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No. 90

FULL SOR

ELECTRONICS

The Maplin Magazine

Britain's Best Selling Electronics Magazine

JUNE 1995 • £2.10

Printed in the United Kingdom

Extend your listening ability with the highly sensitive Ultrasonic Detector

Digital tachometer project – help to enhance your auto's engine performance

Useful guide to produce your own professional quality PCB designs

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How to build the Stereo RIAA Correction Preamp and compact, low power Siren Sound Generator and much more!

National Lottery fever grips the UK – the electronic connection!

Pioneers of telephonic and picture transmissions across the Atlantic – story told by IEE

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These descriptions are necessarily short. Please ensure that you know exactly what the kit is and what it comprises before ordering, by checking the appropriate issue of *Electronics* referred to in the list. The referenced back-numbers of *Electronics* can be obtained, subject to availability, at £2.10 per copy.
Carriage Codes – Add; A: £1.55, B: £2.20, C: £2.80, D: £3.30, E: £3.90, F: £4.45, G: £5.35, H: £6.00.

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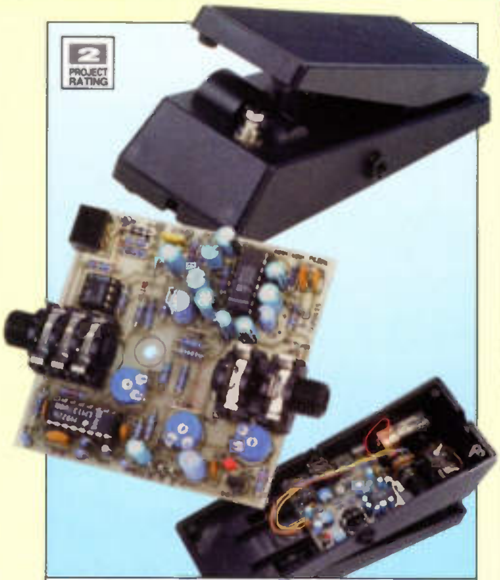
The Maplin 'Get-You-Working' Service is available on all of these projects unless otherwise indicated.

To order Project Kits or back-numbers of *Electronics*, 'phone Credit Card Sales on (01702) 554161. Alternatively, send off the Order Coupon in this issue or visit your local Maplin store.

Maplin: The Positive Force In Electronics

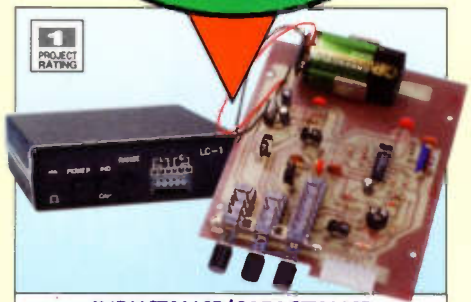
All items subject to availability. Prices include VAT.



2 PROJECT RATING

PSYCHEDELIC WAH WAH PEDAL

Recapture the classic sound of the '70s with this superb '90s technology Wah Wah Pedal. The kit includes a ready-made foot pedal and is ideal for electric guitars and other musical instruments.
Order as: LT43W, **£34.99** B3. Details in *Electronics* No. 82, October 1994 (XA82D).



1 PROJECT RATING

INDUCTANCE/CAPACITANCE METER ADAPTOR

Add inductance and capacitance ranges to your basic digital multimeter. This clever unit produces a DC voltage proportional to the inductance or capacitance under test, which can be measured by your existing meter. (Case not included in kit.)
Order as: RU38R, **£39.95**. Details in *Electronics* No. 82, October 1994 (XA82D).

2 PROJECT RATING

LOUDSPEAKER PROTECTOR

Help protect your valuable high-power loudspeakers from being damaged by DC voltages produced by a faulty amplifier. This unit constantly monitors the input to the speaker and 'disconnects' it if a DC voltage is detected.
Order as: VF44X, **£9.49**. Details in *Electronics* No. 82, October 1994 (XA82D).

2 PROJECT RATING

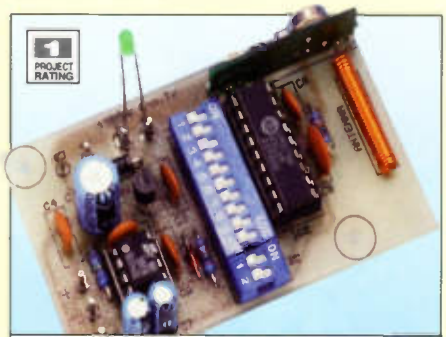
INTELLIGENT CAR INTERIOR LIGHT CONTROLLER

Add the convenience of this 'intelligent' device to your car. It not only keeps the interior light on for 30 seconds after the door is shut, but also turns it off if the ignition is switched on before the 30 seconds elapse. Plus, it turns off the interior light after ten minutes if a door is accidentally left open, avoiding draining the battery. (Case not included in kit.)
Order as: LT65V, **£9.99**. Details in *Electronics* No. 82, October 1994 (XA82D).

2 PROJECT RATING

2 METRE FM RECEIVER

An inexpensive 2 Metre frequency modulation (FM) receiver. Ideal for the newcomer just starting out, or for the dedicated enthusiast who wants to monitor a local frequency whilst keeping more sophisticated equipment free. (Case not included in kit)
Order as: CP21X, **£31.95**. Details in *Electronics* No. 83, November 1994 (XA83E).



1 PROJECT RATING

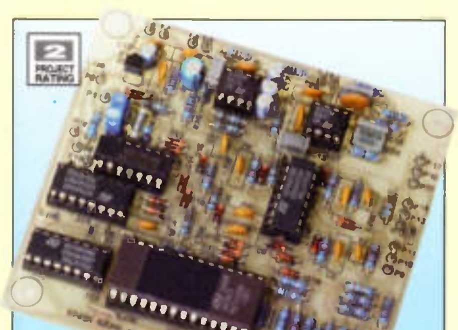
418MHz ENCODED FM TRANSMITTER

A DTI approved transmitter which can be encoded with one of over 4,000 different codes. The transmitter can be triggered by a closing switch contact, which can be simply a push-button, or a negative going pulsed output from other equipment, e.g., the Telephone Bell Repeater kit, LT67X. Applications include remote control, wireless security systems, paging, help buttons, and much more.
Order as: LT87U, **£26.99**. Details in *Electronics* No.83, November 1994 (XA83E).

2 PROJECT RATING

400W MONO/STEREO AMPLIFIER

A compact and robust amplifier with a low harmonic distortion of only 0·003% at 1kHz. It can be configured as either a stereo amplifier producing 100W rms per channel into 4Ω speakers, or as a bridged mono amplifier producing 200W rms into a single 4Ω speaker. Total music output is 400W. Power supply voltage is ±30 to ±35V DC for 4Ω speakers or mono, and ±40 to ±45V DC for 8Ω speakers. (Speaker not included in kit.)
Order as: VF40T, **£59.99** H10. Details in *Electronics* No. 83, November 1994 (XA83E).



2 PROJECT RATING

STEAM WHISTLE/2-TONE DIESEL HORN

A must for serious model train enthusiasts! Three separate trigger inputs allow either or both sounds to be played. This kit really does include everything – even the whistle and horn sounds are supplied on EPROM!
Order as: LT61R, **£14.99**. Details in *Electronics* No. 83, November 1994 (XA83E).

2 PROJECT RATING

418MHz ENCODED FM RECEIVER

A DTI approved receiver for use with the 418MHz Encoded FM Transmitter. The receiver will only respond to a transmitter set with the same code.
When a correctly coded signal is detected by the receiver, an LED lights and a piezo sounder operates. Fitting a relay (not supplied) in place of the piezo sounder allows the receiver to operate other electrical equipment for remote control applications. (Case not included in kit.)
Order as: LT88V, **£39.99**. Details in *Electronics* No. 83, November 1994 (XA83E).

2 PROJECT RATING

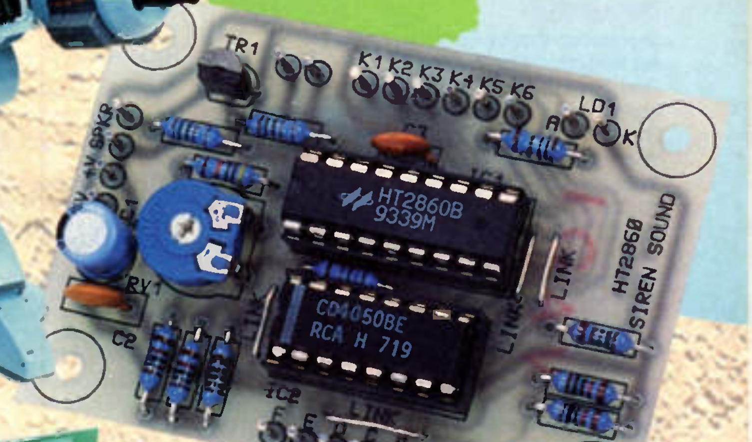
TELEPHONE BELL REPEATER

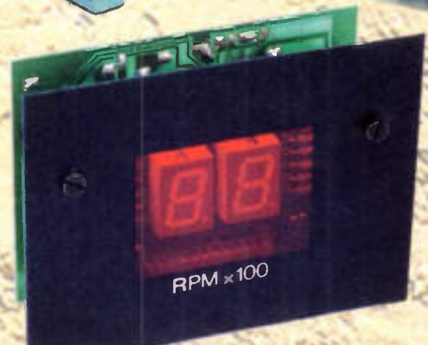
Requiring no direct connection to the telephone system, this unit picks up the ringing sound and repeats it elsewhere via a remotely wired piezo sounder. Alternatively the repeater can be connected to the 418MHz Encoded FM Transmitter and Receiver, LT87U and LT88V, to produce a 'wireless' telephone pager. (Box not included in kit.)
Order as: LT67X, **£10.99**. Details in *Electronics* No. 83, November 1994 (XA83E).

IN THIS ISSUE...

PROJECTS *FOR YOU TO BUILD!*

FEATURES *ESSENTIAL READING!*





REGULARS *NOT TO BE MISSED!*

ABOUT THIS ISSUE . . .

Hello and welcome to this month's issue of *Electronics*! From this issue, project kits and their associated, separately-sold parts, such as front panel labels, PCBs, and so on, advertised in the magazine, will have a new series of order codes, which will consist of a five-numeral form, commencing from '90000', and ascending upwards. Please note, this will only apply to items ordered from the magazine advertisements, with the catalogue order codes remaining as they were before. Rather like the changes made to the telephone dialling codes, this is needed to avoid running out of order numbers, such is the enormity of ever-expanding product ranges on offer here at Maplin!

This month, we present you with four great projects to build, comprising the Ultrasonic Detector, a super-sensitive frequency translator, that allows you to listen to the high-pitch (beyond the upper limit of human hearing) sounds given out by bats and insects, in addition to a multitude of man-made emitters of ultrasound, such as noisy electrical equipment, machine bearings, alarm movement detectors, remote control transmitters, and others. You can even use this instrument to listen to the oscillation of the crystal inside quartz timepieces! Then, there is the Siren Sound Generator, a low-power, compact module, that will come in very handy for bringing models and toys to life with combinations of six different noises, plus the Digital Tachometer, which allows you to equip your car with a revolution (rev) counter (presuming it doesn't already have one!) to keep a check on engine rotation speed, a useful parameter to know about, since this enables you to keep the engine operating within the most efficient region of its 'revband'. Last, but by no means least, there is the Universal Stereo Preamp, a useful 'front end' stage, that can be used with most types of audio amplifier, or in conjunction with other modules in the range, to produce a complete stereo amplifier system.

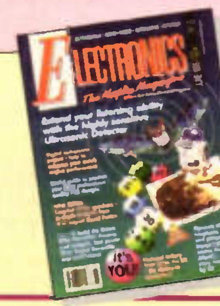
There is a good selection of topics covered in this issue, with articles giving the low-down on the logistics that were required to establish the National Lottery, Making Your Own PCBs Using CAD, which is a useful guide to producing professional-quality PCBs on a DIY basis, with help from your home computer. New series this month, include the IEE's Sailing Ships to Satellite, charting the development of transatlantic telecommunications, and Coupled Cavity Speakers, which describes an ingenious and efficient, alternative design of Hi-Fi loudspeaker cabinet, with comprehensive instructions on making your own set.

In addition, there are the features, History of Electronics, covering the story behind ICs, and RIAA – CD Versus Vinyl, which in this instalment, investigates noise, and includes a design for a high-performance RIAA amplifier for you to build, whilst MS Stereo proffers a number of experiments that are possible with MS reproduction techniques; no, not *those* type of reproduction techniques! All this, plus our usual feast of regulars. So, until next month's exciting edition, from everyone here at *Electronics*, enjoy this issue!

R D Ball

IN FUTURE ISSUES . . .

Look out for these exciting articles, heading your way soon in future issues of *Electronics*! Projects in the pipeline, include the Interactive Doorbell, which can replay prerecorded speech or music to callers at your home, the Mains Power Conditioner, a highly effective filter for removing interference from the mains power supply, the Multi-Strobe, which can flash a Xenon tube in a choice of a hundred dazzling patterns, great for disco's and parties, the Shortwave Regenerative Receiver for round-the-world radio coverage, the PC Teletext Decoder, to enable your PC to display Teletext pages, the Micro Controller/Timer, and a selection of ever-popular audio amplifiers. Forthcoming features, include Colour Printing, describing the latest printing technology, the History of Defibrillation, covering the controlled-shock gadget that has saved many lives. Then, there is an item on 'environmentally conscious' Low Energy Personal Computers, and Compact Disk Interactive (CD-i), giving the low-down on this techno-slice of the multimedia market. Setting up a Radio Shack provides plenty of tips on installing your amateur radio equipment to gain the maximum enjoyment from this hobby, whilst Secure Information highlights the problems created by widespread computer storage of sensitive data, and ways of protecting it from being fiched! UV Radiation gives information about this potentially harmful category of light emission, in addition to its many uses in electronics. Flash EPROMs inform you of this new memory technology, which might one day, take over from conventional disk storage, countered by Magnetic Disks and New Applications, which suggests that disk storage systems are likely to be around for a while yet! Recycling Batteries describes another 'Green' practice, that of rejuvenating spent batteries. Alternative Space Propulsion looks at less hazardous and more efficient methods of sending things into outer space, other than detonating vast quantities of high-octane fuel. Rest assured, however, that *Electronics* will remain down-to-earth and as explosive as ever!



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Project Ratings

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

1. Simple to build and understand and suitable for absolute beginners. Basic of tools required (e.g., soldering iron, side cutters, pliers, wire strippers and screwdriver). Test gear not required and no setting-up needed.
2. Easy to build, but not suitable for absolute beginners. Some test gear (e.g., multimeter) may be required, and may also need setting-up or testing.
3. Average. Some skill in construction or more extensive setting-up required.
4. Advanced. Fairly high level of skill in construction, specialised test gear or setting-up may be required.
5. Complex. High level of skill in construction, specialised test gear may be required. Construction may involve complex wiring. Recommended for skilled constructors only.

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 your nearest store is, Tel: (01702) 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 (01702) 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 number can access the system by simply dialling (01702) 552941. If you do not have a customer number Tel: (01702) 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 (01702) 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: (01702) 552911 and we will happily issue you with one.

Overseas customers can place orders through Maplin Export, P.O Box 3, Rayleigh, Essex, SS6 8LR, England. Tel: +44 1702 554155 Ext. 326 or 351; Fax: +44 1702 553935

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

Subscriptions

Full details of how to subscribe may be found on the Subscription Coupon in this issue. UK Subscription Rate: £21.96/12 months, £10.98/6 months.

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 5th May and 31st August 1995 errors and omissions excluded. 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: (01702) 556001 between 9.00am and 5.30pm Monday to Friday, except public holidays; by sending a facsimile, Fax: (01702) 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

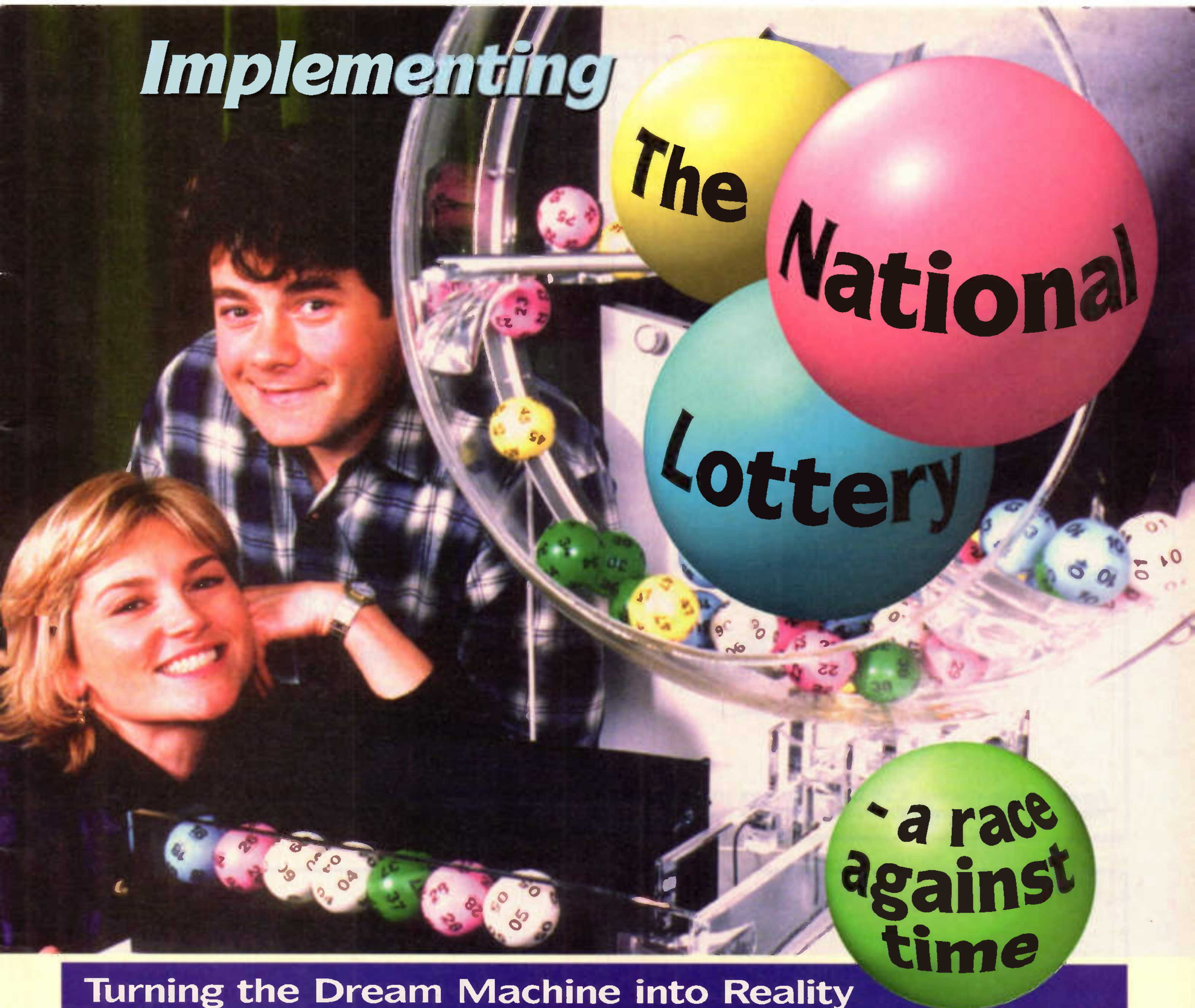
If you get completely stuck with your project and you are unable to get it working, take advantage of the Maplin 'Get You Working' Service. This service is available for all Maplin kits and projects with the exception of: 'Data Files'; projects not built on Maplin ready etched PCBs; projects built with 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 to 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	£17.00
£25.00 to £39.99	£24.00
£40.00 to £59.99	£30.00
£60.00 to £79.99	£40.00
£80.00 to £99.99	£50.00
£100.00 to £149.99	£60.00
Over £150.00	£60.00 minimum

Readers Letters

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

Write to: The Editor, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex, SS6 8LR, or send an e-mail to AYV@maplin.demon.co.uk



Turning the Dream Machine into Reality

For its suppliers and implementors, the run-up to the National Lottery was a bigger gamble than the real-thing. The Camelot Consortium had won the lottery operation prize, by promising an extremely short implementation timescale. This was largely achieved by using tried and tested technology, to avoid equipment unreliability and achieve installation targets. With some sixty million tickets being sold weekly, the system has proved its resilience. That dependability and capacity will be further tested as more and more retailers come on line from outlying towns and villages across the UK, to reach about 40,000 terminals over the next eighteen months. Report by Alan Simpson

If the past was anything to go by, the project was a gamble from the start. The UK's previous flurry with a national lottery was brought to a close back in 1825, when the head of the lottery was last seen scuttling off to Bolivia with most of the profits. The present government, in a last ditch effort to provide that much-hyped 'feel good factor', gave the go-ahead and licensed the Camelot consortium to undertake the project. With partners G-Tech, an experienced lottery operator, security printer De La Rue, Racal and ICL, plus not a little advertising help from Saatchi and Saatchi, the project got under way.

A Race Against Time

So within the period of just 20 weeks, Racal and partners created the world's largest network outside the US. Between July and November last year, Racal Network Services connected over 10,000 retail outlets across the UK, handling some £60 million worth of lottery tickets. In a race against time, Racal also installed 800 satellite links and almost 10,000 land lines, to connect the retail terminals to the lottery network. Retailers will continue to be connected over the next two years, to achieve the target of around 27,000 by the end of 1996. At the same time, BT, a subcontractor to Racal, will have supplied some 23,000 private circuits by the end of next year. No wonder this has become one of BT's largest ever customer contacts.

So far, the only major problems have been those involving remote terminals failing to connect with the central computers. "However, the blame lies, not with the high technology involved, but with the down-to-earth, early generation, copper wires connected to each terminal", said Racal's Steve Hodson, who masterminds the Lottery projects. Here, BT are working to connect that last analogue mile to the X.25 digital network, the coverage of which is shown in Figure 1, or to a satellite system. 90% of the line costs in fact relate to that first mile; approximately £112 per first kilometre, compared to just £2.25 on the main leased lines. "No one would believe,

Above: Close-up view of one of the draw machines, and the current presenters of the BBC National Lottery programme, Gordon Kennedy and Anthea Turner.

Figure 1. Map showing X.25 Digital network coverage of the 1,151 Local Service Exchanges (LSEs) in the UK.

Figure 3. Map showing distribution of the 2,082 V-SAT Local Service Nodes (VLSNs) in the UK.

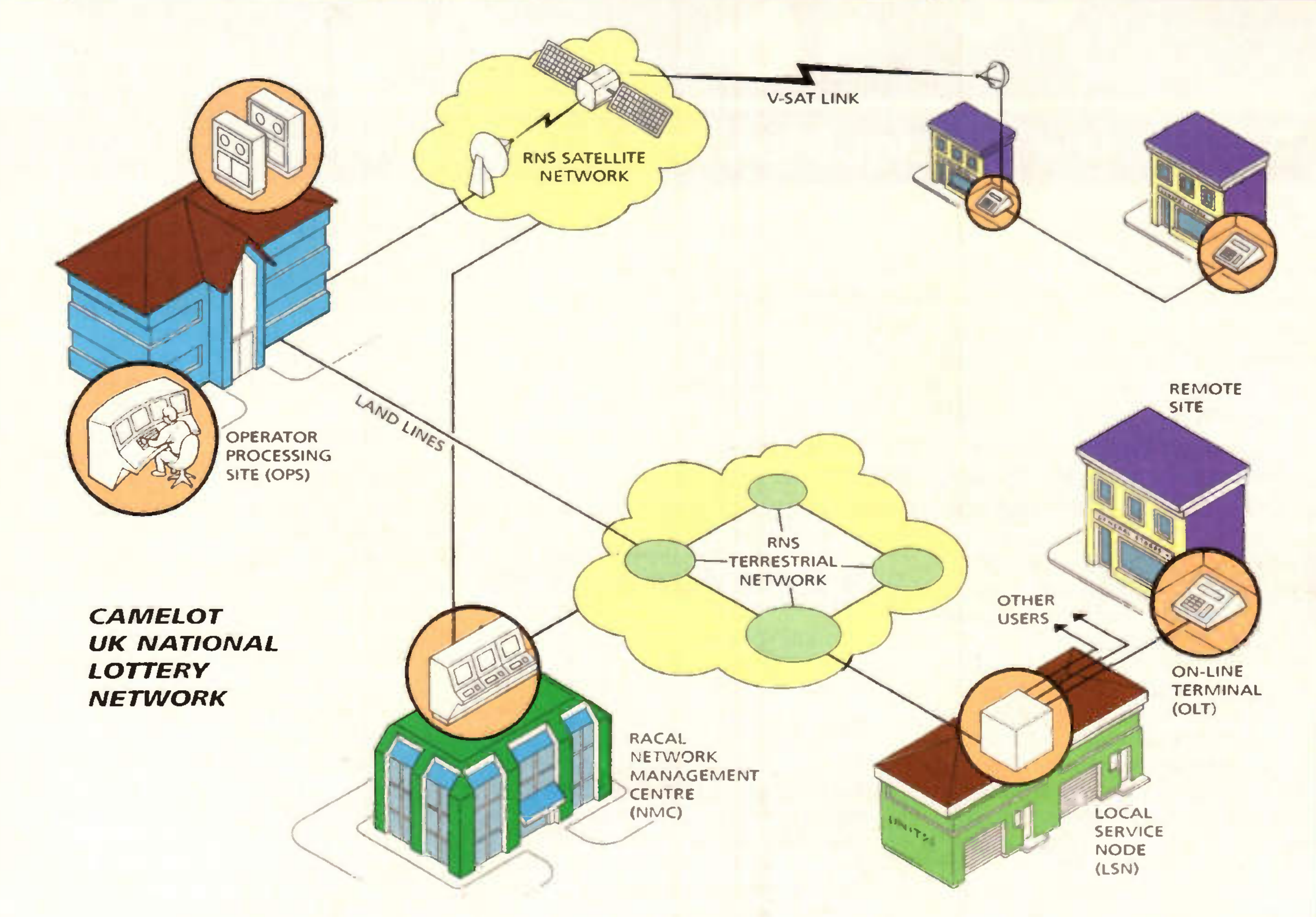


Figure 2. Camelot Consortium's UK National Lottery Network.

what a mad, mad rush it has been, and continues to be, to meet our connection targets."

The downside to all this? Well, many potential punters complained that they were not able to buy tickets (and thus, a potential share of the rewards). But, as Racal confirmed, it was just not physically possible to connect the whole country to the network in the timescales imposed.

A Clear Focus

"From the very start, it was a highly focused job. Wherever possible, we made use of existing technology. We didn't invest in anything new, but made the best use of what was already in the field", said Steve. The main network being used, the Government Data Network (GDN), is it so happens, owned and managed by Racal. Serving some 18,000 government departments and commercial users across the UK, it is by far, Europe's largest private data communications network.

The main processing site is at Rickmansworth, with a back-up centre in Liverpool. Figure 2 shows the extent of this network. Transactions are sent down the X.25 network at a speed of 9·6K-bit/s to the databanks. There are satellite uplift hubs in Stevenage and Kingston, where 120 circuits link by LANs, into Rickmansworth. Overall, there are four independent routes – two BT, two Mercury, one microwave, and one fibre link. The system is designed to process 425,000 transactions a minute, some way above the expectations of generating at the most, some 100,000 transactions a minute at peak flow. In fact, the 'dream-machine' operational offices are based in a standard trading estate in Rickmansworth. Here, the massed banks of DEC computers and disks are flanked with even more massed-arrays of communication equipment, handling the aspirations of the 30 million weekly punters.

Not a Terminal Situation

The lottery terminals have been installed at a variety of retailers, ranging from supermarket chains such as Tesco, to corner shops throughout the country, from Penzance to the Orkneys. Here, the winners are clearly the Camelot equipment and network suppliers. Racal has three major partners assisting the lottery cause. G-Tech, which was responsible for the design of the lottery and for providing the supporting technology, is one of the world's major suppliers of lottery systems, and the UK version was based on their operations in the US and Spain.

At the heart of the processing system is Digital Equipment. This supplier was chosen because G-Tech is a long-term user, and it would have been impossible – given the implementation timescales – to create the many millions of codes to meet the transaction-processing requirements. That same time-factor resulted in DEC's VAX units being chosen over the fast Alpha-Risc processor. In fact, the ordering of the DEC gear itself was a gamble. The system was ordered some five months before Camelot won the lottery bid, with the proviso that DEC would have repurchased the kit if the bid had failed.

Despite losing out on the central processor front, ICL has scored well in the Lottery equipment stakes. Along with G-Tech, ICL is a member of the Camelot Consortium, but has had to settle for the still substantial role of supplying all the terminal equipment. An ICL subsidiary is building the special lottery terminals which dispense tickets and handle the associated accounting routines. Cementing the lottery relationship, the company also recruited Camelot's 500 personnel, supplying each with a PC.

A further ICL rôle, is that of providing training of lottery personnel, as well as being responsible for providing maintenance and repair services on a seven-days-a-week fix-it basis, even to the most remote areas of the UK. In major cities, ICL are guaranteeing that any problems with a terminal will be dealt with within two hours, by having on-hand spare terminals. Service call logistics are impressive. ICL expects to fend-off some 250,000 calls when all 39,000 terminals are in place, but hastens to add, that level of calls do not necessarily relate to faulty equipment. Many are 'user-related' errors such as when replacing paper supplies, or kicking-out the mains plug.

With One Bound – the Satellite Link Expedites the Dream

Where direct land-links are impracticable, Racal is installing satellite links to the Orion commercial satellite, with back-up by Eutelsat birds. Some 20% of users are on the satellite network, resulting in the creation of one of the largest two-way VSAT satellite networks in Europe. Over the next two years this will grow to some 2,000 satellite links, connecting up to 5,000 retailers over the VSAT network. Figure 3 shows the distribution of the VSAT Local Service Nodes (VLSNs) within the UK.

Peak Loads

The network has been designed to handle a peak load without deterioration in speeds. This is well within the tolerance for even Saturday peak loading between 16:00 and 18:30, when over 30% of the tickets are sold. This equates to some 2·4 transactions per terminal per minute (the average time an operator can handle the sales ticket transactions) across the whole network. As Racal's Steve Hodson reports, "The network has been designed for 75% usage running at 37½%, at full load – well within the usage tolerances – and still meet all specifications."

Luck of the Draw

Registering a lottery number will take just five seconds. The customer blocks out six of a total of 49 numbers, which are then scanned into a terminal. Winners claims are processed by running their official receipts through the scanner and network at their local retailer, main post office, or in the case of bumper winnings, from National Lottery offices.

The draw itself is handled by a distinctly non-high-tech, bingo-type rotating drum, from which six precisely-weighted balls emerge at random, one at a time, as shown in Photo 1. The numbers on the balls determine the winners of the National Lottery for that week. The whole event is televised by the BBC, in what has been described as being a tacky show!

Lottery fever grips the UK, as people queue to buy their tickets.

Closed-circuit faxes and computers in the television studio relay the winning combination back to the DEC computer centres.

Safe and Sound

"Anyone out there thinking about cracking or hacking the system had better think again", said Steve. Each transaction is recorded on the DEC computers no less than nine times at both processing centres. Traffic on the X.25 network is encoded using data encryption – in fact, Racal suggest that you would need a supercomputer and several years to break into the system. You might be better off to buy the National Lottery numbers PC program 'Just Lotto', which aims to predict the winning numbers. The program, from COSMI UK, is based on the mathematical iterative 'Link Number' theory, and analyses previous weeks' winning combinations to detect number patterns. Or you could carry on using your 'magic birthday number' formula.

To date, the system has had just the one blow-out since the problems experienced on the opening day. On Christmas Eve last, almost a third of the outlets went down with a systems failure, followed by a network failure on the same day. Both faults were fixed within the hour, claims Racal. Racal has, however, been praised for its achievement by no less than Camelot's

Week ending	Sales Figure (millions)
19th November 1994	£48·9
26th November	£47·9
3rd December	£48·2
10th December	£61·5*
17th December	£54·6
24th December	£55·2
31st December	£53·3
7th January 1995	£57·5
14th January	£69·8*
21st January	£61·2
28th January	£61·3
4th February	£62·2
11th February	£61·7
18th February	£60·9

* Indicates a Rollover week.

Table 1. Sales figures generated by the National Lottery.

Group chief executive, Tim Holley. "The importance of secure and reliable communications to the National Lottery is highlighted by the fact that once fully established, the network should handle transactions worth several billion pounds a year. Against very tight deadlines, Racal Network Services' efforts in rolling out the communications infrastructure have been outstanding."

Even so, there has been criticism that major charities are losing out, because many potential outlets were unable to join the lottery club, and that computer systems are not in place to allocate the money. However, the four other groups of beneficiaries of lottery money, namely, the Arts and Sports Councils, National Heritage, and the Millennium Commission, have got their act together in time to claim their share of the burgeoning funds. There is also the lurking suspicion that the government ignored the popularist claims of Richard Branson, who promised that all the proceeds from his consortium would be devoted to charity. Also suspected was that the government would divert the lottery funds into propping up the health service, or building new army barracks and school classrooms.

Perhaps the most exciting fund project, is the allocation of an anticipated £1·6 billion towards the Millennium celebration. Here, plans exist to make a long-term impact for future generations. Unfortunately, no really big landmark scheme, which would catch the imagination of the nation, has yet emerged. Ideas direct to the Millennium event organisers, not the editor, please!

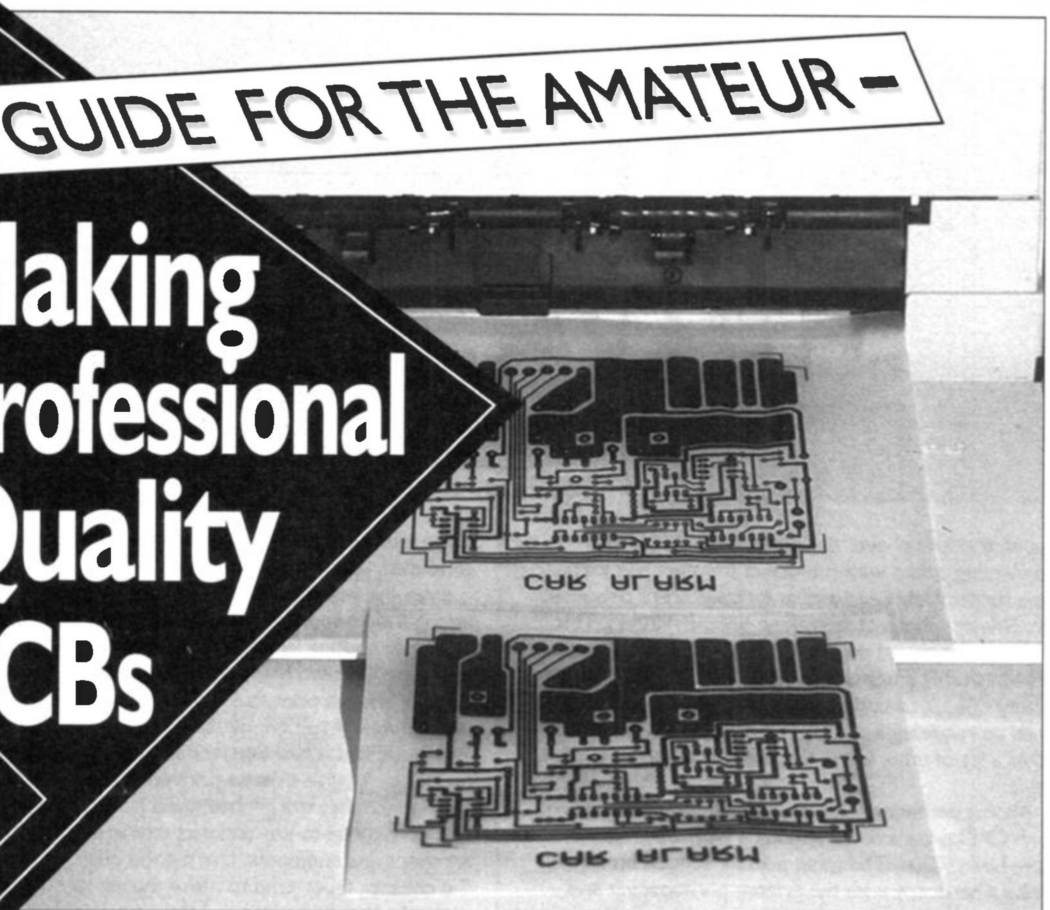
References

The National Lottery Newsroom, Tel.: (01923) 425 456.

The Millennium Commission, 2 Littlesmith Street, London SW1P 3DH. Tel.: (0171) 416 8070.

A GUIDE FOR THE AMATEUR –

Making Professional Quality PCBs



By DAVID FAULKNER

Above: Printing the master.

Below left: Cleaning the board prior to coating with photoresist.

Below right: Applying the photoresist.

MANY home electronics enthusiasts such as myself own or have access to a personal computer, and as the real price of computers continues to fall, many more of us are finding that it makes sense to buy one. In addition to this, the real cost of the software required to run them has also fallen and several different software companies now provide CAD (Computer Aided Design) packages specifically aimed at the home electronics constructor in the form of circuit diagram drawing and printed circuit layout packages. Maplin currently stock Easy PC and Seetrax Ranger, both of which are excellent value at around £100, but there are many more available as public domain software or shareware, which is free of charge (for a limited trial period, after which you should register!) and which represent even better value for the occasional hobbyist who may only want to produce one or two designs a month. My aim in this article is to show, step by step, how to produce a professional quality PCB from an amateur package.

Using a CAD Package

Although command-wise they are all quite different to use, the packages I have tried allow you to place components on the screen superimposed on a 0·1in. grid (which is the industry standard spacing for components). After placing the components, the connecting tracks are laid on one or more layers (single or double-sided boards). You now have the option to realign components and/or tracks to enhance the layout or reduce its overall size. Once this laborious task is completed you can make a hardcopy print of the layout to use as a master for the PCB. This is where I and many of my colleagues have always come unstuck and is the main reason for producing this article.

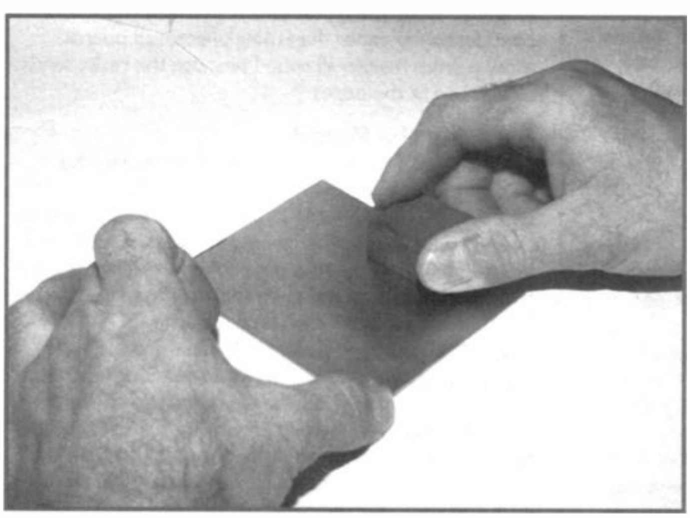
Basic Overview of Operations

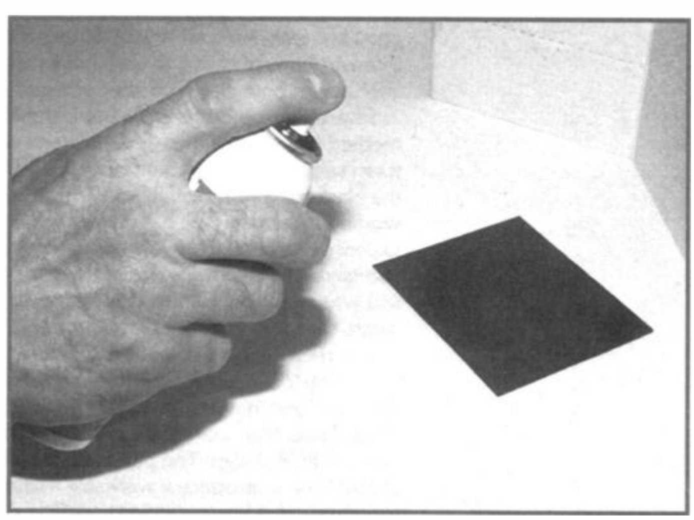
First, a photographic template (known as a positive master) is made up, whereby the black areas (the track) will appear black on a translucent background. This will eventually be placed between the board and an ultra-violet (UV) source. The next stage combines all the processes required to make the actual PCB and comprises:

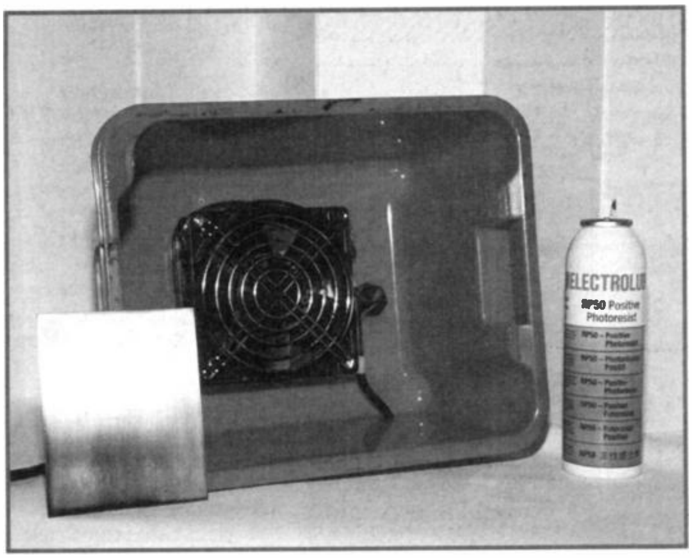
Cutting the board to size.
Cleaning the board to remove oxides and grease.
Applying a UV sensitive coating (known as positive photoresist) to the copper.
Drying of the photoresist and quality checking of coating for dust.
Developing off the exposed photoresist to leave a positive track layout.
Final checking and remedial touching-up of tracks.
Etching the board to remove areas of unwanted copper leaving only the tracks.
Drilling and trimming to size.
Component build and soldering.

