Darlington transistor T9 and relay RY1. Diode D9 clips the high voltage spike generated by the relay switching off, preventing damage to T9. R77 is used to reduce the voltage across the relay.

During the initial powering up of the



The complete 300W Amplifier Module.

amplifier, C24 will be discharged, and T9 will be switched off. C24 will then charge via R40 & R41; these components provide the turn-on delay for the speaker. When the amplifier is switched off, however, the speaker should be disconnected quickly; this is achieved by discharging C24 via R41 & D8.

Looking at the protection circuit, you will notice that there are several different supply voltages; should any of the supply rails fail, the protection circuit will disconnect the speaker from the amplifier – this is the purpose of T2, T3 and associated components. If +V3 or −V3 should not be present, or are of low voltage, T9 will be switched off.

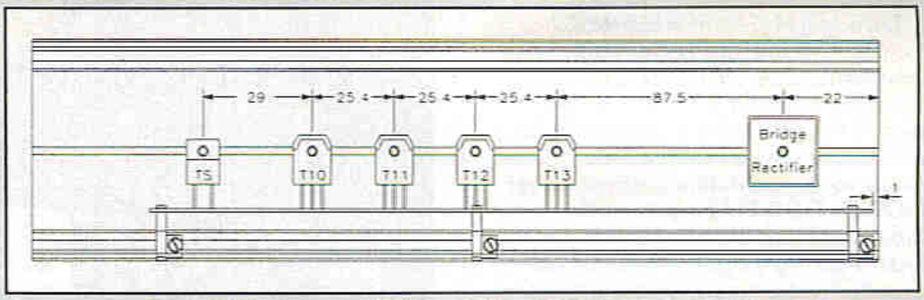


Figure 4. Location of devices on the heatsink – 'left' channel amplifier.

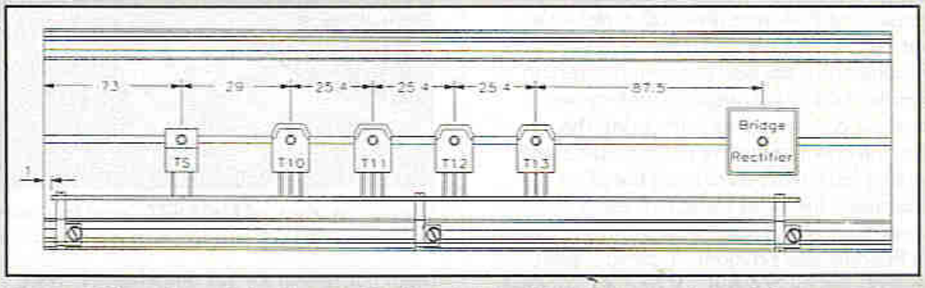
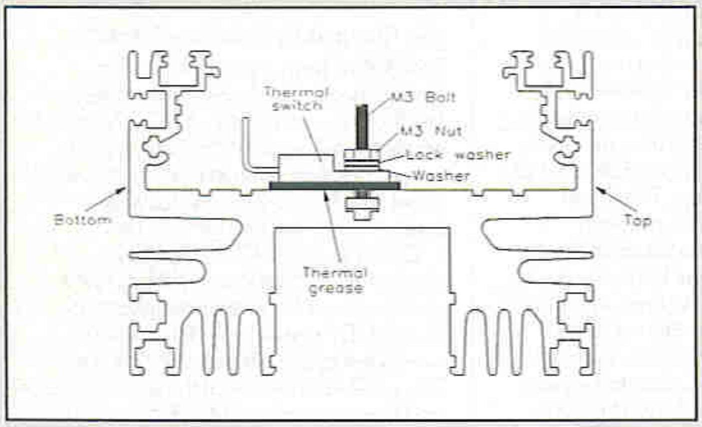
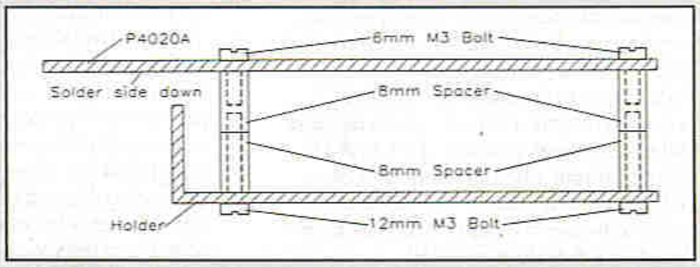


Figure 5. Location of devices on the heatsink – 'right' channel amplifier.

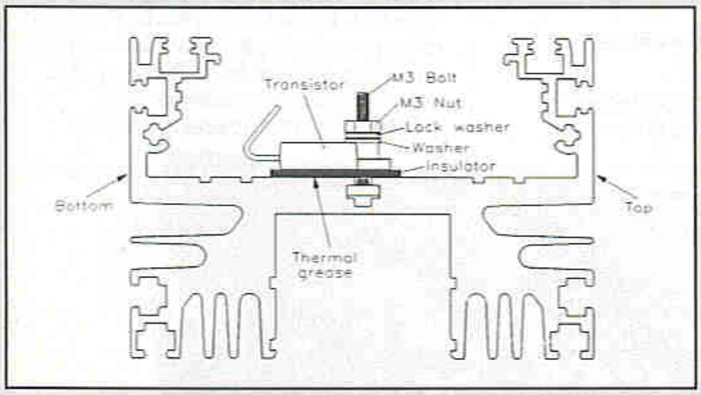
PCB Construction

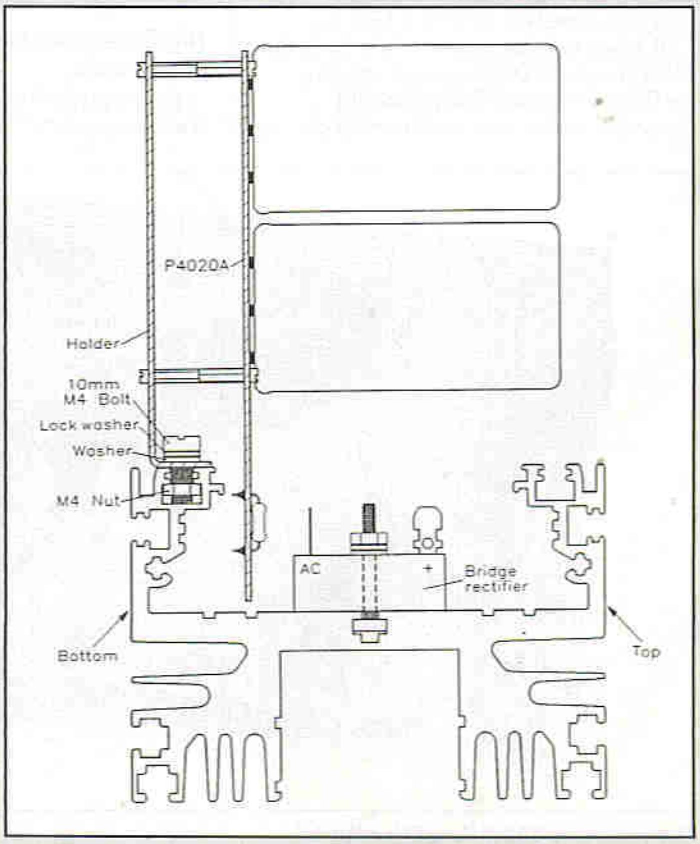
Construction of the PCB (shown in Photo 1) is fairly straightforward, and instructions are given in the manual supplied with the kit. Novice constructors are referred to the Constructors' Guide included in the kit (Order Code XH79L), which is packed with a wealth of sound practical advice. The most important things to watch out for are misplaced components; it is important that you check that the orientation and positioning of a component before soldering it into place; desoldering is time-consuming and could lead to damage of the component or board. In particular, watch out for polarised components (such as semiconductors and electrolytic capacitors). Thankfully, the PCB features a legend to help you correctly position each item. The correct component values are given in the instruction booklet supplied with the kit. Please note that some of the kits will

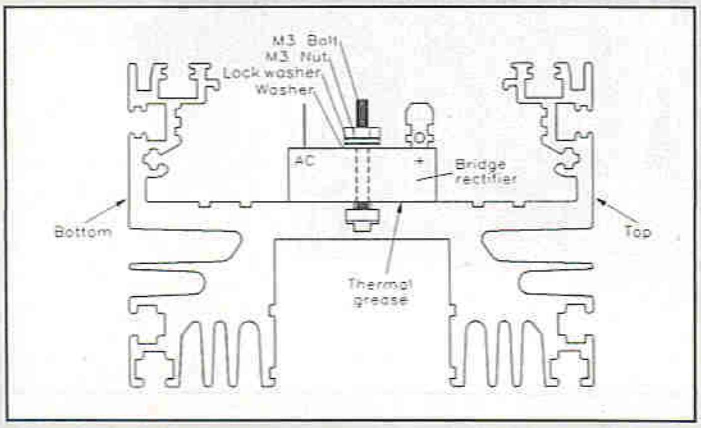




Top left: Figure 6. Fitting the thermal switch to the heatsink.
Centre left: Figure 7. Fitting the transistors to the heatsink.
Bottom left: Figure 8. Fitting the bridge rectifier to the heatsink.
Above: Figure 9. Side view of PCB support assembly.
Below: Figure 10. Fitting PCB assembly to heatsink.







be supplied with a modification sheet. In the original circuit, two thermistors were used in the excessive temperature shutdown circuit, but this has been replaced by a thermal switch. Two of the PCB pins are left off, and a wire link is made, (see leaflet). There are also some resistor value changes, which are also covered by the leaflet – the new values are included in the kit. Please note, however, that a revised PCB (part number P4020A'2) and new instruction book are included in the latest version of the kit.

Fit the smaller components first (PCB pins – fed in from the component side – metal film resistors and wire links). Note that PCB pins are also fitted in the positions of the power transistors (T10 to T13), and those of the thermal switch (more on this later) – these devices are mounted on the heatsink, and their terminals will be soldered to the pins.