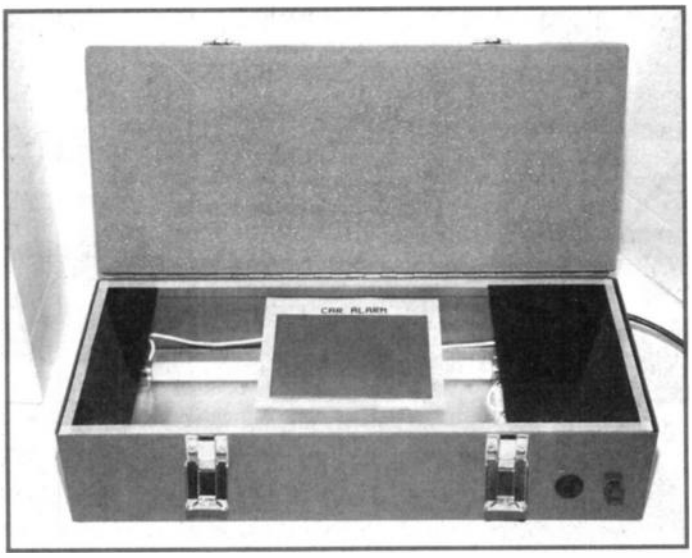
Making the Master

The somewhat laborious method I previously used was to do the design work on the computer, print out onto









Above left: Home-made drying box and the coated board.

Above right: Using the UV lightbox to expose the board.

paper, and 'trace' over the component pads and connecting tracks with rub-down transfers and crêpe tape respectively, onto a clear or translucent polyester film (Maplin photo-etch drafting pack, BW20W). This method has served me well for many years, but has the drawback that if any changes are made to the design it is very difficult to update the master neatly, and usually ends up requiring a complete retrace, which not only takes a lot of time, but is also open to errors at every stage.

Almost without exception, the instructions supplied with CAD programs for making a workable master have been vague. The most popular suggestion is to make a hardcopy with the printer, photocopy it and spray the photocopy with a 'transparentiser' aerosol (such as that made by 3M, but which is very difficult to obtain, and costs around £10 for a small can), the idea being that the paper will go semi-translucent and allow the UV to pass through to the board.

Other suggestions have ranged from spraying the photocopy with water, WD40 and a myriad of other liquids but, after many years of trying I can confidently say that none of these methods work unless you have a design with only a few very thick tracks and are prepared to put up with fuzzy edges and a lot of retouching work prior to etching. Another suggestion was to use an older wet-type photocopier and having eventually tracked one down, I found I could not get the density required with a uniform thickness. This may seem unimportant but if you want a good, neat result, it is essential that the density be uniform, and in any case, wet copiers are now superseded technology.

I tried photocopying onto clear acetate (which melted and stuck to the hot fusing rollers!), then the proper overhead projector film, which looked promising until I held the copy up to the light and found that (being a modern powder-type copier) the black parts were full of minute holes. Copying onto clear film using a laser copier (at a copyshop), seemed quite good but again suffered lack of density and also the inconvenience of having to travel to a copyshop; also, laser copies onto clear film are not exactly cheap.

Several repro-houses were tried, and I found the best method was to take them a double-size copy and get them to photo-reduce it onto Positive Litho film (i.e., the black parts to remain black). This method actually worked extremely well but proved to be very expensive (around £15+ for an A4 sheet) and combined the inconvenience of travelling or posting, and waiting for the results, only to find an error or subtle change in the layout is required.

The recent fall in price of the bubblejet printer, to well under £200, prompted me to buy one (a Canon BJ10 SX), and in doing so, I finally attained the quality which I had been searching for in vain over many years of PCB design. The purchase of the printer finally enabled me to produce a workable master in one step in minutes, and has the added benefit that any changes to be made only require a new printed master to be produced, which only costs a few pence.

Even this was not without problems though, as having tried printing on different thicknesses of paper, polyester drafting film, the proper 'bubblejet overhead projector' film and many others, I still could not obtain a dense enough print that would block UV and would not smudge or rub off. By chance, I tried tracing paper and found that it had exactly the correct absorbency properties to give a dense print which became permanent after the ink had dried (about 15 minutes), was very cheap to buy and was readily available from art shops and stationers. Use a good quality paper, as the cheaper types tend to make the ink bleed, and you end up with fuzzy edges and close tracks running into one another.

It is of the utmost importance that the area to be printed on is NOT TOUCHED or handled, as the slightest trace of grease from fingerprints, etc., will prevent the ink adhering properly.

Depending on the density of the print, you may need to make two copies and sellotape them together along two edges. This may appear risky with thin, densely populated tracks, but I have found the printer to be accurate enough not to cause a problem. The worst case needed four prints to be made and from these, the best matching two selected and stuck together to form the master, but this was an exception rather than the norm.

Making the Board

Having finally obtained a workable master, the next stage is to produce the actual PCB.

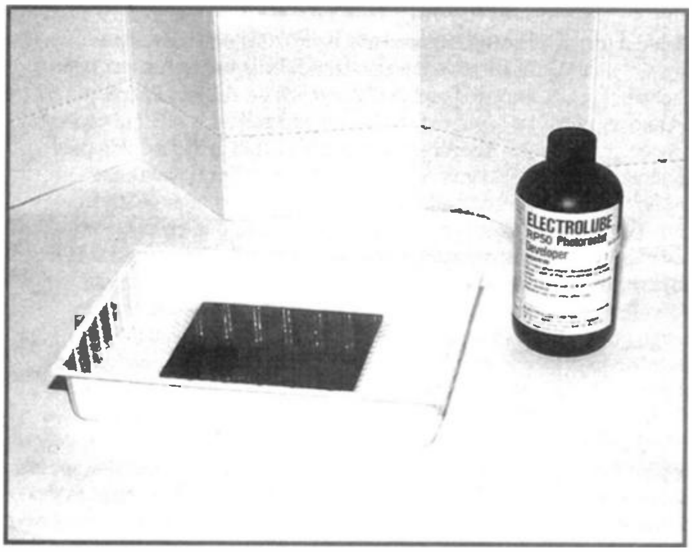
This can be broken down into the following steps, outlined below:

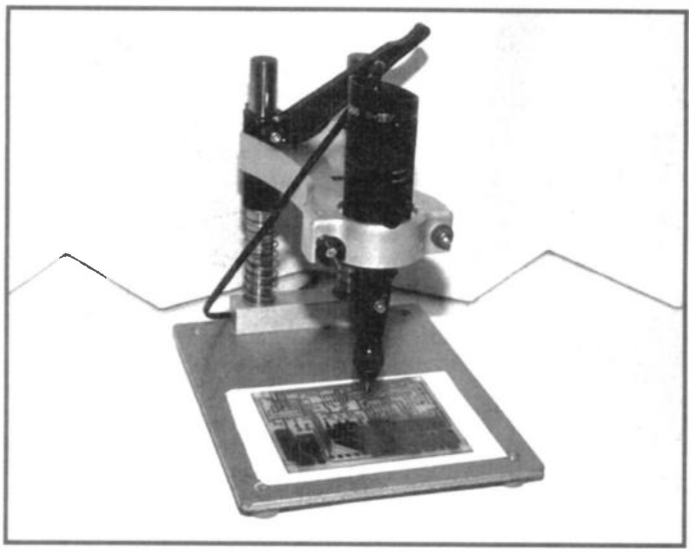
Cutting to Size

The board should first be cut roughly to size. If you intend to spray the board yourself (which works out considerably cheaper than using precoated boards) allow a 3mm margin all round because the resist tends to build up at the edges.

Cleaning the Board

For the resist to have any chance of sticking to the board, it is essential to ensure almost medical cleanliness when handling it. To this end, it must first be cleaned with an abrasive cleaner such as the 'polishing block' (HX04E). The board is rubbed using light parallel strokes until a clean and even shiny surface appears. From now on it is IMPERATIVE that you DO NOT TOUCH the copper surface. Handle using the edges (which is another reason why you left a 3mm margin, didn't you!); if you do accidentally touch the surface (even if you cannot see any fingerprint marks) repeat the cleaning process. Failure to do so will prevent the resist sticking to the board, so you will have to clean it off and start again anyway.





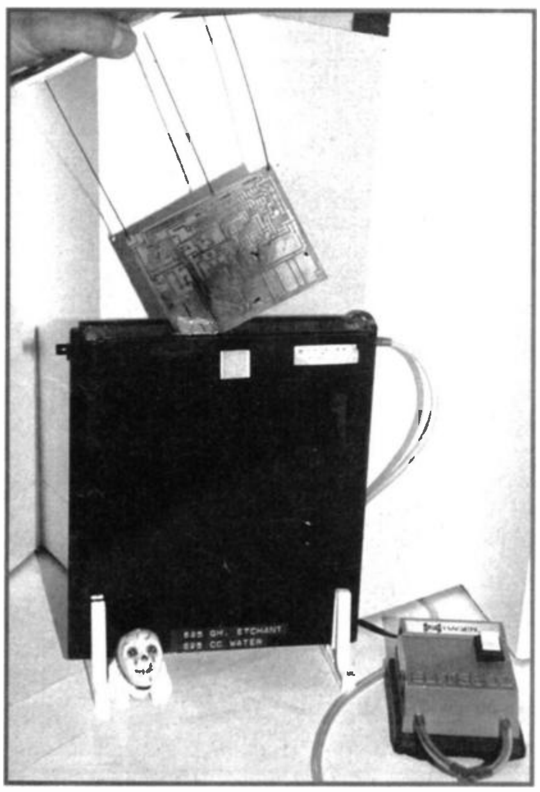
Above left: Developing the exposed board.

Above right: Drilling the board.

Applying the Resist

Having obtained a clean board, the next step is to apply the photoresist which will subsequently be exposed to UV and developed – I use Electrolube RP50 photoresist (YM62S). The board should first be wiped using a clean lint-free cotton cloth to remove the layer of copper dust which will be present. An old (clean!) cotton handkerchief was found suitable for this purpose and the board is then carefully blown clear of any remaining dust. Cover the area that you intend to spray in with newspaper to at least a 2 foot radius. According to the instructions the resist should be applied in subdued lighting as it is UV sensitive. I have not found it necessary to be too critical in this respect – common sense should dictate that you would not spray in direct daylight or under fluorescent lighting.

I recommend that you purchase and use a disposable dust mask – they cost only a few pence and will prevent the overspray being breathed in. Place the board (copper side up) in the middle of the paper and shake the aerosol for at least one minute. A final check to ensure no dust has settled should be made immediately prior to applying the resist. Spray from a height of approximately 10in., and apply one LIGHT coating by overlapping left to right and top to bottom or by using a zig-zag pattern, then immediately cover the board with a box for 30 seconds, to allow the coating to even out.



Left: Etching the board in a bubble-etch tank. Note use of an air pump to assist this process.

As you can see from the photograph, I made a fan assisted drying box by fitting an axial fan to a 'Plysu' stackable plastic storage box. This is not essential, but it does speed up the initial drying process if you have several boards to coat. Switch the fan on after about 30 seconds. Switching on too early will dry the coating before it has had time to even out, too late and you run the risk of dust settling on the wet resist. The fan is mounted so that it draws air in through the 'handles' in the bottom of the box, across the board and out through the top hopefully taking any dust particles with it. If you do make a similar box ensure that you fit finger guards above and below the blades.

Initial Drying

After 2 minutes with a fan box or 15 minutes without, the board should be dry enough to handle – again in subdued light. Now is the time to check to see how much dreaded dust has settled on the coating. Do not be too disappointed, as it is impossible to obtain totally dust-free conditions and some dust must be tolerated. Experience will dictate whether you remove the coating (methylated spirit works best) and start again or if there is not too much dust, to proceed with the next stage. If you do need to clean off the old coating, it is essential to re-clean the copper with the polishing block again or else the new coating will not stick. Do not be tempted to skip this stage because when you reapply the resist, it will adhere like oil on water and will have to be cleaned off again anyway.

Final Drying

Having now got a board coated with photoresist it is necessary to FULLY dry it. This means leaving it overnight in a dark, warm place such as the airing cupboard or using an ELECTRIC oven, preheated for approximately 20 minutes to 100 to 150°C and then switched off. Place the board in for about 20 minutes, resist side up, with the door closed to keep it dark. A fan heater will also work, placed approximately 8in. away at 1kW heat setting, remembering to keep the board in subdued light. I have had no problems using either method, and have found that unless you actually burn the coating, slightly exceeding this temperature does not appear to have any adverse effect. Do NOT be tempted to use a gas oven as the solvent given off is highly flammable. Also do not be tempted to rush this stage, as when the board is put into developer after the next stage, ALL resist will come off if it has not fully cured.

Pre-coated Boards

If you wish, you can use pre-coated boards and the preceding stages can be skipped, enabling you to start here. In some cases (i.e., where the tracks are very fine or close together, it is advisable to use pre-coated boards, and if you need a board quickly this is really your only option).

Exposure

At this point, switch on the heater in the etch tank as it takes about 15 minutes to reach operating temperature. The next stage is to expose the board to UV, the only way to achieve repeatedly good and consistent results being to use a light box. For most users, a small one such as XY10L will suffice and this has a foam pad in the lid which keeps the board firmly in contact with the master. If this pressure is not maintained, UV will creep around the edges and expose the areas you want to keep (i.e., the tracks). To ensure that you put the master the correct way up (down?) it is a good idea to include some text with the design (it is very easy and extremely frustrating to make a board the wrong way up!). Once the board is in the right place, the lid is locked shut and power applied. I have found that with the Maplin box containing 2 × 8W UV tubes, 12 minutes exposure time is just about right. Too long and the edges will be fuzzy, not long enough and the unwanted resist will be difficult to remove. Once locked shut, the lid must not be disturbed until the lamps are out. Failure to observe this will guarantee that the board moves and must be cleaned off and started again from scratch.

Safety Notes

i. This type and strength of UV is not particularly harmful to the eyes, but it is a wise precaution not to stare directly at it.

ii. The ferric chloride used for etching is harmful to the skin, and contact with it is not recommended for any length of time. To this end, the use of plastic gloves (YJ48C) when handling it or boards which have just been removed from the tank is strongly advised. If it does get on your skin, it will stain it brown, though this will disappear after a couple of days. In any event, thorough washing of the skin with copious amounts of soapy water is recommended. The photoresist developer is alkaline-based (e.g., Sodium Hydroxide) and should not be used in contact with the skin for any length of time. Again; the use of gloves is advised. If you work carefully, it is unlikely you will splash any chemicals in your eyes, but it is good practice to WEAR GOGGLES. This may seem like trivial advice, but accidents do happen even to the most careful of us.

If you should splash any chemical in your eyes, wash immediately with copious amounts of water and if you are in any doubt, always err on the side of caution and SEEK MEDICAL ADVICE.

Developing the Board

Having exposed the board, it is now developed to remove the unwanted resist which has just been exposed to the UV and will be chemically soft. If you have coated the board yourself with RP50 photoresist, use photoresist developer (YJ38R) diluted one part developer to four parts water. If you have used pre-coated boards, use PCB developer (AP01B). Either type should develop OK, but my experience has dictated otherwise. I use a flat-bottomed 2 litre ice cream container to develop in, and for small boards I use the bottle cap as a measure.

Ideally, the developer should be maintained at about 20°C but this is not essential. The easiest way of achieving this is to float the developing tray with chemical in on some warm water for a few minutes prior to immersing the PCB. Rocking the tank gently is essential to ensure even development, and also speeds things up. As a guide, expect around 2 minutes in the developer, but this depends on the area to be removed, developer strength and temperature. Observe that the process will speed up after the first minute. Once complete, carefully remove the board and wash under running water for 30 seconds. If you use a tissue to dry it, be careful because the remaining resist will be soft and is easily scratched off. This developer has a usable period of only about 30 minutes once made up and is not reusable.

Safety Note

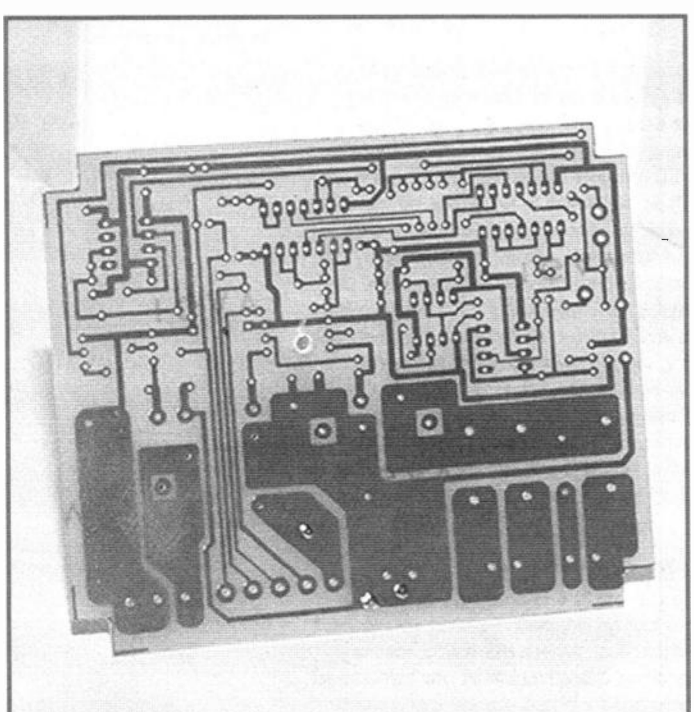
The developers used are based on an alkaline solution and for most people should not irritate the skin, although the recommendation is not to be in contact with it. If in any doubt WEAR PLASTIC GLOVES (YJ48C) when handling the solution and boards.

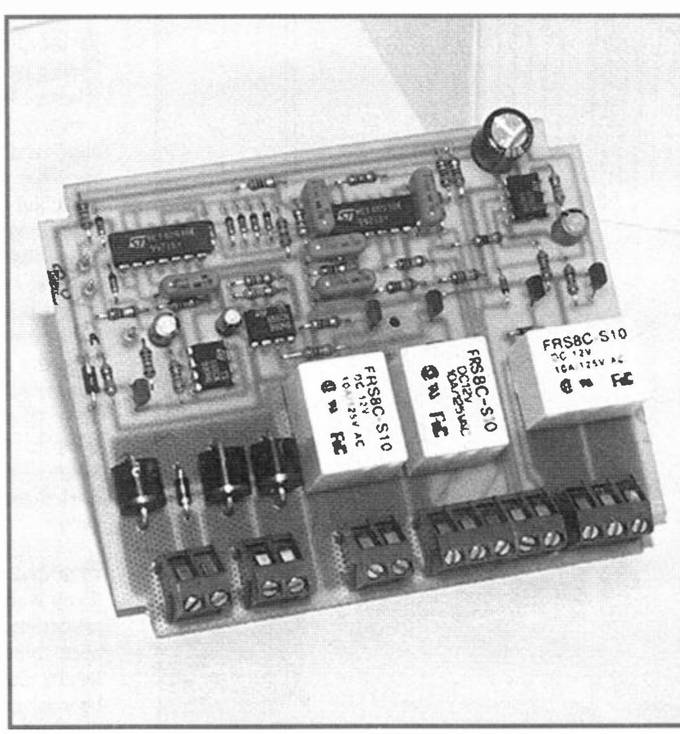
Final Check

When the board has dried, the resist should be closely inspected for flaws, which if left will result in breaks or short circuits in the finished product. Take your time, as this is the last chance you have to correct any errors. Particular attention should be paid to the dust particles which settled during the coating process. Any minor flaws should be retouched prior to the etching stage as follows; tiny dust specks which could bridge tracks can be carefully removed by scraping with a small craft knife. Any areas where the resist has come off can be spotted with a PCB pen (HX02C). A 'Dalo pen' (FP40T) can also be used for this, but may prove too thick for the finer areas. Holding the board at an angle

Below left: The finished PCB, ready to be built up.

Below right: Completed PCB with components mounted.





of 45° away from you with a light reflecting on it makes the task of seeing flaws easier.

Etching the Board

This is the point of no return, as the board must now be etched to remove the unwanted areas of copper. Firstly, two small (2mm) holes should be drilled in a blank section of board near to an edge, to allow it to be suspended in the tank. A quantity of ferric chloride (XX12N – crystals, or WF10L – fluid) suitably diluted, needs to be made up. The etching process can be speeded up by agitating the solution, and the generally accepted method of doing this is to pump air through it using a small air pump (the type used in aquariums is ideal for this). Heating the solution to around 40°C will also considerably speed things up.

I use the Maplin bubble etching tank, comprising of: etch tank (YZ34M), etch tank pump (YZ69A) and etch tank heater (JU66W). The pump forces air through several tiny holes in the bottom of the tank, which not only speeds up the etching process but also gives a more even etch across the board. The above tank may be used with 625 grams ($2^1/_2$ x 250 gram packs) of ferric chloride and 625cc of hot water. Once fully dissolved, the solution is ready for use. If you are using the heater, set the thermostat to maximum (about 40°C) – it takes about 15 minutes to get to operating temperature, when the internal neon will go out. Turning the bubble pump off when the lid of the tank is removed will ensure that no ferric chloride splashes out.

The board is suspended in the etchant on two titanium wires (supplied with the tank), suspended from the lid and hooked through the holes previously drilled. Titanium wire is a MUST as it is not attacked by the ferric chloride. Switch the bubble pump back on and wait. Depending on the strength and temperature of the etchant and the area of copper to be removed, etching will typically take up to 5 minutes with the heater and up to 20 minutes without it, but progress should be periodically checked. Do not leave the board in the etchant for any longer than is necessary as the tracks will start to be 'undercut', i.e., they will be eaten away widthways.

When complete, switch off the bubble pump and heater, and this time definitely wearing plastic gloves (YJ48C), carefully unhook the board from the wires and wash it under running water for 1 minute to remove all traces of etchant. The etchant is reusable until exhausted which means that quite a lot of boards can be made. It should be stored in the etch tank or very carefully transferred into a large glass or plastic jar with lid. I stick a piece of masking tape over the lid of the tank to reduce spillage in case it should be accidentally knocked over.

Drilling the PCB

The last stage in the production of the PCB is to drill the holes for the components, the drills used being typically 0·6 to 1·6mm diameter. If you use glass fibre boards, I recommend the use of the carbide drill bits as they will last ten times longer than the high speed steel (HSS) types. However, use these with extreme caution as they are EXTREMELY FRAGILE and ANY lateral pressure will break them. Remember, they are not carbide-tipped masonry drills, they are solid carbide which is very brittle! At around £3 a go, they are not exactly cheap either. The use of a drill stand and mini drill is desirable for most work of this sort and essential if using the carbide drills. Fortunately, Maplin stock various types in the 'Minicraft' series. The choice is yours, but I suggest spending a little more money and getting the greatest precision you can afford. After all, you will be drilling holes of less than 1mm diameter so any play in the drill shaft bearings will considerably affect the overall size of the hole. Components such as resistors, ICs, diodes and most capacitors require a 0·8mm hole. Rectifiers and large electrolytics require 1·0mm upwards. When using carbide drills, use a slow drill speed and do not be tempted to enlarge a previously-drilled hole as the drill will snatch and break.

That just about completes the operation and the PCB can now be trimmed to size. The remaining resist can be cleaned off with the PCB Cleaner (DM83E) or if preferred, can be left on and soldered through, where it will act as a flux to aid soldering. If cleaned off, clear lacquer or a conformal coating should be applied as soon as possible to prevent oxidisation of the exposed copper. Various coatings are available in (you guessed it) the Maplin Catalogue. Prior to the component build, a last check should be made to ensure that there are no bridges between tracks. Holding the PCB in front of a powerful lamp will enable you to spot any pinholes where the resist was thin, and these can carefully be bridged by flowing a small amount of solder across them. The recommended component build is links first, then small components such as diodes, resistors, ICs, transistors, increasing in physical size to capacitors, connectors and relays. If required, the solder flux can be removed with PCB Cleaner (DM83E) and a protective lacquer coating applied. E

Further Reading

How to Design and Make Your Own PCBs, R. A. Penfold, (WK63T), Price £2.50 *NV*.

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HAMMOND JM 126 – OSC/EOP. DIV/Keyer Board – AMP/Power Supply Board, Mains Transformer – wiring harness, service manual £45, carriage paid, Seon Smyth, 20 Talbot Drive, Glasgow GT13 3RR. Tel: (0141) 959 7466.

HEALTHKIT IM-5284 MULTIMETER. Good condition. Hardly used. £15. Tel: (01923) 236486 (Watford).

SHED CLEAROUT – lots of very cheap components for sale. Send S.A.E. for list to: M. Knight, 10 Daniel Road, Mancetter, Atherstone, Warks. CV9 1PA.

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ELECTRONIC ORGAN CONSTRUCTORS SOCIETY. For details of meetings, Tel: (0181) 902 3390 or write to 87 Oakington Manor Drive, Wembley, Middlesex HA9 6LX.

THE LINCOLN SHORT WAVE CLUB meets every Wednesday night at the City Engineers' Club, Waterside South, Lincoln at 8pm. All welcome. For further details contact Pam, (G4STO) (Secretary) Tel: (01427) 788356.

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: (0181) 699 5732 or Bob Burns G3OOU Tel: (01737) 552170.

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SEEMUG (South East Essex Mac User Group), meet in Southend, every second Monday of each month. For details Tel: Michael Foy (01702) 468062, or e-mail to mac@mikefoy.demon.co.uk.

SOUTHEND & DISTRICT RADIO SOCIETY meets at the Druid Venture Scout Centre, Southend, Essex every Thursday at 8pm. For further details, contact: P.O. Box 88, Rayleigh, Essex SS6 8NZ.

WINCHESTER AMATEUR RADIO CLUB meets on the third Friday of each month. For full programme contact: G4AXO Tel: (01962) 860807.

ULTRASONIC DETECTOR

KIT AVAILABLE (90008) price £39.99 A1

3 PROJECT RATING

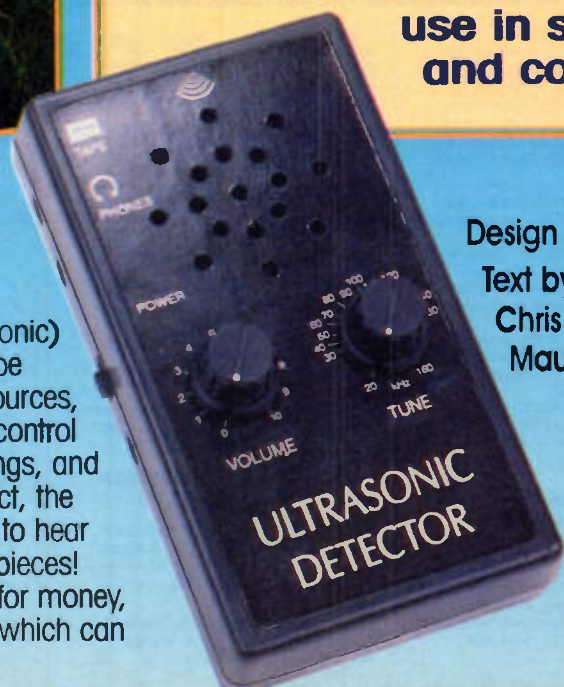
FEATURES

★Tuneable ultrasonic receiver ★High sensitivity ★Low noise ★Built-in loudspeaker ★Outputs for headphones/tape recording ★Internal battery or external power supply input ★Compact and lightweight construction

APPLICATIONS

★Detection and study of Bats ★Detection and location of ultrasonic sources ★Ideal for use in schools and colleges

Build this super-sensitive listening device with a difference, and snoop on the communications between bats and insects that emit high-pitch (ultrasonic) utterances – 'bug' the bugs! May also be used to listen in on other ultrasound sources, enabling checks of alarm and remote control transducers, mechanical system bearings, and as a monitor of noisy equipment. In fact, the unit is so sensitive, that it enables you to hear the crystal vibrating within quartz timepieces! The kit also represents excellent value for money, compared to commercial equivalents, which can cost hundreds of pounds.

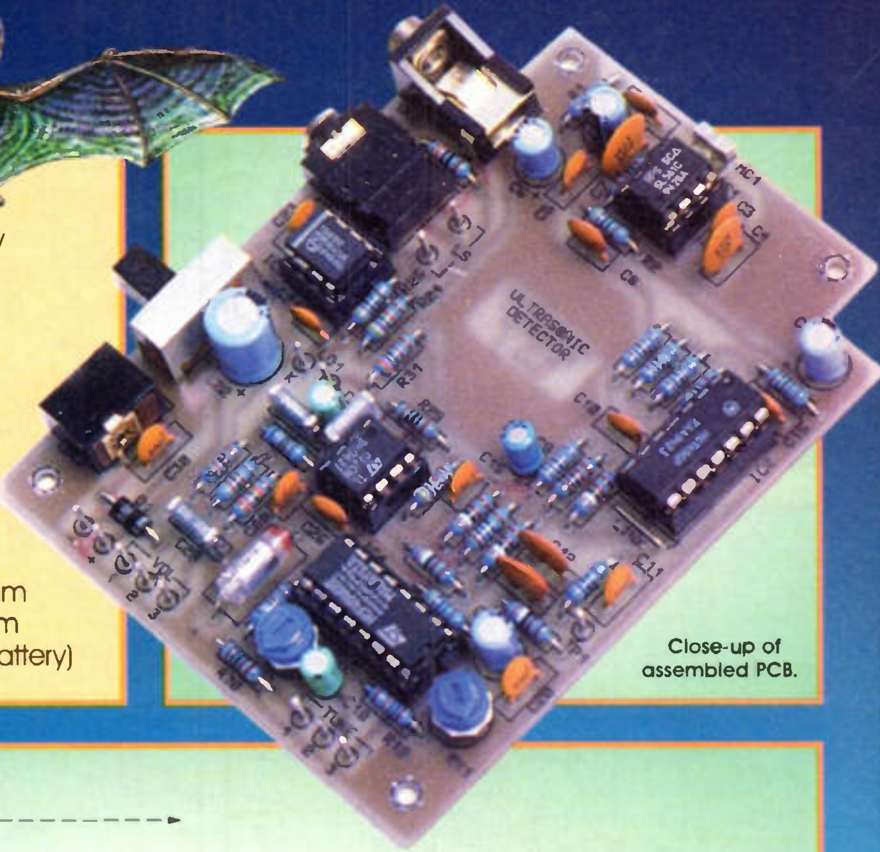


The completed Ultrasonic Detector Unit.

Design by Chris Barlow
Text by Peter Fry, Chris Barlow and Maurice Hunt

Specification

Power supply (internal):	9V DC PP3 battery
Power supply (external):	8V to 11V DC
Supply current:	25mA (min)
	86mA (max)
Frequency range:	20kHz to 160kHz
Loudspeaker amplifier:	382mW rms into 64Ω impedance
Tape output signal level:	20mV rms
Tape output load impedance:	10kΩ
Assembled PCB dimensions:	94 × 73·5 × 17mm
Boxed unit dimensions:	145 × 80 × 34mm
Boxed unit weight:	285g (including battery)



Close-up of assembled PCB.

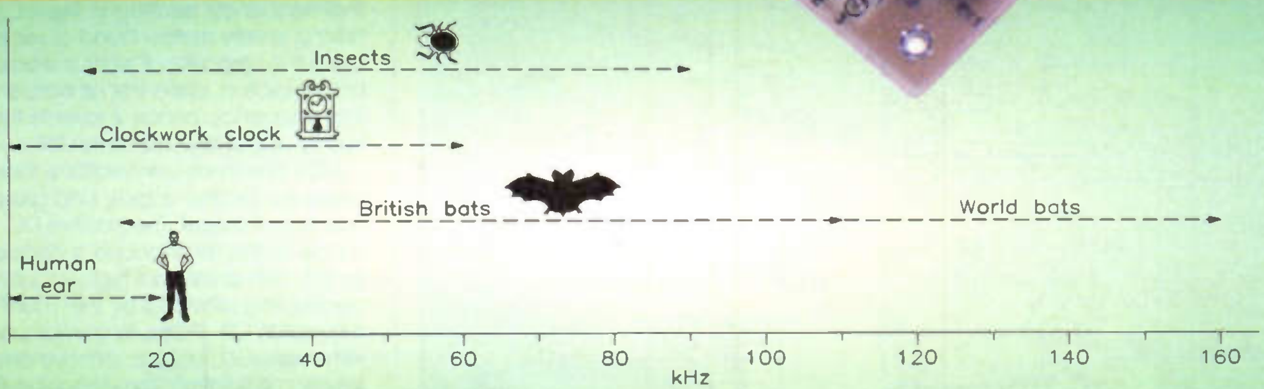
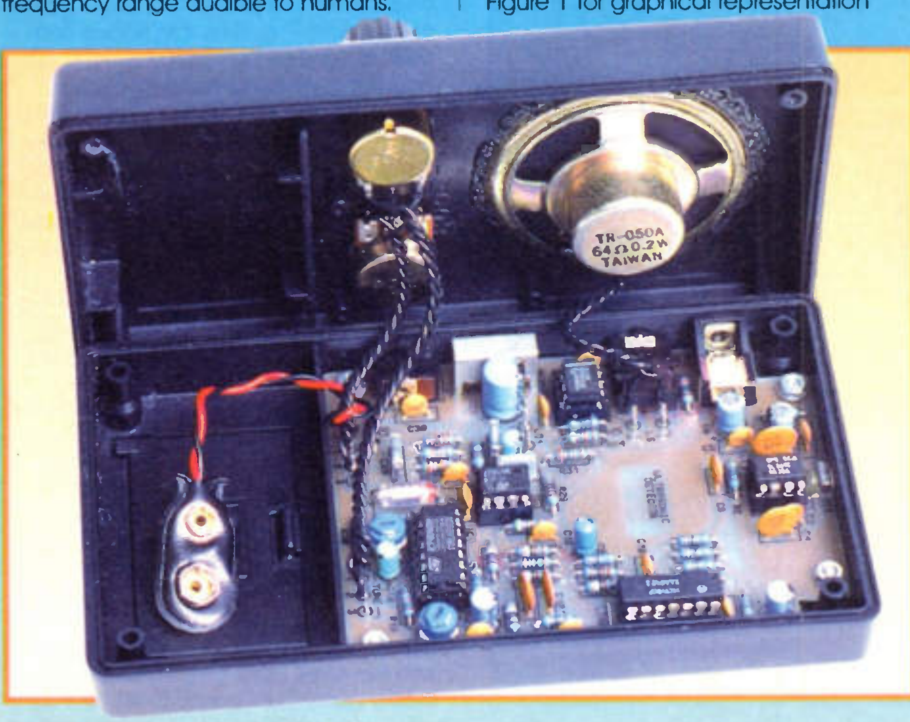


Figure 1. Audio and ultrasonic frequency spectrum.

THIS project has many uses, both for serious applications and amusement purposes, that extend its versatility far beyond that of the originally intended purpose, this being to detect and translate the sound of bats into a frequency range audible to humans.

The unit can convert ultrasonic frequencies across the generous range of 20kHz (beginning of the ultrasonic spectrum) up to 160kHz, catering for all (known!) species of bat, resident both in Britain and across the globe. See Figure 1 for graphical representation of the audible and ultrasonic sound range.

This wide capture range additionally enables many other sources of ultrasound to be translated into audible sound, including obvious sources, for example, ultrasonic intruder alarm and remote control transducers, which operate at around 40kHz, but also some surprising emitters of high-pitched noise, such as quartz crystal-controlled watches and clocks (operating at 32·768kHz), mechanical bearings in motorised appliances, car engines, etc., and 'noisy' electrical appliances, for example, computers, TV sets, and the like, some of which give out quite a din, which makes you thankful that you cannot normally hear them, and also sympathetic to the plight of domestic dogs, who probably can!



Left: The completed unit, installed into the optional box (type HH2).

Circuit Description

Reference to the block diagram shown in Figure 2, and the circuit diagram of Figure 3, will assist with the understanding of the following description, of how the circuit operates. The Ultrasonic Detector employs the direct conversion principle,

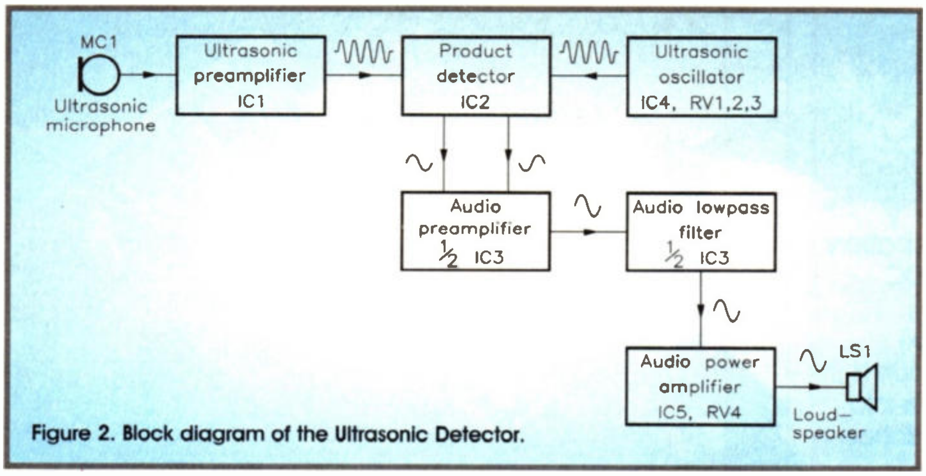


Figure 2. Block diagram of the Ultrasonic Detector.

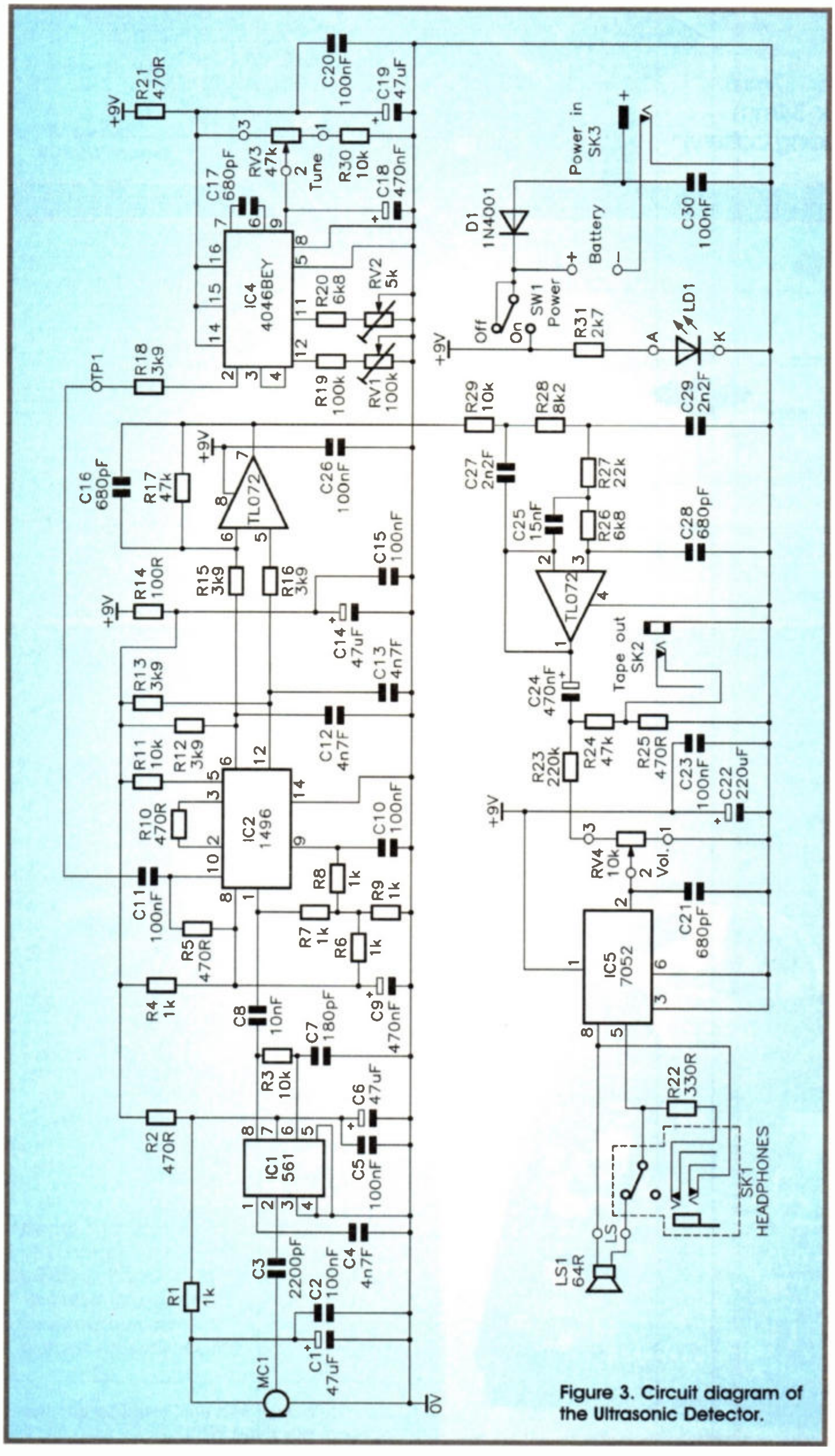


Figure 3. Circuit diagram of the Ultrasonic Detector.

whereby the incoming ultrasonic signal is mixed with a locally-generated ultrasonic carrier of a similar frequency, within a non-linear device. One of the resulting products of this is an audio beat frequency, which is filtered out from the other unwanted mixer products by means of low-pass filtering, prior to being amplified to provide the audio output of the unit.

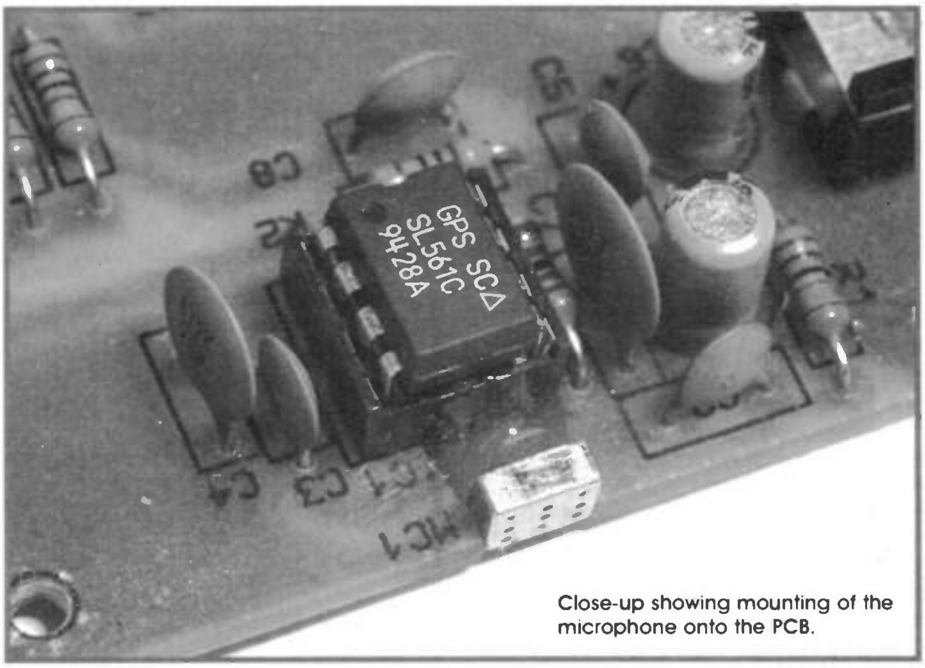
The reason for the excellent range and sensitivity of this unit, is due to the utilisation of a special broadband electret microphone, MC1, which is a subminiature, surface-mount device, originally designed for use in miniature hearing aids, normally specified to operate only over the audio range of 100Hz to 10kHz. However, due to the microphone's high electroacoustical sensitivity, low vibration sensitivity, and flat response, it has an extended frequency range well into the ultrasonic region. Some of the cheaper commercially-available units instead utilise a 40kHz ultrasonic receiver transducer (as used in remote control units, etc.) which only efficiently detects sounds at around that frequency, resulting in the receiver having a very narrow band of reception. This is the opposite of what is wanted for bat detection, since not all bats emit that frequency, hence it restricts the variety of bat one can listen to!