These can be followed by the larger resistors (the large-diameter 1W and rectangular wirewound 5W ones) and capacitors – make sure you orientate the electrolytic devices correctly. Before fitting C34 or C39, the reservoir capacitors, it is advisable to fit the two fuseholders – these may prove awkward to get into position with the capacitors already installed. Incidentally, four 4,700μF (rather than two 10,000μF) reservoir capacitors may be supplied in the kit, but the combined capacitance is of the same order. The two extra capacitors should be fitted in the C41 and C42 positions. Do not fit the fuses or covers at this stage. The transistors, diodes and IC sockets can now follow – in each case, the correct orientation is shown on the board legend. We can now proceed with the LEDs – LD29 and LD30 are 3mm devices, while the rest are 5mm.

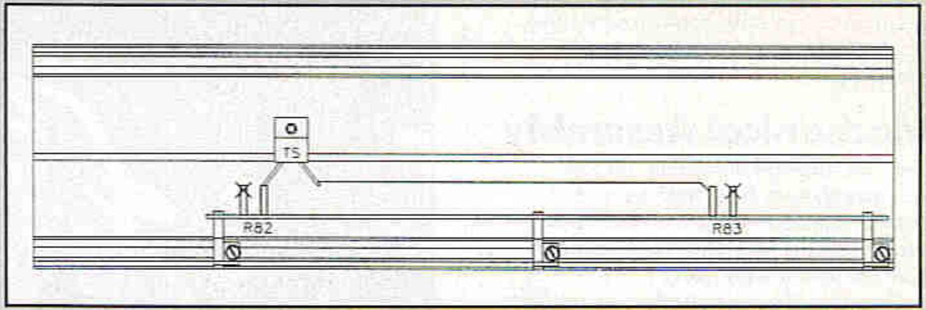


Figure 11. Wiring up the thermal switch (early kits with P4020A'1 PCB).

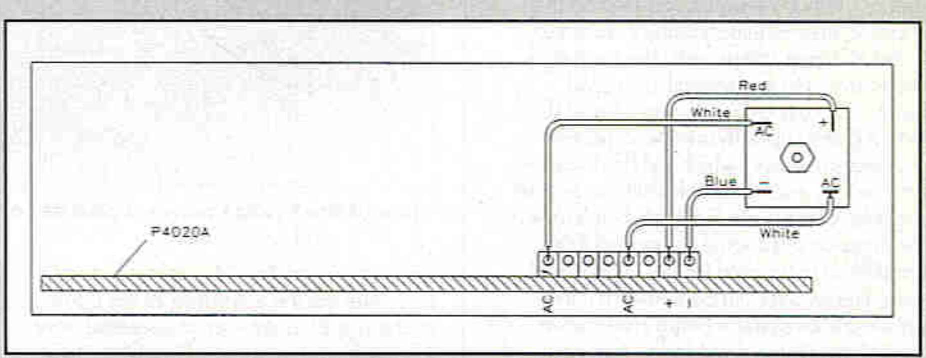
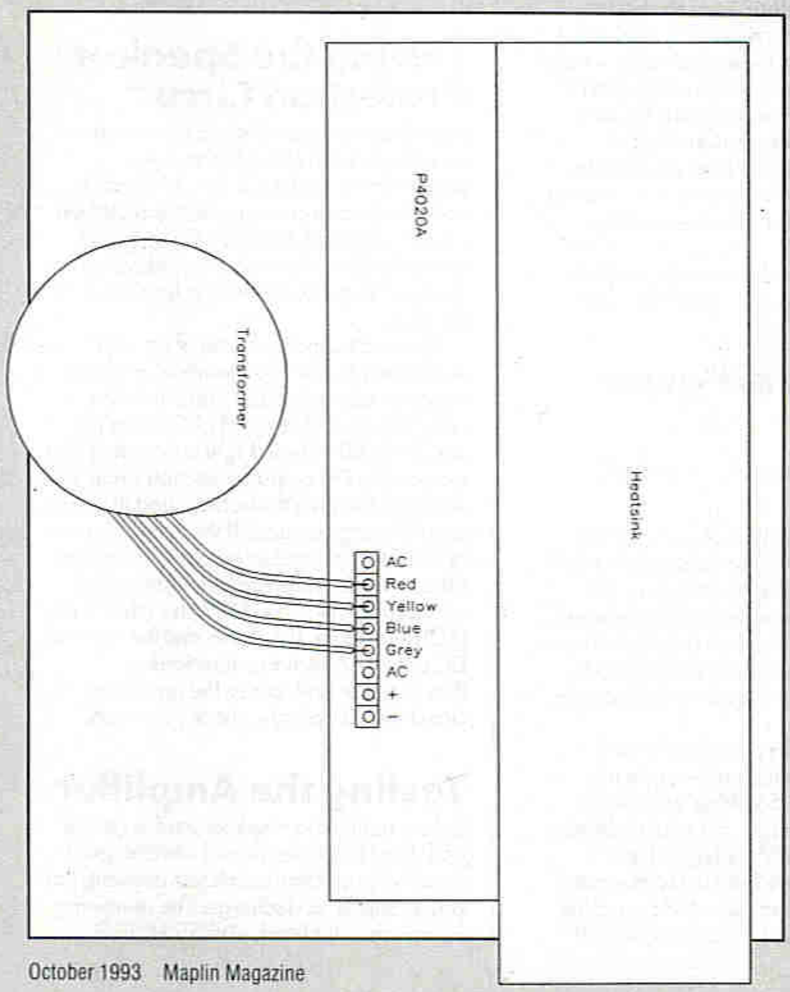
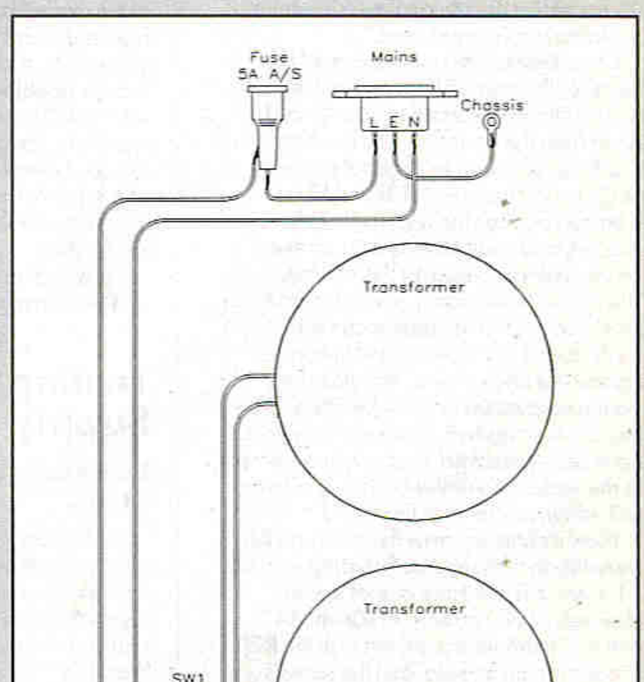


Figure 12. Bridge rectifier wiring.

The final components to be fitted to the PCB at this stage are the relay, phono input socket and J1, which should be orientated so that the apertures for the wires face the edge of the board. J1 is, in fact, made up from four interlocking 2-way segments, which should be assembled prior to fitting the connector to the board. Like all large items, the assembly should be pushed flush against the PCB prior to soldering it in place. Note that there are two positions for the phono input socket, at either end of the board. If you are building two of these modules into a stereo amplifier (more details next month), one should be fitted with the socket in the 'JR' position (right stereo channel), and the other with the socket in the 'JL' (left stereo channel) position. If the module is to be operated in its 'JR' mode, then the link located next to C6 can be omitted.

After assembling the PCB, coat the already-plated tracks (those associated with audio output and power supply) with more solder, so that they can cope with the potentially high currents expected. At this stage, check your work thoroughly.





Left: Figure 13. Transformer secondary wiring.
Above: Figure 14. Mains wiring.

Spotting any mistakes before powering up could save many (possibly expensive!) problems later on.

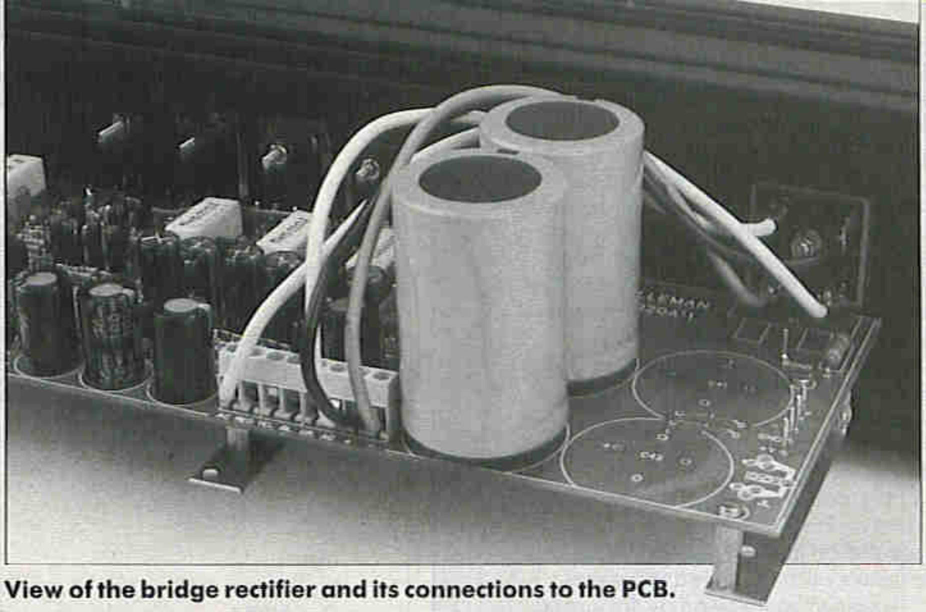
Mechanical Assembly

Detailed assembly instructions for the case are given in the comprehensive manual supplied with the kit. Assembly is straightforward, but a few remarks made here will save trouble later.