MC1 has three connections, these being the positive supply and ground, and signal output. The positive DC supply to the microphone is decoupled by C1, with additional high-frequency decoupling provided by the 100nF capacitor, C2. These, in combination with resistor R1, help to remove any supply modulation from reaching the microphone, which could otherwise result in amplifier instability. To make the most of this microphone, which incorporates an integral, low-noise FET amplifier, the signals (which may be at very low levels with ultrasound) are further boosted by IC1, an SL561C ultra low-noise preamp. This is power supply decoupled by capacitors C5 and C6, with R2 preventing any supply modulation. The ultrasonic signals from MC1 are fed to the input of IC1 via C3, whose value, along with that of C4, determine the low-frequency response, this being set to attenuate frequencies below 20kHz. The 250kHz upper cut-off frequency of the preamp is set by the value of C7, and the high (45dB) signal gain is set by the value of R3 between pin 6 and the output. The value of C8 was selected to reduce the low-frequency response of this stage. The PCB layout was designed to keep the wiring around this sensitive 'front end' to a minimum, to avoid picking up stray RF signals, else the unit would pick up all manner of whistles, which would be indistinguishable from the audio noise that you want to hear. A large ground plane has also been incorporated, to further reduce RF interference.

The amplified ultrasonic frequency signals are fed to one of the inputs (pin 1) of IC2, a double-balanced mixer, with the other input (pin 10) receiving a locally generated signal, produced by the Voltage Controlled Oscillator (VCO) section of IC4, a 4046BE Phase Locked Loop (PLL) chip. The remaining PLL sections are not actually used, but this IC was chosen for its low current consumption, and relatively stable VCO output, in relation to variances in the supply voltage. Since the frequency emitted by bats is not particularly stable (potentially varying across a 10 to 15kHz range), slight changes in the frequency of the VCO output e.g., battery drainage, etc., are not of concern. The upper and lower frequency limits of the VCO are set by RV1 and RV2, respectively. The tuning control, RV3, sets the DC voltage on pin 9 of the VCO, and together with C17, determines the 20 to 160kHz output frequency.

A stable reference voltage, of +6·3V, is generated by an internal Zener diode, and is available from pin 15 of IC4. This is used to power the oscillator on pin 16, maintaining its stability, and provides the tuning reference voltage to RV3. The current drawn by the Zener diode is limited by R21, while C19 and C20 decouple this 6·3V supply.

The mixer, IC2, produces the sums and differences of the two frequencies applied to pins 1 and 10. The audio output required is the difference frequency between the received ultrasonic signal, and the output of the local oscillator (VCO). IC2 produces two outputs from pins 6 and 12, which are in anti-phase (at 180°) to each other, and which comprise of both ultrasonic and audio frequency signals. The unwanted residual ultrasonic signals are shunted to ground by C13 and C14, leaving only the audio products. These signals (still in anti-phase) are then fed via R15 and R16, into the inverting and non-inverting inputs respectively, of one half of IC3, a low-noise J-FET op amp with a gain set at 22dB, which is used to provide a high level audio signal. The resultant overall gain of the unit is around 60dB. The other half of the op amp is configured as a low-pass filter, set to cut frequencies above 4·5kHz. The translated ultrasonic-to-audio frequency signals are then fed to the volume control, RV4, on the input of the final amplifier stage, comprising of IC5, a TDA7052 1·2W power amplifier, designed for use in low-power battery operated equipment, with a gain fixed internally at 40dB.



Close-up showing mounting of the microphone onto the PCB.

This drives either a 64Ω impedance internal speaker (LS1), chosen for a combination of low power consumption yet good volume, or alternatively, personal stereo-type headphones, via SK1 and R22. The socket is configured to connect the pair of (32Ω) headphones in series, to give a 64Ω impedance, matching that of the internal speaker. Additionally, when the headphones are plugged in, the speaker is automatically switched out. Other types of headphones or earpieces may also be used, their impedance not being critical. Resistor R22 is wired in series with the headphones, to keep their volume down to safe levels. Also provided is SK2, which supplies an attenuated audio output for tape recording, derived from the potential divider formed from R24 and R25.

The main 9V DC supply is provided by a PP3-size battery, although an external DC supply can be applied via SK3, which automatically disconnects the battery from the circuit. This supply may be of between 8 and 11V DC, and

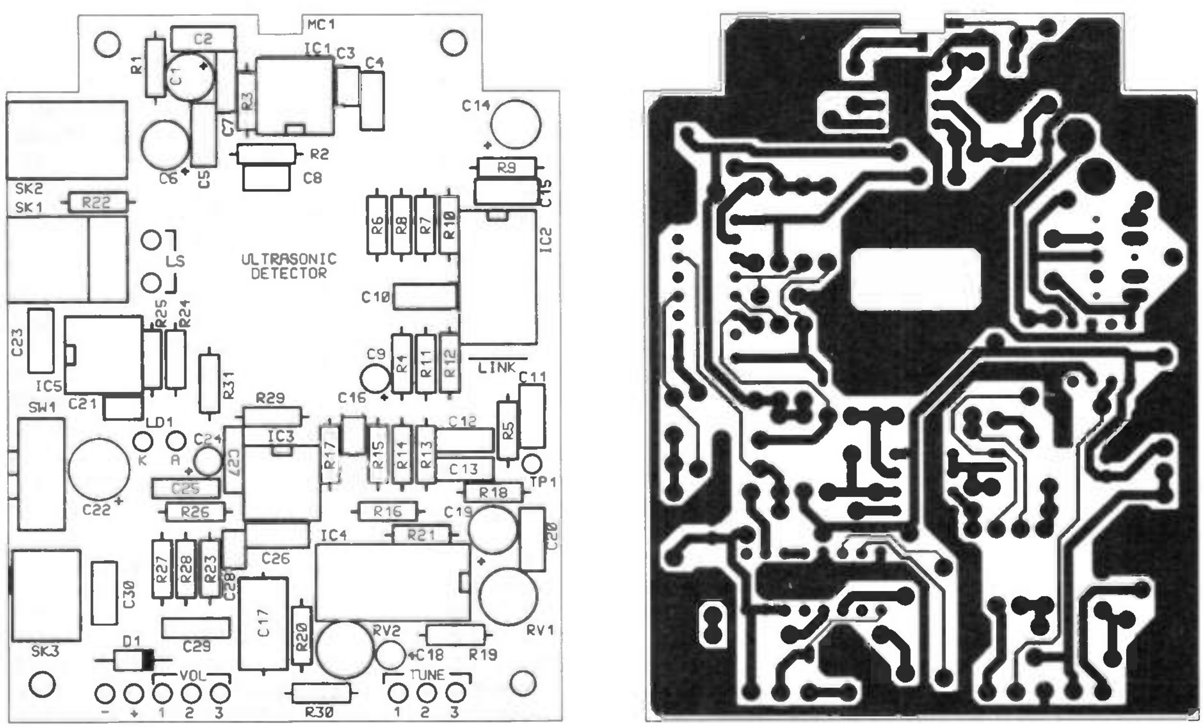


Figure 4. PCB legend and track.

reverse polarity protection is provided by diode D1. Both power sources are switched to the circuit by SW1, and the main supply decoupling is achieved by capacitors C22 and C23. An LED, LD1, is used as a 'power on' indicator. The relatively low power consumption of this unit allows a battery life of several hours on a normal PP3 type, and even longer with alkaline varieties.

PCB Assembly

Reference to the PCB legend and track of Figure 4 will be of assistance when building up the PCB.

Assemble the components in order of ascending component size, commencing with the wire link (formed from a resistor lead off-cut), followed by the resistors, diode and capacitors (observing polarity of the diode and electrolytics), cermet potentiometers, and IC sockets (observing correct orientation of the notch or pin 1 identifier). Next, fit jack sockets SK1 to SK3, and switch SW1, referring to Figure 5 which clarifies their positioning – they must be fitted flush to the board. Leave the fitting of the microphone until the remainder of the components are mounted on the board (with exception of the ICs themselves, which are inserted into their sockets at the final stage of board assembly). The microphone, whose pinout is shown in Figure 6, is an expensive item, and is very small and delicate, so take the utmost care when handling it. This is of extreme importance! However, this device is not static-sensitive, and once it is rigidly mounted on the board, it becomes a rugged and dependable device, designed as it was for a long service life in hearing aids. To assist with holding the microphone in position for soldering, a small quantity of Blu-Tack can be wedged between the body of the microphone and the location cut-out in the PCB, which should then be carefully removed after soldering has been done. Great care must also be exercised when soldering it into its cut-out area on the PCB edge, following the steps shown in Figure 7, since its terminal pads are very small, and may be torn off if the microphone gets knocked after it is soldered in place. For this reason, immediately after soldering its terminals (avoiding excessive heat application), it is vital that the body of the microphone is secured rigidly in position by gluing it to the PCB, filling the void between its body and the socket for IC1, with an epoxy resin glue, as per the last diagram of Figure 7. Be careful not to apply glue to either the front face of the microphone or into the IC socket! In case you were wondering, the area of spare space in the centre of the PCB is there to allow room for the speaker magnet, when it is installed into the casing.

Box Preparation

The Ultrasonic Detector PCB assembly is designed to fit into a hand-held ABS plastic casing, type HH2, chosen for its compact size, and because it is warmer to hold when the unit is used outside in the cold, in comparison to a metal box! Additionally, the RF shielding provided by a metal box is not necessary, since the unit operates well without it, due to careful PCB layout. The HH2 box has five PCB mounting pillars in the lid, with matching (short) self-tapping screws, and the two halves of the box are held together by the four (long) self-tapping screws supplied with it. The mounting pillars are not used, so the short self-tapping screws can be consigned to your spares pot.

Follow the drilling guide depicted by Figure 8, taking care to ensure their correct alignment the first time round! In addition, the unassembled PCB can be used as a template, ensuring it is kept the right way up, since the board is not symmetrical, one side being shorter than the other. Position the PCB mounting holes central to the box, so that the side of the board opposite to where the jack sockets will be mounted is kept tight to the internal side wall of the box. Use the front panel label as a template for drilling the box lid, marking the hole centres by pressing a pointed instrument through the labels' printed hole markings into the lid. Having drilled the holes and cleared them of any swarf, clean the top of the box, ready to take the self-adhesive front panel label shown in Figure 9. Remove the protective backing from the label and push down firmly using a dry, clean cloth, until it is securely in place. Carefully punch through the label in the location of the casing holes, using a pointed instrument. Finally, use some foam padding, for example, foam rubber or the protective acrylic wadding used in the loudspeaker packaging, to prevent the battery from rattling about in its compartment.

Note that the LED does not necessarily have to be positioned adjacent to the 'POWER' script on the front panel label, and you may wish to mount it instead next to the frequency marker that will be used most often, for example, at 40kHz, facilitating easy tuning to this frequency in the dark. Alternatively, you may wish to omit the LED altogether, since it may be distracting when the unit is used in darkness, and may alert the bats to your presence, if they weren't aware already! Another option would be to include an extra switch, so that the LED could be turned off if required, which would also save a few extra mA of battery drain.

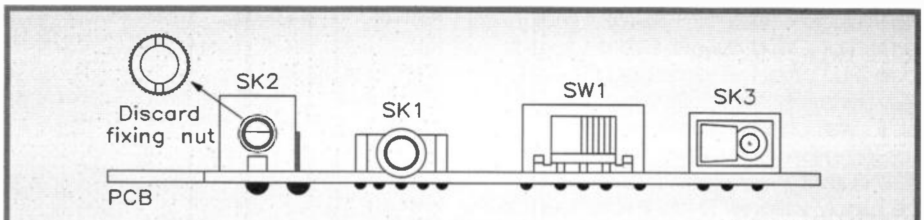


Figure 5. PCB mounting of jack sockets and power switch.

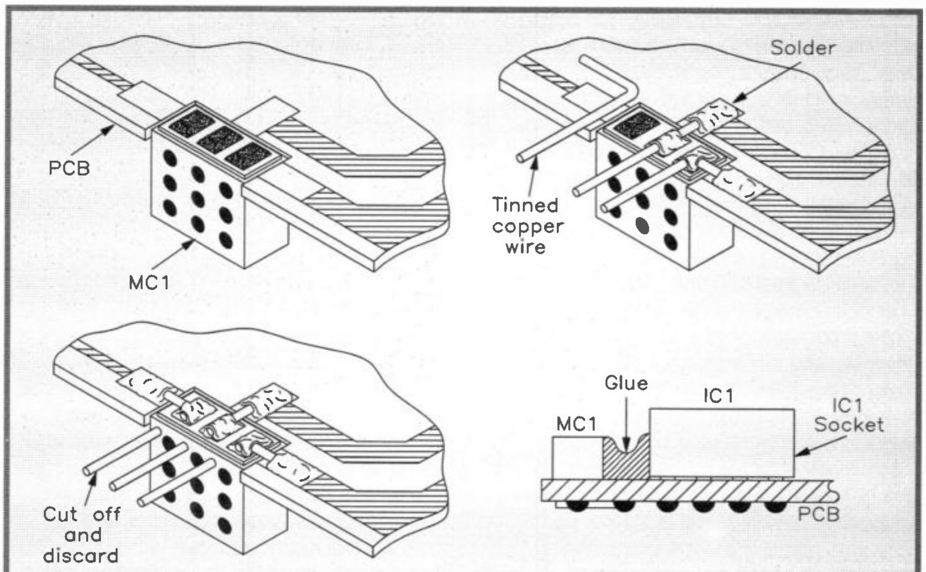


Figure 7. Microphone mounting details.

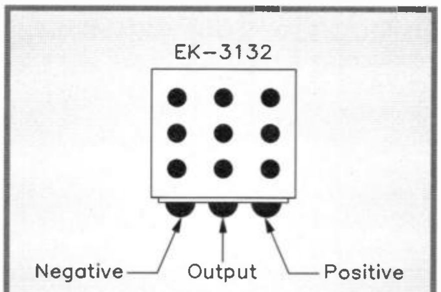


Figure 6. Pinout of the EK-3132 microphone.

Final Assembly

It is highly advisable to test that the circuitry works BEFORE mounting it all into the casing – refer to the section on Testing and Alignment. Prior to wiring to the circuit board, and mounting the volume control (RV4) and tuning control (RV3) to the box, their shafts need to be cut to a length of 13mm to accept the control knobs as supplied with the kit (unless you are using an alternative choice of knob). Clamp the shaft by its end during the cutting, never by the body of the potentiometer. Also remove the locating lug/tag from the body, so that the devices will seat properly. Next, fit the potentiometers into the box, using the washers and fixing nuts supplied. Secure the knobs so that their pointers are at the fully anticlockwise position, and check that they operate smoothly around their travel, without scraping on the front panel. Using a good quality impact adhesive, secure the loudspeaker to the inside of the box lid, taking care not to get any glue on the paper cone of the speaker.

The fiddliest part of the final assembly is installing the completed PCB into the box, since it is a tight fit, and requires raising by means of the 0·125in. M3 spacers, and securing with the M2·5 nuts, 10mm countersunk bolts and shakeproof washers supplied. Figure 10 shows the method of board installation required. Remember to be gentle with the microphone during installation of the PCB into the box.

Wiring

The amount of wiring has been kept to a minimum by using PCB-mounted connectors, switches, jack sockets and microphone, leaving only off-board wiring necessary to the speaker, battery clip, LED, and rotary potentiometers. Follow the wiring diagram of Figure 11 to achieve the correct wire lengths and their placement. The wiring can be twisted together to make it neater, and the battery connector leads can be 'tied' around the tuning control wires to act as a form of strain-relief. Whether the wires are twisted or not has little effect on the stability of the unit.

Testing and Alignment

Before you commence testing the unit, it needs to be set up as follows.

First, ensure that the battery is fresh, then set the PCB preset potentiometers and front panel controls to the following positions:

ON THE PCB: RV1 and RV2 should be set to their half-way positions.

FRONT PANEL CONTROLS: Set the tuning control, RV3, and volume control, RV4, to their fully anticlockwise positions (Tune = 20kHz, Volume = 0).

As a basic test of the completed circuit, DC testing using a multimeter can be carried out, to ensure no short circuits exist before powering up for the first time. The tests involve measuring the resistance between the PP3 battery terminals, in both directions, which should give readings corresponding to those given below. Next, connect just one terminal of the 9V battery, and use the multimeter connected in series between the unused battery terminal and its clip connector, to measure the current drawn by the circuit, which should be approximately equal to the quiescent (minimum) current given in the Specification table (25mA), plus or minus a few mA, depending on whether you have included the power on LED or not. Finally, with the battery connected and the unit on, measure the voltage between ground (0V) and pin 14/15/16 of IC4, which should give a reading of approximately 6·3V. Note that a ground connection can be either of the PCB securing nuts, battery negative PCB pin, or terminal 1 of the volume potentiometer. If any of the readings differ significantly from the stated values, switch off and carry out the usual checks for erroneous connections, solder bridges, etc.

Approximate resistance measurements (using a digital multimeter):

With switch in OFF position: $\infty\Omega$ (infinite resistance),

With switch in ON position, and multimeter leads either way round: $>2k\Omega$

There are three methods of achieving calibration of the instrument's frequency alignment, varing in their degrees of accuracy, as described:

METHOD 1. This is the high accuracy (and hence the preferred) approach, involving the use of a frequency counter to measure the output signal frequency of the Voltage-Controlled Oscillator (VCO) between R18 and C11 (test point TP1 on the PCB), in order that the upper and lower limits of the VCO frequency may be set at 160kHz and 20kHz, respectively. This is achieved by turning

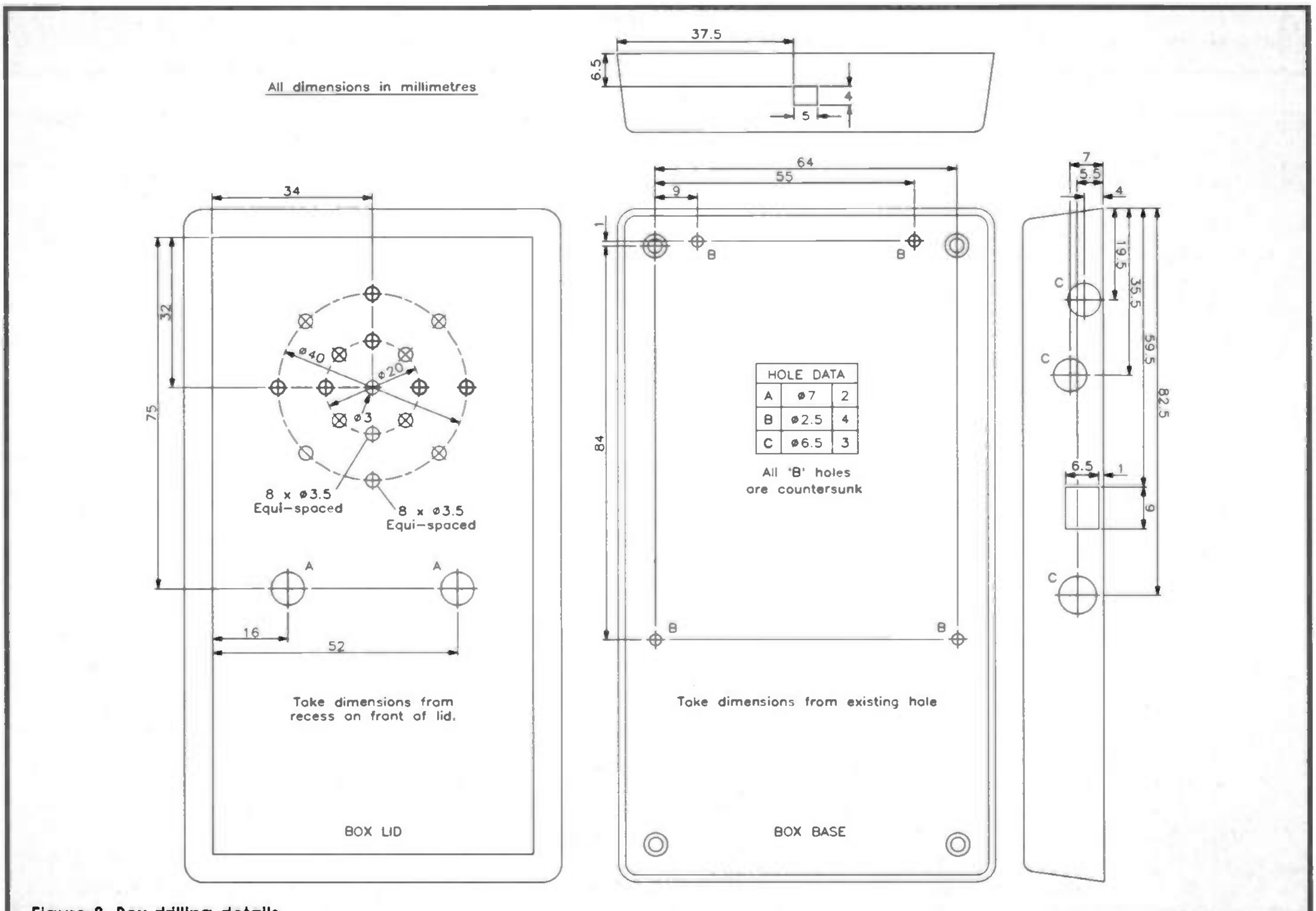


Figure 8. Box drilling details.

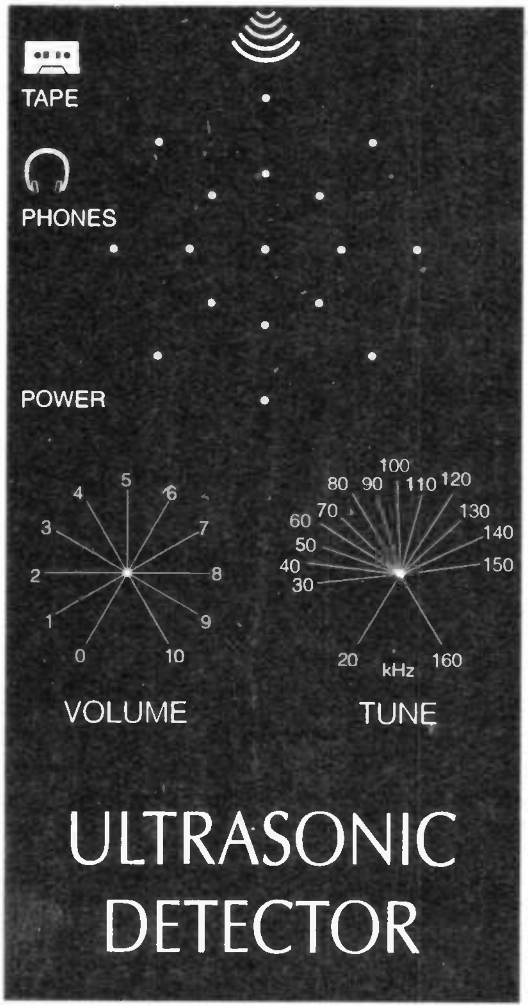
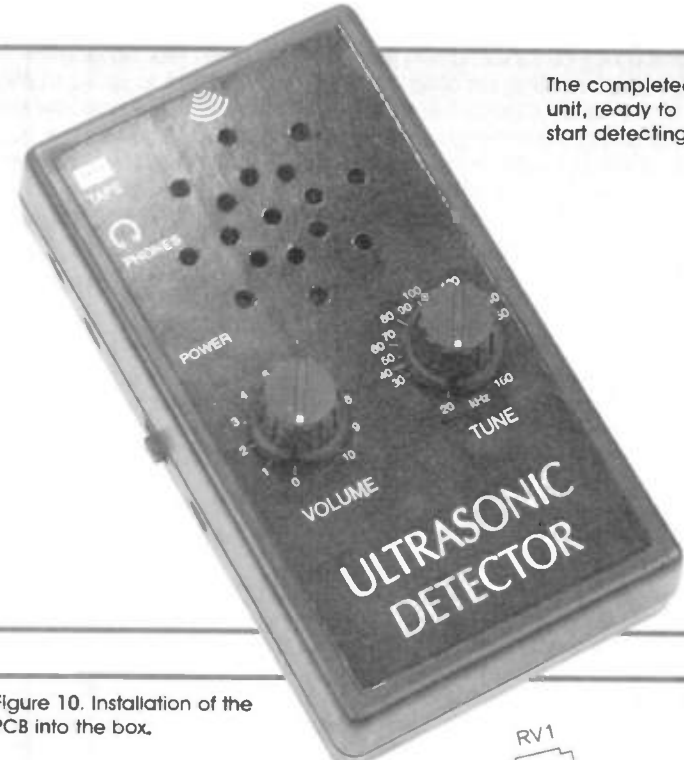
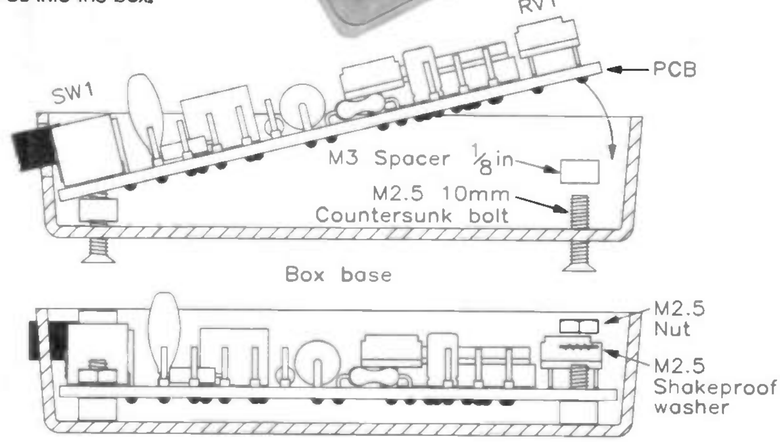


Figure 9. Front panel label.



The completed unit, ready to start detecting!

Figure 10. Installation of the PCB into the box.



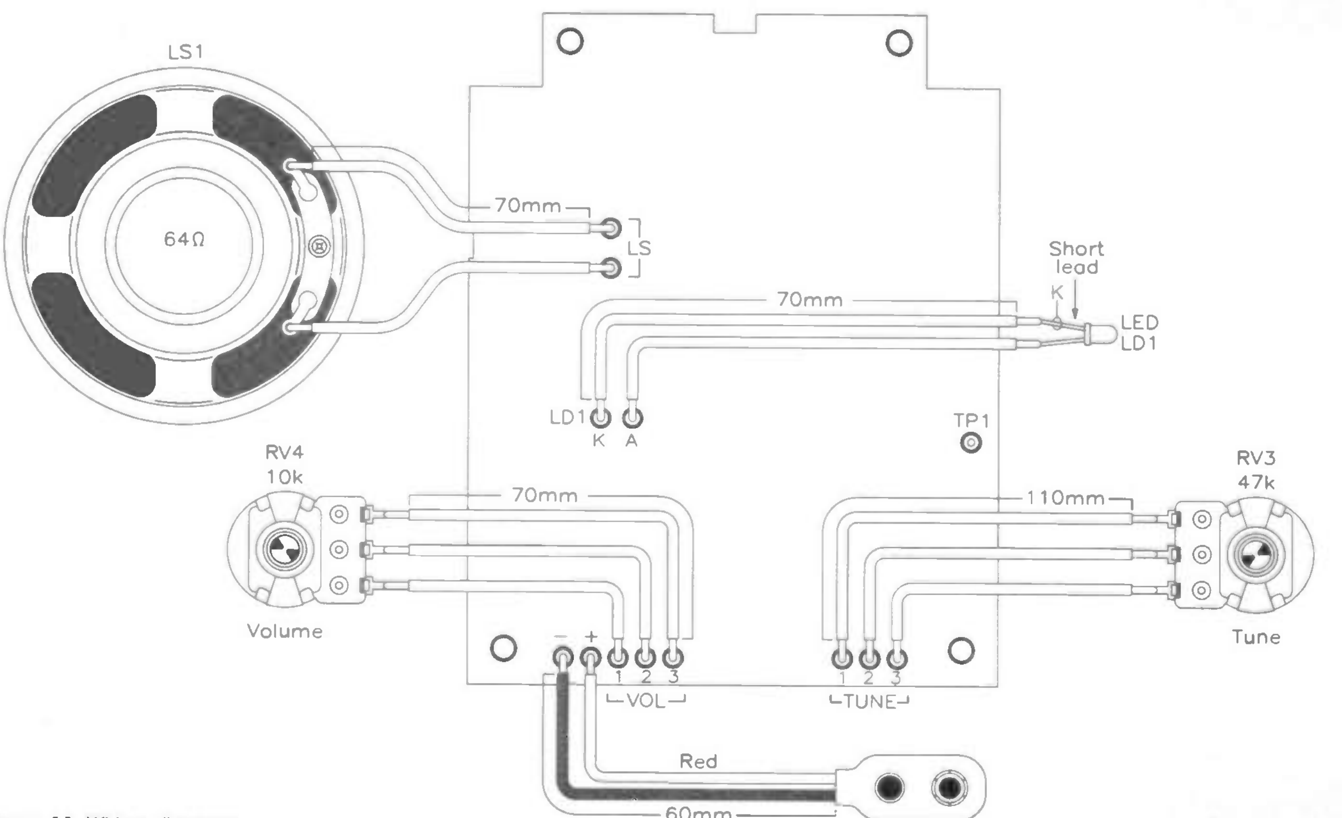


Figure 11. Wiring diagram.

Species	Map regions	Max/min frequency (kHz)	Peak frequency (kHz)	Pulses per second	Intensity	Sweep rate*
Pipistrelle	1 - 11	80 - 45	50	10 - 15	3	Med
Long-eared	1 - 11	70 - 25	40	15 - 25	1	High
Natterers	1 - 11	75 - 35	50	20 - 35	3	High
Daubentons	1 - 11	80 - 35	45	12 - 15	3	High
Whiskered/Brandt	1 - 10	80 - 40	60	10 - 15	3	High
Leislers	1 - 9	45 - 15	25	8 - 10	4	Low
Noctual	3 - 10	45 - 17	25	3 - 10	5	Low
Barbastelle	3 - 8	80 - 25	40	15 - 25	1	High
Serotine	3-5,7	60 - 25	35	7 - 10	4	Med
Lesser Horseshoe	1,3,5,6	110	110	10 - 15	2	CF
Greater Horseshoe	3 - 5	85	85	8 - 10	3	CF

* Abbreviations used in Sweep rate column: Med = Medium, CF = Constant Frequency (no sweep). Note. This table is representative of bats in free flight, as pulses per second increase during insect capture and when the bats are in confined spaces. The last two columns, of intensity and sweep rate, are a guide to the sounds heard using the detector. A high sweep rate will sound like a sharp click, while a low sweep rate will sound more like a hand clap.

Table 1. Bat frequencies.

the main tuning potentiometer, RV3, fully anticlockwise (to the 20kHz marker on the front panel label), and adjusting the trimmer potentiometer, RV1, until the frequency meter gives a reading of 20kHz. Next, turn the main tuning control fully clockwise (to the 160kHz marker on the front panel), and adjust RV2 until the frequency meter reads 160kHz. Now, try various settings of the tuning control, ensuring that the frequency markers on the front panel correlate reasonably closely to the readings of the frequency meter. If so, then the instrument is accurately calibrated.

METHOD 2. This is the medium accuracy approach, to be resorted to if you do not have access to a frequency meter, but do have an oscilloscope to hand. With the oscilloscope input connected to the test point TP1, proceed as per Method 1, but convert the (square wave) trace period (over 1 cycle) into frequency using the relationship: Frequency (Hz) = 1/Period (seconds).

METHOD 3. This is the low accuracy approach, either for basic setting up prior to testing, or for if you have no access to any of the above-mentioned calibration equipment. Simply set the two cermet potentiometers, RV1 and RV2, to their central positions, and this should result in upper and lower VCO frequency limits of around 20kHz and 160kHz. A check can be performed by tuning a long-wave radio to 160kHz on its dial, then, with the tuning control of the Ultrasonic Detector set fully clockwise, and a short aerial wire connected to TP1, bring the unit near to the radio. The radio should emit a blank carrier wave, indicating a VCO frequency of approximately 160kHz, unless the radio has a Beat Frequency Oscillator (BFO), in which case an audio tone would be heard. Additionally, tuning the unit to around 60kHz, and with a short antenna connected to the microphone centre terminal, should allow reception of the Rugby MSF signal (regular bleeps, and a fast code every minute). The cermet potentiometers can be adjusted until this signal is heard with the tuning control set to the 60kHz marker.

Figure 12. Bat population distribution in the British Isles.

Using the Ultrasonic Detector

Turn the volume control to its lowest setting before switching on the unit, particularly if you are listening through headphones. Set the frequency tuning control to either end of its travel, then, with the unit on and volume at a comfortable level, sweep around the tuning dial until an audio note is heard, indicating that an ultrasonic source has been detected. Further fine adjustment of the volume and tuning controls can then be done to procure the best translation sound. The frequency marker adjacent to the knob pointer will indicate the frequency of the source, if the unit has been calibrated correctly.

Note that if used outdoors, treat the unit as you would any precision instrument, and protect it from inclement weather, taking particular care not to get water in the microphone aperture, as this may result in damage to this expensive component. Also avoid dropping or knocking the unit. A carrying pouch (e.g., YN72P) would be useful for storage and carrying of the unit, earphones, spare battery, cassette recorder leads, etc., and would provide protection in bad weather.

It is advisable, in addition to taking a notepad and pen to record notes, to also carry a spare PP3 battery (and headphones if you choose to use them) since a long hike in search of bats could be a frustrating waste of time should you then discover your only battery to be on its last legs! Alternatively, you could use a car battery adaptor (e.g., JY53H), set to give a 9V output, plugged into the power socket. Assuming the bats are to be found nearby an area that is accessible by car, unless you have an off-road vehicle of course. Oh, and don't forget your anorak!

Other Uses

In addition to its main purpose of listening in on bats, the unit has several other applications, described below. If you manage to come up with yet more uses, we would welcome you to write in and share your ideas, which may be of use to others who have built the project!

Leak Finder

The unit could be used to identify leaks in door/window seals in rooms or vehicles, by using an extra piece of equipment, an ultrasound transmitter, to flood the contained volume with ultrasonic sound waves, employing the Ultrasonic Detector to detect waves seeping out through the leaky areas, which would identify seals, etc., that need to be remedied to reduce leakage to a minimum. The ultrasound transmitter could be made from a 555 timer IC astable oscillator, driving an ultrasonic transducer at 40kHz.

Ultrasonic Alarm/Remote Control Transmitter Tester

By tuning the unit to around the 40kHz region, the sound of the transmitter transducers used in some alarm movement detectors, and older-type remote control handsets, could be listened to, to confirm whether they work or not, or to identify flat batteries in the case of remote control transmitters. It would also identify the area of coverage of alarm sensors within a room or vehicle, so that adjustments could be made to optimise the sensitivity and protection that the alarm provides.

Continued on page 42.

This month, we conclude this series on vinyl reproduction and the design of RIAA preamplifiers with a real example of a rather good RIAA equalisation circuit which uses some interesting, unusual and noteworthy design techniques. Firstly though, we must look at a phenomenon which plagues electronic systems of all descriptions, not just audio ones. I am referring, of course, to noise.

by Mike Meechan

A Battle of the Formats – Irretrievably Lost?

PART 3

Noise and the Preamp

In any electrical system, and before we even think about man-made noise or interference, naturally occurring noise is an ever-present evil. It follows, therefore, that the physics of what causes this noise must first be appreciated. Only then can efforts can be made to minimise the effects it might have on an electronic system (such as one intended to amplify, with a great deal of integrity, a low-level signal, and one which may indeed originate from a vinyl record groove). Use of the word 'eliminated' has been avoided here because some noise, as we shall see, is always present. Many forms of noise are naturally occurring, whilst others are synthesised or man-made, as shown in Table 1. Good design techniques, with judicious input filtering, shielding of sensitive areas of the circuit, etc., can just about eliminate the effects of man-made noise. Naturally occurring noise, however, is a different matter altogether.

Noise and Audio

As all music-lovers know, noise in any audio electronics is particularly objectionable, since we can hear it. Noise, and its annoyance factor, is very subjective. The earth might be moving for the manager of *The Thrash Metal Ravers*, as he listens, with blood trickling from his ears, to his prodigies' latest delicate musical offerings. You and I, or the Environmental Protection Agency, on the other hand, might classify it as high-level, highly objectionable noise.

Where very low level signals, high amplification factors, and specific working impedances for optimum performance are required, the problems caused by noise worsen by a very large order of magnitude. More importantly from our point of view, it is the solving of the problems which cause the headaches. It should be obvious that an RIAA preamp falls into every one of the three afore mentioned categories. Moreover, vinyl discs are not inherently robust where good noise performance, sustained over a period of time, is concerned. With this in mind, we shall now look at the mechanics of noise, and what can be done about it. We will then put the theories into practice.

The Physics of Noise

Noise Figure and EIN

Resistors are an integral part of amplifier design and application, and it can be illustrated using statistical mechanics and the laws of thermodynamics that they will contribute noise because of thermal activity. It is a naturally-occurring phenomenon, and is generated irrespective of how perfect the resistor is. Noise *must* be added to any signal dropped across it, irrespective of the quality of the resistor, but dependent on its value.

The coil resistance of a moving magnet cartridge is around 500Ω (although it can be as much as 2kΩ), while that of the moving coil is around a tenth of that, although some have resistances as low as 5Ω. Noise from resistance in series with the amplifier input is generated according to the following equation:

$$\overline{e_n} = \sqrt{(4kTBR)}$$

Where;
e_n = amplifier noise voltage V/$\sqrt{Hz}$
K = Boltzmann's constant ($1{\cdot}38 \times 10^{23}$ J K^{-1})
T = absolute temperature in K, and is typically quoted at room temp (290K)
B = noise bandwidth in Hertz
R = resistance in Ω

The noise voltage is normally quoted in nV/$\sqrt{Hz}$. The value of a 50Ω resistor, with a specified noise bandwidth (B) of 20kHz, is calculated as shown below:

$$\overline{e_n} = \sqrt{4kTBR}$$

$$= \sqrt{4 \times 1{\cdot}38 \times 10^{-23} \times 298 \times 20 \times 10^3 \times 50}$$

$$= 128nV$$

This figure is known as the thermal, or Johnson noise, named after J. B. Johnson, who first explained it in 1928 when he presented his paper, *Thermal Agitation of Electricity in Conductors*. The significance of Johnson noise is that it sets a lower limit on the noise voltage on any signal source or amplifier having resistance. Another naturally-occurring, irreducible form of noise is 'shot noise', which is caused by statistical fluctuations in the current. When referred to the standard reference level of 0·775V (0dBu), noise from a 500Ω resistor (typical moving magnet cartridge resistance) is as follows:

$$20\log\frac{0{\cdot}775}{398\times10^{-23}} = -125{\cdot}8\text{dBu}$$

When the input signal is amplified, so, unfortunately, is the noise, and if the ratio of signal power to noise power is the same at the output of the amplifier as at the input, it is said to be 'noiseless'. With a typical gain of around 45dB from the amplifier, signal-to-noise is typically 81dB. This is the best which can be achieved, and assumes an amplifier which adds no noise of its own. Naturally, this is a practical impossibility. Real amplifiers degrade this ratio by adding their own noise, and this is in addition to any generated by the load resistor at the amplifier input.

The degree of this noise impairment is known as the Noise Figure of the amplifier and is expressed as a ratio in the form:

$$NF=\frac{SIG_{OUTPUT}\times N_{OUTPUT}}{SIG_{INPUT}\times N_{INPUT}}$$

Where NF (dB) = 10log (NF of the power ratio)

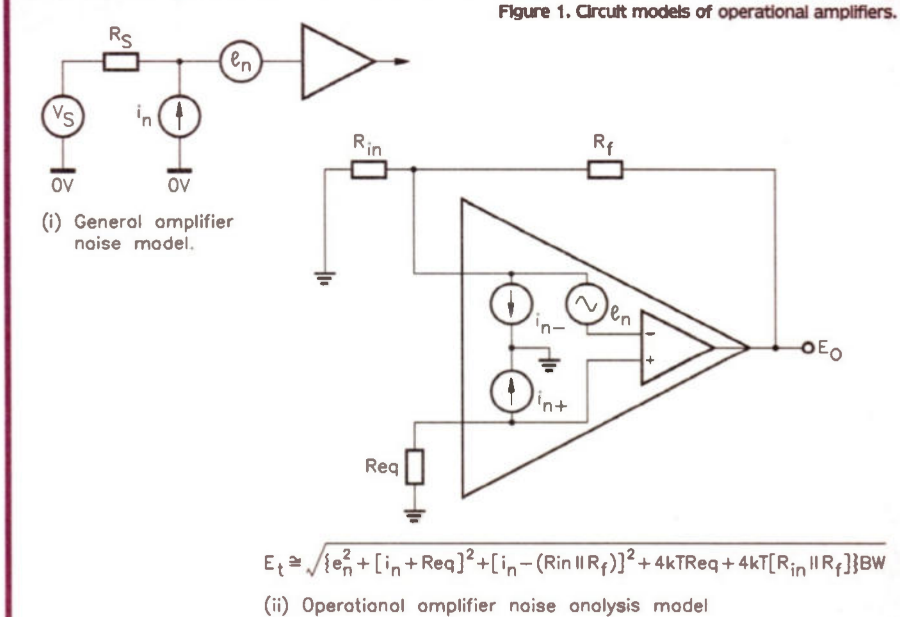
The noise figure could also be described as being the difference in signal-to-noise ratio between the output and the input of the amplifier. These other noise generators are caused by additional noise sources such as 1/f or 'flicker noise', which we will discuss later. In a phono amplifier-type application, keeping the noise figure as near to the theoretical minimum is of paramount importance, since the noise figure is the amount by which the Equivalent Input Noise (EIN) is higher than the thermal noise of a resistor of specified value – or the cartridge – which would normally be connected to the amplifier input. Noise figures of 3dB or less can be assumed to be good, and those of 1dB or less, excellent. It follows, therefore, that EIN is the noise measured at the amplifier output plus the amplifier gain when the input is terminated with a resistor of the nominal value of cartridge impedance. A circuit model is shown in Figure 1.

The noise generators are modelled as a series voltage noise generator, e_n, and as shunt circuit noise generators, i_{n+} and i_{n-}. These generators represent the mean

Source	Nature	Causes	Minimisation Methods
50Hz Mains	Repetitive Interference	Supply lines physically close to op amp inputs. Poor CMRR at 50Hz. Power transformer primary-to-secondary capacitive coupling.	Rerouting of supply wiring. Shielded transformers. Single-point grounding. Battery power.
100Hz ripple	Repetitive Interference	Full-wave rectifier ripple on op amp's supply terminals. Inadequate ripple consideration. Poor PSRR at 100Hz.	Thorough redesign to minimise ripple. RC decoupling at op amp. Battery power.
150Hz	Repetitive EMI	150Hz radiated from saturated 50Hz transformers.	Physical replacing of components. Shielding. Battery power.
Radio stations	AM and FM broadcasts	Aerial action anywhere in the system.	RF Shielding. Output filtering Limited circuit bandwidth.
Relay and switch arcing	High-frequency burst at switching rate	Proximity to amplifier inputs, supply lines, compensation or nulling terminals.	Filtering of HF components. Shielding. Avoidance of earth loops. Arc suppressors at source.
Switching power supply	Repetitive HF glitches in supply and earth	Improper earth return. Radiated noise from switching circuit.	Analogue earth return to AC. Return shield power supply. Liberal power supply bypassing at the op amp.

Table 1. External noise sources.

Figure 1. Circuit models of operational amplifiers.



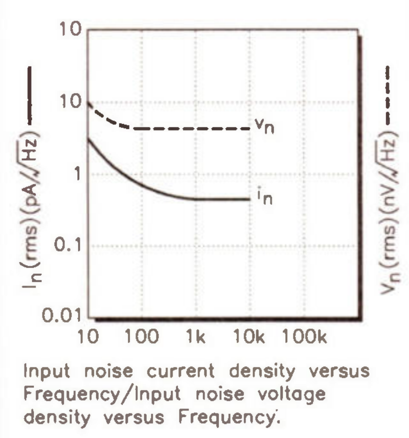


Figure 2. Op amp parameter graph: Input noise characteristics

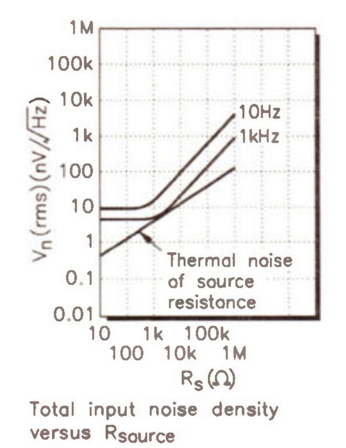


Figure 3. Op amp parameter graph: Total input noise density versus source resistance.

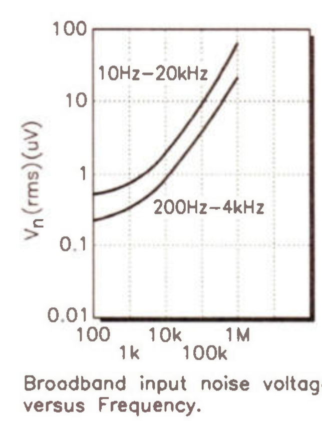
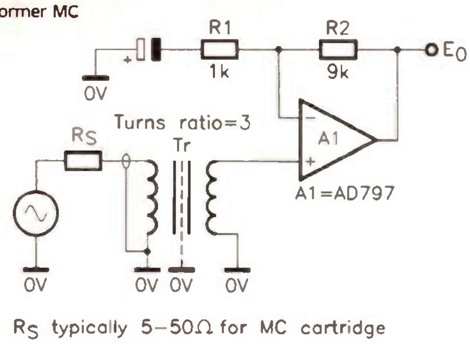


Figure 4. Op amp parameter graph: Broadband input noise versus frequency.

Figure 5. Typical transformer MC cartridge input circuit.



values of voltage and current noise referred to the input of the amplifier. To these noise generators we must add two other noise sources; the thermal noise of the source resistances, R_S, seen by the amplifier, which is R_{EQ}, and $R_{IN}//R_T$. Thus, an amplifier in a real life situation – a phono preamplifier, for example – has five potential sources of noise to be considered for minimising. Firstly, there is the thermal noise of the two source resistances seen by the inputs, which is an irreducible minimum, existing even in an ideal, noiseless amplifier, then there are the noise current and noise voltage generators. For low values of source resistance, the effect of i_n is a minimum, and under these conditions, e_n will dominate as the source of amplifier noise, but as the source resistance is increased, the effect of i_n increases until at high source resistances, $i_{n-}(R_{EQ})$ and i_n $(R_{IN}//R_{EQ})$ are the dominant components of amplifier input noise. When noise sources add, it is not a simple addition of the rms values. Since the noise sources are random and uncorrelated, the sources may add to each other, or cancel one another out, so uncorrelated noise sources add in quadrature.

Thus, in op amp specifications, these two parameters are detailed separately, with e_n specified at low source resistance and i_n specified at high source resistance. Graphs of the important parameters of a typical low noise op amp, the NE5534, a previous audio industry standard, are given in Figures 2, 3 and 4. These curves are given in terms of $e_n/\sqrt{Hz}$ and $i_n/\sqrt{Hz}$, but conversion can be obtained by squaring or extracting the root of the given parameter as appropriate. It follows, therefore, that given values for e_n, i_n and bandwidth, the total noise of the circuit can be approximated as follows:

$$E_n = \sqrt{(e_n^2+[i_{n-}.R_{EQ}]^2+[i_{n-}(R_I//R_f)]^2+4kT[R_I//R_f])BW}$$

Where;
E_T = Total circuit noise
e_n = amplifier noise voltage in $V/\sqrt{Hz}$
i_n = amplifier noise current in $A/\sqrt{Hz}$ (i_n+ or i_{n-})
R_{EQ} and $R_{IN}//R_T$ = source resistances ($R_{EQ} = R_{IN}//R_F$)
K = Boltzmann's constant ($1{\cdot}38 \times 10^{23}$ J/K^{-1})
T = absolute temperature
BW = noise bandwidth in Hertz

From this expression, it is obvious that as e_n and i_n are reduced, the total noise approaches the thermal noise of R_{SOURCE} which will dictate which of the noise generators is dominant and therefore, which specification must be minimised – e_n, or i_n. An absolute minimum of R_{SOURCE} must be used so that R_S is composed largely of generator resistance. Another consideration is that the non-inverting configuration has only half the noise gain of the inverting configuration for equal signal gains, thus offering a distinct advantage in signal to noise ratio.

Where it is possible to control source impedance, the characteristic noise resistance, R_N, of the amplifier may be used to advantage; best noise performance for a given IC is obtained when the source resistance R_S is equal to R_N.

The Use of Transformers in Low Noise Design

Obviously, cartridges have an impedance which cannot be altered, although the impedance of the moving magnet type is high enough that, with the right choice of op amp, it can be amplified directly, with little or no noise degradation. Noise takes on special significance in the design of MC cartridges, since the much lower impedance of the MC type means that such an approach cannot be taken if adequate signal-to-noise ratio is to be maintained, however, there are three accepted solutions to the problem. In the first-mentioned, (which was also the earliest method employed), optimum performance may be obtained by using a transformer with a turns ratio selected to transform the actual source impedance of the cartridge to the noise resistance of the amplifier. However, the transformer has several shortcomings which include cost, distortion at low frequencies, (caused by magnetic nonlinearities in the core which cause saturation) and the inability to handle transients, because of leakage inductance and stray capacitance, which also affects performance at HF. There are further losses from the magnetic properties of the core, and from winding resistance, the latter worsening noise performance because it is, in itself, a source of Johnson noise. Also, the very low level signals present on both the primary and secondary windings of the transformer mean that hum pick up can be a problem, and special, purpose-designed shielding, manufactured from materials such as mumetal, is sometimes used so that noise performance is not impaired. Despite these inherent limitations, transformer coupling is used extensively with moving-coil type cartridges, where 'transformer head preamps' are used. These head preamps match the very low impedance of the MC cartridge to the much higher impedance needed to load the op amp, and also produce the 20 to 30dB of gain necessary of the system. Ortofon, one of the companies who pioneered the manufacture of moving coil type cartridges, use the transformer approach extensively in their head amp designs. A typical transformer MC Input is shown in Figure 5.

Apart from transforming the impedance of the cartridge to the impedance required of the input stage, the transformer must also fulfil certain other important requirements, these being to;

1. Match the source resistance to the characteristic noise resistance of the op amp or transistor so that the best noise performance is attained. This is the case when $R_S = R_N$.
2. Provide some degree of voltage gain for the cartridge input signal.

Refer to Figure 5 and the relevant parts of the op amp specifications, outlined in Table 2.

We have already shown that in order to determine an optimum turns ratio to match a given source resistance, R_{SOURCE}, to the characteristic noise resistance, R_N, of the op amp in the circuit, R_N must be first calculated from the specified data for e_n and i_n, as follows:

$$R_N = \frac{e_n}{i_n}$$

Where e_n is in $V/\sqrt{Hz}$ and i_n is in $A/\sqrt{Hz}$. The turns ratio for T1 may be calculated as:

$$\frac{N_S}{N_P} = \sqrt{\frac{R_N}{R_S}}$$

Model	Conditions	Min	Typ	Max	Units
Dynamic Performance	G = 1,000	110	110		MHz
	G = 100		450		MHz
	G = 10		6		MHz
	V_o = 10V p-p				
	R_{LOAD} = 1kΩ		280		kHz
	R_{LOAD} = 1kΩ	12·5	18		V/μs
Input Voltage Noise	f = 0·1 to 10Hz		50		nV p-p
	f = 10Hz		1·7	2·5	$nV/\sqrt{Hz}$
	f = 1kHz		0·9	1·2	$nV/\sqrt{Hz}$
	f = 1MHz		1·0		μV rms
Input Current Noise	f = 1kHz		2·0		$pA/\sqrt{Hz}$
Total Harmonic Distortion	R_{LOAD} = 2kΩ		–98		dB
	f = 250kHz, 3V rms				
	R_{LOAD} = 600Ω		–110		dB
	f = 20kHz, 7V rms				

Table 2. Specifications of the Analog AD797 operational amplifier.

As a real example, the Analog Devices AD797 op amp is in the vanguard of integrated amplifier packages at the moment, having phenomenally low input noise and distortion characteristics. Values for e_n and i_n for this type give a noise impedance so low that it could almost be used directly as an MC cartridge amplifier, with little or no noise degradation. However, for the sake of this article, we will use it with a transformer (in order that noise is optimised to be as near the theoretical minimum as possible). The values for e_n and i_n are $0{\cdot}9nV/\sqrt{Hz}$ and $1{\cdot}8pA/\sqrt{Hz}$ respectively, therefore:

Since both e_n and i_n will change with frequency, R_N will also change with frequency so that an approximate value for R_N can be used with little error for calculation purposes in broadband amplifiers.

In this example, if R_S is 50Ω, then the turns ratio for T1 will be:

$$R_N = \frac{e_n}{i_n}$$

$$= \frac{0{\cdot}9 \times 10^{-12}}{1{\cdot}8 \times 10^{-9}}$$

$$= 500\Omega$$

$$\frac{N_s}{N_P} = \sqrt{\frac{R_N}{R_S}}$$

$$= \sqrt{\frac{500}{50}}$$

$$= \sqrt{10}$$

$$= 3{\cdot}16$$

A transformer which fulfils this requirement would then be selected for T1 – the transformer, of necessity, would be a shielded type and one suitable for operation in a low-level environment. The equivalent input impedance R_{EQ} seen by the amplifier is thus:

$$\text{Input Impedance } (R_{eq}) = N^2 \times R_{CARTRIDGE}$$

$$= 10 \times 50$$

$$= 500\Omega$$

The use of a transformer allows the input stage to achieve an equivalent input noise (referred to T1 input) that is only fractions of a decibel above the theoretical limit (i.e. very close indeed to the thermal noise of the source resistance). As an example, the thermal noise of a 50Ω resistor in a 20kHz bandwidth at room temperature (normal operating conditions) is:

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

$$= \sqrt{4 \times 1{\cdot}38 \times 10^{-23} \times 298 \times 50 \times 20 \times 10^3}$$

$$= 128nV$$

Thus, using the noise figure of 0·9dB taken from the manufacturer's data, the circuit shown in Figure 5 can be expected to have an input referred noise of 128nV or less with a 50Ω source.

One of the other requirements which we specified, that of gain, is also provided for by the turns ratio of the transformer. This gain can be advantageous in that it is 'noiseless' in the sense that the only source of wide-band noise will be the impedance of the transformer windings. The output voltage from the amplifier can thus be of sufficient magnitude that noise contributions from succeeding stages can effectively be swamped.

For a given circuit gain, A_V, this reduces the gain required of the op amp, A, to:

$$A = \frac{A_V}{N_S/N_P}$$

It follows that the composite gain is the product of the transformer gain (N_S/N_P) and (R1 + R2) / R1. This is advantageous in that it allows more loop gain and so greater accuracy and lower distortion since in practice, almost all of the full unloaded voltage gain of the transformer is realised. This is because it looks into the bootstrapped non-inverting input of the op amp, which has an impedance of many megohms.

Transistor Preamp Stage

The second method is to use transistors, two examples of such preamps being illustrated in Figure 6. The need for a very low value of circuit input impedance, in order to minimise thermal noise effects, can be met because of the much lower characteristic noise resistance or optimum source impedance (OSI) of the transistor, so that it can be used directly to amplify the signal. With transistors, noise voltages and noise currents alter in magnitude, and in ratio to one another. Lower collector current gives rise to lower noise current – not inconceivably, since the current noise is due to minor random discontinuities in the device currents, i.e. shot noise, which adds to the fluctuations caused by noise. The ratio between the two – noise impedance – can therefore be altered. Reference to the noise model of a transistor, shown in Figure 7, will clarify the parameters used in graphs depicted in Figures 8 to 12, which show the various plots of noise figure, current noise and voltage noise against collector current for the Fairchild 2N5087, a typical low noise bipolar transistor.

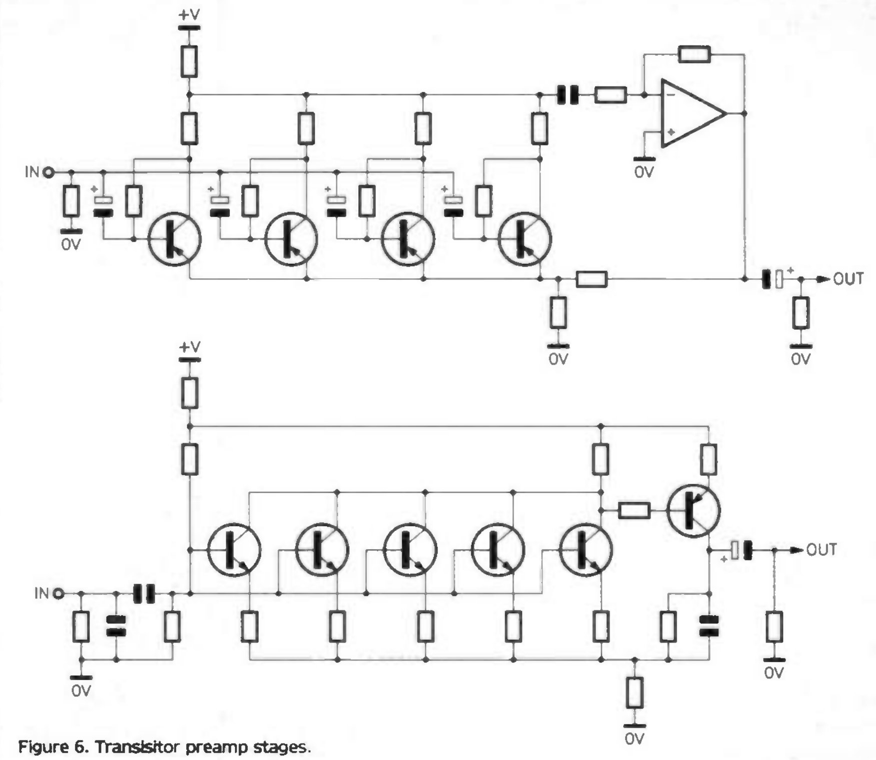


Figure 6. Transistor preamp stages.

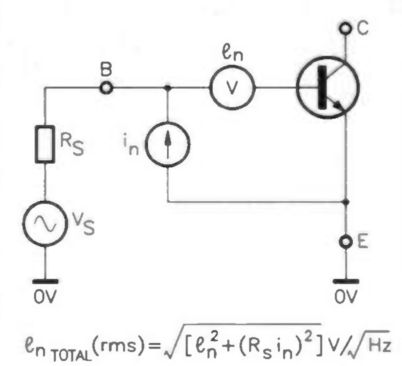


Figure 7. Bipolar transitor noise model.

Somewhat fortuitously, the resistance value at which the device is optimally quiet for audio purposes is also the value which coincides with that required for optimum device transfer characteristics. In other words, there is good frequency versus phase linearity response, and so the device will be stable at high-frequency, and in high feedback-low gain configurations.

With bipolar transistors, the theoretical value for emitter-base voltage noise is a function only of absolute temperature and collector current, in accordance with the formula:

$$e_n = kT\sqrt{\frac{2}{q\,I_c}}$$

This indicates that a reduction in voltage noise, e_n, can be made low in value by increasing collector current. This is indeed borne out in practice – I_C can be increased until a level is reached where parasitic transistor noise limits any further reduction. This noise floor is usually created by and modelled as an equivalent resistor ($r_{bb'}$) – the so-called 'base-spreading resistance' – in series with the base of the transistor. This is, in fact, the

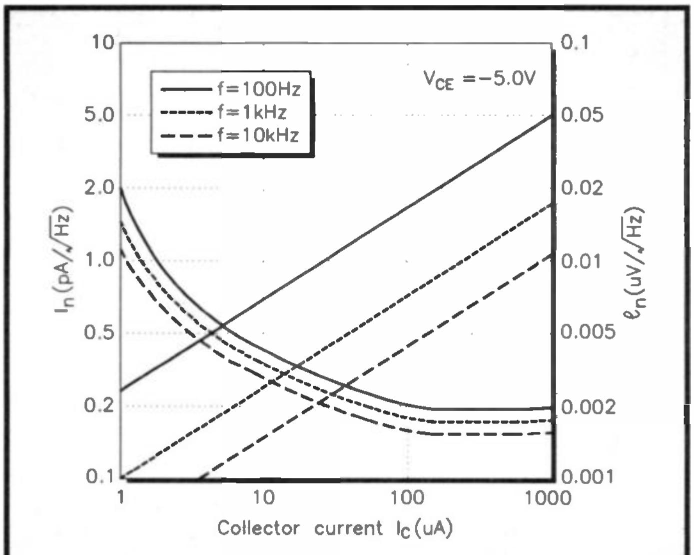


Figure 8. Graph of input noise versus collector current for low noise bipolar translator, 2N5087.

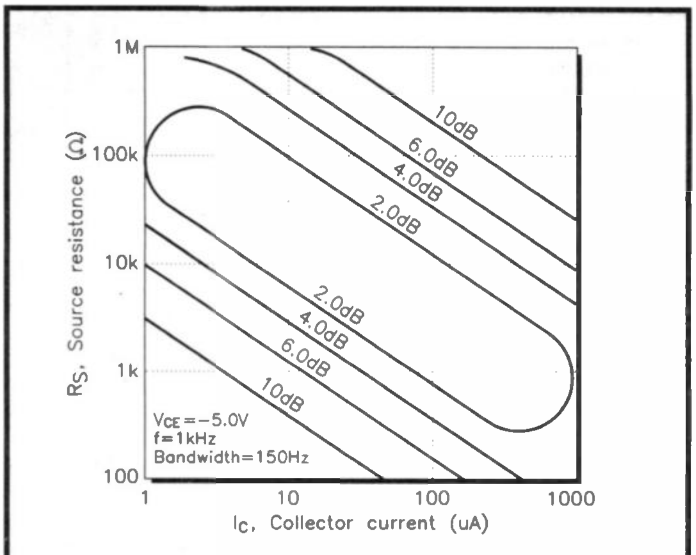


Figure 9. Graph of contours of constant narrowband noise figure for low noise bipolar translator.

real part of h_{ie}. Low parasitic transistor noise is therefore an important factor in ultra-low noise applications.

For finite source impedance, current noise must be considered as a quadrature addition to voltage noise. Shot noise is white noise (equal energies at all frequencies) which worsens with increasing emitter current: see Equation 2 in Table 3. With a super-matched pair, base current noise (i_r) is a well-defined function of collector current and can be expressed as in Equation 5.

Base spreading resistance decreases with increasing emitter current, so thermal noise because of this parasitic resistance decreases also. This gives rise to something of a conflict of interests – low emitter current lessens shot noise but increases thermal noise, because $r_{bb'}$ increases, while higher current lessens the thermal noise effect but worsens shot noise.

To find the collector current which yields the minimum overall equivalent input noise with a given R_S, i.e. a compromise between thermal noise and shot noise, the total noise formula can be differentiated with respect to I_C and set to zero for finding a minimum. For very low R_S (as in the case of a microphone) the $r_{bb'}$ of the transistor must be added to R_S in the calculation.

Referring to the graph of collector current, I_C against e_N and i_N in Graph 1, we can see that the fact that e_N drops and i_N rises, with increasing collector current, means that we have a very simple method of optimising transistor noise for a given operating source impedance. A noiseless source has

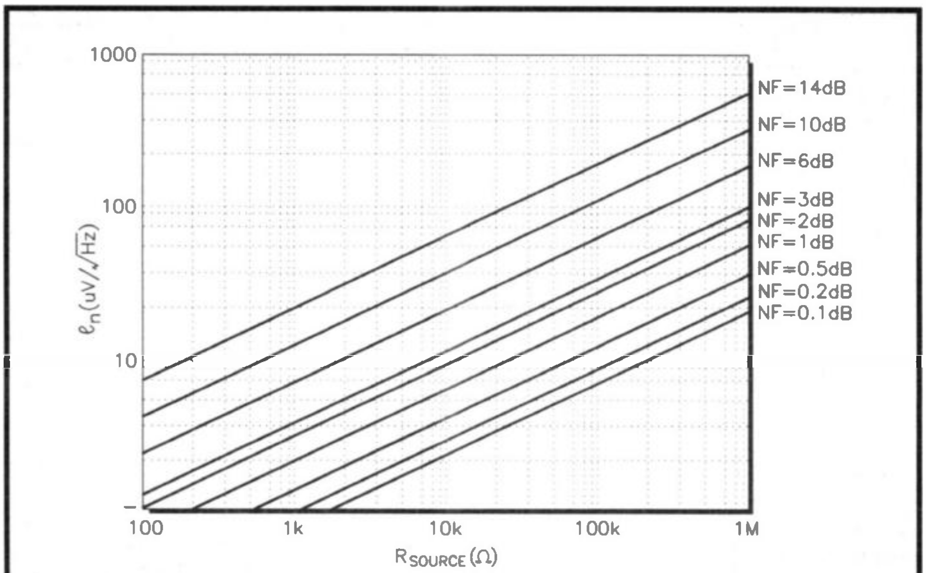


Figure 10. Graph of effective noise volatage versus noise figure and source resistance.

an irreducible source of Johnson noise from the value of its source resistance and the amplifier adds its own noise. Consequently, the amplifier's noise voltage is added to the input signal while its noise current generates a noise voltage across the source impedance. Since, as far as audio frequencies are concerned, the noise is uncorrelated, the square of the values are added. It is the low noise designer's job to pick I_C from the graph of e_N and i_N versus I_C so that the e_N + ($i_N R_S$) term is minimised for a given source resistance in the area of the frequency of interest.

From this graph, we can see that the sum of voltage terms with a 50Ω resistance is minimised for a collector current around 0·5mA. In the interests of lower noise figure, it might be prudent to use a slightly lower I_C, since current noise is reducing at a greater rate than voltage noise is increasing. However, with a low source resistance – 50Ω cartridge – low e_N is more important, so in practice, we in fact run the transistor at a much higher value of collector current than at first seems prudent.

OSI can be brought down in value by reducing the ratio of inherent noise voltages and currents, which in practice is achieved by paralleling identical, low noise, input devices. Noise voltage remains the same but noise current alters, and so proportionately changes the noise impedance. This is because the base spreading resistance of the transistor (which, as far as noise is concerned, adds itself to the source resistance of the cartridge) is reduced by a factor dependent upon the number of devices placed in parallel. Noise is thus reduced by the square root of this paralleling factor.

Furthermore, shot noise (or Schottky noise) contribution can be reduced by main-

Equation 1:	$e^2_{SOURCE} = 4KTR_s$ (V^2/Hz)
Equation 2:	$e^2_{AMPLIFIER} = e_n^2 + (i_n R_s)^2$ (V^2/Hz)
Equation 3:	NOISE FIGURE = $10\log_{10}(1 + \frac{e_n^2 + (i_n R_s)^2}{4KTR_s})$ dB
Equation 4:	$e_n^2 = 4KT_{r_{bb'}} + 2qI_c r_e^2$ $= 4KT_{r_{bb'}} + \frac{2(KT)^2}{qI_c}$ V^2/Hz
Equation 5:	$i_n = \sqrt{\frac{2qI_c}{h_{FE}}}$ A/√H

Table 3. Bipolar transistor amplifier characteristic equations.

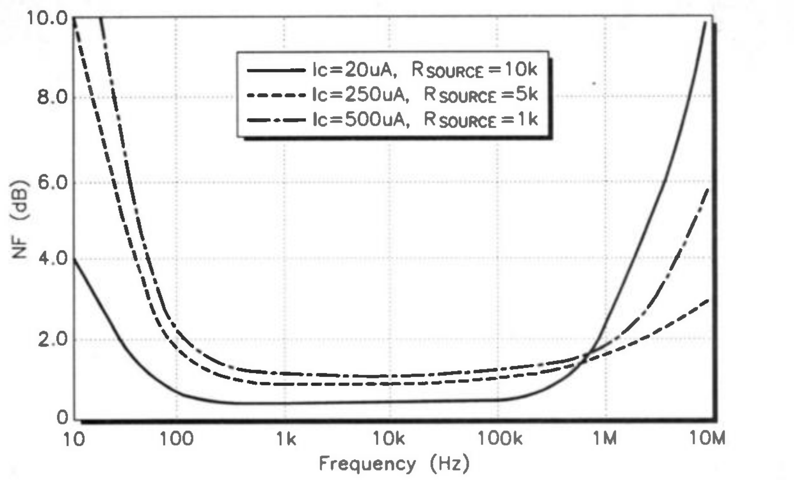


Figure 11. Graph of noise figure versus frequency at different collector currents for 2N5087.

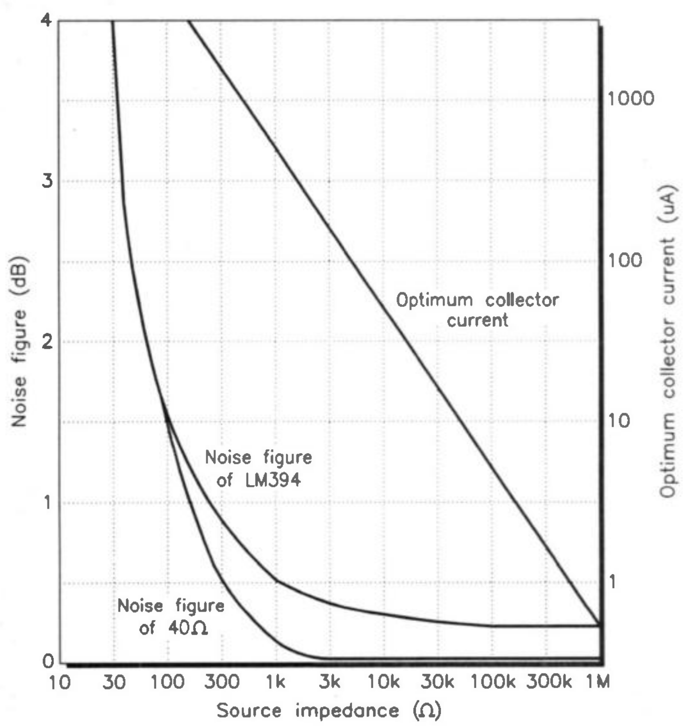


Figure 12. Graph of noise figure versus source impedance for LM394 supermatched pair.

taining a high collector current (which reduces dynamic emitter resistance), while voltage noise is inversely proportional to the square root of stage current. Conversely, current noise increases proportionally to the square root of stage current. Fortunately, high current noise is of less importance when dealing with low impedance sources such as MC cartridges, and optimisation of impedances is not necessary. Designs of this type are marketed by companies such as Braithwaite, Linn/Naim and Ortofon. From a commercial point of view, careful selection and matching of components is a time-consuming – and therefore costly – process. To even out the spread in characteristics of electrically unmatched, but ostensibly identical devices, where there may be differences in the base-emitter turn-on voltage, for example, resistors are sometimes used to create a biasing network. Regrettably, resistors in the collector arm of the circuit mean a loss of some usable signal. Conversely, circuit topologies based around a common base connection between all transistors use individual emitter resistors. This swamps any differences in device characteristics, at the expense of a small but finite addition to the base-spreading resistance of the transistor in question, which in turn, worsens noise performance.

Supermatched Pairs

An ideal way to supplant the use of the transformer in a head amp design is to use what is known as a super-matched pair. This exploits the low-noise-at-low-source-impedance characteristics of the transistor, but without either the attendant selection/matching problem, or the introduction of superfluous and performance-damaging passive component arrays.

Monolithic transistor arrays have been around for a long time, but ultimate performance was compromised, until recently, by statistical fluctuations in the material itself, and in the processing environment. The so-called 'super-matched' transistor differs in that many individual transistors are physically located in a way which tends to average out any residual process or material gradients. This yields a pair which offers order-of-magnitude improvements both in matching properties, and in parasitic base and emitter resistance specifications, since the paralleling of many devices reduces overall $r_{bb'}$ and r_{ee}, which are around 40Ω and 0·4Ω respectively, for packages such as the SSM2220 and the LM394. Such values are considerably smaller than for other small signal transistors. Typical h_{FE} mismatch is 2%, and is valued at 500 minimum when I_C is equal to 1mA. Broadband noise is very low, and the devices have no excess noise at lower current levels.

With supermatched pairs, base current noise is a well-defined function of collector current and can be expressed as:

$$i_n = \sqrt{\frac{2q.I_C}{h_{fe}}}\ A\sqrt{Hz}$$

To find the collector current which yields the minimum overall EIN with a given source resistance, R_S, the total noise formula can be differentiated with respect to I_C and set to zero for finding a minimum.

$$e_{N}^{2} = e_n^2 + (i_n^2.R_s^2) + 4kT.R_s$$

$$(4kT.R_s = \text{noise}^2 \text{ of } R_s)$$

$$= \frac{2K^2.T^2}{q.I_C} + \frac{2q.I_C.R_S}{h_{FE}} + 4kT.R_S$$

$$\frac{d(V_N^2)}{d(I_C)} = \frac{-2k^2.T^2}{q.I_C^2} + \frac{2q.R_S^2}{h_{FE}} = 0$$

$$I_C(\text{optimum}) = \frac{kT}{q} \cdot \frac{\sqrt{h_{FE}}}{R_S}$$

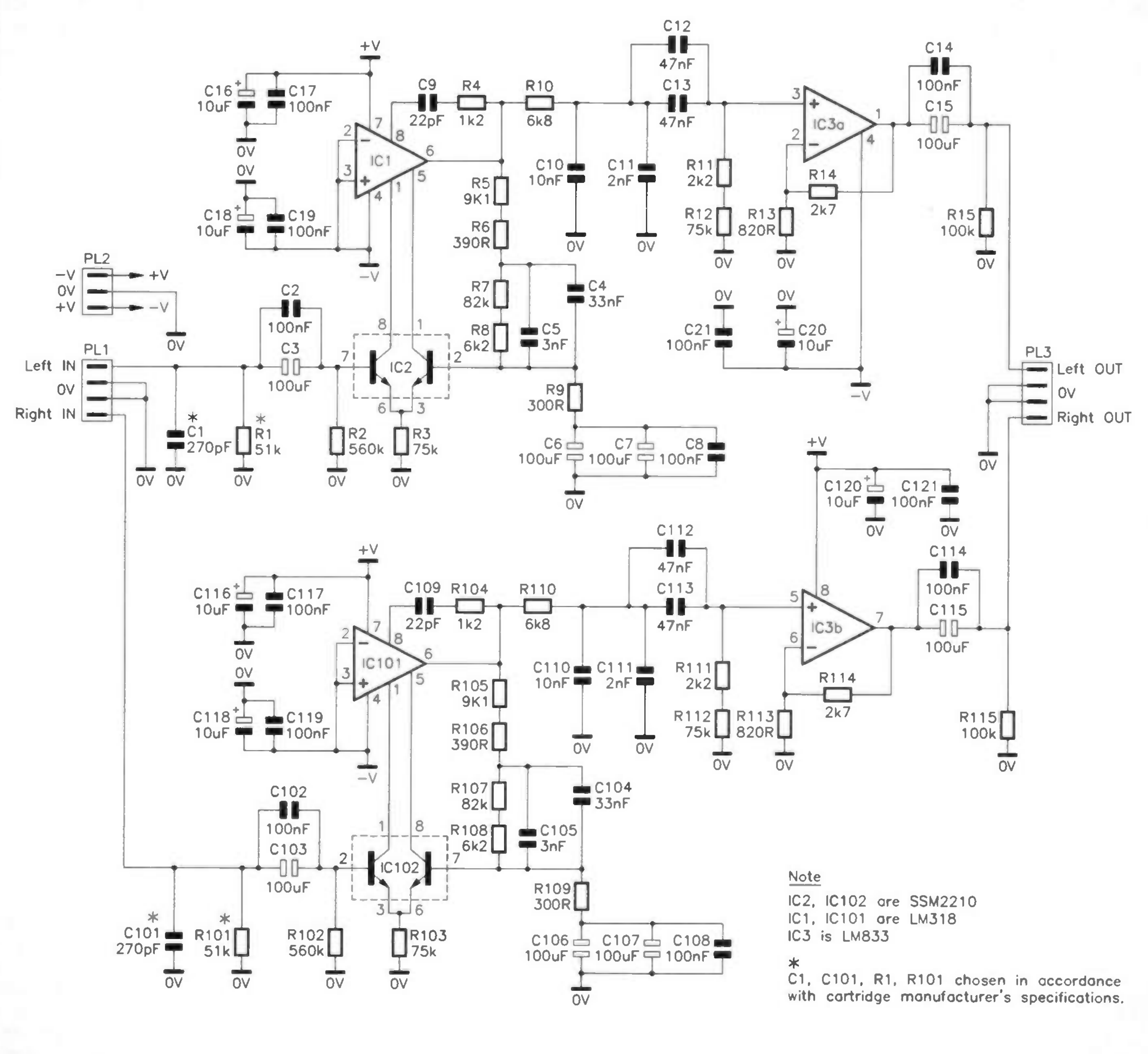
The graph of Noise Figure versus Source Impedance shown in Figure 10 show what all this theory means in practice. Because the curves are shallow, the actual current can be varied over a 3:1 ratio without worsening the noise figure by more than 1dB. The formula does not take into account noise from successive stages, or that which is injected into the amplifier via noisy supply lines. In most cases, the voltage gain of the supermatched pair will swamp second stage effects, but only if the gain from this stage is at least three times $v_{n'}/v_N$ where $v_{n'}$ is the voltage noise of the second stage and v_N is the desired EIN.

Maverick Design

The design featured here uses a somewhat unusual approach. Input is via one half of a super-matched transistor pair. The first input stage of the op amp is shut off and the supermatched pair used in its place. This avoids the loop stability problems which plague designs where stages are added – avoidance of loop instability is of prime importance in a phono preamplifier, where 100% feedback at high frequencies is necessary. The circuit can be configured in one of two ways – as a single-stage design, with all of the gain and equalisation provided for by this single stage (and a somewhat unwished-for unity gain at extreme HF), or as a two stage design, with gain and equalisation split between the two stages.

For ultimate ultra-fidelity performance, the second approach is most definitely the one to follow. It adheres very accurately to the

Figure 13. Circuit diagram of the RIAA preamp.



RIAA (sorry, DIN) curve, rolling off, as the specification prescribes, at 6dB/octave below 20·2Hz and with a gain which asymptotes to zero at the same rate at frequencies above 2,122Hz. Nevertheless, it should not be thought that the single-stage design is inferior in any noticeable aspects, since it possesses an amplitude response of better than 0·1dB accuracy, and excellent noise and distortion performance.

Components used in the equalisation network are necessarily 1% tolerance or better. The only capacitors of this tolerance come from the polypropylene, polystyrene or mica families. Apart from the tolerance aspect, other characteristics of this family of capacitors make them particularly suitable for high quality audio design work. Fine inspection of the circuit diagram (and component overlay) might suggest that the use of smaller capacitances within the design would have made for a correspondingly smaller, more compact design, since polystyrene capacitors larger than say, 10nF, are rather big in stature, and tolerances tend to diminish with increasing capacitance. However, there are other factors which determine the size of the capacitors that we can use in the equalisation network. For good stage noise performance, resistor R7 must be kept at a size which is in the same order of magnitude as the resistance of the cartridge (typically 500Ω to 2kΩ, as we have already said). Since this resistor, in combination with the feedback network, sets the stage gain at any nominal reference frequency, we are further restricted in the size of capacitor which we can use, since small capacitors mean larger resistors (to achieve the same time constant) and so greater overall gain (which might be undesirable).

It is also worthwhile noting that many designs (in manufacturer's application notes, textbooks and commercial designs) use simple, four component-style networks. The time constants specified simply *cannot* be yielded accurately with single, preferred values, and to achieve any type of performance, as regards good amplitude response, requires the use of additional series or parallel elements in the network. For the sake of perhaps two or three extra components, it is difficult to see why this approach is not more widespread. Some of the amplitude errors which inaccurate time-constant values can cause can be corrected by simple tone controls (if these are fitted), whilst others – perhaps in the midrange – cannot. In any case, it is undesirable to have to alter tone control settings when changing from one signal source to the other.

Designed-in Differences

All of the electrolytics used here have been bypassed since improperly-used polarised electrolytics can cause distortion. This is because, despite proper biasing for DC conditions, AC signals can reverse-bias the capacitor and produce distortion. The distortion is caused by the diode effect apparent when the electrolytic is in this condition. Furthermore, inductances internal to the capacitor can become significant at the lower impedances prevalent in solid-state design, to the extent that high-frequency response can be affected because of rising impedance of the capacitor at these frequencies. Bypassing the electrolytic with a lower value, lower equivalent series resistance (ESR), high performance type can help to alleviate some of these attendant problems. If the constructor is able to track down the 'Cerafine' type of electrolytic,

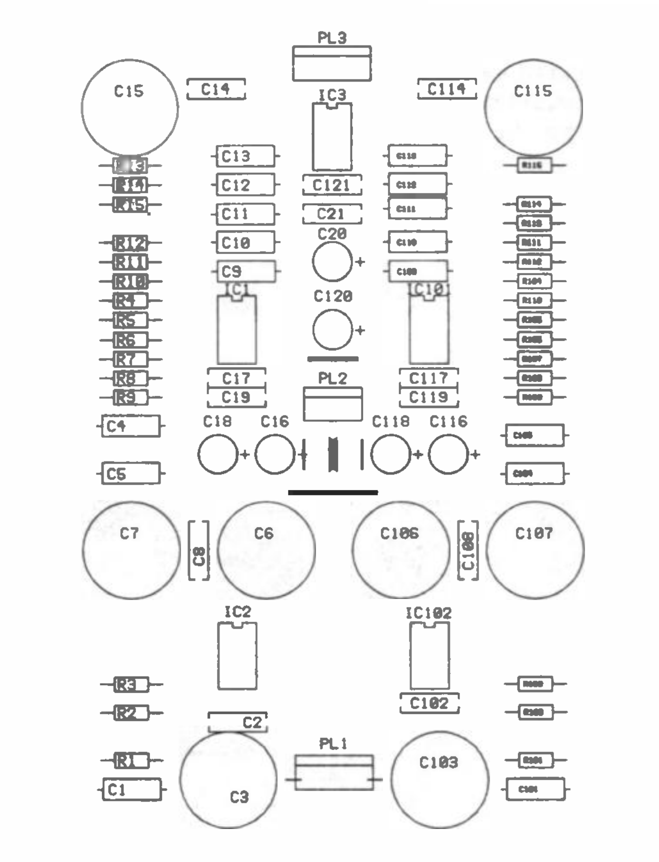


Figure 14. PCB legend.

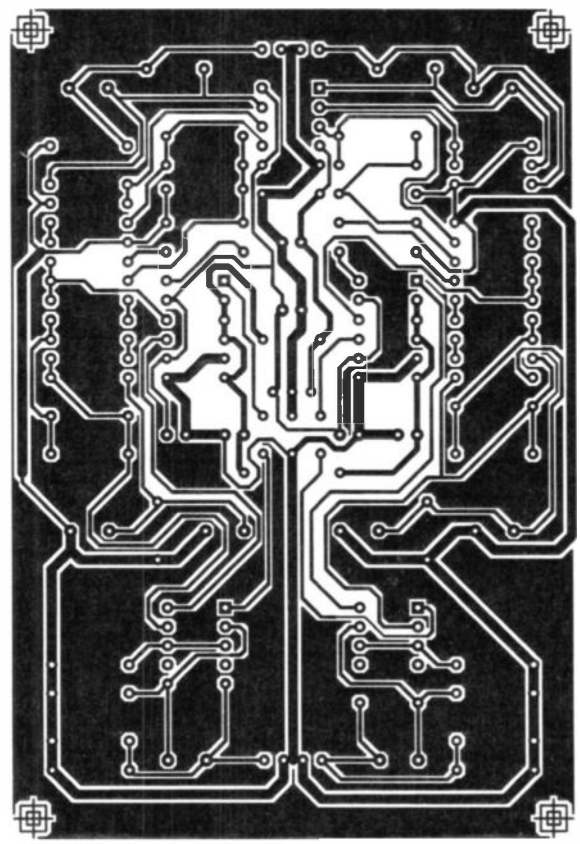


Figure 15. PCB track.

these should be fitted, since this type has an ESR which is typically half that of the traditional electrolytic. If these cannot be sourced, non-polarised types should be fitted in their place.