Care should be exercised when installing T10 to T13, and the thermal switch. These are, as already revealed, installed on the heatsink, their terminals being connected to the PCB pins afterwards. The transistors are screwed to the heatsink using M3 hardware, as shown in Figures 4 and 5. When paired up with another amplifier module, something which will be discussed next month, each heatsink will form one of the sides of the case. Figure 4 shows how the components should be spaced if the amplifier is to be used for the left channel, while Figure 5 should be followed if the right-hand amplifier is being constructed. This information is provided so that you can plan the location of each device and prepare the mounting area. Note that the bridge rectifier is also attached to the heatsink, but this is connected via insulated wire to four of the PCB terminals, rather than to PCB pins. The hexagonal heads of the 12mm M3 screws are passed along the central channel of the heatsink; the threaded shaft of the screw will now protrude and the component to be mounted can now be passed over it. The components can now be fitted as shown in Figure 6 (thermal switch), Figure 7 (transistors) and Figure 8 (bridge rectifier). Heatsinking compound should be smeared thinly on the tab of the device, and also on the correct area of heatsink in the case of the transistors and thermal switch, where insulating washers are used.

Once the devices are in place on the heatsink, the support brackets for the PCB can be fitted; note that they are spaced apart from the board by 16mm, using two 8mm threaded hexagonal spacers as shown in Figure 9. A 12mm M3 screw is passed through the relevant hole in the bracket, and one of the spacers screwed on and tightened against the bracket. This should leave about 3mm of thread protruding; the other spacer can now be threaded into position and tightened against the original one. The other five 16mm spacers should now be fitted; each bracket requires two. Once all the brackets have been prepared, they can be screwed to the solder side of the PCB using a 6mm M3 screw, as shown in Figure 10.

Now it's time to screw the PCB/bracket assembly to the heatsink. Referring to Figure 11, a M4 nut is slid into one of the end channels of the heatsink. A 10mm M4 bolt and washers are fed through the PCB bracket mounting hole, and the screw's thread is loosely mated with the nut. Note that the each of the three brackets is held to the heatsink by this method. The assembly can now be slid along the heatsink so that the heatsink-mounted devices line up with their PCB pins. In each case, the optimum mounting position should be such that the side of the PCB nearest the end of the heatsink (in the case of both left and right channel amplifiers, the phono socket end) is inset by 1mm. The M4 screws can now be tightened. It is advisable, at this point, to check that all devices are isolated from the heatsink – using a multimeter set to its highest resistance range, connect one probe to the heatsink (scrape away the anodisation on one of the heatsink's internal surfaces, to reveal the aluminium underneath and ensure a good connection) and, with the other probe, visit all of the power MOSFET terminals in turn and check that the resistance registered is infinite (i.e. open circuit). Solder the thermal switch connections to its PCB pins, or according to Figure 11 if you have the earlier version of the kit (with the P4020A'1 PCB). Do not solder the power transistors to the PCB pins yet.



View of the bridge rectifier and its connections to the PCB.

The next stage is to wire up the bridge rectifier with the supplied heavy-duty insulated wire, and the secondary winding of the mains transformer, as shown in Figures 12 and 13 respectfully. Figure 14, meanwhile, shows the mains wiring – note that the double-pole mains switch works with both live and neutral lines. It is very important, for safety reasons, that all exposed mains connections are covered up, using heatshrink sleeving. An insulating boot is available for chassis-mounting fuseholders.

Construction is now virtually complete, and we can move onto testing the unit.

Testing the Power Supply

The first test involves the −V and +V supplies.

At this stage, recheck all connections – particularly those to the secondary of the transformer, and the mains wiring. It is imperative that the latter is well-insulated, and that no possible short circuits can occur; in addition, check that the mains lead is secure. *Remember – mains electricity can kill!*

Connect a mains plug, fitted with a 5A fuse, to the mains lead – or, as an alternative, use a 'Safebloc' connector; testing can now begin. Set your multimeter range switch to 50V (or higher) and connect its negative lead to 0V (the outer ring of the phono socket will do), and the positive lead to the positive side of C39. Connect the mains plug to a 13A outlet, and turn the mains switch on. An off-load reading of approximately 40V should be obtained. After disconnecting it from the module, refit the meter's positive lead to the 0V point, and its negative lead to the negative terminal of C40. Similar results should be achieved. Switch off the unit and disconnect from the mains supply. Allow the PSU to discharge and fit the two fuses, which are both 5A fast-blow types, followed by the fuseholder covers.

Apply power again; this time, all four power supply LEDs (LD31, 40V; LD32, −30V; LD33, 50V; LD34, −50V) should illuminate. On the PCB, there are several links which are labelled with the power supply voltage – using a multimeter, check to see that they are all present and correct with reference to ground. If not, check your work. After testing, remove power.

Testing the Speaker Protection Circuit

Now that we have checked the power supplies, we can check the speaker protection circuit. Fit IC5 (LM324) into its socket, ensuring correct orientation. When power is applied, the relay (RY1) should energise after a few seconds, indicating that the input surge protection circuit is working properly.

Connect the positive side of an 1·5V AA battery to the 'LS+' terminal, and the negative side to the 'LS−' terminal. The relay should click off, and LD30 (one of the 3mm LEDs) should light up, proving that the positive DC output protection circuit is working. Remove the battery, and the relay should energize again. If the battery is now applied to the speaker output terminals the other way, the relay should again switch off, accompanied by LD29 (the other 3mm LED) illuminating. This means that the negative DC output protection is functioning.
If, in either or both cases, the protection circuit fails to operate, check your work.

Testing the Amplifier

Before testing the amplifier itself, a period of at least 5 minutes should have elapsed since the protection circuit test, allowing the power supply to discharge. The remaining ICs can now be fitted – NE5534 (IC6), TL061 (IC7), TL072 (IC8, IC9), and the four power transistors soldered to their PCB pins.

Short out the input, using a suitably-wired phono plug or croc lead. Apply mains power once again, and measure the voltage across R78, R79, R80 & R81 in sequence – approximately 25mV should be recorded in each case. If a reading of 50mV or more is obtained, switch off immediately and check your work. Since the resistor lead nearest the heatsink is hard to gain access to, the link to the immediate left of the resistor (as seen when facing the heatsink) may be used instead.

This concludes the testing of the amplifier – it is now ready to be used in its intended application. Although it has been designed for use as one half of a stereo pair, it can be used in its own right as it features its own power supply. A suitable case must, of course, be used. The output connector, which should be wired to the 'LS+' and 'LS–' (0V) can be as per your specification – binding posts, XLR or ¼in. jack.

Next Month

In the second instalment of this article, we will look at how two of these amplifiers – the 'left' and 'right' versions as described earlier – can be combined, both physically and electrically, into a 300W per channel stereo amplifier, or a 600W mono bridge amplifier.

OPTIONAL PARTS LIST

(Not Included in Kit)

13A Nylon Mains Plug	1	(RW67X)
5A Fuse	1	(HQ33L)
Insulating Boot for Fuseholder	1	(FT35Q)
Heatshrink Sleeving	As Req.	
Heat Transfer Compound	1 Syringe	(FL79L)
Double Pole Mains Switch	As Req.	
Panel Mounting Fuseholder	As Req.	
AA Battery Box	1	(YR59P)
AA Zinc Carbon	1	(FK55K)
3-Core 6A Mains Cable	As Req.	(XR03D)

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

Order As VF19V (300W Mono MOSFET Amplifier) Price £129.95. H11

Please Note: None of the items supplied in the kit are available separately.

The stereo/bridged mono version of this amplifier (to be covered next month) is also available:

Order As VF17T (600W Mono/Stereo MOSFET Amplifier) Price £299.95. H29

NEXT issue

In next month's super issue of 'Electronics – The Maplin Magazine', there are some really great projects and features for you to get your teeth into! To whet your appetite, here's a taste of some of the goodies on offer:

INFRA-RED SWITCH

Ever wondered how the hot-air hand dryers in public conveniences work? Chances are that an infra-red (IR) switch is responsible; IR energy is emitted from a source (typically an LED), reflected by the triggering body (in this case, your wet hands) onto a sensor, which activates a switch. This module works in much the same way, but can be used for much else besides – an automatic light or doorbell, a security system, part of a production-line counter, a reversing aid for parking, or even in washroom automation!

BROADCASTING TO THE WORLD

In times of crisis, many people turn to the BBC World Service, which has a worldwide reputation as a source of unbiased news. Started between the wars, the World Service was originally born out of a need to broadcast to the Empire. Of course, the world has changed since then, and the BBC World Service has followed suit. But what goes on behind the scenes, and how does the broadcaster fit into today's 'global village'? Ian Poole finds out.

WIDE-RANGE LIGHT METER

Serious photographers need an accurate light meter in order to work out the optimum exposure time and aperture size. Whilst many are commercially available – and indeed some are built into the camera body – they all tend to suffer from a limited range. This proved to be a problem during some enlargement work, and so this wide-range version was developed. A lot cheaper than those on offer in your photographic emporium, as well!

POWER ELECTRONICS

In the past, 'power' and 'electronics' were treated separately in the world of electrical engineering. Many semiconductor devices, though, have applications in both fields, the diode being an obvious example. Over the years, the use of these rapidly-advancing electronic components in the power field has led to the creation of a new subject – power electronics. In a new series, Graham Dixey finds out how the two disciplines have become interwoven.

IMPEDANCE MATCHING

Audio, radio and many other electronic systems consist largely of chains of modules, through which signals pass from one end to the other. At every interface between modules, impedances need to be suitably matched to ensure correct operation. Surprisingly, there is a lot of misunderstanding associated with this important topic, and so this article sets out to reveal the facts!

TRAIN CONTROLLER

As past readers' letters have testified, there is a lot of interest in the electronic supervision of model railways which, when suitably implemented, can give an authentic feel to a layout. This microcontroller-based system allows 14 individual locomotives to be controlled, four of them simultaneously.

Plus, of course, there's all the usual features for you to enjoy!

'ELECTRONICS – THE MAPLIN MAGAZINE', BRITAIN'S BEST SELLING ELECTRONICS MAG.

CLASSIFIED

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.

Placing an advertisement is easy! Simply write your advertisement clearly, in capital letters, on a post-card or sealed-down envelope. Then send it, with any necessary payment, to: Classifieds, 'Electronics – The Maplin Magazine', P.O. Box 3, Rayleigh, Essex SS6 8LR. Advertisements will be published as soon as possible, space allowing. No responsibility is accepted for delayed publication or non-inclusion of advertisements.

Private individuals only are permitted to advertise in this section; commercial or trade advertising of any kind is strictly prohibited by law. Advertisements are only accepted by the Publisher on this proviso. Readers who have reasonable grounds to believe that they have been misled as to the nature of an advertisement are advised to contact the Publisher and their local Trading Standards Office.

WANTED

HELP REQUIRED FOR HNC ELECTRONICS PROJECT. Contact: Mr. M. Milligan, 45 Upper Newtownards Road, Belfast 4.

LOAN OF OR COPIES OF CIRCUIT DIAGRAMS for Iskra frequency meter (scaled 45-65Hz-240V) and Matsui radio/cassette recorder model MX5510. Tel: Keith, (0239) 810214 (Cardigan).

WANTED INFORMATION, MANUAL, etc. on the Stag PP29 EPROM programmer. Will Pay; also wanted EPROM Eraser. Tel: (0268) 524968.

EZ40, EL41, EBC41, EF41, ECH42 valves to restore Pye P76F radio receiver, circa 1954. Tel: Alex Jackson, (0597) 823615.

VARIOUS

SONY SL-C3OUB, Betamax Video Cassette Recorder, mint condition, complete with 31 cassettes, mostly 750s and two cleaning cassettes, £95. Buyer collects. Tel: (0474) 334997.

ELECTRONIC COMPONENT CLEARANCE. First-grade unused, post free. 100 resistors £1, capacitors £2, transistors £5. 100 ICs, switches, pots, etc.; £10. Butler, 50 Toolrack Road, Harrow Weald, Middlesex, HA3 5HU. Tel: (081) 427 1378.

GOULD (1421) Digital Storage Oscilloscope; £425 o.n.o. Tel: (0792) 588647.

COMPLETE MULTI-SATELLITE TV SYSTEM FOR SALE. 1·2m offset dish with ground stand, activator, Polar Mount, Polariser and LNB. Salora XLE Receiver; 144 channels, fully tunable stereo sound, 2 decoder loops, built-in amplifiers, etc., etc; £250 the lot. Also Ferguson 3V43 VCR with NICAM Retrofit LP/SP, Dolby linear and Hi-Fi stereo sound, insert assemble edit, etc., etc.! £200. Have both items for bargain price of £400. Tel: Martin, (0702) 603557.

MASSIVE COMPONENT CLEARANCE. Big packages of unused components including a large mix of devices and values. Switches, Opto-electrical, Semiconductors, Pots, Capacitors, Inductors, Connectors, etc. Only £12 per package, a fraction of the normal cost. M. P. Cole, 73 Hazelhurst Road, King's Heath, Birmingham, B14 6AB.

CLUB CORNER

WIRRAL AMATEUR RADIO SOCIETY meets at the Ivy Farm, Arrowe Park Road, Birkenhead every Tuesday evening, and formally on the 1st and 3rd Wednesdays of every month. Details: A. Seed (G3FOO), 31 Withert Avenue, Bebington, Wirral, L63 5NE.

CRYSTAL PALACE & DISTRICT RADIO CLUB. Meets on the third Saturday of each month at All Saints Church Parish Rooms, Beulah Hill, London SE19. Details from Wilf Taylor, G3DSC. Tel: (081) 699 5732.

ELECTRONIC ORGAN CONSTRUCTORS SOCIETY. For details of meetings. Tel: (081) 902 3390 or write 87 Oakington Manor Drive, Wembley, Middlesex, HA9 6LX.

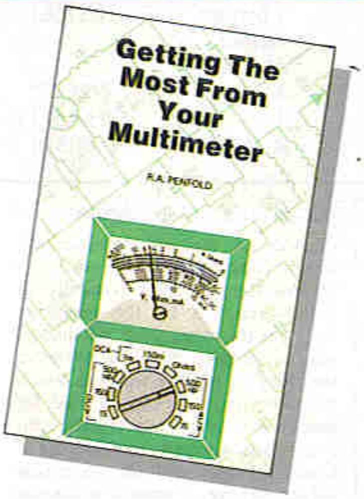
TESUG (The European Satellite User Group) for all satellite TV enthusiasts! Totally independent, TESUG provides the most up-to-date news available (through its monthly 'Footprint' newsletter, and a teletext service on the pan-European 'Super Channel'). It also provides a wide variety of help and information for its members. For further information, contact: Eric W. Wiltsher, TESUG, Rio House, Stafford Close, Ashford, Kent, TN23 2TT, England.

THE BRITISH AMATEUR ELECTRONICS CLUB (founded in 1966), for all interested in electronics. Four newsletters a year, help for members and more! UK subscription £8 a year (Junior members £4, overseas members £13.50). For further details send S.A.E. to: The Secretary, Mr. J. S. Hind, 7 Carlyle Road, West Bridgford, Nottingham, NG2 7NS.

These are our top twenty best selling books based on mail order and shop sales during July '93.
Our own magazines and publications are not included in the chart below.

The Maplin order code of each book is shown together with page numbers for our 1994 catalogue. We stock over 250 different titles, covering a wide range of electronics and computing topics.

Number ONE



Getting The Most From Your Multimeter
by R.A. Penfold
A unique, and very useful book, showing you how to best use your multimeter. *(WP94C) Cat. P746.*
Previous Position: 2.
Price £2.95.

2

Home VCR Repair Illustrated, by Richard Wilkins & Cheryl Hubbard. *(WZ32K) Cat. P755.* Previous Position: 3. **Price £13.95.**

3

IC555 Projects, by E.A. Parr. *(LY04E) Cat. P751.* Previous Position: 1. **Price £2.95.**

4 NO CHANGE

The Complete VHF/UHF Frequency Guide, by B. Laver. *(WT70M) Cat. P719.* Previous Position: 4. **Price £9.95.**

5 NO CHANGE

Loudspeaker Enclosure Design and Construction, *(WM82D) Cat. P721.* Previous Position: 5. **Price £9.95.**

6

An Introduction to Loudspeakers and Enclosure Design, by V. Capel. *(WS31J) Cat. P720.* Previous Position: 8. **Price £2.95.**

7 NO CHANGE

Power Supply Projects, by R.A. Penfold. *(XW52G) Cat. P748.* Previous Position: 7. **Price £2.50.**

8

International Transistor Equivalents Guide, by Adrian Michaels. *(WG30H) Cat. P745.* Previous Position: 9. **Price £3.95.**

9

How to Expand, Modify and Repair PCs and Compatibles, by R.A. Penfold. *(WS95D) Cat. P729.* Previous Position: 6. **Price £4.95.**

10 NO CHANGE

How to Use Oscilloscopes and Other Test Equipment, by R.A. Penfold. *(WS65V) Cat. P746.* Previous Position: 10. **Price £3.50.**

11 NO CHANGE

The Washing Machine Manual, by Graham Dixon. *(WS98G) Cat. P755.* Previous Position: 11. **Price £12.95.**

12

How to Use Op Amps, by E.A. Parr. *(WA29G) Cat. P734.* Previous Position: 15. **Price £2.95.**

13

More Advanced Power Supply Projects, by R.A. Penfold. *(WP92A) Cat. P748.* Previous Position: 20. **Price £2.95.**

14

The Robot Builder's Bonanza, by G. McComb. *(WT77J) Cat. P729.* Previous Position: 12. **Price £14.95.**

15

Electronic Music Projects, by R.A. Penfold. *(XW40T) Cat. P722.* Previous Position: 14. **Price £2.95.**

16 NO CHANGE

Towers' International Transistor Selector by T.D. Towers. *(RR39N) Cat. P745.* Previous Position: 16. **Price £19.95.**

17 RE-ENTRY

Scanners, by Peter Rouse. *(WP47B) Cat. P719.* Previous Position: Re-Entry. **Price £8.95.**

18 NO CHANGE

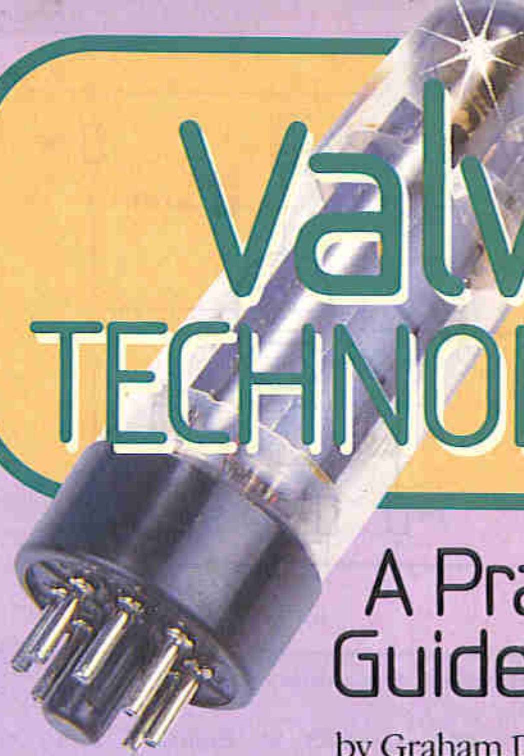
Remote Control Handbook, by Owen Bishop. *(WS23A) Cat. P747.* Previous Position: 18. **Price £3.95.**

19

A Concise Introduction to MS-DOS, by N. Kantaris. *(WS94C) Cat. P761.* Previous Position: 13. **Price £2.95.**

20 NEW ENTRY

Mastering C Programming, by W. Arthur Chapman. *(WZ09K) Cat. P758.* Previous Position: New-Entry. **Price £5.99.**



Valve TECHNOLOGY

A Practical Guide- PART FOUR

by Graham Dixey C.Eng., M.I.E.E.

The Tetrode Valve

The tetrode was developed from the triode by the addition of another grid, which is situated between the control grid and the anode. This second grid is known as the 'screen grid' because it acts as an electrostatic screen between the two named electrodes. In order that it can perform this function, the screen grid must be connected to ground (0V) at signal frequencies. However, if it is connected directly to the 0V line, then the resulting drop in potential that occurs in the electron path between control grid and anode will exert a force of repulsion on the electrons in transit to the anode. In effect, it would behave just like a second control grid, though at fixed potential.