How It Works – High Performance RIAA (DIN) Phono Equaliser

Refer to the circuit diagram shown in Figure 13 to assist in the description that follows. The moving magnet cartridge is shunted by the 51kΩ resistance of R1 and the 270pF capacitance of C1. These are both arbitrary values and can be altered to suit the particular cartridge being used. C3 provides a DC block, so that no DC from the input circuitry can pass to the cartridge and damage it, while C2 bypasses the electrolytic for reasons given in the main body of text. Rather than be applied directly to the op amp input stage, the signal is applied to one half of the super-matched transistor pair comprised of IC2, with resistor R2 determining the input impedance of this part of the circuit.

The SSM 2210 is similar to the famous LM394 type, but is manufactured by PMI (now a part of the much larger Analog Devices), rather than by National Semiconductor. Its very low base-spreading resistance gives it superlative noise performance of 0·9nV/√Hz, so it is ideally suited to low noise, low distortion audio amplification. The first input stage of the LM318 of IC1 is closed down by tying both of the op amp inputs (inverting and non-inverting) to the negative supply rail. Replacing this stage with the SSM2210 transistors avoids the loop stability problems inherent when stages are cascaded and large amounts of negative feedback are used at high frequencies (as is the case with any RIAA equalisation network).

Two of the breakpoints on the curve are provided by the RC network – comprised of R5-8, and C4 and 5 – enclosed within the feedback loop of the supermatched pair/op amp combination. The first breakpoint, at 3,180µS, is provided by C4//C5 and R7, R8, with the use of two resistors and two capacitors in the parallel network allowing very close agreement between specified and actual breakpoints. The second breakpoint, at 318µS, is provided by C4//C5 and the parallel combination of R7, R8, and R5, R6. Again, the use of more than a single resistor in this leg of the network allows us to adhere closely to the specified breakpoint. Midrange gain (at an arbitrary reference frequency of 1kHz) is set by the ratio of the impedance of the network at this frequency (which equates to R7 + R8) to 8·058 × R9, and equates to 36·5 (approximately 31dB). Capacitors C6 and C7 (which, again, are bypassed by a smaller value capacitor, C8), roll off gain below 3Hz or so, and hence stop any DC or subsonic frequencies present at the op amp input from being amplified and passed to the next stage.

Capacitor-to-resistor ratios are kept such that overly large values of capacitance are avoided, since precision capacitors (close tolerance polystyrene or polypropylene types) are available only in values up to about 47nF (where they are so bulky as to be almost unusable on a compact board such as in the example here).

The third breakpoint, at 75µS, is provided by a passive RC network comprised of C10, C11 and the parallel combination of R10 and R11, R12 (rather than just C10, C11 and R10, as we might first have thought). Because this stage is followed by another network which provides the fourth breakpoint at 7,960µS, resistor values are scaled such that interaction between the two is avoided. In practice, this means at least a 10:1 ratio, with absolute values chosen such that capacitances of C12, C13 and C10, C11 translate to sensible values (i.e. not too large or too small). Interaction of components for this breakpoint include R10, which must be added to the R11 and R12 values before the total is combined with C12//C13 to form the 7,960µS breakpoint.

The use of a passive network to generate the 2,122Hz breakpoint means that stage gain can asymptote to zero at some infinitesimally-high frequency, rather than to unity, as is usual with series feedback arrangements. Fidelity at high frequencies is thus assured in this design. IC3 provides the final gain (4·2, or approximately 13dB) which brings a cartridge input signal in the order of 3·5 to 4mV up to a standard 775mV at the output.

Construction

Construction is straightforward, but will be made easier still by referring to the PCB legend and track, given in Figures 14 and 15, respectively. Components are inserted and soldered in order of ascending size, with resistors and wire links first, followed by IC sockets and small capacitors. R1 and C1 can be left as they are or altered in value as per the cartridge manufacturer's instructions/specifications. Move on to the bulkier types – large value polystyrene and radial electrolytics – ensuring, of course, that polarity conscious types are inserted correctly with regard to orientation, and finish with the right-angled PCB plug. This can be dispensed with, and replaced by Veropins if the constructor so desires. None of the ICs

Continued on page 35.

DATA FILE

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

1 PROJECT RATING

HT2860 Siren Sound Generator

Above: Close-up of assembled PCB. Right: A selection of siren-rated modules.

Design by Tony Bricknell

Text by Robin Hall and Tony Bricknell

FEATURES

* Single Power Supply 2·4V to 4·5V
* Low stand-by current (1μA typically at 3V)
* Auto power-off
* Six different sounds
* Variable pitch control
* Speaker or piezo sounder outputs
* Current limited LED output

APPLICATIONS

* Source sounds for security devices
* For use in model toys
* For use in local alarm systems

KIT AVAILABLE (90011) PRICE £6.99

THE HT2860 is a CMOS LSI IC capable of six different alarm sounds. The IC is specially designed for sound effect applications. Each of the six sounds can be either played independently by triggering one of the key inputs (K1 to K6), or can be cascaded, according to the key priorities (K1 to K6 from high to low) by triggering more than one key simultaneously. The device can directly drive a piezo transducer connected to pins 17 and 18 (PIEZO), or a loudspeaker driven through a driver transistor connected to pin 17 (SPKR). Additionally, pin 4 can source enough current to drive an LED via a suitable series resistor, (R1 on the PCB). The information given in this article should be enough to allow you to tailor the specially designed PCB for any task within the device's specification. The applications for the HT2860, as described, are mainly in the context of providing source sounds for security devices or model projects.

The HT2860 Siren Sound Generator

IC1 is the heart of the project a custom designed 18-pin DIL IC with six digitally recorded sounds. Figure 1 illustrates the Siren Sound Generator block diagram, which mainly consists of the internal block diagram of the HT2860 IC. Referring to Figure 2, which shows the Siren Sound Generator circuit diagram, RV1, R2 and R3 control the speed of the internal oscillator and, therefore also the pitch of the replayed sounds. R1 provides current limiting to the pulsed LED output of IC1. This output is only active when the IC is actually replaying sounds. The output of IC1 is available at two pins labelled PIEZO (shown on the PCB legend in Figure 3). It is possible to connect a piezo sounder directly to these pins. However, if a louder output is required, a loudspeaker may be attached to the pins marked SPKR. This output is buffered and driven by TR1. Alternatively, you may wish to attach the piezo sounder to the pins marked 'SPKR'. This will produce a slightly quieter output than connecting the piezo directly to the pins 'PIEZO'.

Pin Connections

The pinout connections for the HT2860 are shown in Table 1.

Table 2. details the electrical characteristics of the HT2860 with the absolute

maximum ratings shown in Table 3. The supply voltage to the HT2860 must not exceed 4·5V.

A trigger voltage (2·4 to 4·5V) the same potential as the supply to IC1 must be applied to pins K1 to K6 for the required siren sound or sounds.

Alternatively, fitting IC2 with R6 through to R11 onto the PCB will allow a voltage of 4 to 15V to be applied to pins A to F on IC2. This will select the same sounds as pins K1 to K6 respectively, but without damaging the IC1, see Table 4 for both options.

Construction

Construction is fairly straightforward, refer to the Parts List, and Figure 3 for the PCB legend and track. Begin with the smallest components first, working up in size to the largest. Fit the wirelinks from the offcuts obtained from the resistors, insert the PCB pins from the track side, be careful to correctly orientate the polarised devices, i.e.

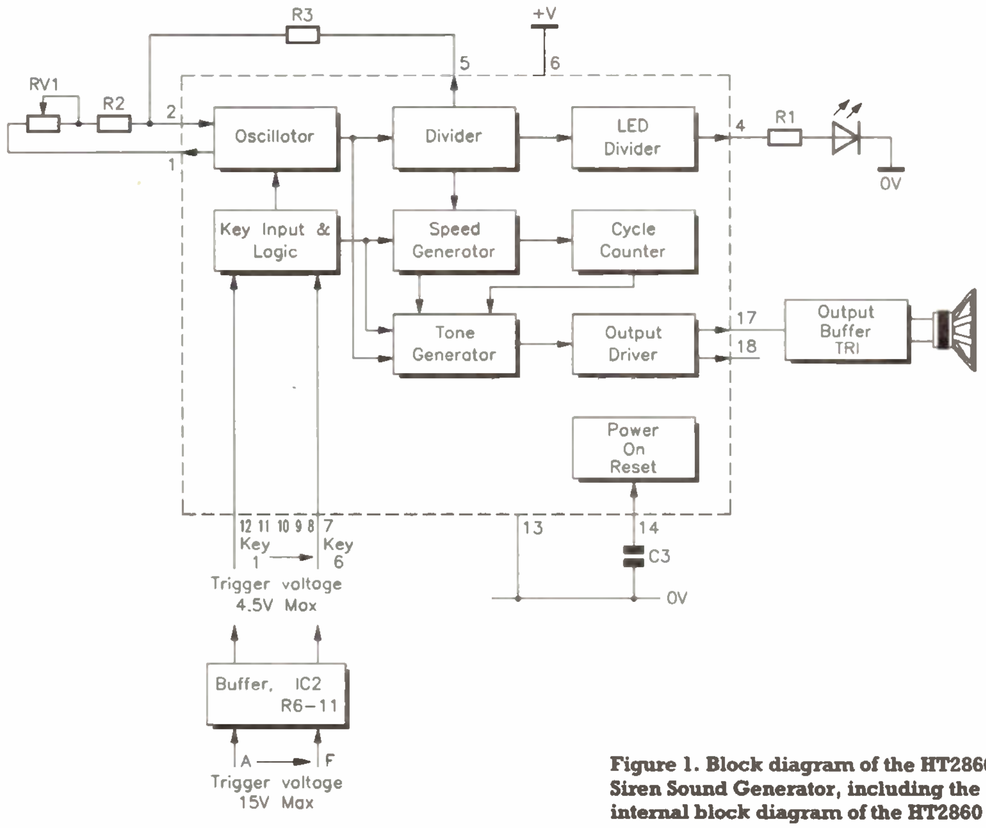


Figure 1. Block diagram of the HT2860 Siren Sound Generator, including the internal block diagram of the HT2860 IC.

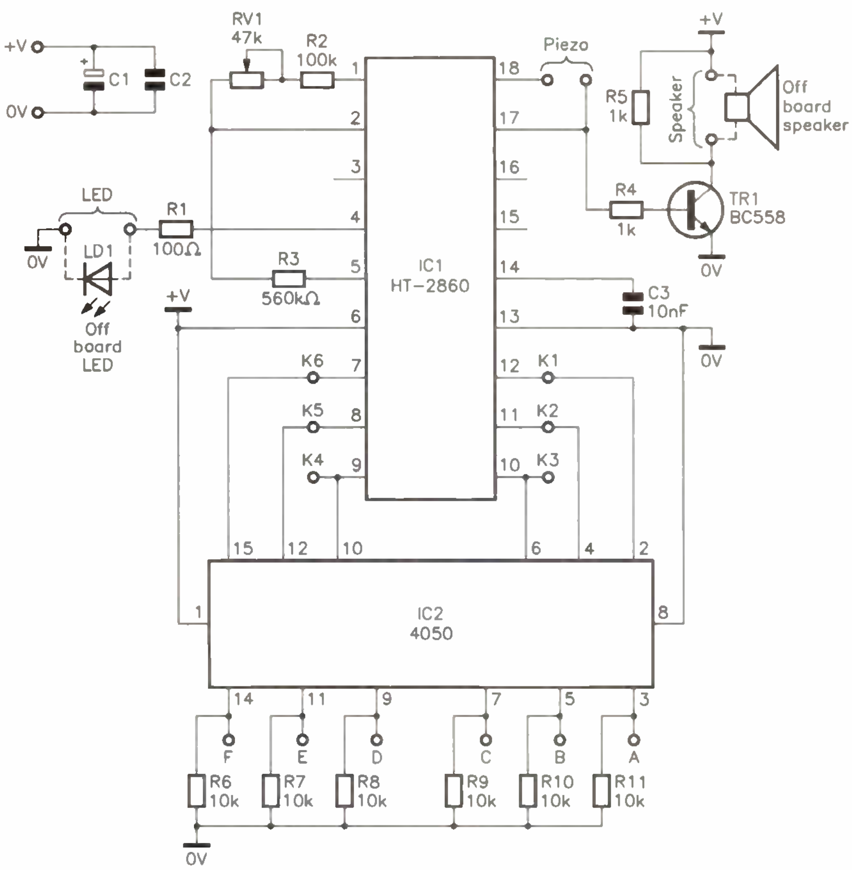


Figure 2. Circuit diagram of the HT2860 Siren Sound Generator.

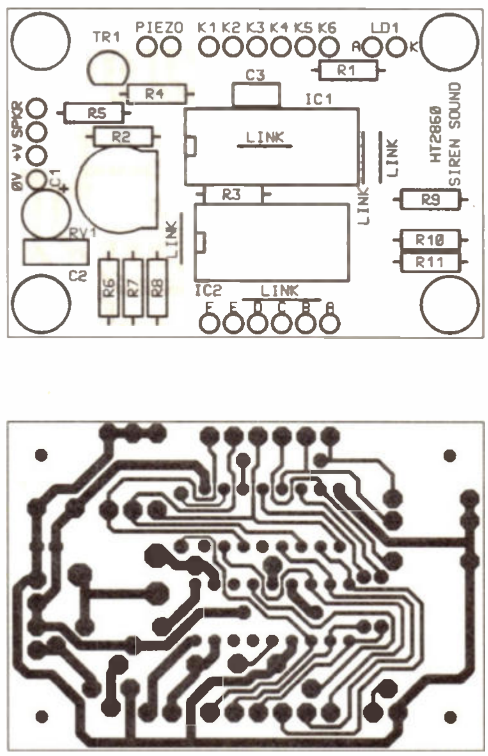


Figure 3. PCB legend and track.

Figure 4a. Wiring diagram for PSU connections.
Figure 4b. Wiring diagram for I/P trigger configurations.
Figure 4c. Wiring diagram for O/P sound configurations.

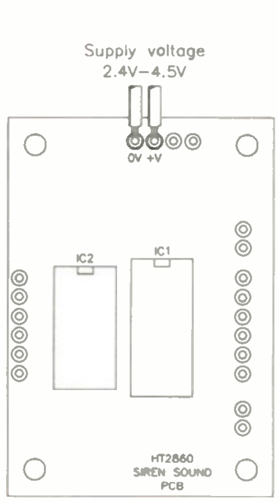


Figure 4a.

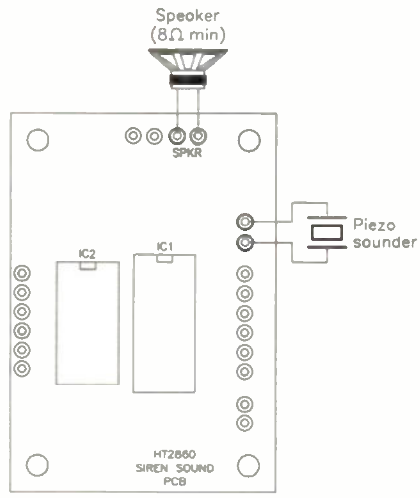


Figure 4c.

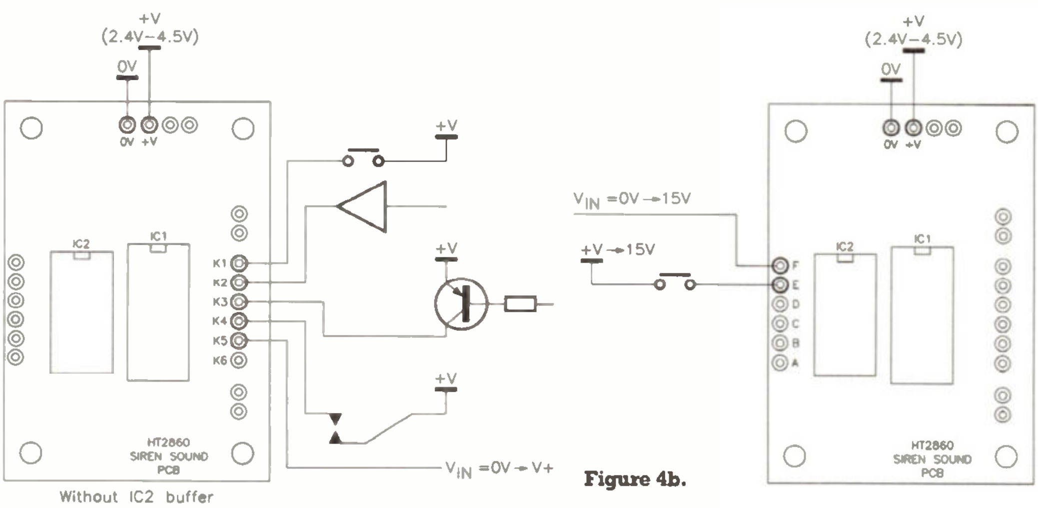


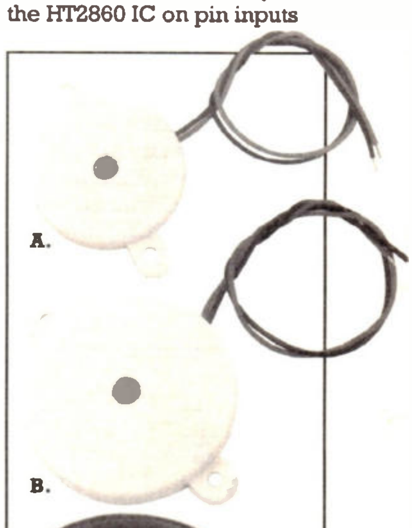
Figure 4b.

electrolytic capacitor and ICs. The ICs should be inserted into their sockets last of all.

Triggering Methods

The 2·4 to 4·5V DC supply to the HT2860 PCB is shown separately in Figure 4a. There is no board regulation of the supply, so care must be exercised when using or testing the device with a mains power supply or adaptor.

Figure 4b shows various triggering methods used to activate the HT2860 IC, such as a switch, output from an IC, a switching transistor, or a relay contact. These are shown interfaced directly to the HT2860 IC on pin inputs

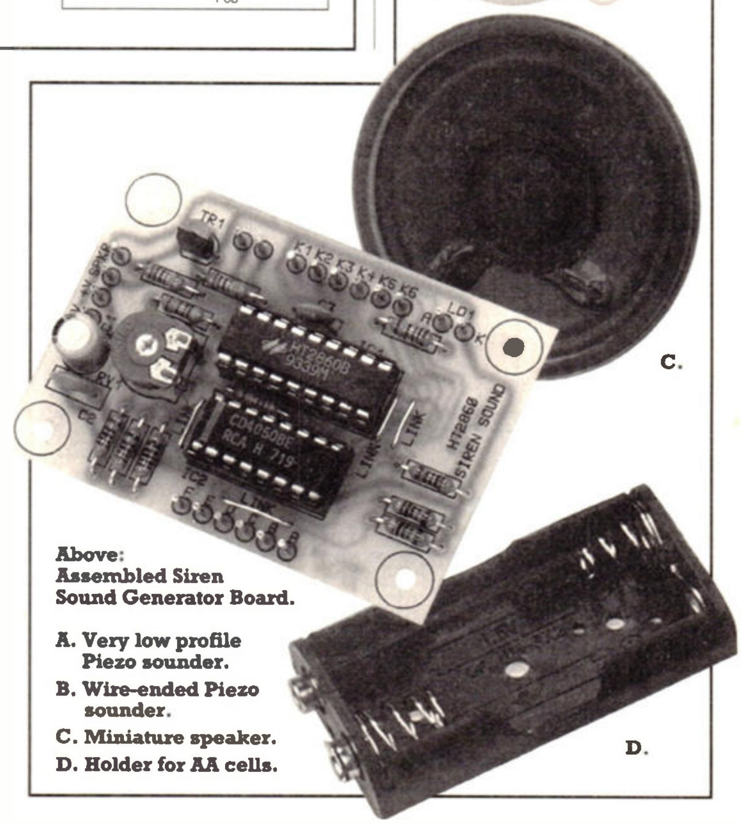


A.

B.

Pin Number	Name	I/O	Description
1	Osc1	0	Oscillator output pin
2	Osc2	1	Oscillator output pin
3	Test3	0	NC for IC test only
4	LED	0	LED flash output pin
5	Osc3	0	Vibration oscillator output pin
6	V_{DD}		Positive power supply
7	K6	1	K6 input pin, active high
8	K5	1	K5 input pin, active high
9	K4	1	K4 input pin, active high
10	K3	1	K3 input pin, active high
11	K2	1	K2 input pin, active high
12	K1	1	K1 input pin, active high
13	V_{SS}		Negative power supply, GND
14	PWR	1	Power on reset pin
15	Test2	0	NC for IC test only
16	Test1	0	NC for IC test only
17	Output	0	Sound output pin
18	Output	0	Sound output pin, out of phase to pin 17

Table 1.



C.

D.

Above:
Assembled Siren Sound Generator Board.

A. Very low profile Piezo sounder.
B. Wire-ended Piezo sounder.
C. Miniature speaker.
D. Holder for AA cells.

Characteristics	Symbol	Test Condition		Minimum	Typical	Maximum	Unit
		V_{DD}		Condition			
Operating voltage	V_{DD}		2·4	3	4·5	V	
Standby current	I_{DD}	3V		1	5	μA	
Operating current	IoP	3V	No Load		100	200	μA
Output source current	IOH	3V	VOH=2·5V	1	2		mA
Output sink current	IOL	3V	VOL=0·5V	1	2		mA
LED source current	Iled	3V	VOH=2·5V	0·7	1·5		mA
Oscillator frequency	Fosc	3V	R=120kΩ		128		kHz
H input voltage	VIH	3V	2·1			V	
L input voltage	VIL	3V			0·9	V	

Table 2.

Parameter	Symbol	Minimum	Maximum	Unit
Supply voltage	V_{DD}	0·3	5	V
Input/output voltage	V_i, V_o	V_{SS} 0·3	V_{DD} +0·3	V
Storage temperature	Tstg	50	125	°C
Operating temperature	Top	0	70	°C
Absolute Maximum Ratings (T_a=25°C)				

Table 3.

Trigger input 2·4 to 4·5V (IC1)	Trigger input 4 to 15V (IC2)	Sound Selection (IC1)
K1	A	Siren 1
K2	B	Siren 2
K3	C	Siren 3
K4	D	Siren 4
K5	E	Siren 5
K6	F	Siren 6

Table 4.

K1 to K5. In practice it is probable that one method of switching will be used. The switching voltage must be within the same range as the supply, namely 2·4 to 4·5V. Any excursion above this will damage the IC. For this reason a second IC has been added to the design, which uses IC2 as a buffer, enabling voltages (V_{IN}) of up to +15V to be used, or via a switch to trigger IC2, thus triggering IC1 within its voltage limits.

Applying power to two or more of the trigger pins on IC1 or IC2 results in the selected sounds sounding separately but in a timed sequence.

Figure 4c shows the connections from the PCB to either an 8Ω loudspeaker, or a piezo sounder. If the HT2860 is to be used as a security siren, then the audio output should be taken to a loudspeaker, or if HT2860 is to be used in a model toy or kit, to a piezo sounder as shown.

Setting Up

As the supply voltage is low, a small battery pack of AA cells (2×1·5V) can be used, or any other combination of cells (mercury or lithium) just as long as they do not exceed 4·5V.

Setting up is very easy, the only adjustment is to RV1 which adjusts the pitch of the selected sound or sounds.

If the piezo sounder is too loud in some applications, it can be connected to the 'SPKR' connection instead, operating at a softer audio level.

Applications

There are many applications for this Data File project, especially as it is possible to have up to six independent sounds, or a cascade of sounds.

In a model toy for instance where probably only one sound is required, a suitable sound will have been selected from the six, the pitch altered before fitting into the model, and the LED output for a flashing light used, e.g., such as on a spacecraft model. E

HT2860 SIREN SOUND GENERATOR PARTS LIST

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

R1	100Ω	1	(M100R)
R2	47k	1	(M47K)
R3	560k	1	(M560K)
R4,5	1k	2	(M1K)
R6-11	10k	6	(M10K)
RV1	100k Horizontal Enclosed	1	(UH06G)

CAPACITORS

C1	100μF 10V Electrolytic	1	(RK50E)
C2	100nF Mini Disc Ceramic	1	(YR75S)
C3	10nF Ceramic	1	(WX77J)

SEMICONDUCTORS

IC1	HT2860B	1	(AE15R)
IC2	HCF4050BEY	1	(QX22Y)
TR1	BC558	1	(QQ17T)
LD1	5mm Red LED	1	(WL27E)

MISCELLANEOUS

	Single-sided PCB Pins	1 Pkt	(FL24B)
	18-pin DIL Socket	1	(HQ76H)
	16-pin DIL Socket	1	(BL19V)
	PCB	1	(90012)
	Instruction Leaflet	1	(XV51F)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

Loudspeaker	1	(WB04E)
Piezo Sounder	1	(FM59P)
AA Cells	1 Pkt	(YU65V)
AA Battery Box	1	(YR60Q)
Battery Clip	1	(HF28F)

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

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

Order As 90011 (HT2860 Siren Sound Generator) Price £6.99

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

The following new item (which is included in the kit) is also available separately, but is not shown in the 1995 Maplin Catalogue.

HT2860 Siren Sound Generator PCB

Order As 90012 Price £2.29

A BRIEF HISTORY OF ELECTRONICS

PART 5: Miniaturisation and the Coming of the IC

by Ian Poole

THE invention of the transistor was one of the most important developments in electronics. By the early 1960s transistors were in widespread use; they were being used in a vast number of commercial and industrial applications. The transistor portable radio soon became widely available.

With the dramatic increase in sales, prices fell to levels where it was possible to obtain transistors for a few pence. Soon this success meant that valves were removed from their position of supremacy, and their use was confined to a few relatively specialised applications such as cathode ray tubes (CRTs) in television sets and oscilloscopes, magnetrons, TR cells and klystrons in radar, and in high power applications.

With the transistor well established, people soon started to wonder if several components could be placed on the same piece of semiconductor material. If this could be accomplished then considerable improvements in performance and reliability would be obtained in addition to reductions in size.

Military Motivation

One of the main driving forces behind the development of the IC came out of the need for improved military equipment. The Second World War had conclusively proved the value of electronics beyond all doubt. Radar had been an outstanding success, and many other new uses had been found for electronic equipment. One of these was an early computer called 'Colossus' which was developed by the British to help decipher German encrypted messages. It contained over 1,500 valves, and generated a phenomenal amount of heat. It was the most complicated piece of electronic equipment at the time and it proved to be very successful although somewhat unreliable.

As electronic equipment became more sophisticated and complicated a number of problems arose, first the physical size grew. This was a particular disadvantage for aircraft where size and weight were very important. As a result it limited the equipment which could be carried in aircraft. The second disadvantage was even more important. As the complexity of the circuitry grew, so the reliability fell. It often fell to a point where the maintenance time was longer than operational time. This was particularly true of the early valve based computers.

Some of these problems were diminished but not solved by the use of new construction techniques. Smaller valves enabled the size of equipment to be reduced, as did the introduction of printed circuit boards (PCBs), with an increase in reliability. Despite these improvements though, the basic problems were not solved, reliability was still too low, and the equipment too large.

Then in 1948 the Soviet Union exploded its first nuclear bomb. The USA saw this as a great threat. It meant that the Soviet Union could easily launch an atomic attack on the USA. With existing technology the USA would not be able to detect this until it was too late. Better methods for detecting possible threats were needed, and this required more complicated electronics.

Tinkertoy

One of the first major attempts to solve the problems of size and reliability was started in 1951 when the US Government funded a study Code named 'Tinkertoy'. It investigated a number of possibilities, many of which are still in standard use today. Double-sided and even multilayer boards were developed, as well as the techniques for making plated through holes on a board. Whilst the transistor may have seemed an obvious candidate for inclusion in the project, it was not used because the technology was very new and unreliable at the time.

Other developments and ideas were beginning to surface. Across the Atlantic in England, Dr. G. Drummer from the Royal Radar Establishment proposed the idea of building a circuit as a solid block without any interconnecting wires. However, this was more of a vision of the future because there were no practical ideas to support it. Nevertheless it was a remarkably accurate prediction of what the future might hold.

A year later, in May 1953, the first patent for an integrated circuit was filed by H. Johnson, working for the Radio Corporation of America (RCA). He proposed that all the components for a phase shift oscillator could be contained on a single chip of silicon. He detailed how the individual components could be made, but as the first p-n junction transistors had only just been made the technology did not exist to be able to manufacture it.

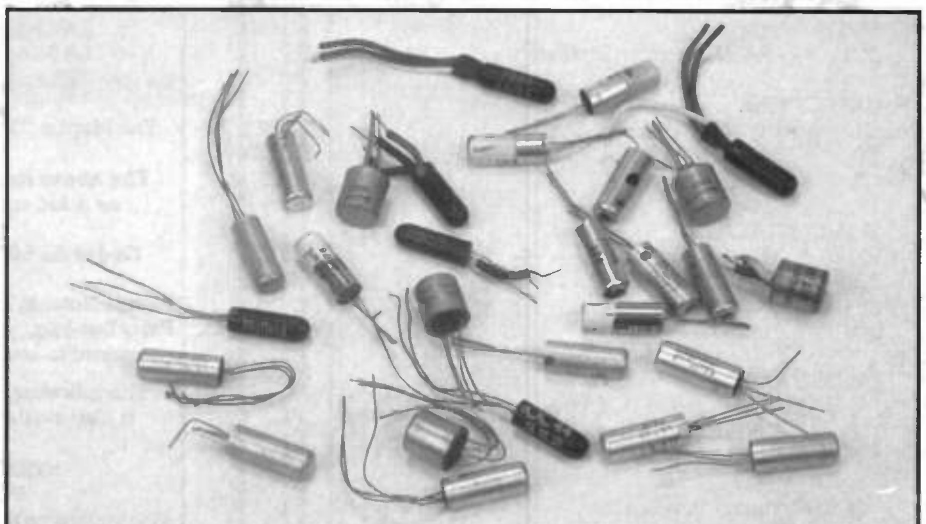
Meanwhile back in the UK, Drummer kept working on his idea. In 1957 he placed an order with the research wing of Plessey to investigate methods which could be used to manufacture an IC.

It took some time for work on the project to start properly. In fact it was not until 1959 that work was really under way. By this time it was too late because work was progressing far more swiftly in the USA.

More Miniaturisation

By 1957 transistors were becoming widespread, they were beginning to find their way into more equipment. Even military equipment, which tended to use tried and tested technologies, was starting to become transistorised in some areas.

With this change it soon became apparent that transistors could give significant improvements in reliability and size reduction. This



Collection of early germanium transistors.

caused the US Government to update their 'Tinkertoy' project to include various aspects of semiconductor technology.

Their work was split up so that a number of different companies progressed separately, but followed similar lines of research. One of the companies which had been awarded a contract was Texas Instruments, the first company to produce a silicon transistor, and one of the first to produce field effect transistors. A very gifted young engineer, named Jack Kilby joined the company about a year after the project had started.

It was as a result of a quirk in the company bureaucracy that major advances were made. When Jack Kilby joined Texas Instruments he had very little leave entitlement. When the annual company shut-down occurred he offered to work there on his own. This gave him the opportunity to follow many of his own ideas through.

Kilby started by making a number of phase shift oscillators on a single chip of germanium. The circuit was simple, but quite sufficient to be able to prove the feasibility of the technology. During the shut-down Kilby made tremendous progress, first deciding the pattern to be made on the germanium substrate and then transferring these onto the semiconductor substrate. Then, on 12th September 1958, he succeeded in making the first of his circuits work. Figure 1 shows details of Kilby's first IC. Following on from this success he made a further batch to prove the repeatability of the process. Again he was successful and produced a high yield from the circuits he had made.

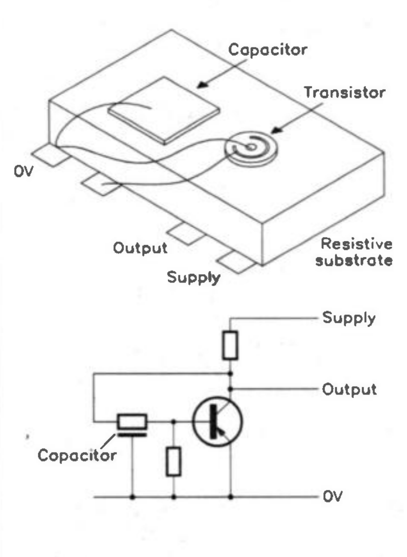


Figure 1. Kilby's first IC.

Similar Lines

As the US Government had a number of similar contracts with several companies, it was hardly surprising to find that they were reaching the same conclusions. Robert Noyce, working for Fairchild, reasoned that it was foolish to make a large number of transistors on a chip which was then cut up to make individual devices. In the manufacture of equipment these devices were then assembled together. Instead he thought it would be more sense to remove the splitting and reassembly stages. Using this reasoning, Noyce applied his knowledge of transistor production technology to lay the foundations of much of today's IC technology. In view of their complementary work, Kilby and Noyce are jointly credited with the invention of the IC.

More Impetus

Like many revolutionary ideals the IC was not an immediate success. The idea caught the imagination of many engineers and scientists but the reality of their high cost limited their use to a very small number of specialised applications. It was not until 1961 that the first ICs were marketed. Even then only two com-panies: Texas Instruments and Fairchild were producing any, and at $120 for a typical IC, it was hardly surprising their use was limited.

Then, in 1961, President Kennedy announced his vision for space research saying that America would place a man on the moon by the end of the decade. For this to be achieved vast amounts of money had to be made available to develop the new technology needed.

One of the prime areas for research was in electronics. Size weight and reliability were some of the prime requirements. As a result of this new impetus more ICs soon became available, although their cost was still very high.

ICs Develop

The early progress of the IC was not easy. The high cost gave an indication of the difficulties which were being encountered. Yield was a major problem. Only a limited amount of accuracy was available with the processes available at the time, and this meant that only a small proportion of the chips worked correctly. The more complicated the chip, the smaller the chance of it working. Even circuits with a few tens of components gave yields of about only 10%.

Most of the development in the 1960s was devoted towards increasing the yield. It was recognised that the key to success in this field lay in being able to manufacture ICs economically. This could only be achieved if the percentage of working circuits in a wafer could be significantly increased.

Most of the advances were made in the USA because of the amount of money which was available for space research. Despite this

Titan II rocket launch (Gemini manned series).

other countries made a number of significant advances. Europe was well up with the field. In the UK a lot of preparatory work had been undertaken by Plessey for the Royal Radar Establishment. Other companies including Ferranti, Standard Telephones and Cables (STC) and Mullard (now part of Philips) all joined the IC club. Other countries in Europe saw similar interest in these new devices.

Japan, which was fast becoming a very major force in world economics, saw the significance of semiconductor technology. In most areas of research from the first production transistors to IC technology itself they were only about two years behind the USA. One of the first Japanese companies to produce ICs was the Nippon Electric Company (NEC) which brought its first products to market in 1965.

Realising the vast amounts of research which would be needed to gain a world leadership, five of the largest Japanese IC manufacturers co-operated on a joint research venture with the Government in 1975. This scheme paid enormous dividends placing some of these companies right at the top of the table for IC sales.

New Technologies

All the early work on IC technology had been undertaken using bipolar technology. Very soon it was found that heat dissipation was the greatest factor limiting the size and complexity of ICs. With the number of components on an IC being packed into a very small area, heat problems were many orders of magnitude worse than if the circuit had been built up using discrete components.

Initially work was concentrated on finding more efficient ways of removing the heat, but this only gave limited success. It soon became obvious that a more revolutionary approach was needed if integration levels were to rise.

The answer came in the form of a new transistor technology. First manufactured in 1963 the field effect transistor had great advantages in that the gate consumed virtually no current. Also the channel had a relatively low 'on' resistance and a high 'off' resistance. This made it ideal for digital applications where the current consumption could be reduced by many orders of magnitude.

Texas Instruments were again leading the way, and they were the first company to launch an MOS device onto the market in 1966. Their first device was a binary to decimal converter, but many others followed shortly afterwards.

Further Integration

As MOS technology had largely conquered the problem of heat dissipation, the way lay open for much higher levels of integration. Progress was very rapid. Only a year after Texas Instruments launched their first device, Fairchild took the lead by manufacturing a device with over a thousand transistors. The chip was a 256-bit RAM and it was the first major attempt at conquering the dominance of the magnetic core memory which was used in computers at this time. Whilst it was a milestone in semiconductor technology the device was not a commercial success. The chip was about twice as expensive as the traditional core memory, and it did not sell. However, it showed the way which semiconductor technology was to progress. Only when 1K-bit RAMs were launched did semiconductor devices start to show an advantage.

As the 1970s progressed MOS technology became the dominant format for ICs. Although linear ICs were gaining in popularity and chips like the famous 741 operational amplifier were introduced, it was MOS technology which dominated the market. Integration levels continued to increase and new ideas started to develop in the minds of IC designers.

The Microprocessor

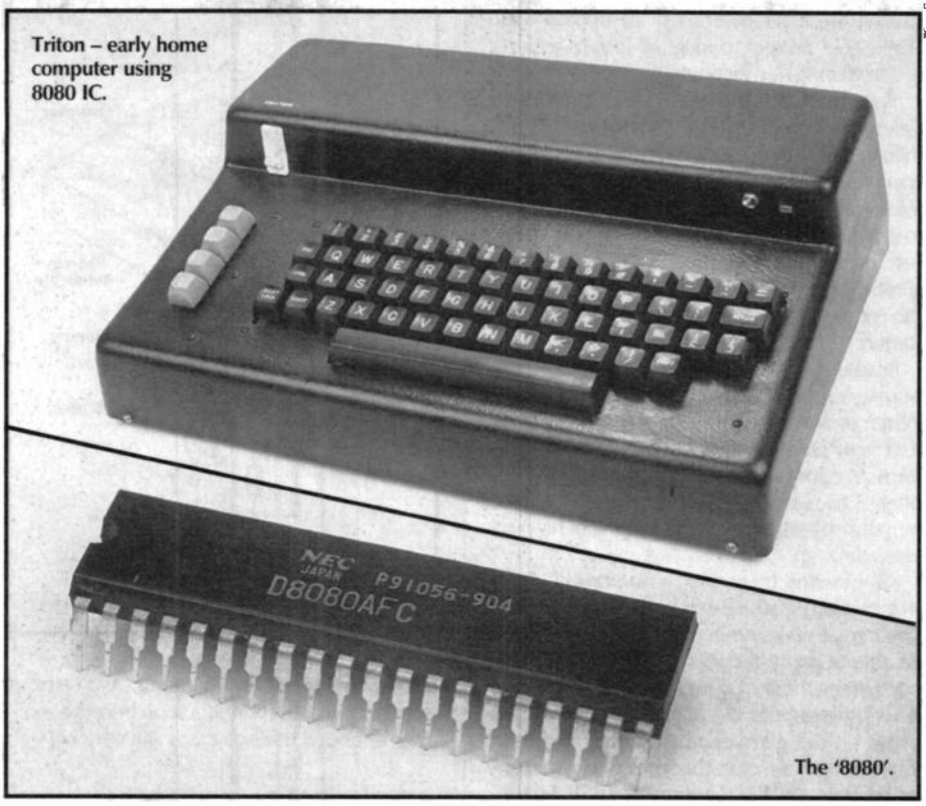
By the early 1970s the levels of integration had risen dramatically. In 1964 the maximum number of transistors in an IC was only ten, by 1969 this had risen to about a thousand. However, by 1975 this number had risen to 32,000 and it was rising fast. With this increase the functionality contained in each chip had also risen.

The increase in complexity of integrated circuits had made many new products possible. Pocket calculators were now a reality, although they were initially expensive the price soon fell. Clive Sinclair hit the limelight several times by introducing low-cost calculators which almost anyone could afford. In 1971 he launched the Executive at £79 and shortly after this came his Cambridge Scientific, again at a price of under £100. Their cost was much lower than anything else on the market. Soon Sinclair topped the UK market as well as selling vast quantities abroad.

It was out of the need for cheaper calculators that the microprocessor was born. In 1969 a Japanese manufacturer approached Intel about the possibility of them developing a chip set.

Intel had been set up in 1968 by Robert Noyce and Gordon Moore when they left Fairchild. Banking on the success of semiconductor memory over the more traditional core memory they had aimed the company at this market. Intel's first product was a 64-bit static RAM introduced in 1969, only nine months after the company was founded. This was very successful and enabled them to continue their developments. In 1971 they introduced further chips. One of these the 1103 became the world's largest selling MOS memory in 1972.

With this background Intel decided to accept the contract from Japan for the calculator chips. The designer, M. E. Hoff, adopted a totally new approach. Instead of designing a set of ICs for a calculator, he decided to design a set of general-purpose building blocks which could be programmed to perform the function of a calculator. This new set of chips contained a central processor unit (CPU), Random Access Memory (RAM), Read Only Memory (ROM) and a shift register to allow for I/O expansion. The new processor chip was called the 4004 and it was announced in 1971.



Triton – early home computer using 8080 IC.

The '8080'.

The 4004 was a 4-bit chip, and was moderately successful. To improve on its performance a year later Intel upgraded the design and launched the 8008. This was an 8-bit processor, and it was capable of addressing up to 16K-bytes of memory. This new device was considerably more versatile and could be used in a much wider number of applications.

Microprocessors soon started to catch on and other manufacturers joined the bandwagon. Texas Instruments launched their first 4-bit processor in 1974 and Motorola launched their 6800. The UK was not left out of the race as Ferranti introduced a device of their own.

Intel needed to keep ahead of the field. In 1974 they announced their third processor. Called the 8080 the chip used NMOS technology making it five times as fast as the 8008. This chip more than any other brought success to Intel. Soon after its launch it was chosen by the Digital Equipment Corporation (Dec) for use in its new range of PDP computers.

Home Computers Arrive

Sales of all microprocessors started to rise as the potential of the new chips was recognised. They enabled a new breed of small cheap computers to be designed and manufactured. Many new companies were started up. Names like Apple in the USA and Acorn in the UK started to produce computers which even the home enthusiast could afford.

Prices fell even further when Clive Sinclair launched his ZX80 in February 1980. Costing under £100 it very quickly notched up sales of over 100,000. However, it did have some limitations and within six months its successor the ZX81 was launched. This was even more successful, selling over a million units. It was without doubt the ZX80 and ZX81 which brought computing into the home more than any other computer.

Whilst Sinclair had shown a market for the home enthusiast, there was a vast business market as well. Looking to this IBM launched their PC or personal computer in 1980.

In designing their PC, IBM had looked very carefully at all the available options before finally settling on the Intel device. The success of the PC was beyond the expectations of many observers. Other companies were set up to manufacture these computers and a whole new industry was launched.

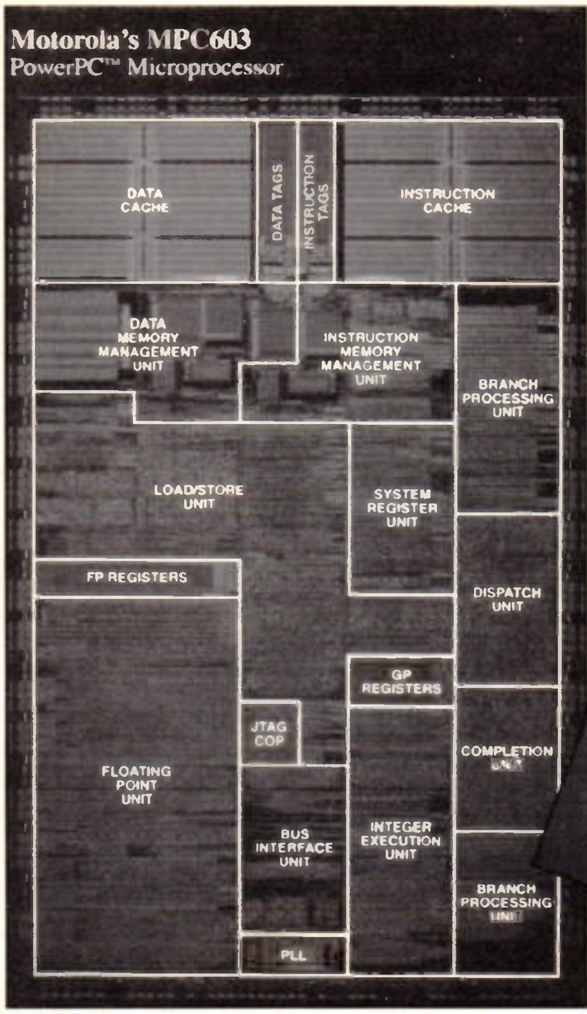
To keep pace with the increasing requirements further updates of the popular 8080/8085 were launched. First came the 8086 in June 1986, and this was followed by the 80286, 80386, 80486 and finally the Pentium.

Despite its undoubted successes, Intel did not take all the market. Motorola took its share as well. The 6800 series of processors was chosen for the Apple Macintosh computer which was a great success in many areas of the computer market. In addition to this they aimed much of their marketing towards the high performance work-stations like Apollo and Sun who both use Motorola.

ZX Spectrum – successor to the ZX81 computer.

Finale

It is probably true to say that the integrated circuit has been responsible for affecting everyday life more than any other invention in electronics. In the days of valves the only pieces of electronic equipment in the home would



PowerPC 603™ advanced modern computer microprocessor.

The device 'up-close'.

have been a radio set or a television. Transistors gave considerably more flexibility, but even so the major items of electronic equipment around the home would still have been radios and television sets. Items for controlling electrical equipment around the home were still electromechanical.

The arrival of the integrated circuit changed this. Using an IC, and a handful of other components, it was often possible to achieve the same result. Usually this could be done more cheaply and with the introduction of additional features. As a result a whole host of new electronic devices started to appear. Everything from clocks, watches and timers through to sophisticated video systems contained these new chips.

However, it is worth remembering that today's latest developments would not have been possible without all the other discoveries before them. Early pioneers like Galvani and Volta, or later ones like Fleming or Shockley all played their part in the development of electronics as it is today.

The future of electronics will also be based very much on what we know today. However, the direction it takes is another matter. Only time will tell exactly what will happen. But my guess is that computer technology and Artificial Intelligence will be the main driving forces. To achieve the required performance much faster and more complicated computers will be needed. This may mean that a totally new technology will have to appear. One which offers some very exciting prospects is in the field of optical computers. However, they are still very much in their infancy and only time will tell what the next chapters in this series might be. E

CD VERSUS VINYL – *Continued from page 37.*

used are particularly static-sensitive, but care should be exercised insofar as they should not be inserted until correct supply voltages have been ascertained on the appropriate IC socket pins. As far as the supply rails are concerned, any split supply, from about 9V upwards, can be used, bearing in mind that there is a corresponding loss of headroom at the lower supply voltages. The circuit was originally designed for a large audio mixer, hence the somewhat unusual rail voltages quoted. The module should be grounded to the system star earth of the equipment to which it is fitted, and the input connections made via screened lead and terminated in good quality (gold-plated) phono plugs or similar. The outputs should also be connected to any subsequent preamplifier or power amplifier stages using screened lead, with the screen connected only at the module end if the outputs are taken to further circuitry within the same enclosure. This avoids creating a hum loop. Before connecting a cartridge, check for DC on the module input pins. If all is well, connect to a turntable, put on a favourite record, sit back and enjoy vinyl as it was intended to be enjoyed. E

HIGH PERFORMANCE RIAA PREAMP PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,101	51k	2	(M51K)
R2,102	560k	2	(M560K)
R3,12,103,112	75k	4	(M75K)
R4,104	1k2	2	(M1K2)
R5,105	9k1	2	(M1K5)
R6,106	390Ω	2	(M390R)
R7,107	82k	2	(M82K)
R8,108	6k2	2	(M6K2)
R9,109	300Ω	2	(M300R)
R10,110	6k8	2	(M6K8)
R11,111	2k2	2	(M2K2)
R12,112	75k	2	(M75K)
R13,113	820Ω	2	(M820R)
R14,114	2k7	2	(M2K7)
R15,115	100k	2	(M100K)
CAPACITORS			
C1,101	270pF 1% Polystyrene	2	(BX50E)
C2,8,14,17,19, 21,102,108,114, 117,119,121	100nF Polyester Layer	12	(WW41U)
C3,6,7,15,103, 106,107,115	100µF Non-Polarised Electrolytic	8	(JH35Q)
C4,104	33nF 5% Polyester Layer	2	(WW35Q)*
C5,105	2n7F 1% Polystyrene	2	(BX61R)
C9,109	22pF Polystyrene	2	(BX24B)
C10,110	10nF 1% Polystyrene	2	(BX86T)
C11,111	1n8F 1% Polystyrene	2	(BX59P)
C12,13,112,113	47nF 5% Polyester Layer	4	(WW37S)*
C16,18,20,116, 118,120	10µF 63V Radial Electrolytic	6	(JL10L)
SEMICONDUCTORS			
IC1,101	LM318	2	(AY17T)
IC2,102	SSM2210P	2	(UL79L)
IC3	LM833N	1	(UF49D)
MISCELLANEOUS			
PL1,3	4-way PCB Latch Plug	2	(YW11M)
PL2	3-way PCB Latch Plug	1	(BX96E)
	8-pin DIL Socket	5	(BL17T)
	Screened Cable	As Req.	
	PCB		

Note: Asterisks (*) indicate capacitors originally specified by the author as being 1% Polystyrene types, not stocked by Maplin in these values, hence the nearest equivalent is stated instead.

The Maplin 'Get-You-Working' Service is not available for this project.
The above items are not available as a kit.

Text by Alan Williamson and Maurice Hunt

DIGITAL TACHOMETER

Typical installation position of the Digital Tachometer on the vehicle dashboard, easily visible to the driver.

FEATURES

- ★ 2 Digit LED display
- ★ Adjustable display brightness
- ★ Suitable for 2- and 4-stroke petrol engines
- ★ Configurable for engines of between 1 and 12 cylinders
- ★ Simple installation and calibration
- ★ Front panel included
- ★ Contact bounce suppression

3
PROJECT RATING

The majority of modern cars, and practically all 'high performance' models (or 'wannabees'!), are equipped with a tachometer, or rev (revolution) counter, which gives an indication of the number of revolutions per minute (rpm) that the engine's crankshaft is turning at. This is a very useful instrument to have, since it enables the driver to maintain the engine turning at its most efficient rate for the maximum production of either power (BHP), or torque (the pulling force being exerted), factors which coincide with specific engine speeds (the values for which may be found in the vehicle handbook, or magazine road test reports). Hence, this can be used to give maximum acceleration, or optimum flexibility, particularly useful when climbing steep inclines or towing caravans, boats, etc.

KIT AVAILABLE (90013)
Price £25.99

An additional use for a tachometer is as an aid to servicing, since it enables the engine idling speed to be set to the value specified by the manufacturer, in the event of it idling too fast or slow, as is often the case. However, many older, or 'base-spec' vehicles, are not equipped with a tachometer. This situation is easily rectified, by installing the digital version presented here, which is simple to fit, calibrate and use. Furthermore, by using a suitable sensor (i.e., one that simulates the switching action of the contact breaker), the unit allows rpm measurement, or the number of movements per minute, of any rotating or moving mechanical part – it does not necessarily have to be an engine!

This digital tachometer may be adapted for use in any car, van or motorcycle powered by a petrol engine, whether it is a 2- or 4-stroke engine, and no matter how many cylinders. The only proviso is that the vehicle must be wired negative earth, as most vehicles less than 20 years old are. The kit differs somewhat from conventional analogue tachometers, because the moving hand is replaced by two seven-segment LED displays, giving a reading of the number of rpm, in figures. Some advantages of this technique are an easy and unmistakable reading, compact size, and robustness, since there are no delicate moving parts to wear out.

The displays give a reading in thousands and hundreds of rpm, for example, 2,300rpm would be displayed as '23' (×100rpm). The intermediate values (of higher resolution, e.g., 57rpm) are of no interest, because the true number of engine revolutions is unstable, which would result in an ever-changing reading (analogue tachometers have damped movements to counter this effect).

Only one simple setting of a preset potentiometer is needed to calibrate the circuit to suit the vehicle engine type, giving a fully linear scale across the rpm range. A second preset allows adjustment of the display brightness, which will depend on where the unit is mounted, and/or the ambient light level. The unit is compact and easy to box, and an attractive front panel is included with the kit, to enable a professional-looking installation.

Circuit Description

Reference to the block diagram of Figure 1, and circuit diagram of Figure 2, will assist in following the circuit description.

The input voltage, which in a vehicle, may normally range between 10 and 15V, depending on the state of charge

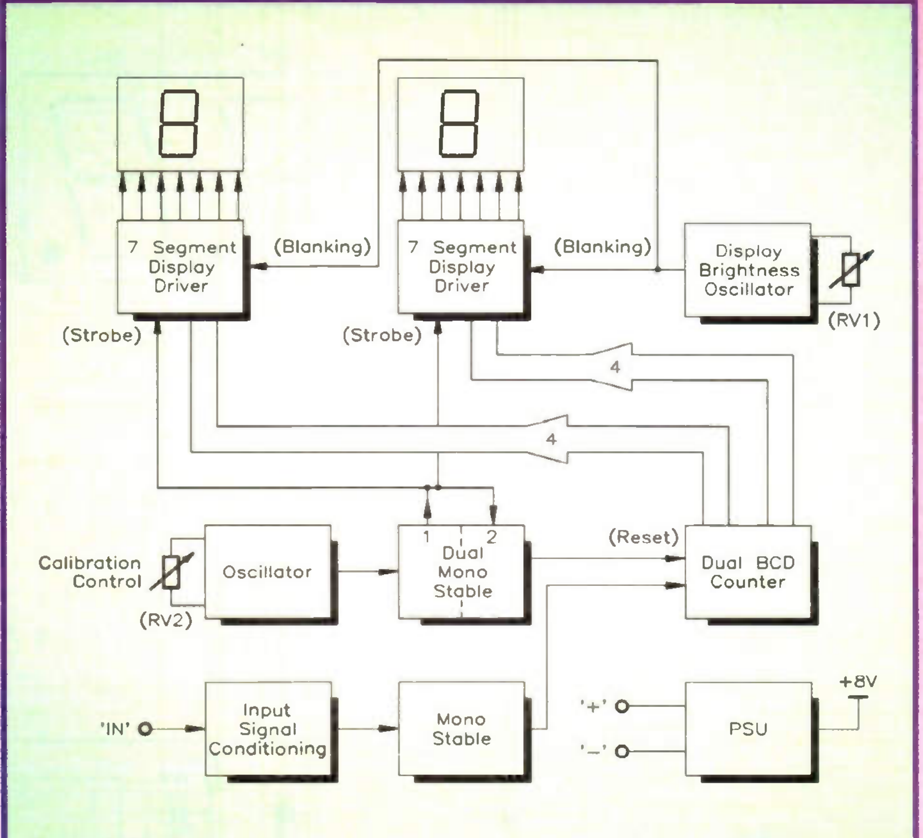
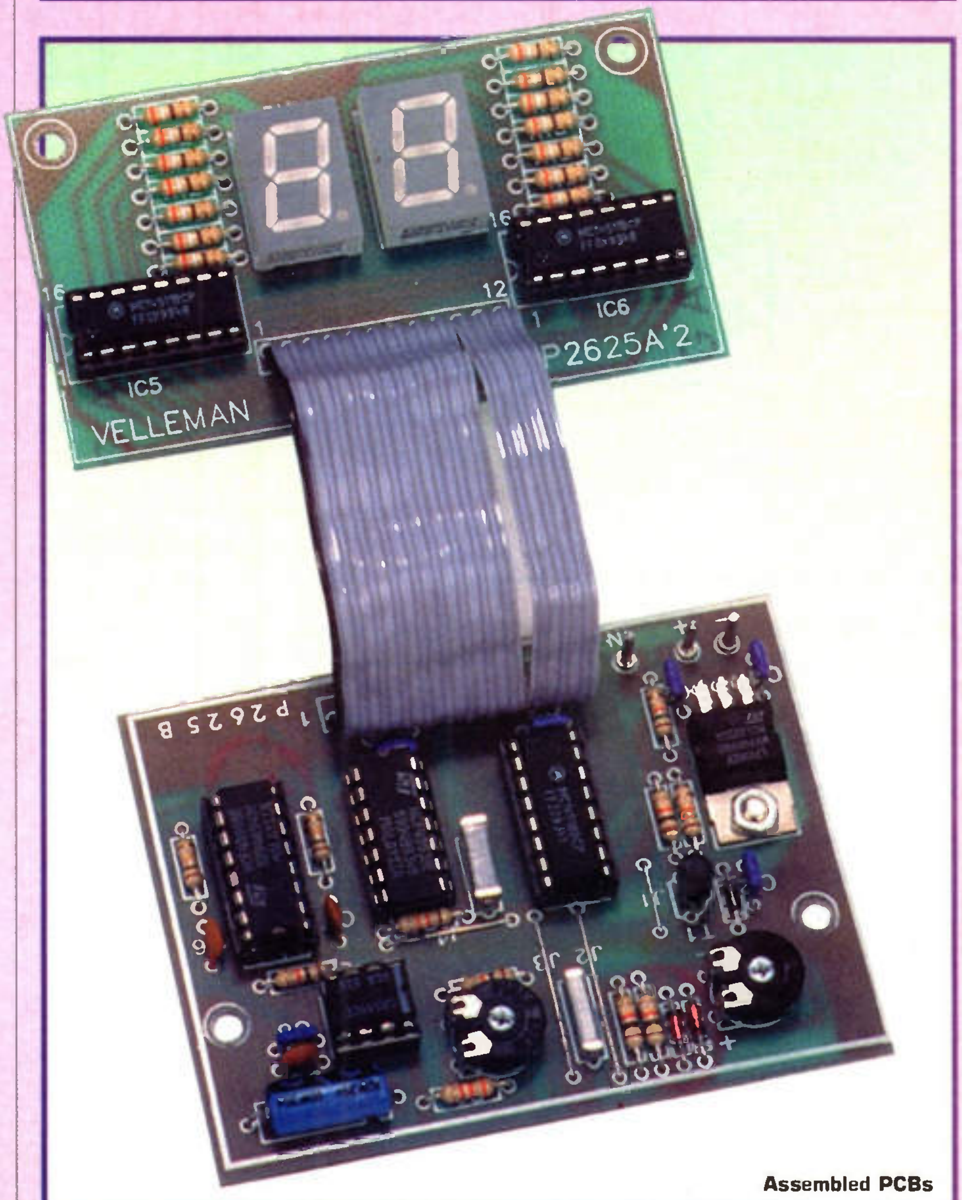


Figure 1. Block diagram.



Assembled PCBs

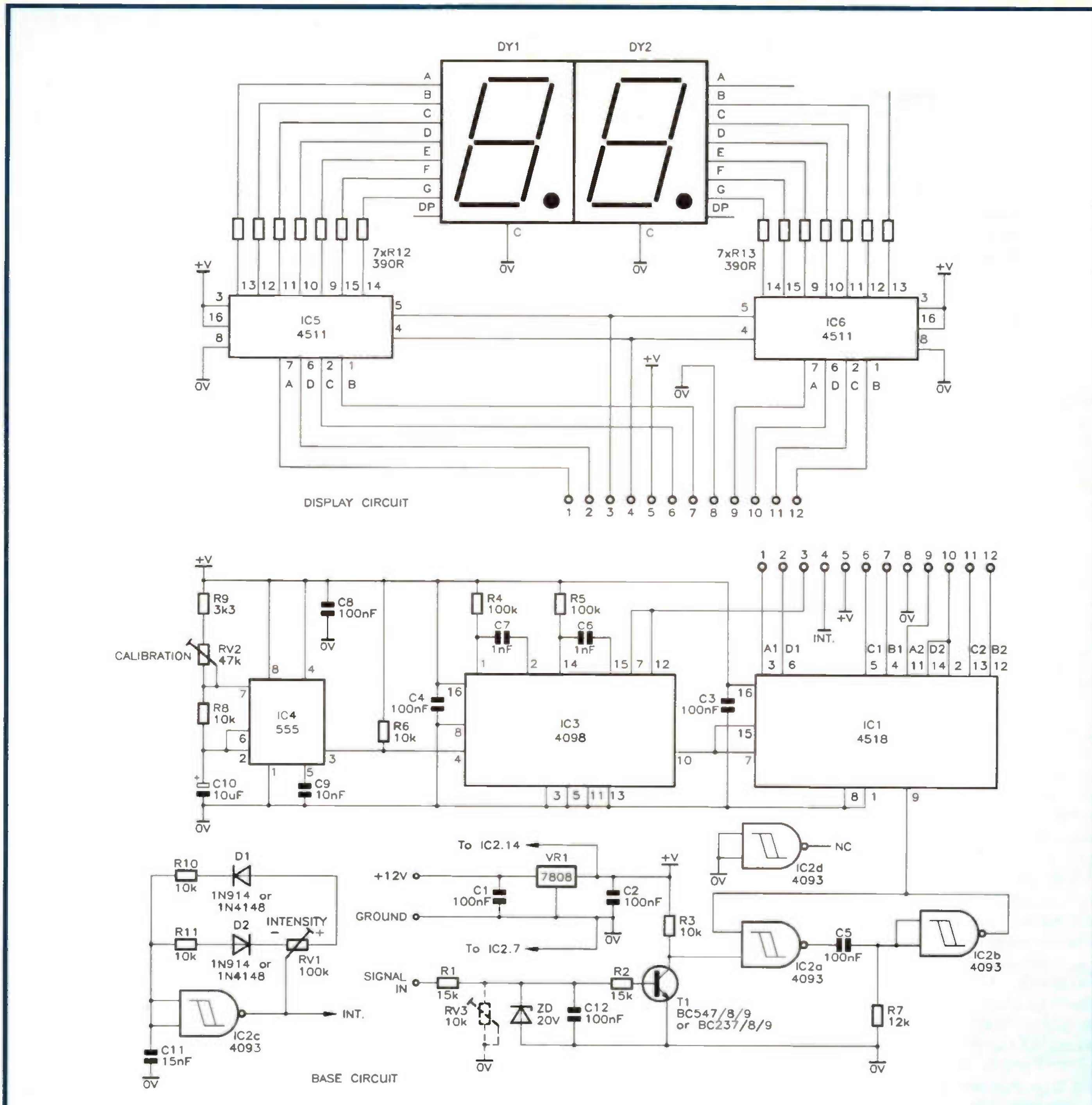


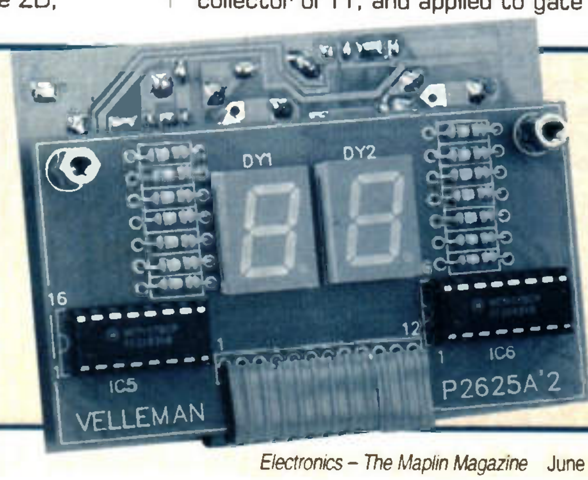
Figure 2. Circuit diagram.

of its battery, and whether the engine is running or not, is stabilised by the voltage regulator VR1, which gives an output of a constant 8V. Capacitors C1 and C2 provide high-frequency decoupling of the regulator supply lines. The signal to be measured (the frequency of which is proportional to the rate at which the vehicle's ignition coil is switched on and off, and hence engine rpm) is connected to the 'IN' input, which is then applied to the base of the preamplifier transistor T1, via R1 and R2; Zener diode ZD, protects T1 from excessive input voltage which results from the back e.m.f. generated by the ignition coil.

The inverted and squared off ('cleaned up', to eliminate ringing from the coil) signal is taken from the collector of T1, and applied to gate 1

Specification

Supply voltage:	10 to 15V DC, unstabilised (built-in regulator)
Supply current:	200mA (maximum)
Display range:	100 to 9,900rpm
Resolution:	100rpm
Display type:	2 × 0·5in., 7-segment LED (static)
Input sensitivity:	3V (minimum), 20V (maximum)
Input impedance:	30kΩ (typical)



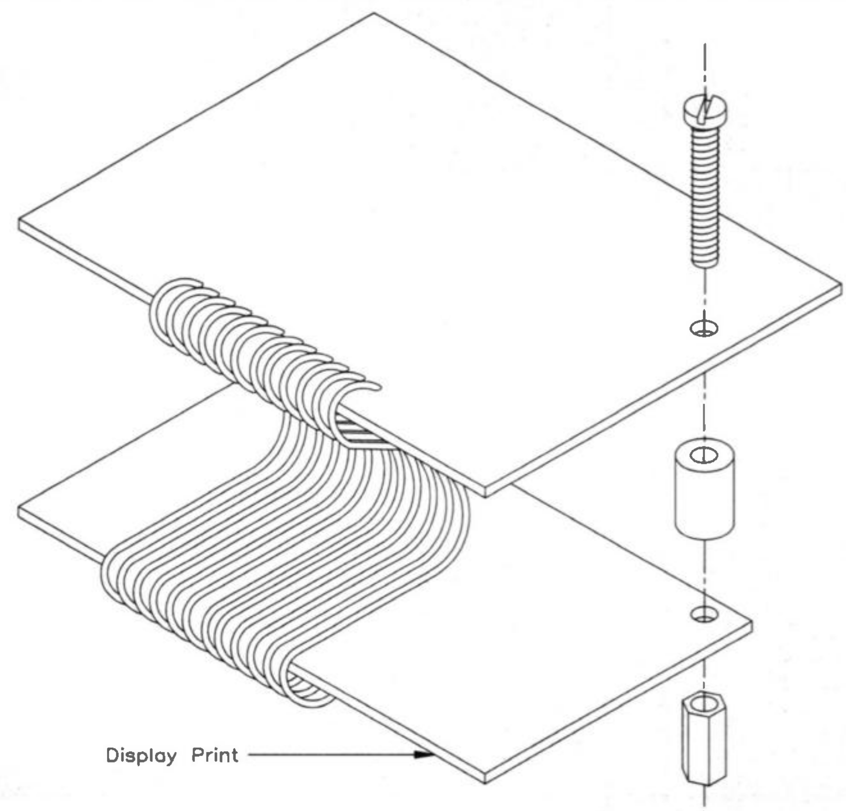


Figure 3. How the Main and Display PCBs fit together.

(N1) of IC2, a 4093BE Quad 2-input NAND Schmitt trigger IC. Gates N1 and N2, and components C5 and R7, are configured as a monostable multivibrator, to suppress the contact bounce of the input signal (assuming the vehicle ignition system uses conventional contact breaker points). The monostable produces a signal with a fixed pulse width, which is independent of the input frequency or pulse width.

The output pulse of the monostable is then applied to the count input (pin 9) of IC1, a 4518BE dual Binary Coded Decimal (BCD) counter, the twin sets of BCD outputs of which are fed to IC5 and IC6, a pair of 4511BE BCD to 7-segment display driver ICs. The 7 × R12 and 7 × R13 resistors limit the current through the displays DY1 and DY2, respectively.

IC4 is the ever-popular 555 timer, configured for astable operation. The frequency of the oscillator can be adjusted by RV2. The output of IC4 is applied to the input (pin 4) of IC3, a 4098BE. This IC contains two monostable multivibrators, which are coupled together in series. An output pulse from IC4 triggers the first monostable within IC3, producing a short pulse from the output (pin 7).

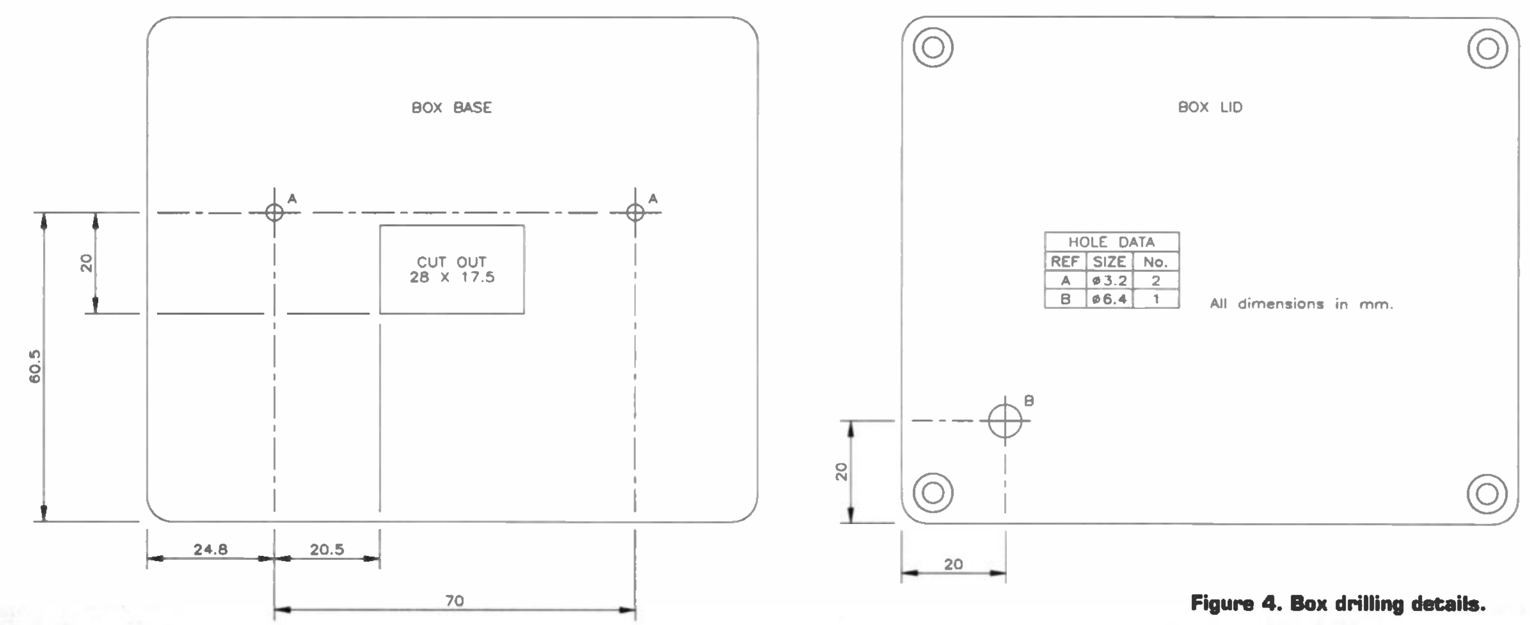


Figure 4. Box drilling details.

Number of cylinders	50Hz signal		60Hz signal	
	2-stroke	4-stroke	2-stroke	4-stroke
1	3,000	6,000	3,600	7,200
2	1,500	3,000	1,800	3,600
3	1,000	2,000	1,200	2,400
4	750	1,500*	900	1,800*
5	–	1,200	–	1,440
6	–	1,000	–	1,200
8	–	750	–	900
10	–	600	–	720
12	–	500	–	600

* Indicates most popular types of engine

Table 1. Calibration table.

This pulse is then applied to the 'strobe' inputs (pin 5) of IC5 and IC6, which will then latch and enable the BCD value present on the counter outputs to be displayed. The output of the first monostable (pin 7) within IC3 is also connected to the input of the second monostable (pin 12); the second monostable is triggered on the reset edge of the pulse from the first monostable. The short pulse produced from the second monostable output (pin 10), resets IC1's BCD counters, which will begin counting again from '00'.

The output from the oscillator formed around N3 of IC2, is applied to the 'blanking' inputs of IC5 and IC6, and by altering the duty cycle

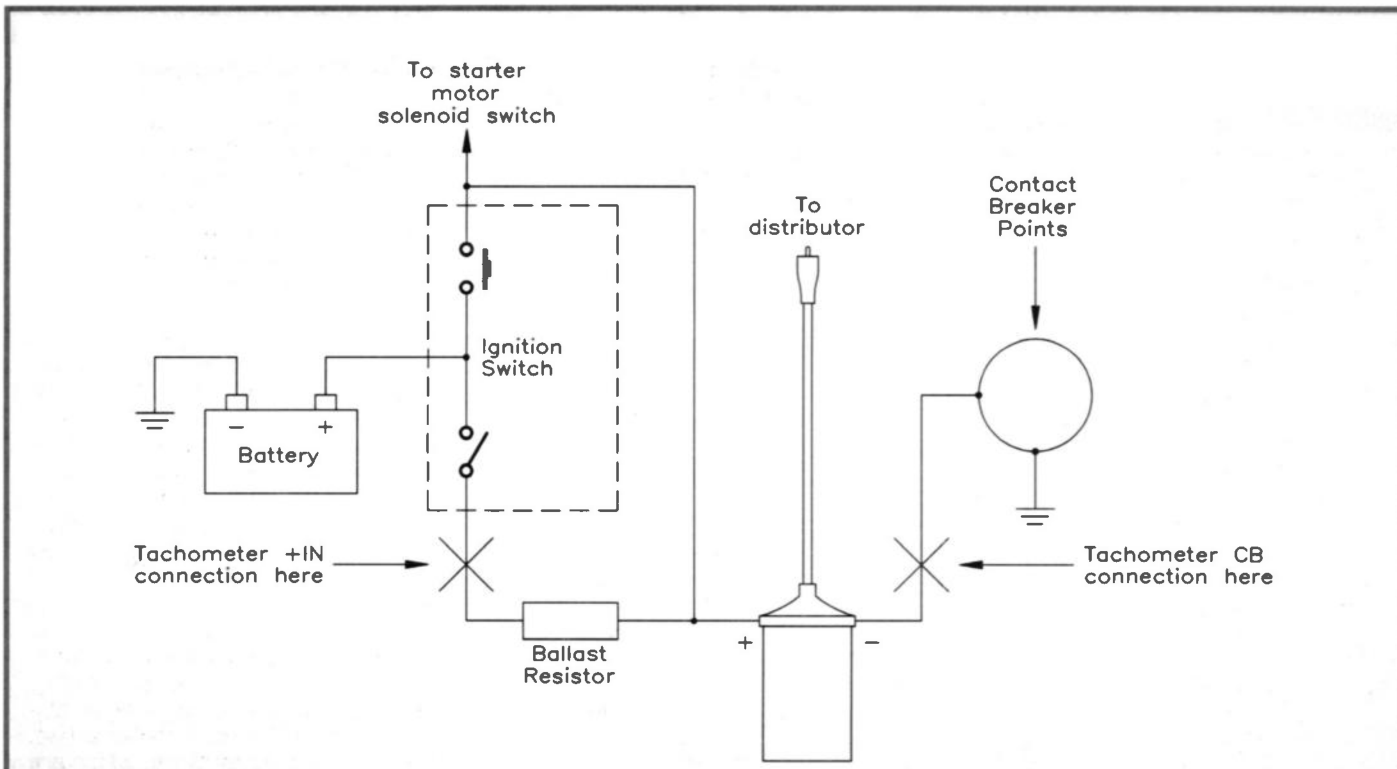


Figure 5. Wiring diagram.

of this oscillator by means of RV1, the brightness of the display can be adjusted.

PCB Construction

Construction is fairly straightforward, and following the leaflet supplied will be of assistance. Start with the four wire links, and proceed in order of ascending component size, not forgetting the PCB pins. Be careful to correctly orientate the electrolytic capacitor C10, IC holders and ICs, diodes D1, D2 and ZD, transistor T1, and voltage regulator, VR1. The regulator should be clamped down onto the PCB using the 6mm M3 bolt and M3 nut supplied. The ICs should be inserted into their sockets last of all. Thoroughly check your work for misplaced components, solder whiskers, bridges and dry joints. Finally, clean all the flux off the PCB using a suitable solvent. When all the components are fitted to both the main and display PCBs, as shown in Photo 1, they are then linked, as shown in Figure 3, via short (approximately 7cm) lengths of ribbon cable, one a 9-way section, the other a 3-way.

Final Assembly

Again, following the diagram shown in Figure 3, attach the two PCBs, back to back, together with the front panel, as follows. Use the two black 6mm M3 bolts, pass through the holes in the front panel, and screw (not too tightly) into the two 10mm hexagonal metal M3 spacers. Next, with the two PCBs 'folded over' back to back, and the ribbon cables tucked into the space between them, pass the two 15mm M3 bolts, one at a time, through the holes in the main PCB, and through the two 10mm plastic spacers which separate the PCBs, screwing them into the free ends of the hexagonal spacers. Again, do not overtighten the bolts, as this will crack the PCBs and/or plastic spacers. This completes the assembly of the unit.

Testing

Connect a 10 to 15V DC supply to the (+) and (–) pins on the PCB (ensuring correct polarity!). The displays should read '00', irrelevant of the position of RV2's wiper. Adjust RV1 to alter the brightness of the display to suit the location that the unit will be mounted in.

The calibration of the tachometer can be performed in two different ways, as outlined below:

1. By using a transformer (UK 50Hz, Europe and USA 60Hz). This should be of the step-down type, giving an output voltage (Pk-to-Pk) within the specified input signal level.
2. By using a signal generator, set at 50 or 60Hz.

In either case, the calibration method is the same. A specific number of revolutions on the display corresponds to a specific frequency at the input `IN'. However, the ratio required depends on the type of engine and the number of cylinders that the unit will be used with. The ratios are given in Table 1.

Calibration Using a Transformer

Use a transformer with a secondary voltage between 3 and 15V AC; the VA rating of the transformer is unimportant. Connect the transformer to the (–) and 'IN' pins of the tachometer. Trim RV2 as per Table 1, to obtain the correct value displayed, in accordance with the type of engine and its number of cylinders. As already mentioned, the tachometer will only display the 'thousands' and 'hundreds' of (rpm) units.

Calibration Using a Signal Generator

This method requires a very accurate oscillator or signal generator, set to exactly 50Hz (or 60Hz). The output signal can be sine or square wave. Connect the output of the generator to the (–) and 'IN' pins; the signal should have a minimum amplitude of 3V. Trim RV2 as per Table 1, to obtain the correct value displayed, in accordance with a specific type of engine with a specific number of cylinders.

Using the Digital Tachometer

Connecting the unit to a vehicle is very simple. First, connect the 'auxiliary' (switched, or ignition-controlled) positive supply to the module (+) terminal, via a suitably rated fuse (of 500mA maximum). Next, connect the 'ground' lead to the module; an earth can be sourced from any suitable part of the vehicle's body, presuming it is of metal construction. Last of all, connect a lead from the contact breaker ('points') side of the ignition coil to the 'IN' input terminal. The correct side of the coil is easily found, as it is the only connecting lead passing to the contact breaker, sometimes marked (–) or 'CB' on the coil itself. Note that the condenser (cylindrical capacitor fitted in parallel to the 'points') should be retained. When the engine is started, the number of revolutions per minute will be displayed. The unit may either be installed directly into a suitable, unused area of the dashboard, or mounted in an optional plastic box (e.g., MB3 type) fitted externally to the fascia. Figure 4 gives drilling details for a suitable box. Mount the unit in a position where the display will be clearly visible, but not so that bright sunlight is likely to shine on it, as you will not be able to see the reading! Also bear in mind the safety aspect, and mount the unit away from the position that parts of your body (knees, etc.) might impact the dashboard in the event of a crash, to minimise the risk of injury. Additionally, ensure that the interconnecting cables are of sufficient power rating (5W or higher), and that grommets are used where they pass through the bulkhead into the engine compartment, since if they chafe through and short circuit, there is a risk of fire breaking out, or damage occurring to the vehicle's wiring.

Figure 5 shows the wiring diagram for the unit.

NOTE:
On some cars (especially those with an electronic ignition system) the tachometer may display zero at high engine speeds. In this case, fit the 10kΩ potentiometer, RV3, (supplied) in parallel with the Zener diode, as per the schematic diagram. Adjust the trimmer until the meter responds correctly at all engine speeds.

DIGITAL TACHOMETER PARTS LIST

RESISTORS: All ¼W 5%		
R1,2	15kΩ	2
R3,6,8,10,11	10kΩ	5
R4,5	100kΩ	2
R7	12kΩ	1
R9	3k3Ω	1
R12,13	390Ω	14
RV1	100kΩ Horizontal Cermet Potentiometer	1
RV2	47kΩ Horizontal Cermet Potentiometer	1*
RV3	10kΩ Horizontal Cermet Potentiometer	1

* This value may be changed, i.e. 47kΩ to 50kΩ with no effect on performance.

CAPACITORS		
C1-4,8,12	100nF 63V Resin-dipped Ceramic	6
C5	100nF 250V Polyester Layer	1
C6,7	1nF Ceramic Disc	2
C9	10nF Ceramic Disc	1
C10	10μF 35V Axial Electrolytic	1
C11	15nF 400V Polyester Layer	1

SEMICONDUCTORS		
DY1,2	0·5in. Common Cathode Red LED Display	2
IC1	4518BE	1
IC2	4093BE	1
IC3	4098BE	1
IC4	NE555	1
IC5,6	4511BE	2
T1	BC547B	1
VR1	L7808CV	1
ZD1	20V 500mW Zener Diode	1
D1,2	1N4148	2

MISCELLANEOUS		
	M3×6mm Bolts, Black	2
	M3×6mm Bolt, Silver	1
	M3×15mm Bolts, Silver	2
	10mm Plastic Spacer	2
	10mm Hexagonal Threaded Spacer	2
	M3 Nut	1
	Polycarbonate Front Display Panel	1
	Main PCB	1
	Display PCB	1
	9-Way 8cm Flat Ribbon Cable	2
	Single-ended PCB Pins	3
	8-Pin DIL Socket	1
	14-Pin DIL Socket	1
	16-Pin DIL Socket	4
	Wire Links	4
	Leaflet	1
	Constructors' Guide	1

OPTIONAL		
	MB3 Black Plastic Box	1

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 90013 (Digital Tachometer) Price £25.99

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

What's On?

RSGB in the Park

As part of the major national celebrations of the 50th anniversary of the end of the war in Europe, the RSGB will be in Hyde Park, London, on a stand shared with the Air Training Corps. Over the three days of the Spring Bank Holiday weekend (6 to 8 May), the Society will be telling the public of the part played by radio amateurs during he war, and providing a focal point for members present at the celebrations.

Contact: RSGB, Tel: (01707) 659 015.

Waters & Stanton Open Day

For the fifth successive year, Waters & Stanton will hold a free Open Day at their Hockley premises on Sunday, 21st May between 10.00 a.m and 5.00 p.m. There will be a vast quantity of special offers, end of line and reconditioned items for sale plus loads of bargains. Refreshment provided free of charge for visitors.

Information Superhighway Exhibition

Newcomers to communication technology are invited to explore the future of global communication in Information Superhighway, the latest in the Science Box series of small temporary exhibitions, which opens at the Science Museum on Wednesday 26 April. Today, more families own a home computer than ever before, and children are often more computer-literate than either their parents or grandparents. But, how many of us understand what is meant by 'Information Superhighway' or realise its full potential? This hands-on, interactive exhibition asks what the Information Superhighway is and whether it actually exists. Explaining the technology behind global computer networks, it looks at how they might develop in the future. 'Surf City' invites visitors to find out what 'surfing the Net' is like. A special hub of computers, staffed by experienced helpers, lets first-time users have a go on the Internet – an existing global communications network. You will find a wealth of information – news, views, recipes, jokes and games, and even pages published by the Science Museum – literally at your fingertips. Looking to the future, the exhibition asks whether the information Superhighway will transform our lives through developments such as virtual surgery and the arrival of the global office. Will our social lives take place 'on line' or shall we continue to meet in the local pub?

Contact: Science Museum, Tel: (0171) 938 8080.

Sekers Makes Up Convention's Fab Four

If there is one thing you cannot accuse Alan Sekers of, it is thinking small. Sekers is the man who turned an airship into the world's biggest video screen, and it is that kind of imagination which marks him out as one of the most innovative thinkers in the imaging world today. He is also one of the leading apostles of the electronic revolution, being head of IT at design consultancy Addison, and the latest big name to join the panel of speakers at the British Institute of Professional Photography's, 'Programmed for Change' convention on Monday, June 5. He says his aim in life is to, "Rake technology out of the hands of technologists and put it into

the hands of artists and craftsmen". He will be doing just that at the BIPP Convention at Birmingham's International Convention Centre. Sekers joins leading photographers Ralph Romaguera, Don Fraser and Martin Beckett to form the fabulous foursome which is set to take a packed ICC audience by the scruff of its neck and shake it until phobias and fantasies which currently dog attitudes to digital and conventional imaging are well and truly exorcised. Tickets for the day-long Convention cost £60 for BIPP members with vouchers to the tickets value, £150 for non-members, and £20 for students.

Contact: British Institute of Professional Photography, Tel: (01920) 464 071.