The reason for including the screen grid at all is to reduce the value of the stray capacitance, C_{ag}, between anode and control grid. The value of this in a triode is typically 2 to 10pF. This may not sound very much, but at radio frequencies the reactance of this capacitance becomes so low that a significant amount of feedback can take place between the output (anode) and input (control grid). This may result in instability, thus effectively setting a limit on the use of the triode at such high frequencies. While there are techniques for 'neutralising' C_{ag} and so avoiding unstable operation, it is more usual to employ a valve which has been designed so as to minimise the value of C_{ag}, thus making higher frequency operation possible. The tetrode was developed for this specific reason and, while it is nothing more than a staging post on the way to a proper solution, it is worth knowing how such development came about, in that it will throw some light on other facets of valve theory. Apart from that, the development of the valve makes an interesting story in its own right.

The action of the screen grid is as follows. Since it is connected to a positive potential, electrostatic lines of force will exist between it and both the cathode and the control grid, since the latter electrodes are at lower potential. Further, since its potential is, in turn, lower than that of the anode, there will also be electrostatic lines of force between the screen grid and the anode. In both cases, the direction of the lines of force is towards the anode. Since the screen grid has a positive potential, it seems reasonable that it would act, in effect, as a collector of electrons, rather like the anode. This is true; however, there is a significant difference between the construction of the screen grid and the anode. Whereas the latter is usually of solid form, e.g., made as a cylinder from a pair of plates, the screen grid is of open mesh construction, like the control grid. As a result, the electrons moving towards both the screen grid and the anode will have such a degree of momentum that they will tend to pass between the open wires of the screen grid and continue on their way to the anode, where they will be collected in the usual way. Some electrons will, of course, be collected by the wires of the screen grid, giving rise to a flow of screen current, I_s. As a result, the current flowing in the cathode lead is no longer the same as that in the anode lead, as it is in the case of triodes, but is equal to the sum of the screen grid and anode currents. Denoting the cathode current by I_k, we have the Kirchhoff's Law relation that:

$$I_k = I_s + I_a$$

This concept of lines of force between the various electrodes can be used to understand how the introduction of the screen grid reduces the anode-grid capacitance.

First of all a fundamental fact needs to be considered. If it is possible for electrostatic lines of force to exist between two conductors, then self-capacitance exists between those conductors.

Suppose that the screen grid and the anode were at the same potential. All the lines of force emanating from the control grid would land on the screen grid; none would reach the anode (Figure 1(a)). Consequently, there would be no capacitance at all between control grid and anode; the screening would be complete. Obviously, in this situation, because the anode and screen grid are at the same potential, there cannot be any lines of force between them. Thus, while there must be some stray capacitance between the control and screen grids (of no significance in this context), there will be none at all between control grid and anode. When the anode has a higher potential than the screen grid, as is usually the case, there will be some lines of force between control grid and anode (Figure 1(b)), thus giving rise to a small value of C_{ag}, but most of the lines of force arising from the control grid will terminate at the screen grid. The order of reduction in the value of C_{ag} possible by introducing the screen grid is about 1000:1, a very real improvement. Typical values of C_{ag} for tetrodes are in the range 0·001pF to 0·02pF.

Figure 2(a) shows the circuit symbol for a tetrode valve while Figure 2(b) shows the circuit connection for such a valve. The actual screen voltage may be derived by means of a potential divider (with the lower

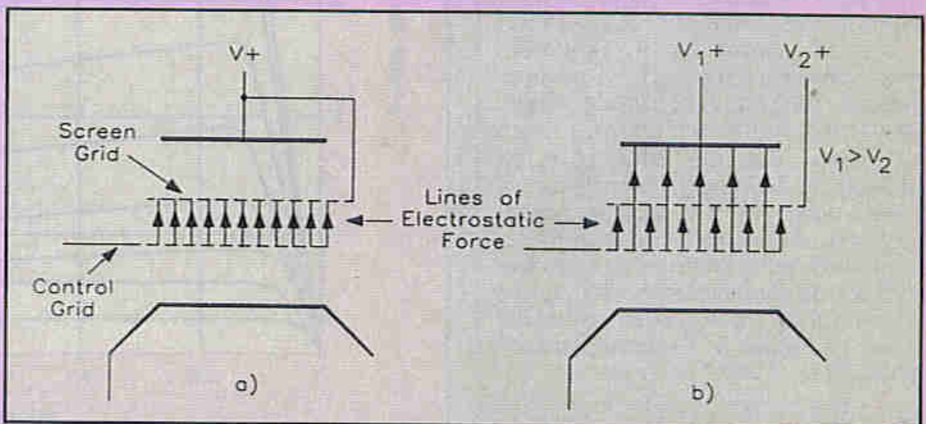


Figure 1. Lines of electrostatic force in a tetrode valve when (a) anode and screen grid are at the same potential; (b) anode is at a higher potential than the screen grid.

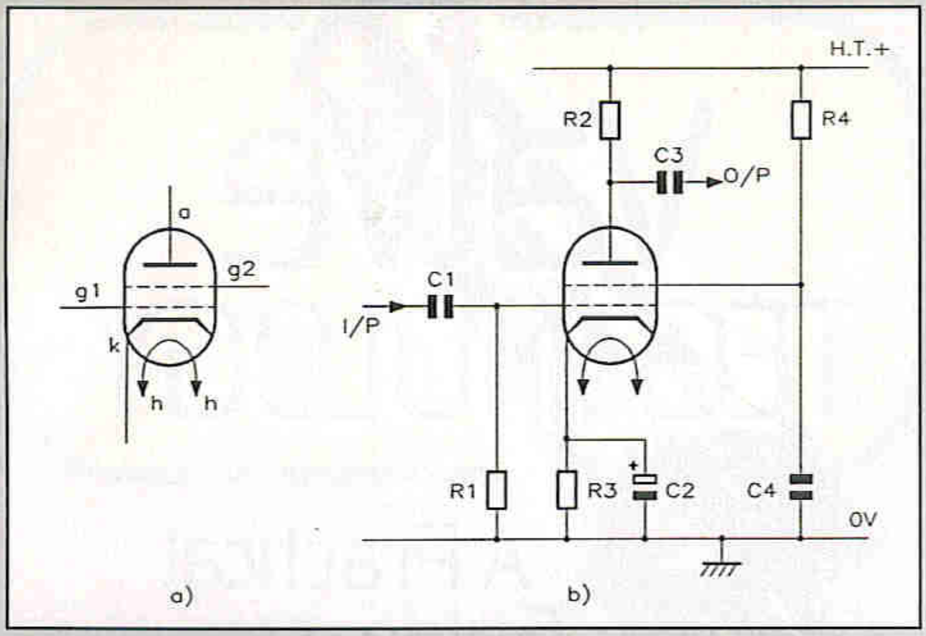


Figure 2 (a) symbol for a tetrode valve; (b) circuit connection for a tetrode valve.

section bypassed by a capacitor) or, as shown in the figure, by a series dropper resistor R4, with a capacitor C4 decoupling to 0V in order to 'ground' the screen grid (as far as AC is concerned). Typically, the screen voltage is set at about two-thirds of the anode supply voltage, though there are, of course, exceptions.

Tetrode Characteristics and Parameters

Figure 3 shows a set of anode characteristics for a tetrode valve, and it will be immediately apparent that these are dramatically different from those for the triode. Rising steeply and quite linearly at first, they then show a region of negative slope before rising again, this time in a non-linear fashion. The initial range of linear voltage/current variation is very limited in the example shown, terminating at a value of anode voltage that is slightly less than 10V. By comparison, the region of negative slope goes up to about 60V and has a significance that is not immediately obvious. Consider what is happening in terms of the voltage and current changes in the anode circuit over this range of anode voltage. The graph shows that, as the anode voltage *increases*, the anode current actually *decreases*. This may not be the sort of behaviour we would expect, but there is a good reason for it. However, before investigating such a reason, consider the value of anode slope resistance r_a in this region.

We know that the value of r_a is obtained by dividing an increment in anode voltage by the corresponding increment in anode current, these increments being taken from one of a set of anode characteristics of V_a/I_a for various values of V_g, such as those shown in Figure 3. Expressed mathematically:

$$r_a = \frac{\delta V_a}{\delta I_a}$$

Whichever of the characteristics we consider in Figure 3, there is a substantial range of anode voltage and current whence, giving specific values for δV_a and δI_a, we find that the increment δI_a is negative. Thus, the quotient $\delta V_a/\delta I_a$ will, over this range, itself be negative. Since this is equal to r_a, the latter will have a negative value of resistance over this range of anode voltage and current. While this has no real use when the device is used as an amplifier, it does allow it to function as an oscillator of a particular type, since the implication inherent in the concept of a negative resistance is that, far from introducing the losses into a circuit that resistance normally does, it must actually be able to compensate for some losses in that circuit. This we know to be essential to the operation of an oscillator, since continuous oscillations can only be maintained when the losses inherent in the frequency determining components (whether LC or RC combinations) have been made good. An LC oscillator using a tetrode valve did exist, and was known as a 'dynatron oscillator'.

The discussion of these implications from the shape of the tetrode's anode characteristics does not, however, explain how that shape arises in the first place of course. For that we must look at another phenomenon known as secondary emission.

Secondary Emission

Cast your mind back to Part One, where we introduced the various methods for making a material emit electrons. The commonest and easiest method, as shown in Part One, is where the cathode surface of a valve emits electrons because of its high temperature; this makes it possible for some electrons to attain such high energy levels that they are able to escape from the material. However, this is not the only way in which electrons can be emitted from materials. Other methods include secondary emission, high field emission and photoelectric emission. The first of these, secondary emission, occurs in a tetrode valve, and it is *this* effect that is responsible for the curious shape of the anode slope characteristics seen in Figure 3, and which actually makes the tetrode unsuitable as an amplifier; it would seriously distort each negative half-cycle of the signal.