ULTRASONIC DETECTOR – *Continued from page 19.*

Dog Whistle Tester

Ensure you are not being ripped off when purchasing a dog whistle, by taking this unit along to listen to the whistle (which should give an ultrasonic note when blown). You could take the dog along too, for extra confirmation that you are getting your money's worth.

Car Engine Checker

Use this unit to listen to the ultrasonic frequencies emitted by a running car engine, and identify if that used car you are thinking of buying is heading for a catastrophic and expensive-to-fix internal bearing failure in the near future, in which case a lot of discordant, irregular high-pitched noises would be heard. Particularly effective when buying from unscrupulous traders, who may have disguised an obviously worn engine with copious quantities of sound-deadening gunge in the sump!

Rugby MSF Time Signal Receiver

By using an aerial connected to the centre microphone connection on the PCB, the unit will act as a radio receiver, and if tuned to around 60kHz, it is possible to receive the MSF time signal, characterised by a single frequency modulated by on/off keying, and a fast code sent every minute.

Opera Singer Tester

Some opera singers (usually female!) claim to have voices that extend beyond the range of human hearing. Test their claims by taking this unit along to the next opera you attend, and with the unit on at full volume (to drown out the wail of the music), you may be able to detect if their voice does indeed extend above 20kHz, and if not, demand a refund.

Noisy Appliance Tester

Use the unit to identify noisy electrical and electronic equipment/components, for example VDU monitors, motorised devices, etc., and if an item is particularly noisy at ultrasonic frequency, this may indicate that excessive electrical noise is also being emitted from the same source.

Enhancements

For the more adventurous constructors among you, additional features could be incorporated into the unit, to make the project even more useful and interesting than it is already! A couple of suggestions are to add an LCD frequency module, wired in to the output of the VCO (at the test point, TP1, for example), which would give an immediate indication of the frequency range being detected, rather than having to rely on the dial markings of the Tune control. The LCD could also be backlit for use in darkness. Additionally, and perhaps in conjunction with the first suggestion, a form of ramp generator could be added, which would feed the VCO voltage input (pin 9 of IC4), and provide automatic frequency sweep tuning of the unit, although it would also be possible to have selectable manual tuning if desired. Feedback from a demodulator could be used to stop the ramp generator when a strong ultrasonic input signal is detected by the microphone, thus providing rapid tuning-in to the frequency you wish to translate. These features would make for a very sophisticated piece of equipment, but will obviously add substantially to the cost and complexity of the finished product.

The completed unit, with optional car power adaptor, and carrying pouch.

Bats Facts

In Britain, we have 14 bat species, comprising of one third of our land mammals. The Pipistrelle, with a 20cm wingspan, is the most common, and the Noctual is the largest, with a 35cm wingspan. All British bats are quite harmless, and hunt their insect prey using complex sonar systems. The following paragraphs on the habits and habitat of bats should enable you to find bats on your first trip out, however, please remember that bats are a protected species, and whilst you can study them flying freely, you should NOT enter a bat roost or disturb bats at rest.

As bats are warm-blooded, insect-eating mammals, they need to hibernate during the winter when food is scarce. The times of hibernation will depend on whether we have an early or late winter/spring but generally they will emerge in mid March and hibernate in mid October. Bats are also very sensitive to daily temperatures, and they will not waste energy by coming out on cold, wet or windy days, even in the summer. Given the right conditions, the bats will start to emerge around sunset and will be very active for the next 2 to 3 hours. There is then little activity until dawn, when the bats will return to the day roost. Depending on the species, day roosts may be hollow trees, caves, lofts, or even behind the hung tiles of a modern house.

Having determined above when bats emerge, the next question to consider is where can they be found? As with most wildlife, bats can be found where their prey, flying insects, are plentiful, and this can be several kilometres from their roost. A good starting point to study bats is by a small pond or stream, preferably one that has some trees or a hedge at the side. Bats also need roads, hedges or lanes to navigate by, and will, therefore, not normally be found in large open spaces or isolated ponds. As churches make good roosts and often have trees around them, these also make good places to look. Bats can also be found in towns, feeding on insects swarming around street lights or in gardens. If you do go rambling in search of bats, remember the country code, take a torch, and inform someone of where you are going in case of emergencies.

Bat Sonar

As already mentioned, all bats hunt and navigate using a sophisticated form of pulsed sonar. The frequencies used range from approximately 18kHz for the Noctual bat, to 110kHz for the Lesser Horseshoe; see Table 1 for further details. Within the British species, there are two distinct types of sonar, downward swept and continuous frequencies.

The continuous type is produced by the two Horseshoe species, whose name derives from their peculiar horseshoe-shaped noseleaf. The Greater Horseshoe emits a frequency of about 85kHz for about 20ms, from two half-wavelength-spaced nostrils. These bats can therefore be thought of as humming through their noses, rather than shouting through their open mouths as in the other species. The pulses are repeated at a rate of about 10 per second. The object of this is to produce a narrow beam of soundwaves, and hence greater accuracy.

The rest of the British species all use downward swept pulses, which are all of much shorter duration, typically 2 to 6ms long. The sweep rate can be tens of kHz per ms, but may, as in the case of the Pipistrelle, include a few ms of continuous frequency at the end of the call. Depending on the species and what the bat is doing, these pulses will be continuously repeated at a rate of between 5 and 25 per second. When homing in on their prey, the pulse repetition rises to a buzz, which can be distinctly heard on a bat detector, and indicates that the bats are feeding.

On a bat detector, very rapid sweep rates are heard as a sharp click, whilst the slower sweep rates sound more squeaky. This can be demonstrated with the common Pipistrelle, by gradually tuning from 70kHz down to 45kHz, and noting the change of sound on the slow sweep rate at 45kHz. It is important to note that whilst a bat detector is an invaluable tool in the study of bats, accurate species identification is very difficult. In field studies, experts use the detector along with other clues, such as flight patterns, size and habitat to provide identification. Figure 12 shows the approximate distribution of bat species in the U.K.

Counter Measures

It is by no accident that the crest of the RAF Electronic Counter Measures Squadron features a moth with the motto *Confundemus*, which loosely translates into 'We throw into confusion'. Bats have been on earth for 50 million years, and during this time, some moths have evolved effective counter measures against the bat sonar. Moths such as the one on the RAF badge, actually transmit jamming signals back to the bat, whilst others can be observed, especially round street lights, falling to the ground as soon as they hear a bat coming. It is thought that the very quiet sonar and the very sensitive ears of the Long eared bat species has evolved as a counter, counter measure, in that the moths will not be able to detect the bats before it is too late.

Bats and the Law

Bats and their roosts are protected under the Wildlife and Countryside Act of 1981. It is an Offence to intentionally injure or disturb a bat, or to damage its roost. Provided you are not very close to a roost entrance, the study of bats in free flight with a detector causes little disturbance, and is permitted.

Further Information

The Bat Conservation Trust, 45 Shelton Street, London WC2H 9HJ. Tel: (0171) 240 0933. This organisation will be able to supply further information, plus details on your local Bat group (most counties have one).

Bat Groups of Great Britain, 10 Bedford Cottages, Great Brington, Northampton, NN7 4JE. A cassette of bat sounds is available.

References

Which Bat is it?, R. E. Stebbings.
Bats of the British Isles, A. A. Wardhaugh.

ULTRASONIC DETECTOR PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1,4,6,7,8,9	1k	6	(M1K)
R2,5,10,21,25	470Ω	5	(M470R)
R3,11,29,30	10k	4	(M10K)
R12,13,15,16,18	3k9	5	(M3K9)
R14	100Ω	1	(M100R)
R17,24	47k	2	(M47K)
R19	100k	1	(M100K)
R20,26	6k8	2	(M6K8)
R22	330Ω	1	(M330R)
R23	220k	1	(M220K)
R27	22k	1	(M22K)
R28	8k2	1	(M8K2)
R31	2k7	1	(M2K7)
RV1	Cermet 100k	1	(WR44X)
RV2	Cermet 5k	1	(WR41U)
RV3	Miniature Linear Potentiometer 47k	1	(JM73Q)
RV4	Miniature Logarithmic Potentiometer 10k	1	(JM77J)
CAPACITORS			
C1,6,14,19	47µF 16V Sub-miniature Radial Electrolytic	4	(YY37S)
C2,5,10,11,15, 20,23,26,30	100nF 16V Disc Ceramic	9	(YR75S)
C3	2n2F Metallised Ceramic	1	(WX72P)
C4,12,13	4n7F Metallised Ceramic	3	(WX76H)
C7	180pF Metallised Ceramic	1	(WX59P)
C8	Ceramic 10nF	1	(WX77J)
C9,18,24	470nF 63V Sub-miniature Radial Electrolytic	3	(YY30H)
C16,21,28	Ceramic 680pF	3	(WX66W)
C17	680pF Polystyrene	1	(BX34M)
C22	220µF 16V Radial Electrolytic	1	(FF13P)
C25	15nF Polyester Layer	1	(WW31J)
C27,29	2n2F Polyester Layer	2	(WW24B)
SEMICONDUCTORS			
D1	1N4001	1	(QL73Q)
LD1	Low Current 3mm Red LED	1	(CJ58N)
IC1	SL561CDP	1	(DB47B)
IC2	MC1496P	1	(QH47B)
IC3	TL072CN	1	(RA68Y)
IC4	HCF4046BEY	1	(QW32K)
IC5	TDA7052	1	(UK79L)
MISCELLANEOUS			
MC1	EK-3132 Miniature Electret Microphone	1	(AY18U)
LS1	64Ω Miniature Loudspeaker Type 5064	1	(YT28F)
SW1	Right Angled SPDT Slide Switch	1	(FV01B)
SK1	PCB Mounted 3·5mm Stereo Jack Socket	1	(JM22Y)
SK2	PCB Mounted 3·5mm Mono Jack Socket	1	(FK02C)
SK3	PCB Mounted 2·5mm DC Power Socket	1	(FK06G)
	8-pin DIL Socket	3	(BL17T)
	14-pin DIL Socket	1	(BL18U)
	16-pin DIL Socket	1	(BL19V)
	7/0·2mm Hook-Up Wire Black (10m)	1	(BL00A)
	Single-ended PCB Pin (1mm)	1 Pkt	(FL24B)
	PP3 Battery Clip	1	(HF28F)
	Front Panel Label	1	(90010)
	PCB	1	(90009)
	Instruction Leaflet	1	(XV35Q)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	M2·5 10mm Pozidrive Screw	1 Pkt	(JC68Y)
	M2·5 Steel Nut	1 Pkt	(JD62S)
	M2·5 Shakeproof Washer	1 Pkt	(BF45Y)
	M3 Spacer 0·125in.	1 Pkt	(FG32K)
B1	Alkaline PP3 Battery	1	(ZB52G)
	Car Power Adaptor	1	(JY53H)
	Plain Black Hand-held Box Type HH2	1	(ZB16S)
	Matt Black Knob Type K14B	2	(FK39N)

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 90008 (Ultrasonic Detector) Price £39.99 A1

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

The following new items (which are included in the kit) are also available separately, but are not shown in the 1995 Maplin Catalogue.

Ultrasonic Detector PCB **Order As 90009 Price £3.99**
Ultrasonic Detector Front Panel Label **Order As 90010 Price £2.29**
EK-3132 Mini Electret Mic **Order As AY18U Price £19.99**

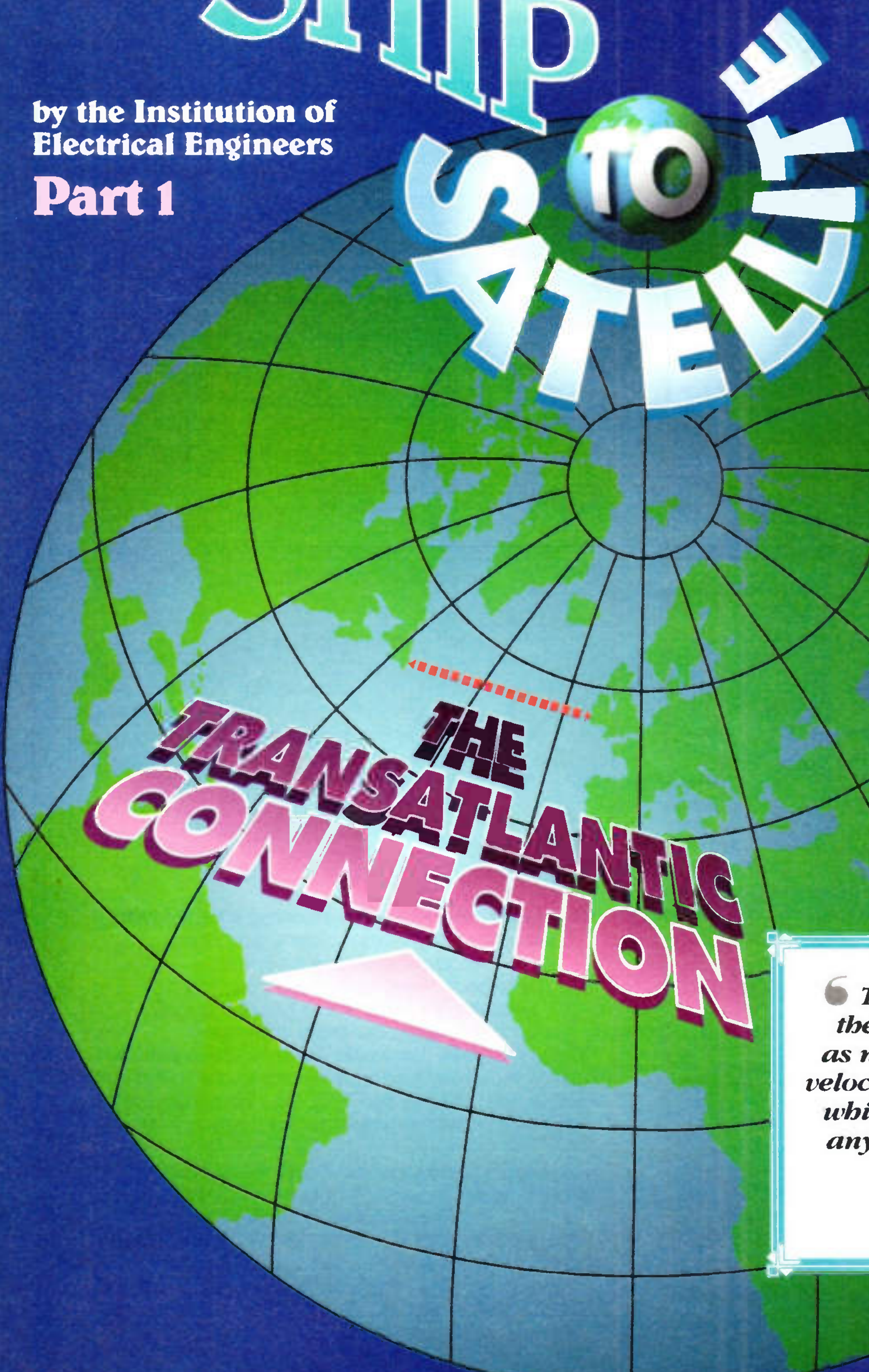
SAILING SHIP TO SATELLITE

THE TRANSATLANTIC CONNECTION

This is the story of the conquest of the communications barrier, of the North Atlantic Ocean. As will be seen, the theme running through this entire story is the collaboration at all stages between the North Atlantic nations.

by the Institution of Electrical Engineers

Part 1



Communications across the North Atlantic

From the early seventeenth century, when the first permanent British settlements were made on the North American continent, until the late 1850s there was an inevitable time lapse between events in one place and reactions to them in another. Delays could lead to unnecessary action, as, for example, at the end of the War of 1812: in February 1814, after the peace treaty had been signed in Europe, a US army fought and won the Battle of New Orleans against British forces, before news of the peace reached Louisiana.

Indeed, the speed of communications had changed little since the days of the Roman Empire. Over long distances the speed of message transmission was limited to the speed of a galloping horse or the fastest sailing-ship, though there had been marked improvements in sailing speed. Electricity (in the form of the telegraph) changed all that. In 1837 when Queen Victoria ascended the British throne, working telegraphs were produced on both sides of the Atlantic – by Samuel F. B. Morse in Baltimore and William Fothergill Cooke and Charles Wheatstone in London. By 1840 the telegraph had been developed into a commercially viable instrument of vast potential, and within ten years telegraph lines covered much of Britain, Europe and the settled regions of North America. But the telegraph stopped at the edge of the sea.

In 1858, a group of far-sighted men succeeded in laying a telegraph cable across the North Atlantic, and suddenly, with the click of a telegraph key the communications gap between Europe and America shrank from four to six weeks to only a few hours. But the technological problems necessary for long-distance, deep-water cables had not yet been solved, and within weeks the cable had failed. It took another eight years for the courage and persistence of the promoters of the cable to succeed. Their efforts form one of the greatest engineering triumphs of modern times, and our story of the transatlantic connection begins with the first Atlantic telegraph cables.

The first cables of the 1850s and 1860s were laid with British technical skills and paid for by British capital, and Britain became the centre from which cables girdled the earth. Vast distances from London were encompassed within minutes, with tremendous consequences for politics and commerce.

> *The fastest mail express, or the swiftest ocean ship, are as naught compared with the velocity of the electrical impulse which practically annihilates any terrestrial dimension.*
>
> Captain George S. Squier
> US Army Signal Corps, 1901:
> quoted by Daniel R. Headrick.

The original promoters forecast some of the changes, but other profound consequences caused by the links are hardly appreciated even today.

The cables spawned their own technology, including unique signalling and receiving methods to cope with the long distances covered, through lines submerged in water. Early submarine cables had a fundamental limitation, they could transmit telegraph signals, but they could not transmit over long distances the complex pattern of vibrations constituting speech.

In 1901 a rival system – radio – appeared when Marconi achieved the transmission of Morse signals across the Atlantic. In 1927 a transatlantic radiotelephone service began which, although expensive and subject to considerable atmospheric interference, established a small niche for traffic across the Atlantic during the 1930s and 1940s.

In 1956 the first transatlantic telephone cable was laid between Scotland and Newfoundland – the limitation of cable design which allowed the transmission of speech through an underwater cable, over short distances only, had been overcome. Twin cables, each with more than fifty complex amplifiers, were laid along the sea-bed in a joint British and American engineering project. It was conceived and designed jointly by the American Telephone and Telegraph Company and the British Post Office – a superb example of a modern dual national engineering enterprise.

However, voice transmission across the Atlantic was soon augmented by satellite transmissions. In 1962, transmissions from the US communications satellite Telstar were eagerly awaited in Britain: the first instantaneous transmissions of live television images across the Atlantic. In 1965, Intelsat I, the first geosynchronous satellite, solved the problem of 24-hour trans-ocean telephone and television transmission. For telephony, however, the slight delay while voices were transmitted up to the satellite and back was a disadvantage. After the first fibre-optic cable was laid across the Atlantic in 1988, the balance of advantage swung back to forms of cable transmission. With each improved method of communication, has come an increase in load-carrying capacity, and demand has risen with the capacity. In the 1990s instantaneous international voice communication is taken for granted.

The Transatlantic Cables 1857–1866

Our story begins in Britain with the first transatlantic cables of the late 1850s.

It is understandable that the first submarine cables originated in Great Britain, who alone possessed the economic incentives, sufficient capital, and the technological skills to promise success. In the mid-nineteenth century British trade was expanding rapidly across the globe and needed quick and reliable communications. The British were experienced in dealing with large engineering projects such as railway development. Most importantly, by 1850, several technological breakthroughs in separate fields occurred in Britain which when combined would produce a successful under-ocean cable.

They were: long distance electric telegraphy; the use of steam engines to power large ships; the discovery of a water-resistant insulating material which could be extruded around the core of the cable.

America drops England a line (Punch). IEE Archives.

> *Spanning the mighty gulf of the Atlantic.*
>
> Henry M. Field, 1866.

By 1850 telegraphy had been well-established on land. In 1837 Cooke and Wheatstone demonstrated their five-needle telegraph, and in 1840 they patented a telegraph in the USA (the same year that Morse patented his telegraph). In 1842 Paddington Station in London, and Slough were connected by telegraph (a distance of 19 miles) and in 1844 Baltimore with Washington (50 miles). By the end of the decade a web of telegraph wires covered Britain, Europe and eastern USA, and telegraph agencies sprang up to transmit news to businesses and newspapers.

Steamships were essential for laying cable at a controlled rate in a fairly straight line. For the first Atlantic cable attempt in 1857, there was no ship afloat with sufficient carrying capacity for an ocean's worth of cable, so two ships were used: the Royal Navy's *Agamemnon* and the US Navy's *Niagara*. Each required structural alterations to provide cable tanks to carry 1,000 miles of cable. (The first purpose-built cable-laying ship was not constructed until 1874.)

The third essential prerequisite was the insulation for underwater cables. Gutta percha, the natural latex of the Palaquium tree which grew in the Malaysian rain forests was introduced into Britain in 1843. In the next few years techniques for working it, and extruding it around a copper wire, were developed.

The First Undersea Cables

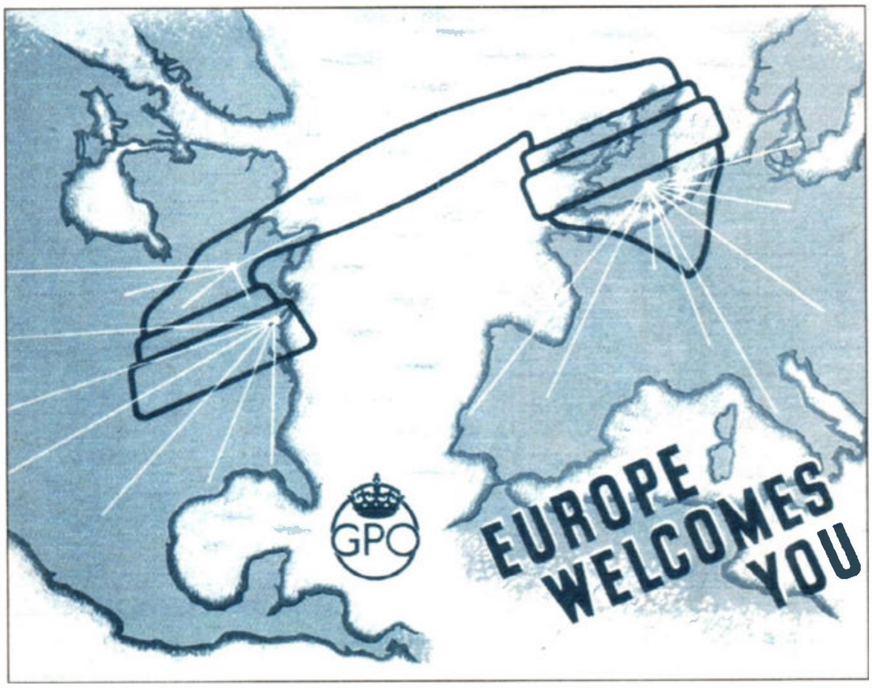
In August 1850, Jacob and John W. Brett laid the first undersea cable – a single strand of copper wire covered in gutta percha – from Dover to Calais. It worked for a few hours before being cut by a French fisherman, who thought its copper core was gold. The next year, in November, Thomas Crampton's Submarine Telegraph Company laid another cable consisting of four copper wires coated with gutta percha and protected by an outer sheathing of iron rope. It lasted 37 years.

Even before the Channel connection was made the idea of spanning the Atlantic had been mooted. The Brett brothers approached the British government for a subsidy, but were turned down. The vision and indefatigable energy of an American, Cyrus W. Field (aged 34) brought the project to completion. Field, having made a fortune in the wholesale paper business, was looking for a new venture. By chance he met Frederic W. Gisborne, who was deeply in debt after trying to lay a telegraph line across Newfoundland, and a cable link to the North American mainland. Field and four associates completed that project, but did not see why it should stop at Newfoundland. They obtained landing rights for a transatlantic cable and in 1854 began promoting a cable from there to Ireland – the two closest points across the ocean. In the United States Field obtained the support of Samuel Morse and Lt. Matthew Maury of the Naval observatory and aroused much popular enthusiasm, but very little money. In 1855 he travelled to England to raise money for the venture. Most of the £350,000 required for the formation of the Atlantic Telegraph Company was raised from the bankers and merchants of Manchester, Liverpool and London in £1,000 shares. Both the British and US governments offered assistance: soundings of the ocean floor and the loan of naval vessels for laying the cable – but no direct subsidies. The core of the 2,500 nautical miles of cable was manufactured by the Gutta Percha Company, and two companies, Glass Elliott and Co. and Newall, who each armoured half the cable. It was completed in four months.

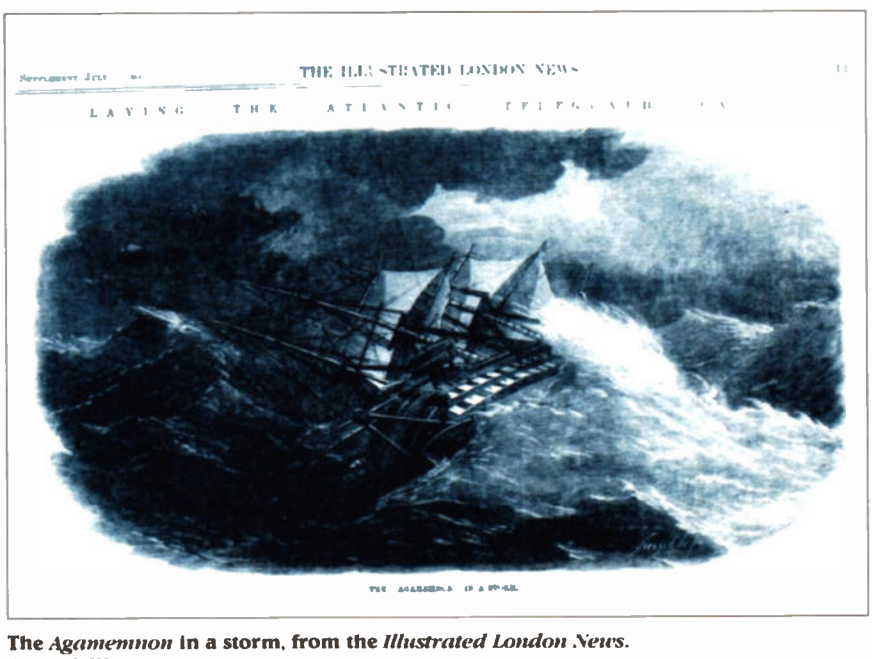
Laying the Cable

On 6 August 1857, the frigate *Niagara*, the newest and most advanced ship in the US Navy, began laying cable from Valentia, Ireland. The plan was for the Royal Navy's *Agamemnon* to take over in mid-ocean, but after the cable broke twice, it became apparent that the project would have to be abandoned. The ships returned to port and were unloaded. An additional 700 miles of cable was ordered for another try the following year. On 10 June 1858, *Agamemnon* and *Niagara* started out again carrying some 3,000 miles of cable. This time they planned to meet in mid-Atlantic, splice the cable and sail in opposite directions. After surviving one of the worst storms ever recorded in the North Atlantic, during which *Agamemnon* nearly capsized, the ships met and began paying out cable on 26 June. Continuous electrical tests on both ships monitored the condition of the cable. William Thomson, later Lord Kelvin, was the engineer on *Agamemnon*. Three times the cable broke, and once the ships returned to port before steaming back to mid-ocean for another attempt. Finally, on 5 August, *Agamemnon* steamed into Valentia while *Niagara* arrived at Trinity Bay, Newfoundland.

Even with Thomson's sensitive mirror galvanometer, especially designed by him, to detect the faint signals from the cable, the signals were too weak and slow to be easily deciphered. Even so, preparations were made to open the line, and on 13 August Queen Victoria and President Buchanan exchanged messages, and celebrations began in America. Coastal cities organised parades, dinners, and speeches, and even in inland cities prayers were said and fireworks set off to celebrate the occasion. Souvenirs of the expedition were avidly collected. Sections of cable were purchased by Tiffany & Co. of New York and made into three-inch lengths which were sold with a certificate of authentication signed by Field. In Britain celebrations were rather more restrained, although Charles Bright was knighted at the age of 26 for his role as supervising engineer of the cable-laying operation.



Europe welcomes you – poster. BT Museum.



The *Agamemnon* in a storm, from the *Illustrated London News*. Cable & Wireless.

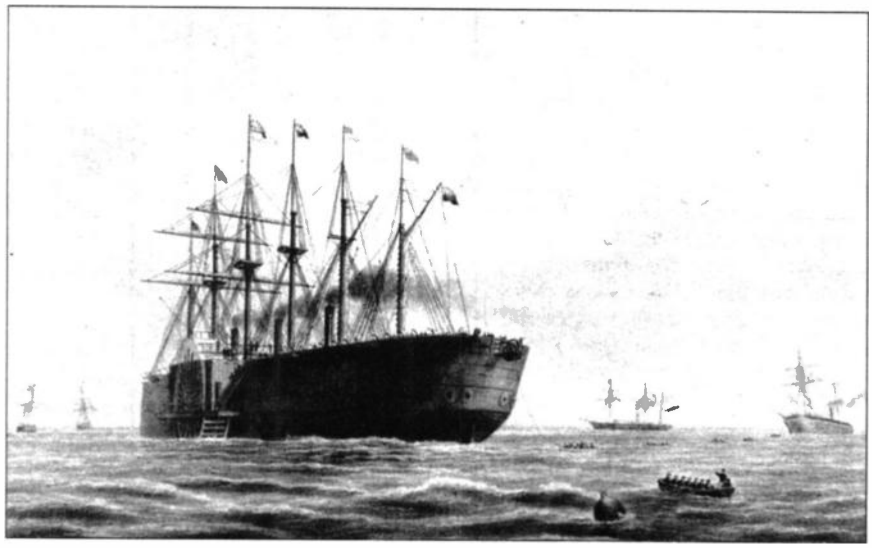
Problems with Cable Performance

Unfortunately, the condition of the cable deteriorated rapidly, and signals became progressively more difficult to decipher, until on 25 October, they ceased altogether. But the cable had already proved its worth when the British government sent a message to Canada, to cancel an order to despatch two Canadian regiments to sail to India, thereby saving £50,000. The cable was never opened to ordinary commercial traffic.

The disappointment was so great that the British government set up an official commission of enquiry, into the reasons for the failure. Its report, published in April 1861, investigated every aspect of submarine telegraphy in exhaustive detail and became a classic in electrical engineering literature. It concluded that the cable had been hastily manufactured, tossed about at sea, and stored dry on the deck exposed to the elements during the winter of 1857-58, to the ultimate degradation of the insulation. Moreover, any weaknesses thus produced were exacerbated by the 3,000V pulses from Wildman Whitehouse's giant induction coil. (Whitehouse, a surgeon turned electrician, had been appointed electrician to the enterprise, although it was William Thomson who went on both cable-laying voyages.) The

Commission report blamed Whitehouse for the failure, but the real fault lay with the promoters (who had been in too great a hurry) and with the cable designers who had produced a cable (in haste) that was too slender and badly insulated. Indeed, the gutta percha was incapable of withstanding exposure to air for any length of time, and later practice would be to protect gutta percha from heat and air by storing the cable underwater, at the factory and on board ship.

The performance of the 1858 cable, disclosed that submarine cables displayed different characteristics from land telegraphs. William Thomson played a pivotal role both in analysing the problems, and in developing ways to overcome them. In 1858, he devised his mirror galvanometer to detect the faint signal which emerged from the cable. (A century later cables would be boosted by amplifiers along their length, but that is a later part of the story.) Additionally, the faint signal appeared smeared out at the receiving end, thus restricting the number of pulses that could be transmitted and identified, in a given time. This occurred because the undersea cable acts as a long capacitor storing up the electrical pulse, and then gradually releasing it, so making signals hard to read. Thomson devised a way to sharpen signals by sending a short reverse pulse immediately after the main pulse. He also invented better sending and receiving instruments, and improved the efficiency of deep-sea soundings. For these and other contributions to engineering, he was knighted in 1866 and was raised to the peerage as Baron Kelvin of Largs in 1892.

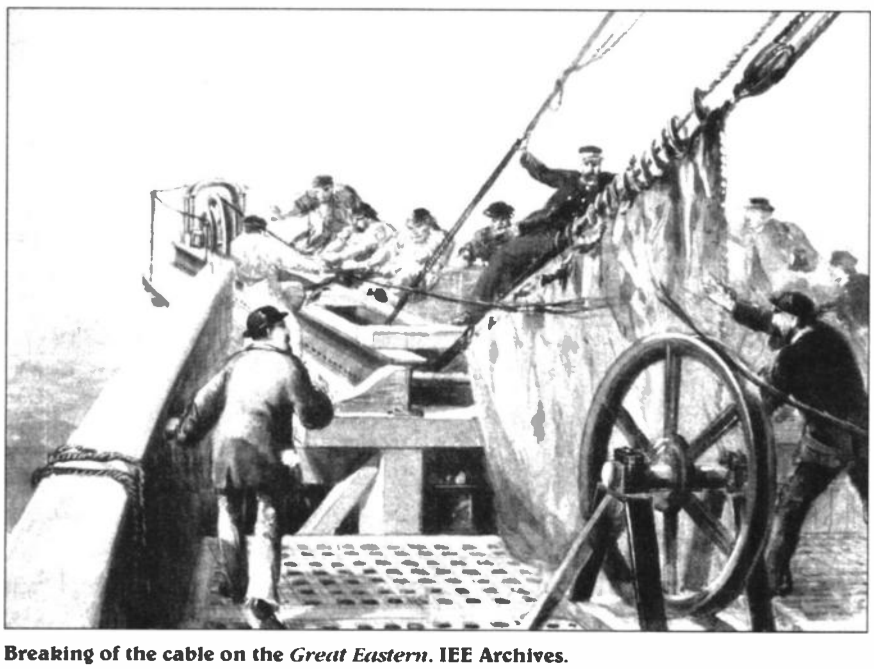


The *Great Eastern*. IEE Archives.

Manufacturing Techniques

It was also obvious that cable manufacture needed to be refined and more care exercised in the operation. The fears of British investors and the Civil War in the United States (1861–1865) militated against an early rerun of the project. Nevertheless, as the Civil War drew to a close, Field decided to try again. He sought £500,000 in shares of £5 each, to attract more investors; at this point, John Pender, a Manchester cotton manufacturer, stepped in. He engaged his whole personal fortune and business skills in launching a new company, the Telegraph Construction and Maintenance Company, in 1864. The new company was an amalgam of the old Gutta Percha Company, makers of cable cores, and the cable sheathing company, Glass Elliott. This company took shares in the Atlantic Telegraph Company in part payment for manufacturing the new cable. The shore ends were made by W. T. Henley & Co. This cable was mechanically far stronger than the earlier one had been. It was laid by the world's largest ship, Brunel's *Great Eastern*, which was able to contain the entire cable in her specially adapted hold. She left Valentia on 23 July 1865 and paid out 1,186 nautical miles of cable, before there was a break during an attempt to mend a fault in the cable. Attempts to retrieve it failed and she returned to port.

The following year the promoters tried again. An additional £600,000 was raised by a new company, the Anglo-American Telegraph Co., and on Friday 13 July the *Great Eastern* set out again. This time the cable was laid without a break, and she reached Heart's Content, Newfoundland on 27 July 1866. She then returned to find and retrieve the cable lost the previous year. A new length was spliced on, and that line was completed to Heart's Content on 8 September. Two cables now spanned the Atlantic. The age of instant global communication had begun.



Breaking of the cable on the *Great Eastern*. IEE Archives.

For nearly a century the basic design of the submarine telegraph cable remained unchanged. Indeed, sections from the 1873 cable from Ireland to Newfoundland were still in service in the 1950s after more than 80 years of continuous operation. The cables across the North Atlantic were laid in three bursts of intense activity, separated by long lulls: from 1866 to 1884, from 1894 to 1910, and from 1923 to 1928, and for most of that century the centre of activity remained in Britain. In the 1870s many of the new lines were consolidated by John Pender to form the Eastern Telegraph Company which grew into a giant of the industry. Moreover, most of the world's cables were manufactured by one or other of three companies, on the banks of the Thames near Greenwich.

The basic cable design – a stranded copper core covered by gutta percha insulation and iron armouring – remained unchanged, but several innovations were introduced to amplify weak signals and increase the speed of transmission and receiving equipment. Automatic transmission machines fed by a punched tape were introduced. Problems at the receiving end were complex, although some solutions were found as early as the 1870s. In 1870, William Thomson devised a siphon recorder which was less sensitive than his mirror galvanometer, but made a permanent record of the received signal on paper. This was an immense boon in the days when all messages had to be sent and received manually, by telegraph clerks. Much effort was spent designing instruments to send messages automatically, thus reducing transmission time and errors spent in reading the tape and retransmitting the message.

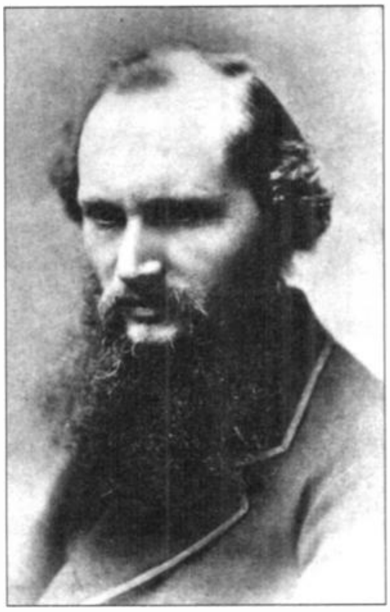
Improving the System

An important development was a method of sending signals in opposite directions simultaneously through the cable. Duplex telegraphy was developed on land line telegraphs in the 1850s but was not introduced to the undersea cables until the 1870s. This almost doubled the working capacity of the cable. It is done by making the receiver at the transmitting end insensitive to the impulses being transmitted from its end of the cable, while still leaving it capable of picking up incoming signals. Thus the cable could transmit and receive simultaneously. The next development was multiplexing, in which several messages could be sent in the same direction at the same time. Thus one could, for example, have a single cable carrying eight separate messages simultaneously – four in each direction. It was done by allowing a rapidly operating switch to connect the line to each of the sending instruments in turn: each would have the use of the line for a fraction of a second and then release the line to the next sender. At the other end, the receiving instruments would be switched in and out at exactly the same rate.

As early as the 1880s, Oliver Heaviside postulated that if the cable had inductance, the distortion due to the capacitance between it and the surrounding sea-water would be reduced. Around the turn of the century experiments were conducted on short lines with loading coils, but these were impractical for long lines. What was needed was a material with high magnetic permeability which could be wrapped around the cable core. In the 1920s two such metals were introduced: an iron-nickel alloy, Permalloy, by Western Electric in the United States, and a copper-iron-nickel alloy, Mu-metal, by the Telegraph Construction and Maintenance Company in Britain. The first loaded cable was laid in the Atlantic in 1924, and others followed.

With the use of these techniques and new materials, by the 1930s it was possible to send up to 400 words a minute across the most modern of the Atlantic cables. This was about 100 times better than the 1858 cable – even during the moments when it was working properly – and was nearly ten times faster than the average speed of the very best cables.

But, throughout the telegraph cable era, customers had another measure of speed – the time it took a message to reach its destination. The North Atlantic was a fast route with several competing cables and only two retransmissions. By the 1890s, the London and New York stock exchanges were only two to three minutes apart, from submission of the message to delivery at the destination. At this time customers for cable services were mainly government agencies and commercial interests.



William Thomson, later Lord Kelvin. IEE Archives.

Just after the turn of the century a new innovation in communications presaged even faster communication across the Atlantic – Marconi's wireless. Although radio could transmit voices, communicate with ships and broadcast to many receivers at once, cables were more private and (unlike transatlantic radio) worked 24 hours a day. In the 1920s the rapid development of route capacity via cable and radio services played a vital role in the development of international business. The next section traces the story of the transformation of radio signals to the international transatlantic and globe-encircling radio services of the late 1920s.

Transatlantic Radio

The next great leap across the Atlantic occurred as the result of the vision and experimental tenacity of Guglielmo Marconi, who spent over thirty years working on the expanding technology of radio. In the 1860s the great mathematical physicist, James Clerk Maxwell, proved mathematically that all changes in electric and magnetic fields cause electromagnetic waves in space. He calculated that these waves should travel with a speed equal to the ratio of the electrodynamic to the electrostatic units of electric force. The value of this ratio had been determined by Friedrich Wilhelm Kohbrausch and Wilhelm Eduard Weber to be very close to the value for the velocity of light, and Maxwell hypothesised that light itself was an electromagnetic wave. In 1887 a German scientist, Heinrich Hertz, conducted a series of experiments to test Maxwell's theory. He generated what he described as an 'outspreading of electric force'. These Hertzian waves excited the interest of many scientists, but Marconi transformed them into a practical signalling medium over long distances.

Enter Marconi

Guglielmo Marconi was born on 25 April 1874 in Bologna, Italy, the son of an Italian father and an Irish mother. He received his first elementary education in England while there for two years, after which the family returned to Italy where he completed his education. In his teens he came into contact with the renowned Professor Righi, and studied his papers on electromagnetic radiation. A paper on the experiments of Hertz which he read while on holiday in the Alps fired him with the idea of using those waves as a means of communication. He returned to his

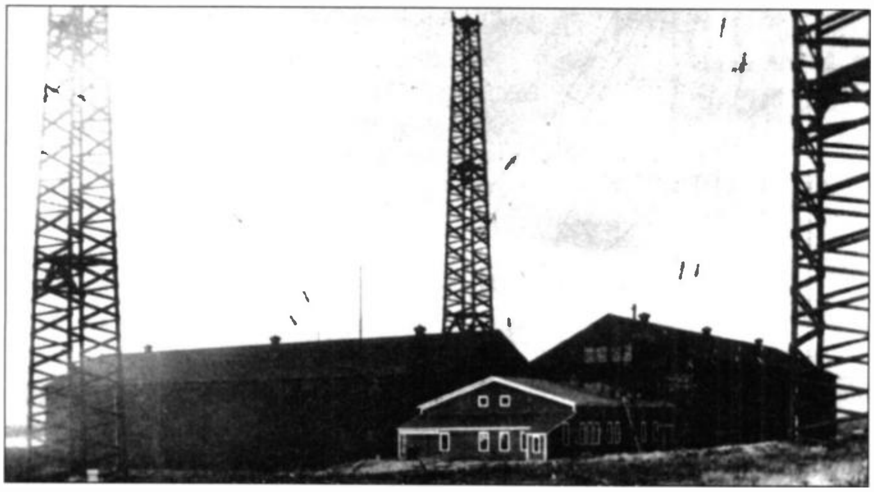
> ***'Can you hear anything, Mr Kemp?'***
>
> **Guglielmo Marconi.**

parents' villa in Bologna and began experimenting, using the same type of apparatus as his contemporaries. In a series of careful experiments he succeeded in transmitting signals across a distance of over a mile.