When electrons strike a suitable

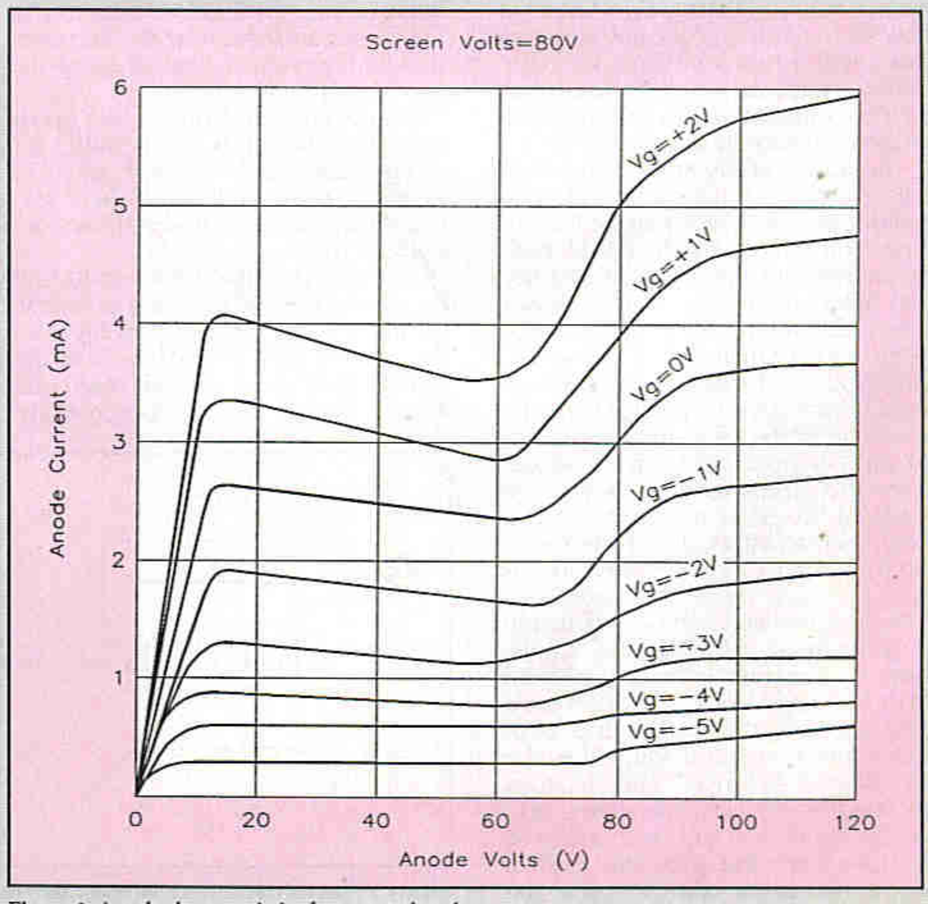


Figure 3. Anode characteristics for a tetrode valve.

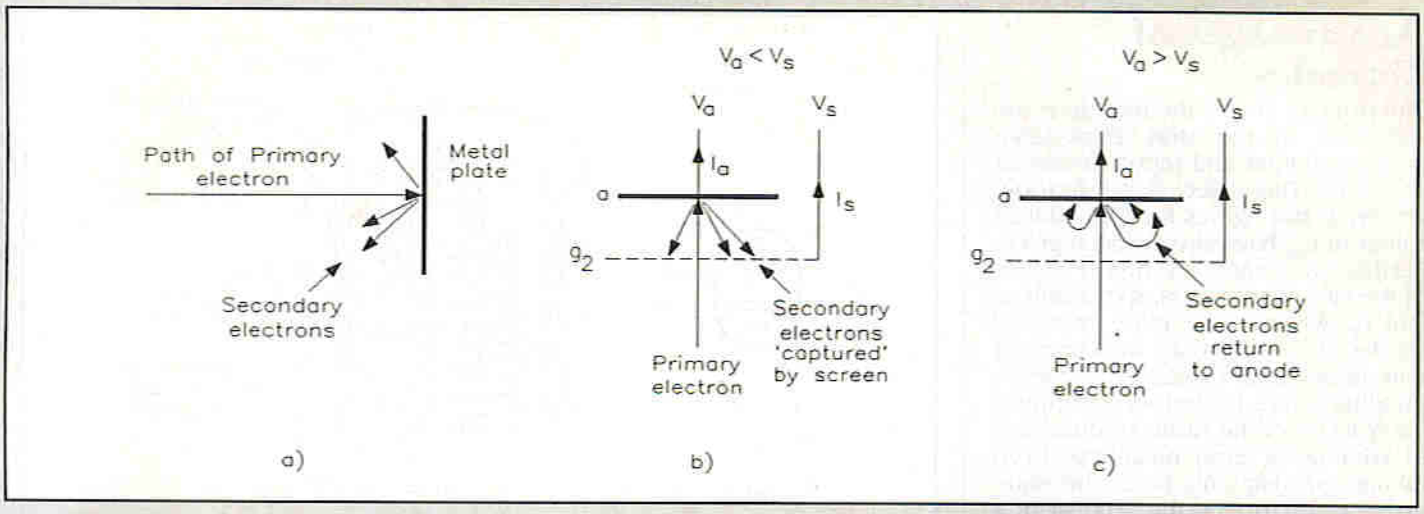


Figure 4 (a) the principle of secondary emission; (b) secondary emission in the tetrode when $V_a<V_s$ and (c), when $V_a>V_s$.

surface at high velocity, secondary electrons will be emitted (Figure 4(a)). This is true of both conductors and insulators. The number of secondary electrons emitted depends upon the velocity of the primary electrons striking the surface and the nature of the surface itself. As a rough indication, a pure metal surface may yield three secondary electrons for each primary one when the conditions are right. It is possible to fabricate surfaces that will produce figures of 10 secondary electrons per primary electron. Naturally, this would normally be done in circumstances where we wish to enhance the effect. Such is not the case in the instance of the tetrode valve. Here the phenomenon arises from the nature and the construction of the device and is quite accidental. What we need to consider is not how to make use of this secondary emission, but how to eliminate its effect!

In the case of the tetrode, there are two electrodes where secondary emission can occur. These are at the screen grid and at the anode, that is to say, either of these electrodes can be bombarded by primary electrons (originating at the cathode) to yield secondary electrons. What happens to these secondary electrons depends upon the relative potentials of screen grid and anode.

Suppose that, in the first case, the anode has a lower potential than the screen grid. The secondary electrons produced at the surface of the anode will be attracted to the screen grid; this will increase the flow of current I_s in the screen grid circuit. If instead we assume that the anode has a higher potential than the screen grid, then the secondary electrons produced at the screen grid will be collected by the anode, this time producing a rise in the anode current I_a. These situations are illustrated in Figure 4(b) and (c).

This interchange of electrons between anode and screen grid is superimposed upon the flow of primary current between the cathode and these two electrodes. It commonly occurs at potentials of between 25 and 75V. At potentials less than 25V, the primary electrons have insufficient energy to produce secondary emission. At potentials greater than 75V, secondary emission takes place, but the potential of the emitting electrode is high enough to attract the secondary electrons back immediately.

In a nutshell, then, where in Figure 3 the anode voltage is less than 10V, anode current rises in proportion to anode voltage. Between 10 and 70V, secondary emission from the anode, by its being bombarded with what are now higher energy electrons from the cathode, causes an electron flow from the anode to the screen grid, 'stealing' a proportion of anode current, so anode current falls. When the point is reached where anode voltage is *equal* to the screen grid voltage this cannot happen, and then when the grid is *less* than the anode, secondary emission from the screen grid takes place, but is so small as to be practically insignificant, or is suppressed.

The voltage and current relations can be seen more clearly in Figure 5. In this diagram, we have plots of all three valve currents against anode voltage as a common parameter. As we would expect from the previous discussion, the shapes of the anode and screen grid current curves are mirror images of each other. This being so, naturally the cathode current is a constant, since it is the sum of the other two currents. This cathode current is often known as the total space current. To be absolutely correct about it, as the curves of Figure 5 show, the curve for this total space current is not quite horizontal but has a slight positive slope, showing that an increase of anode voltage does produce some increase in total current through the valve. A further point to note about the shape of any one of the curves of anode current against anode voltage is that, once the anode voltage is greater than the screen grid voltage, the anode current is very nearly independent of anode voltage. This is an important characteristic – one that should cause us no problems, since the collector current and collector voltage in a bipolar transistor have the same form of characteristic once the collector voltage is past the 'knee' of the curve. However, in the case of the transistor, the knee occurs at a very low voltage value, a fraction of a volt in fact, and it is not difficult to avoid operation in this area. By contrast, the only way to use a tetrode as an amplifier with no significant distortion is if we ensure that the anode voltage never falls below the value of the screen grid voltage, a value that may typically be 80V or more.

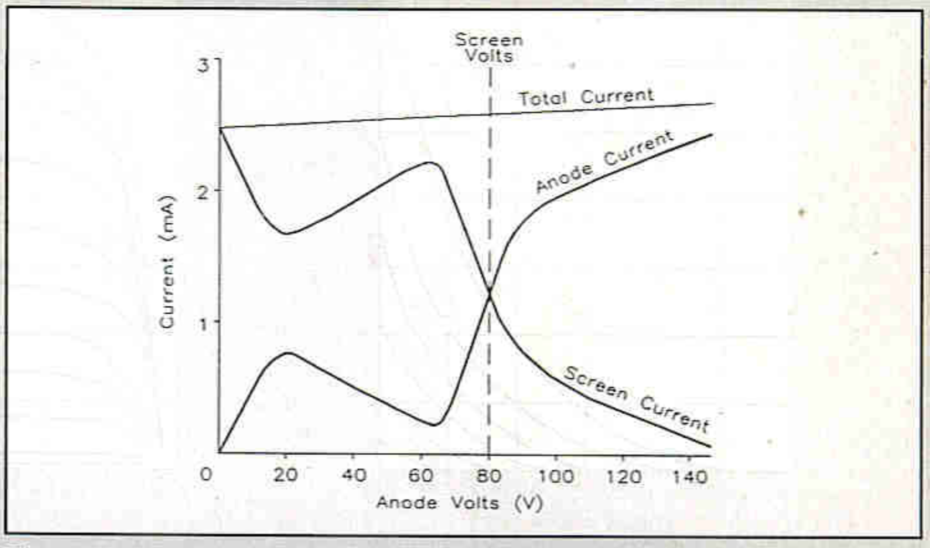


Figure 5. Variation of screen grid current and anode current with anode voltage for a screen grid (tetrode) valve.

Advantages of Tetrodes

The primary aim of the tetrode is the reduction in the stray capacitance between output and input circuits of the valve. This object is satisfactorily achieved, and figures for the reduced values of C_{ag} have already been given. Further advantages are higher values of the valve parameters, specifically μ and r_a. Whereas the value of r_a for triodes is usually only measured in tens of kilohms or less, the corresponding values for tetrodes are more likely to be of the order of hundreds of kilohms or even megohms. Even though gm may only be of the same order as for triodes, the product of a nominal g_m and a very high r_a naturally gives a very high value of μ, the amplification factor. As a result, the voltage gain of tetrode amplifiers (and their derivatives) can be very much higher than in the case of triodes. What we have is not just a valve with extended bandwidth, but also one with superior gain. If only the distortion could be got rid of.

Enter the Pentode Valve

The pentode, as the name implies, has five electrodes. Four of them are exactly the same as for the tetrode, but the extra fifth is called the 'suppressor grid', and it is located between the screen grid and the anode. Figure 6 shows the circuit symbol and physical construction for a pentode valve. The suppressor grid is usually connected directly to the cathode, often internally within the valve envelope, but sometimes an external connection is allowed for. The function of this additional grid is to create a lower voltage region (a negative electric field) between the screen grid and the anode, and this prevents the interchange of secondary electrons between these two electrodes. As a result, the pentode retains the advantages of the tetrode in terms of its high amplification factor and ability to operate at high frequencies, but the kink in the anode characteristic is totally eliminated!

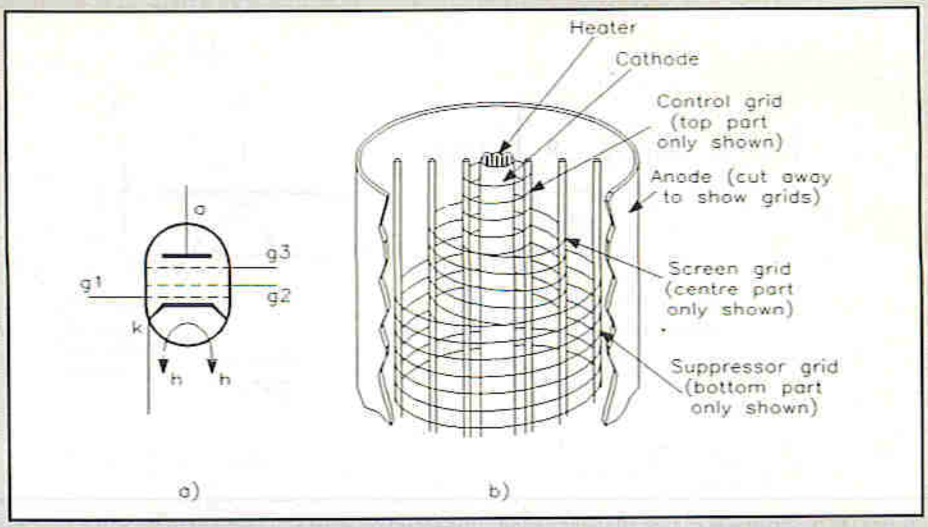


Figure 6. The pentode valve (a) circuit symbol; (b) physical construction.

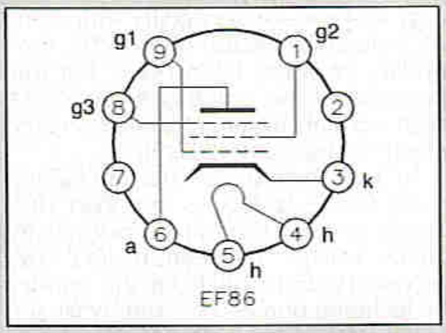


Figure 7. Base diagram for the EF86 pentode.

Alternative Terminology for the Grids

We have now met the most complex valve type that we shall be talking about in this brief series. We know that it has three grids, which are termed the control grid, the screen grid and the suppressor grid. Each of these is a bit of a mouthful for constant repetition, so, it is common to refer to them simply as: the grid, screen and suppressor, respectively. However, when it comes to annotating valve base diagrams, even these abbreviated titles occupy too much space and an alphanumeric reference is used instead. In this system, the three grids are called g_1, g_2 and g_3, respectively. These symbols, together with h for the heater, k for the cathode and a for the anode are used in Figure 7, which is the base diagram for an EF86 pentode.

Pentode Characteristics

Mutual and anode characteristics for the CV138 (EF91) pentode valve are shown in Figure 8. Note that these are typical curves for the conditions stated. The screen volts are set fairly high at 250V and the suppressor is strapped to the cathode. The mutual characteristics show that this valve is what is known as a short grid base

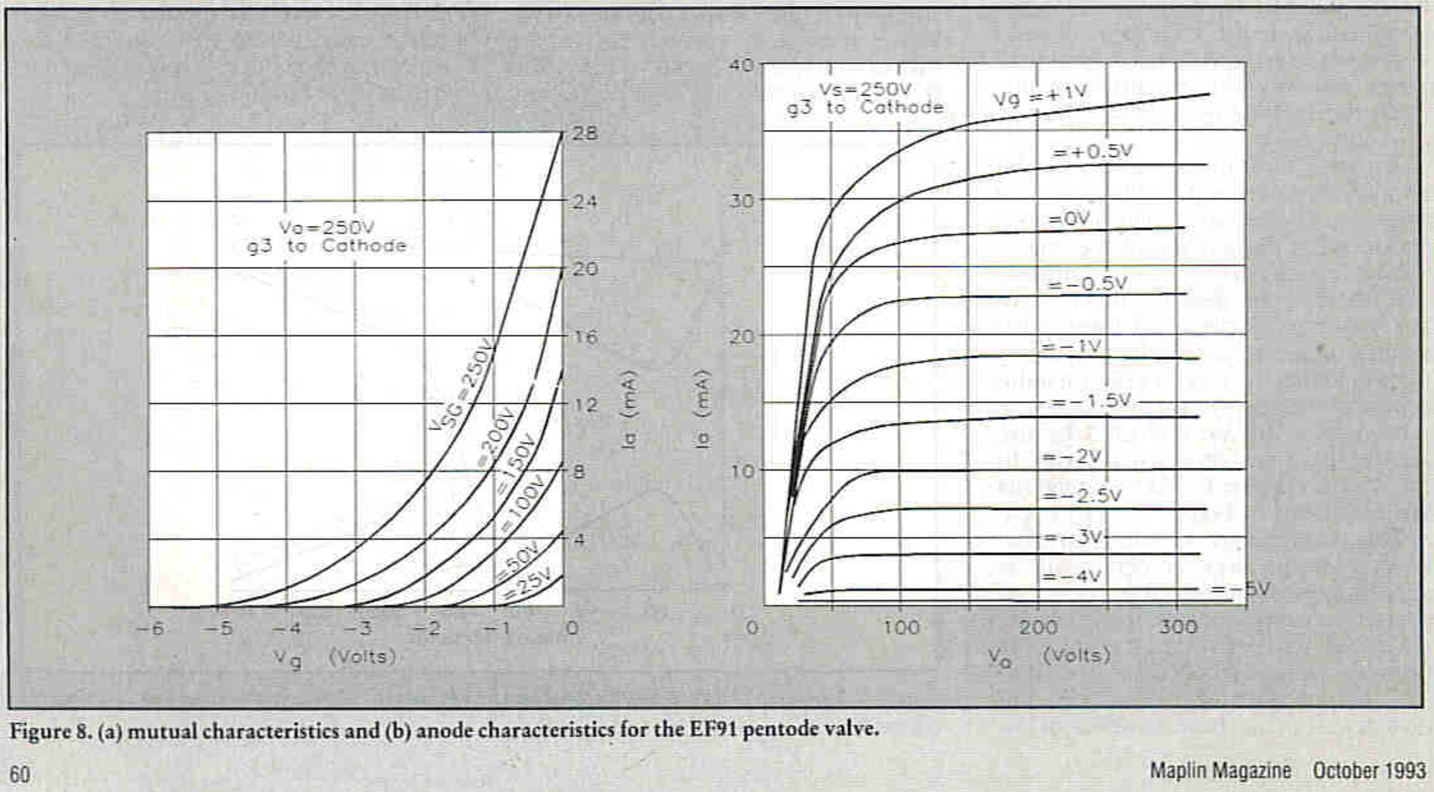


Figure 8. (a) mutual characteristics and (b) anode characteristics for the EF91 pentode valve.

type, by which is meant that a relatively small negative grid bias voltage is required to cut it off, even with quite high anode potentials. For example, with an anode voltage of +200V, only −4V is required on the grid to cut the anode current off completely.

Amplification Factor

The value of the mutual conductance, g_m, for pentodes is similar to that for triodes. However, as is the case with the tetrode, the value of r_a for the pentode is extremely high, leading to a high amplification factor. It is useful to look at the case of the EF91 to see how superior is its performance as a high gain amplifier compared with a triode.

For the EF91, the three parameters are:

$g_m = 7{\cdot}5mA/V$; $r_a = 1M\Omega$; $\mu = 7500$.

Compare these parameter values with those for the 12AT7 (ECC81) double- triode:

$g_m = 4{\cdot}8mA/V$; $r_a = 12k\Omega$; $\mu = 57$.

Suppose we were to use these respective valves as voltage amplifiers with the same value of anode load (say 47kΩ) in both cases. Since the VAF is given by:

$$VAF = \frac{(\mu \times R_L)}{(r_a + R_L)}$$

Then for the respective cases, we should get the following results.

(i) Triode amplifier (using ½ ECC81):

$$VAF = \frac{(57 \times 47)}{(12 + 47)} \text{(working in k}\Omega)$$

$= 45{\cdot}41$.

(ii) Pentode amplifier (using EF91):

$$VAF = \frac{(7500 \times 47)}{(1000 + 47)} \text{(working in k}\Omega)$$

$= 336{\cdot}68$.

Thus, using the same value of anode load in both cases, the pentode has an edge of 336·68/45·41 = 7·4:1 in terms of its ability to amplify a signal voltage, compared with the triode.

Variable-μ Valves

It is often desirable to be able to control the amplification of a valve, either manually or automatically (as in the case of AGC in radio receivers). This is done by constructing the valve in such a way that the mutual characteristic shows a very gradual cut-off, leading to the obvious inference that the slope of this characteristic varies widely from a high value at small negative grid bias values to a low value at large negative bias values. Such a characteristic is shown in Figure 9, where the mutual characteristic of a normal short grid base pentode is included for comparison. Since the slope of the mutual characteristic is equal to the parameter g_m, then it is g_m that is actually varying as the grid bias voltage is varied. But, since $\mu \propto g_m$, then μ also varies with the grid bias voltage.

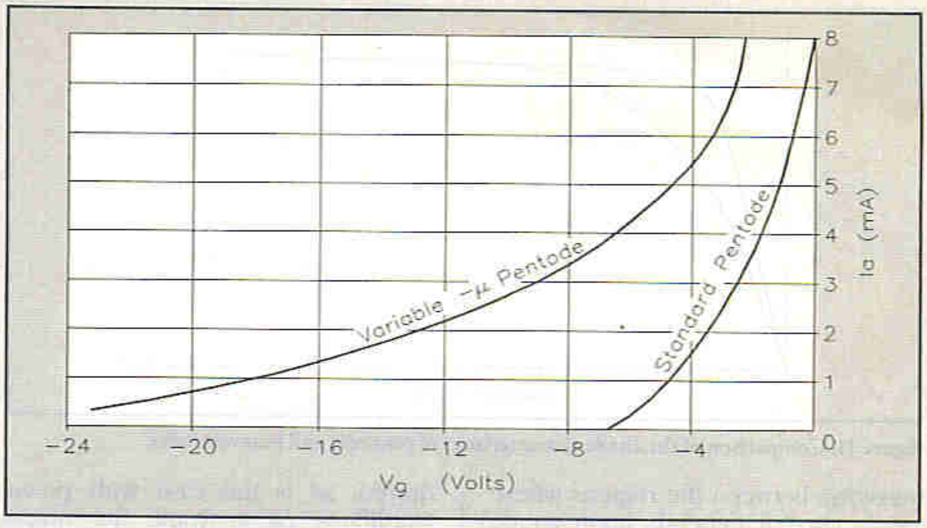


Figure 9. Mutual characteristics for variable-μ and short grid base pentodes.

In practice the way that the construction of a variable-μ valve differs from that of a standard pentode is in the spacing of the control grid wires. In a normal valve, they are equally spaced, whereas in a variable-μ valve the spacing gradually changes from being closely spaced at the centre to being wider spaced at the ends. In use, the rectified IF at the detector end of a radio is returned as negative DC to the signal grid of the variable-μ valve via its grid bias resistor. Since this negative bias increases as a result of an increase in the IF signal level at the detector, from a corresponding increase in received RF at the tunerhead, gain is reduced. The variable-μ valve would often be the first IF stage.

The Beam Tetrode

This valve offers an alternative solution to the problem of the 'tetrode kink', and the way in which it does it is by using a pair of beam forming plates instead of a suppressor grid. The construction of a beam tetrode is shown in Figure 10.

The essential action is obtained by using a large anode-screen distance, and forming the electrons in transit from cathode to anode into two well defined, high density beams. As a result, there is the effect of a large 'space charge' in existence between screen and anode which, being highly negatively charged, will tend to repel any secondary electrons emitted by either of these two electrodes. This potential minimum between screen grid and anode effectively behaves like a suppressor grid. The beams are formed, by repulsion, by the two plates shown, which are connected internally to the cathode.

The behaviour of the beam tetrode is much the same as that of the pentode, but there is one essential difference. This is seen in the anode characteristics of Figure 11. The

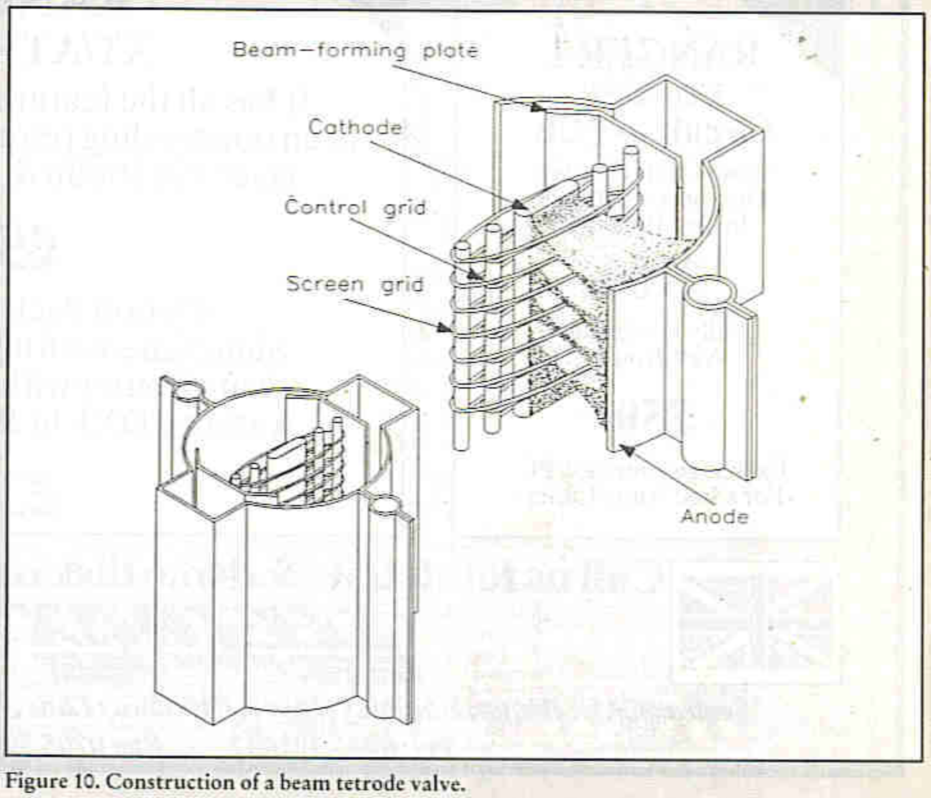


Figure 10. Construction of a beam tetrode valve.

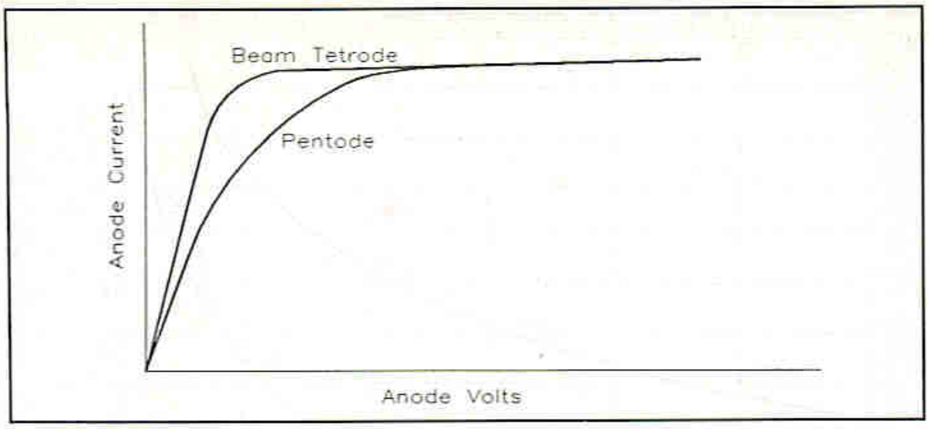


Figure 11. Comparison of the anode characteristics of pentodes and beam tetrodes.

transition between the regions where anode current depends upon anode voltage and where it is independent of anode voltage is very much more abrupt than in the case of the pentode. This is very useful where large undistorted signal swings are required, as is the case with power amplifiers. As a result, the output stages of Hi-Fi audio amplifiers frequently use beam tetrodes instead of pentodes. However, this is often not evident since it has been quite common practice in the past to treat beam tetrodes as if they were pentodes, especially when it comes to applying circuit symbols to them, so that often only direct reference to manufacturer's literature will determine what a particular valve actually is.

Even more confusing, however, is the so called 'beam pentode' (such as GEC's KT55, KT66 and KT88 series), but all that's happening here is that the suppressor grid has been 'developed' into a pair of beam forming plates in order to give the device the sharp-cornered curve of the tetrode, and hence a large signal swing capability. It's practically indistinguishable from a beam tetrode in construction. Such exotic devices are nearly always power output valves and very unlikely to be small signal devices.

Next month we shall be plugging in the soldering iron again, ready for another 'build and test' experiment on practical pentode amplifiers using the EF86.

DID YOU MISS US?

If you've ever wanted to lay your hands on an elusive issue of *Electronics – The Maplin Magazine*, then we can help! Many editions are still available, as back issues. Where issues are out of print, details of projects that are still current can be found in Maplin Projects Books and Best of Maplin Projects Books. Copies of back issues (subject to availability) can be obtained from Maplin Stores countrywide; by Mail Order, using the Order Coupon in this issue, or by calling the Credit Card Hotline on 0702 554161. If you are not sure which issue or projects book you require, call Customer Services on 0702 552911. Photocopies of out-of-print feature articles are available; a charge will be made, dependent on the length of the article to be copied – call Customer Services for details.


COMING SOON TO A FRONT ROOM NEAR YOU...
THE NEW MILLEN-NIUM 4-20 AMPLIFIER
Millennium 4.20
IT'S NOT A DINOSAUR!
FOR TIMELESS QUALITY VALVE SOUND — AT AN AFFORDABLE PRICE!
Look out for the January and February 1994 issues of *Electronics — The Maplin Magazine* for detailed instructions of how to build this superb amplifier yourself!
January and February 1994 issues of *Electronics – The Maplin Magazine* are on general release at outlets near you from 3rd December 1993 and 7th January 1994
Electronics — The Maplin Magazine is available on subscription (see coupon in this issue), from Maplin's regional stores, **WHSMITH**, **Martin the newsagent**, **R S McColl** and other leading news stockists.