In 1896, after the Italian government refused to finance the development of his new invention, Marconi packed his wireless apparatus in a suitcase, and left with his mother for England. Here, with the assistance of William (later Sir William) Preece, Chief Engineer of the Post Office, and George Kemp, Marconi continued to develop his invention. On 2 June 1896, he applied for the world's first patent for wireless telegraphy, and by the spring of 1897 he had transmitted signals some eight miles; by November he had reached 18 miles over water and had been granted a British patent on his device. In 1899, he installed the first ship-to-shore wireless station at the South Foreland Lighthouse near Dover. Here, on 27 March 1899, he received the first message from across the English Channel.

Six months later Marconi was in *New York* to supervise arrangements for the reporting of the America's Cup races for the *New York*

G. S. Kemp, Marconi and P. W. Paget at Newfoundland, December 1901. GEC-Marconi.



Marconi wireless station. Glace Bay, Nova Scotia *c.* 1902. GEC-Marconi.

Herald and *Evening Telegram*. From a small ship with an antenna rigged to its masts, Marconi followed the yachts around the course, transmitting to a ship moored to the shore for onward transmission by line telegraph to the newspaper offices where they were received within 75 seconds. The American yacht *Columbia* defeated the British yacht *Shamrock* and retained the Cup. Marconi's triumph was even greater. The America's cup success led Marconi to realise that his next great challenge must be the transmission of messages across the Atlantic.

In July 1900, Marconi turned his mind to 'the big thing' – transmitting across the Atlantic. To achieve this two transmitting stations needed to be set up, one in Britain and one in America, vastly more powerful than anything which had been constructed before. Marconi, aware of his own limitations, called in help. He enlisted Dr John Ambrose (later Sir Ambrose) Fleming as the Marconi Company's scientific adviser. Fleming was a distinguished scholar and university professor who had long been interested in electromagnetic waves and had repeated Hertz's experiments. In addition he had carried out work on high-voltage alternating currents. He began work as a consultant with Marconi in July 1900 while still retaining his position as Professor of Electrical Engineering at University College London.

First Steps in Radio Communications across the Atantic

First a suitable European site had to be found, preferably on the British mainland, but physically as near as possible to America. Marconi found a site that met these criteria in Cornwall (the south-western tip of England) at Poldhu. Here construction of the transmitting station began in October and was ready for preliminary testing in mid-January 1901. The power plant was designed by Fleming, and the original antenna system, constructed by one of Marconi's senior engineers, R. N. Vyvyan, consisted of twenty wooden masts, 200 feet (61m) high, arranged in a circle 200 feet (61m) in diameter supporting 400 aerial wires forming an inverted cone.

Marconi then left for America to establish its counterpart. Accompanied by Vyvyan, he inspected several sites along the New England coast, before choosing Cape Cod, Massachusetts. He selected a site at South Wellfleet and, leaving Vyvyan to supervise construction of the station, returned to London. A station similar to that at Poldhu was constructed.

Transmitting experiments at Poldhu continued all summer, but during the autumn disaster struck when the worst gale in memory hit Poldhu in full force, leaving all twenty masts collapsed in a heap of shattered timber and tangled wire. Kemp and his men cleared the wreckage, and Marconi designed a new, simpler, fan-shaped antenna consisting of 54 wires suspended at one metre intervals between only two 160-foot (49m) spans. He also decided not to try to reach Cape Cod but to try transatlantic reception at the point of nearest landfall – Newfoundland. He was wise. On 25 November a severe Atlantic storm wrought the same havoc on the elaborate antenna system at Cape Cod.

On 26 November 1901, Marconi set sail in great secrecy with Kemp and one other assistant, P. W. Paget, carrying a miscellany of receiving apparatus, balloons and kites. He took hydrogen-inflated balloons because these could be used to elevate antennas vertically while the kites could be used in stronger winds than could balloons. With the enthusiastic approval of the Newfoundland authorities, Marconi chose a site on Signal Hill some 600 feet (183m) above St John's harbour – not far from Heart's Content where the first Atlantic cable was landed in 1858. The governor offered him the use of two rooms in the abandoned fever hospital at the top of the hill.

By 9 December all his preparations were completed, and a cable sent to Poldhu requesting that the Morse letter 'S' should be transmitted continuously from 3.00pm to 7.00pm Greenwich Mean Time, the transmission to begin on 11 December. The Newfoundland weather was very cold. Most days were very squally, rendering it a struggle to keep the antenna-bearing kites and balloons in the air.

On the crucial day, Fleming at Poldhu began the transmissions as planned, the power employed, according to his estimate, being between 10 and 12kW with a wavelength of the order of 1,200 feet (366m). At Signal Hill the wind freshened and later developed into a full gale, rendering it impossible to raise the balloon to the desired height. Later, in a strong gust of wind, the balloon was lost. On the next day, Thursday 12 December, a successful attempt was made to raise one antenna by means of a kite. Suddenly at 12.30pm Newfoundland time, Marconi handed the earpiece to George Kemp and asked quietly, "Can you hear anything, Mr Kemp?" He could indeed. Through the earphone he heard the rhythm of three clicks followed by a pause, and then three more clicks and so on in repetition until the clicks were drowned in static. Marconi's diary entry for that day records simply 'Sigs. at 12.30, 1.10 and 2.20.'

Although the weather worsened on the following day, they did manage to raise a kite for a brief interval, when they again heard faint signals. On the 14th the weather continued foul, and for the time being Marconi abandoned further tests. However, he cabled the news to his London office and on the 16th he informed the press.

Not All are Convinced

The first reaction came on the evening of the 16th in the form of a letter from the solicitors of the Anglo-American Telegraph Company whose cable had carried Marconi's telegram to London two days earlier. It called Marconi's attention to the fact that the company had a monopoly of communications throughout Newfoundland and forbade infringement of their rights under threat of legal action. In response, Alexander Graham Bell immediately offered Marconi the use of land at Cape Breton, Nova Scotia. But some press and technical journals doubted the results, for Marconi's results were counter to the accepted ideas of how Hertzian waves behaved. If radio waves behaved like light, they could not bend round the curve of the earth. As Arthur C. Clarke has stated, a searchlight in Cornwall, no matter how powerful, could not be seen more than a few miles out in the Atlantic: after that distance its rays would have beamed on out into space above the falling curve of the earth. In 1902, Oliver Heaviside in Great Britain and Arthur Edwin Kennelly in the USA, independently and simultaneously postulated that at a very high altitude in the atmosphere there was a reflecting layer which bounced radio waves back to earth rather than allowing them to escape into space.

Marconi realised that to receive signals from Poldhu during transient experimental periods was one thing – to establish a reliable two-way commercial service was quite another. He quickly established a new station at Glace Bay, Canada. By January 1903, another new station had been completed at South Wellfleet on Cape Cod, and on 18 January it transmitted 2,000 words, including a message from President Theodore Roosevelt, to Glace Bay for retransmission to England. Conditions were so good that the message was picked up directly by Poldhu, the first wireless message received in England direct from the USA. Although Marconi established a permanent transatlantic radio service in October 1907, he provided no real competition to the cable services for many years. Although the use of radio for broadcasting was developing fast, individual messages over long distances continued to be handled mainly by telegraphy over cables.

In Part Two we will cover the expansion of the various systems; with changes in technology enabling speech, visual images, and later, computer data to be transmitted, as well as the use of new communication media such as satellites. E

A readers' forum for your views and comments. If you would like to contribute, please address your replies to:

The Editor, Electronics – The Maplin Magazine P.O. Box 3, Rayleigh, Essex SS6 8LR, or send an e-mail to: AYV@maplin.demon.co.uk

AIR YOUR VIEWS

STAR LETTER

In this issue, Jody Florian of South Croydon, Surrey, wins the Star Letter Award of a Maplin £5 Gift Token for his critical acclaim of Maplin's services.

You're a Bounder, and a CAD!

Dear Sir,
Regarding 'Stray Signals' (April 1995), I find there are several misconceptions contained in the last section of the article, namely the virtues of both CAD and Microflitches (sic). With every young person who is involved in Engineering training likely to undertake at least one course in CAD during their training (in Essex, this is most likely to be AutoCAD 12), there is likely to be a credibility gap shown in your statements. Microflitches (sic) come into their own in points of sale operations, where time and money are of the essence. A standard connection charge of 37 pence for a telephone access to a computer database with as many as 600 access points across the country is not as cost-effective as producing a book of 40 pages, 1 foot square, containing up to 100 individual drawings. That is the cost-effective power of a microflitch (sic). However, for a National or International Engineering group, such as a motor manufacturer, holding master drawings on a database is more cost-effective when you have multiple manufacturing sites. On a CAD system (I did a course on AutoCAD 12 last year), you can reduce a complex drawing to the size of 1 pixel, so with a screen of 600×400 pixels, you could fill a screen with 240,000 drawings – enough to put the Space Lab on a single sheet of paper. How can you tell if all the drawings are there? You can either explode the whole drawing, or selected parts of it. The PC is as good as your memory capacity allows it to be. Microprocessors merely accelerate the access speed to individual files. You could conceivably use a Sinclair ZX80, but you might have to wait several years before you could be ready to obtain a printout, and then be prepared to wait months for the printout to be ready. Even so, the slower processors still have their place as training aids, and indeed, are not replaced until absolutely necessary. The trouble with most professional writers, is they allow themselves to be convinced by the salesman. In the present economic situation, it is the finances which dictate the speed of technological change, and raising interest rates only slows the process still further.
J. C. E. Moore, Chelmsford, Essex.

Well! You must have been really reading between the lines to have gleaned 'several misconceptions' from what was only ever intended as a footnote to some light-hearted, generalised observations rather than a serious article dedicated to CAD and 'Microflitches' (whatever they are – I take it you meant microfiches?!) By and large, professional writers tend to be quite a cynical lot (in my experience at least!), and certainly not given to flights of fantasy due to sales spiel, from whatever source it originates from, since, in the course of their work, they are often bombarded with sales brochures, mailshots, and the like. However, as you say, the economic climate does have a significant influence on the rate of progress of technological advances.

Leave Your Name and Your Number, and I'll Get Back to You . . . !

Dear Editor,
In connection with The History of Electronics series, you may be interested in the following, which our local History Society reports, appeared in the Ormskirk parish church magazine in October 1900; "Some of the telephone subscribers in Copenhagen are using an automatic register for messages spoken into their instruments when they happen to be out. The apparatus is a modification of the Edison phonograph, using a steel tape instead of a wax cylinder as a receiver. The steel tape is passed between the poles of an electromagnet, with whose coil a telephone is connected, and is variably magnetised at different portions of its length as the current is varied by the speech vibrations in the telephone. The magnetism is long retained, giving a reproduction of the vibrations and speech when the tape is again passed through a similar electromagnet, as is done when the telephone owner returns home." It makes one wonder whether our local magazine was or was not the forerunner of Electronics, and whether, perhaps, Keith Brindley was the contributor of the piece!
Peter Tyler, Aughton, near Ormskirk, Lancashire.

How's about that then! Actually, the telephone had been around for almost a quarter of a century by then, having been invented in 1876, so it is perhaps surprising that the answerphone took so long to come into being, but then many folk at that time who could afford a telephone would also be likely to have servants or domestics. The Maplin empire and some of the contributors to Electronics have been around for a good few years now, it's true, but rest assured, we're all still relatively young and dynamic around here, or at least, we like to think so!

Might I Suggest . . .

Dear Editor,
I am an extremely keen 14 year-old 'electronic hobbyist' (or whatever we call ourselves), who uses his Dad's credit card to buy stuff from Maplin. I think Maplin is the absolute best in user-friendly service and products, the descriptions of which are extremely good, as are the notes of what they do, as supplied in the kits. The 'It's a Fact' boxes in the catalogue are absolutely brilliant, and there should be a lot more of them. A really interesting idea, would be to have a Maplin Catalogue on CD-ROM, as searching for items would be ever so much easier with a search facility. Also, the CD-ROM could incorporate a program (hopefully much more user-friendly than when ordering via the Internet), where, if you have a modem, orders could be made via the telephone. When there is a price change or new product, etc., the CD-ROM version could be updated via the modem, with the information sent to the hard drive. This comment has been made before in *Electronics*, but I also think there should be many more kits, to add to the already quite large selection. I still have another four years of schooling left, and until then, unless I phone from school, I will have difficulty in trying to contact the Maplin Customer Services, let alone Technical Enquiries. All that would change if both these lines were open until 6.00 p.m. on one or more weekdays, or perhaps a few hours on Saturday. I also think Maplin should send a questionnaire to all members, and encourage them to fill it in by having a prize draw every 6 months or so. Finally, could Maplin start having a look at surface-mount technology in a bit more detail?

Thank you for your opinions and suggestions concerning the Maplin publications and customer services. I trust that you ask your dad's permission prior to using his credit card! Good to hear that you find the 'Its a Fact' boxes useful – we certainly do, here on the magazine! To have the Maplin Catalogue available on CD-ROM is certainly an interesting idea, and one which we have been looking into, even before you mentioned it! It is a distinct possibility for the future. . . . Regarding the kits, these are being conceived all the time, but not all appear in the catalogue, since some kits are offered after the catalogue has gone to print. Instead, these are advertised in the magazine, first as project articles, then in the 'Did You Miss These Projects?' pages, until finally, they appear in the next catalogue. Unfortunately, the Customer Services and Technical Enquiries services cannot be opened beyond their present working hours, since, in the case of Technical Enquiries, written replies need to be compiled and sent out after the phone lines have closed for the day, otherwise this department would become inundated with paperwork! However, orders may be made 24 hours a day, via either the Telesales, Cashtel (via modem), or using the Key Call service (detailed in the December 1994 issue of Electronics*), in which your order is sent in coded form, using a dual-tone, multi-frequency (DTMF) telephone, or DTMF dialler unit in conjunction with a conventional telephone. The Key Call service is in fact, quicker than using the modem method. Maplin did give out questionnaires to its readership some time ago, however, due to the huge number of returns, it presented quite a problem when it came to processing them all, and some of the questionnaires were still being sent in almost a year after being sent out! And besides, we do offer 'Air Your Views' for your suggestions and comments! Finally, Maplin do intend to offer more projects using surface-mount technology (and hence, more articles and details), as reader feedback of opinions about this new technology has been largely favourable.*

Engine Embezzlement System

Dear Sir,
Now that most modern, and practically all new cars, have their engines governed by sophisticated electronic engine control units (ECUs), a worrying new phenomenon is appearing to emerge, of certain unscrupulous (or crafty!) car manufacturers, mostly Japanese, it has been suggested, deliberately creating a 'bug' in the built-in control program, which after a certain mileage, say, 60,000 miles, causes the engine to incur sudden blow-ups, without any warning beforehand. This is apparently an effort by the manufacturers, who have become worried at how reliable modern cars have become and consequently, how their owners 'hang onto them' for more years than the makers would like, to gain extra profits, due to motorists having to buy expensive parts, replacement engines, or even brand-new models, as a result of this hidden sabotage. My neighbour's Nissan 200SX recently suffered such unexplained damage, despite his very conscientious ownership, rigidly adhering to the servicing schedule, and changing the engine oil every 3,000 miles, etc. I look forward to your comments on this matter, and by the way, thanks for a terrific magazine, eagerly awaited each month!
A. B. Rhoade, Pratts Bottom, Kent.

Thank you for your enthusiasm about the magazine. I have also heard of the rumour you mention, but it is unsubstantiated. It would be an easy 'fast one' to pull however, since the majority of motorists have no idea of how engine management systems operate, what goes on under the bonnet, how to open the bonnet, or even how to drive properly, it sometimes seems! Perhaps a representative of a car manufacturer, or an experienced vehicle mechanic or technician, would care to write in and elaborate further on the secrets of such 'black boxes'!

Text by Alan Williamson and Robin Hall

KIT AVAILABLE (90014) PRICE £7.99

2 PROJECT RATING

STEREO RIAA CORRECTION PREAMP

With the advent of CDs over the last decade or so becoming popular in place of records, many people have replaced their original stereo systems to take full advantage of the new medium. In many cases, this has left many valuable record collections gathering dust as many new stereo systems do not cater for this now obsolete format.

FEATURES: * RIAA CURVE * INTERCHANGEABLE WITH UNIVERSAL STEREO PREAMP (90022) * STANDARD CONNECTIONS

Replacing a large collection of vinyl records is not only prohibitively expensive, but some of the older material may not even be available on CD. There is also the added dilemma of buying a replacement CD, when you know you would rather have that new release (how much of your old collection have you replaced so far!).

Got an Old Turntable?

These days record decks cannot generally be plugged directly into a stereo amplifier, so an intermediate RIAA (Recording Industry Association of America) preamplifier is needed; this is to amplify to line level and re-equalise the frequency response from a record.

This project is suitable for turntables fitted with a moving magnet or high output moving coil cartridges (turntables fitted with ceramic cartridges do not require an RIAA EQ stage and can be plugged directly into a line level input).

If exemplary performance is not too important, and you would like to listen to your old record collection, this project may be the one for you!

So what are you waiting for, go and fetch that turntable you stashed in your loft all those years ago, and have a go at this project.

The preamplifier power requirements are low and therefore do not put any excess strain on the power supply, especially if integrated within the main amplifier. The PCB is small enough even to be

Specification

Power supply:	10 to 30V DC
Supply current:	typical 5mA
Amplification:	(1kHz) 35dB
Input impedance:	47kΩ
Input signal:	5 to 10mV

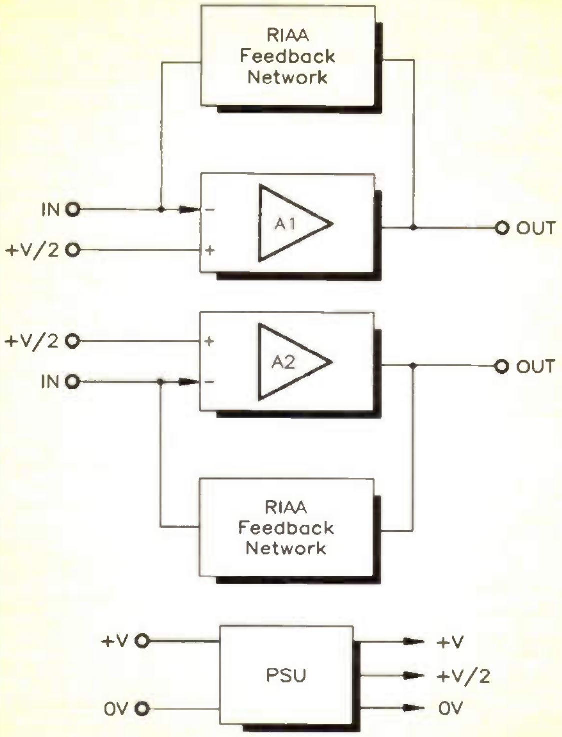
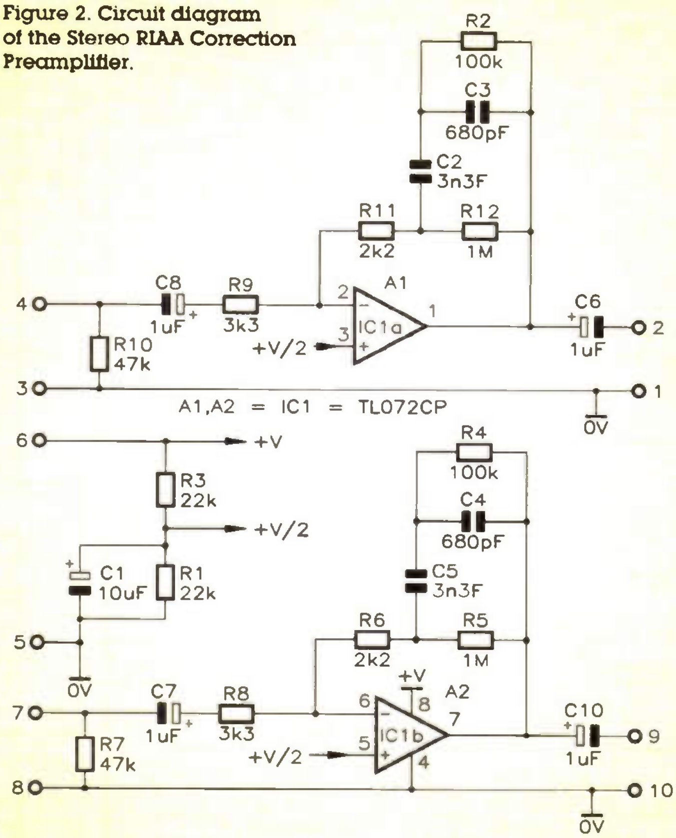


Figure 1. Block diagram of the Stereo RIAA Correction Preamplifier.

Figure 2. Circuit diagram of the Stereo RIAA Correction Preamplifier.



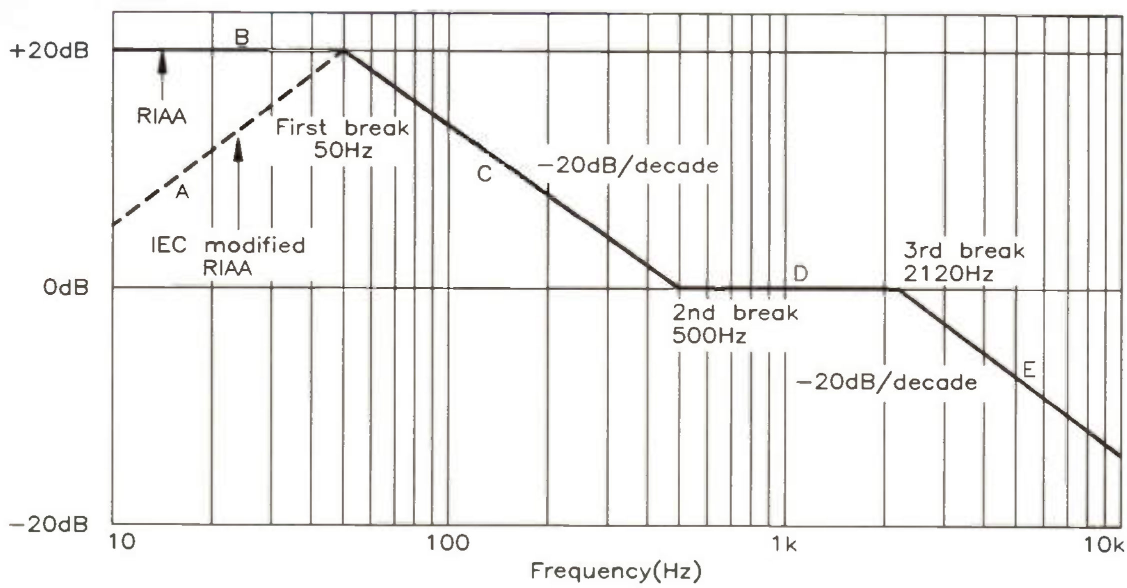


Figure 3a. Idealised RIAA EQ and IEC modified RIAA curves.

incorporated within the turntable plinth (which is really the best place for it), enabling the arm's sensitive leads to be kept as short as possible.

Circuit Description

The block diagram for the Stereo RIAA Preamplifier is shown in Figure 1, and the circuit diagram in Figure 2; these will help the reader to understand how the circuit works.

Common components serving both amplifiers A1 and A2, are the resistors R1 and R3 which form a half supply reference for the non-inverting inputs of the op amp IC1, and capacitor C1, used for decoupling the half supply.

The components making up the two amplifiers A1 and A2 are identical; to save confusion, only the A1 preamp circuit will be described.

The amplifier A1 is inverting, and has a frequency dependent feedback loop.

The 47kΩ input impedance required to correctly terminate a moving magnet cartridge is provided by the resistor R10. Refer to Figure 3a for the idealised RIAA and IEC EQ curves. The fall in gain at lower frequencies is shown as Line A, which is determined by the capacitor C8 and the resistor R9 forming a low-frequency (subsonic) rumble filter; this is the IEC modification to the RIAA EQ. R9 is basically the input resistor to the inverting input of the op amp and the feedback network. The non-inverting input is held at the half supply. The maximum gain of the op amp is shown by line B, and at the first break point; which is determined by -R11+R12/R9. R11 and R12 determine the gain at low-frequency. The reduction in gain at the higher frequency at line C (the second break point at 500Hz), is caused by the reduction in the reactance of capacitor C2; which places the resistor R2 in parallel with R12. The gain will then level off to line D; which can then be approximated as:-R11+(R2//R12)/R9 (ignoring C2). The final reduction in gain at high-frequency, line E, is attributed to C3 effectively short circuiting R2; the gain is then -R11/R9; which is less than -1. The gain falls off to unity gain at 20kHz. Output is via C6 to the next stage.

A typical RIAA and IEC response are shown in Figure 3b (note that the vertical scale is in dB). The actual response of the Stereo RIAA Correction Preamplifier is shown in Figure 3c (the vertical scale is linear).

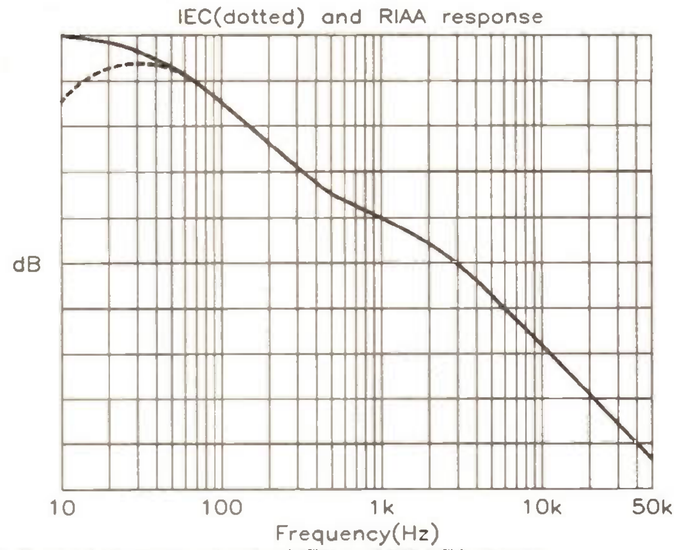


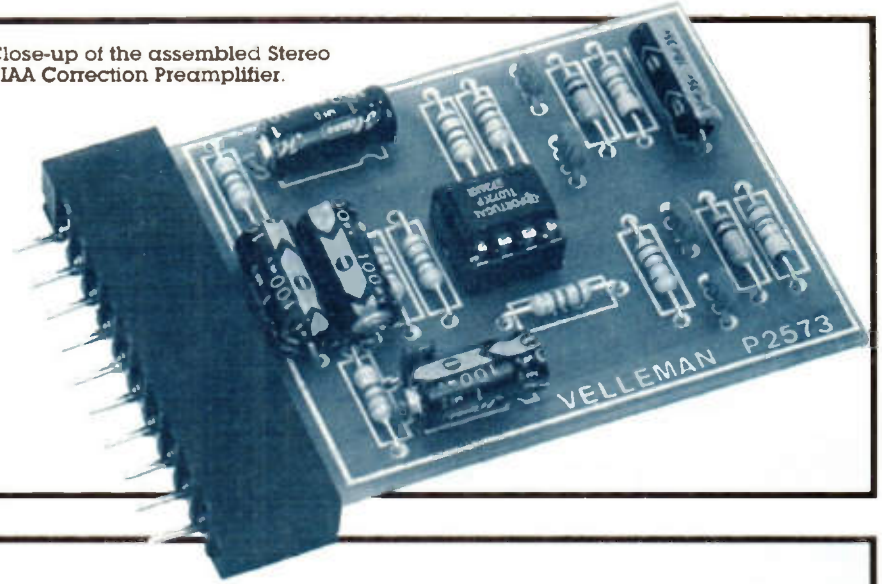
Figure 3b. Typical response of actual IEC and RIAA EQ curves.

Construction

Construction is fairly straightforward; with all the components mounted on the legend side. Begin with the smallest components first, working up in size to the largest. Be careful to correctly orientate the polarised devices, i.e. electrolytic capacitors and the IC. Fit the 8-pin DIL socket, making sure that the notch on the socket matches the legend on the PCB. The last stage of construction should be to insert the IC into its socket, again making sure that the orientation of the notch is correct.

Thoroughly check your work for misplaced components, solder whiskers or bridges, and dry joints. Finally, clean all the flux off the PCB using a suitable solvent.

Close-up of the assembled Stereo RIAA Correction Preamplifier.



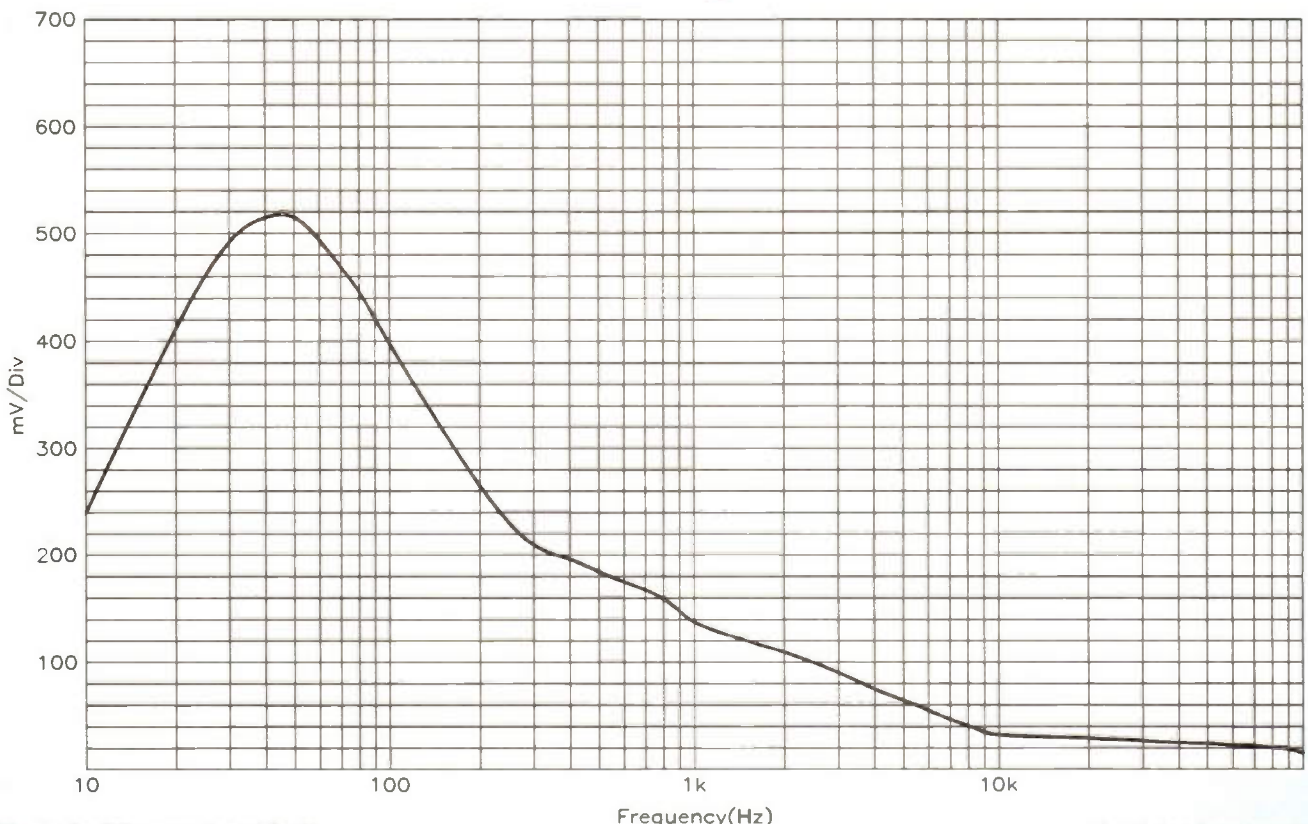
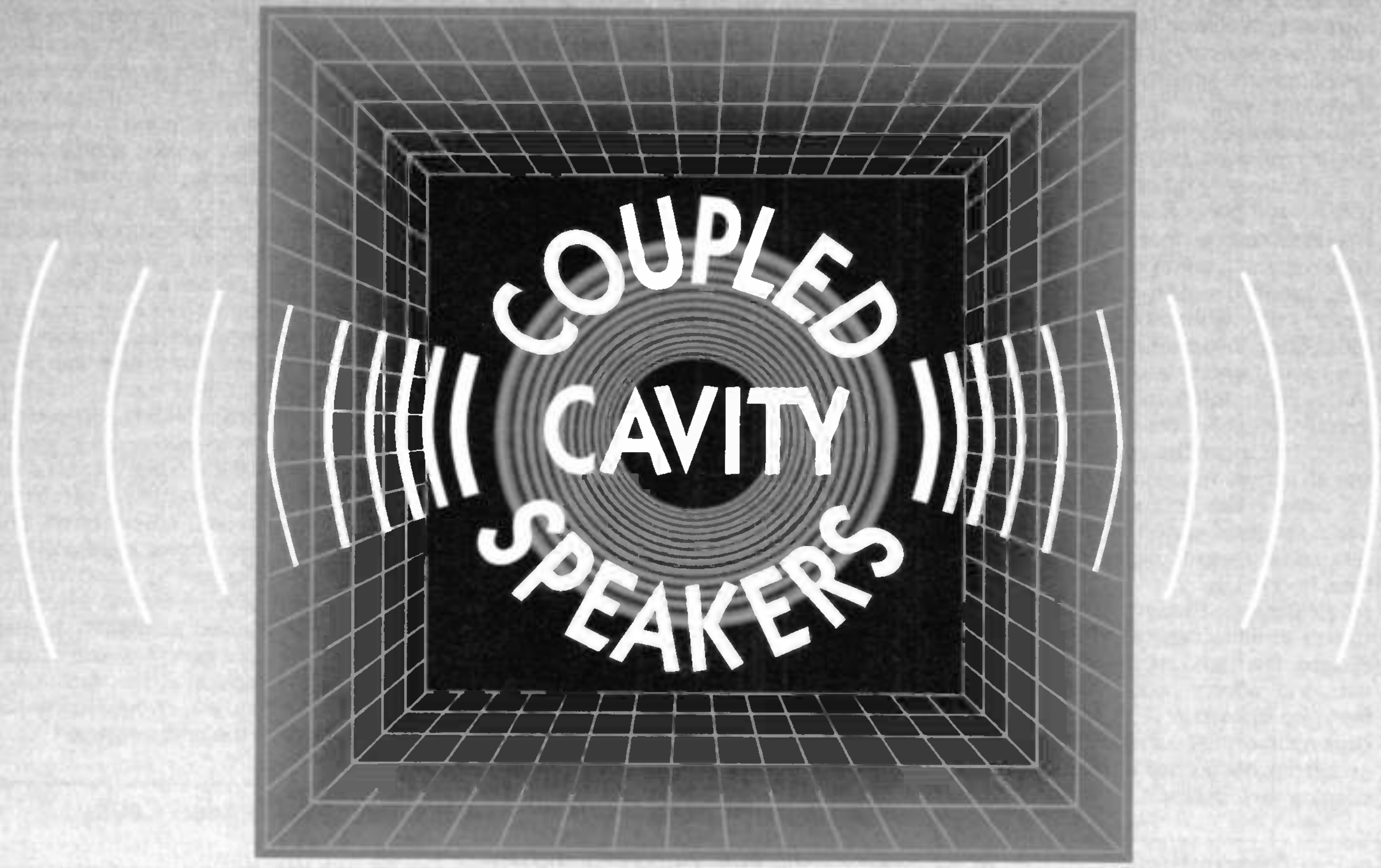


Figure 3c. EQ curve (input 5mV).

Continued on page 57.



Coupled Cavity Speakers

PART 1: THEORY

by David Purton

Accurate reproduction of the lowest octaves underpin the music, producing tangible image size and scale. Those people who enjoy live music or have been fortunate enough to hear professional monitoring systems will be aware of the shortcomings of most small sealed box Hi-Fi speakers in bass reproduction.

MANY will also appreciate the problem of integrating a traditionally-designed large loudspeaker into a domestic environment, an arrangement rarely found to induce domestic bliss! The articles in this series will attempt to show how a coupled cavity sub-woofer is the elegant solution to these inherent problems, and will be of particular benefit to those that have relatively small two-unit loudspeakers.

Theory – A Designer's Viewpoint

Looking at Figure 1, you will notice that the sub-woofer rolls its response at both ends of the frequency scale, by itself, with no crossover requirement. Because it operates as a band-pass filter, the parameters are tunable, and because its response is achieved by tuning, the cost of the driver becomes less relevant. Virtually all loudspeakers are compromises. Coupled cavity loading reduces the compromises considerably, and has a design flexibility that no other system can match.

Budget – A Designer's Nightmare!

The trade-off here is usually to minimise costs whilst achieving maximum performance. The majority of the cost of a loudspeaker is disproportionately spent on the cabinet required to reproduce those bottom second and third octaves, and in reality, this is the only part of the musical spectrum that requires a cabinet at all. Inevitably, most designers have opted for the simplicity of a two unit, small cabinet system, the benefits being as follows:

- Smaller cabinets have smaller panels. These are more rigid than large panels, and tend to resonate outside the bass/midrange driver's operating range.
- The crossover is simplified, and because it operates at the tweeter crossover frequency, the DC resistance of the inductors can be kept small. This enables your power amplifier to exert virtually all of its damping ability.

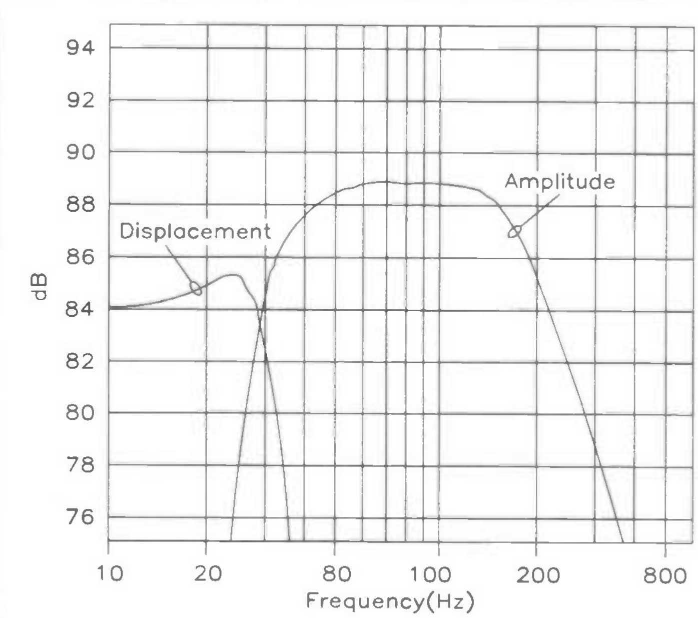


Figure 1. Sub-woofer response curve.

- The reduced frontal area of the baffle is more likely to enhance the loudspeaker's ability to image well. This is reinforced by having only one acoustic centre, between the two drivers.

The disadvantages are as follows:

- The compromise of trying to cover too many octaves with one drive unit. Cone technology plays a substantial part. Manufacturers continue to introduce new cone materials, but all have their failings and strengths, some more suited to bass reproduction, while others are better at reproducing the upper ranges.
- The cone diameter is directly related to the driver's ability to disperse sound evenly throughout the listening environment. The larger the cone, the more it beams at high-frequency. A smaller cone will suffer in bass reproduction, unless it has substantial piston movement, but this will also lead to higher distortion at bass frequencies.
- Many designs today use small cone drivers in accurately-tuned bass reflex designs. The tuning improves bass extension, and reduces cone excursion, thus reducing distortion. The reflex design does not have the transient stability of a sealed box design, and so once again is a compromised design!

Design Alternatives

A well designed three unit speaker (bass, midrange and tweeter), has many apparent advantages. Each drive unit's diameter, excursion ability, material and power handling can be dedicated to the frequency band it is handling. Preventing bass from entering the midrange driver must be a good thing !

However, the disadvantages of this arrangement are as follows:

- Sheer size and cost.
- Panel areas are much larger, and will resonate at much lower frequencies, thus becoming more audible as coloration.
- A three-way passive crossover is far more complex than a two-way. The filter sections load themselves in very peculiar ways. Use of a serious design program, accounting for the driver's amplitude, impedance and baffle positioning is about the only way of achieving good results. MLSSA, or one of the real-time measurement systems, is another option, but not a cheap one. Additionally, due to the inevitably low crossover point of the bass unit, large inductors are required in the crossover. Even expensive low-loss inductors have a DC resistance that will prevent the power amplifier from exerting its maximum damping ability. Shame really, as it is the bass unit that could do with it the most!
- Go active! This may seem the best solution. Maximum damping, theory correct filter performance, etc. Apart from the substantial cost of needing separate amplifiers, and all those extra connectors, the active filter itself, unless it is of state-of-the-art design, will often introduce more 'electronic' forms of coloration, and a cheap one is just noisy! An 'off the shelf' one is unlikely to get it right, as it will take no account of the driver response and positioning on the baffle.

Coupled Cavity to the Rescue!

If you already own a compact sealed system loudspeaker, then you will benefit from the addition of a pair of coupled cavity sub-woofers. You probably chose your present system for qualities of imaging, articulation and naturalness, etc., areas in which the small sealed box speaker excels. Many add-on sub-woofers fail miserably at the task of seamlessly extending the response of satellite or compact loudspeakers, and have therefore not achieved a particularly good reputation. Almost all suffer from the fact that they are not 'band-pass' in operation, and therefore entail all the complications of crossing them over at very low frequencies, with all the problems of having to use large value inductors. Also, adding another network, generally based on theory values, will unpredictably load your current speakers. This will lead to diminished performance from your normal listening speakers.

The active solution has a different set of compromises. Apart from cost, you are putting another electronic circuit before the normal listening speakers, and this may introduce coloration and noise – in other words, you are still affecting the performance of your normal speakers. It is, therefore, best to leave them alone! With coupled cavity sub-woofers connected in parallel to your main system, you will not affect the performance of your normal speakers. The woofers themselves can be tuned to fill in those bottom octaves, matching exactly in efficiency and required bandwidth, to the existing system. The benefit of 'band-pass' design is that it negates all the criticism levelled at the standard add-on sub-woofer. No bass crossover is the best crossover!

What is a Coupled Cavity Bass Unit?

If you look at the sectioned drawing of Figure 2, you will see that a drive unit is mounted on a baffle inside a box. The driver sees a contained volume of air on both sides of the cone. The rear chamber may be loaded in the three normal ways: sealed, vented to the outside or vented into the front cavity. Different loadings will produce different response shapes. Different drivers also prefer different loading. The drawing shows a series ducted (i.e. back cavity vented to the front cavity) example.

For future reference, these different forms of loading are as follows:

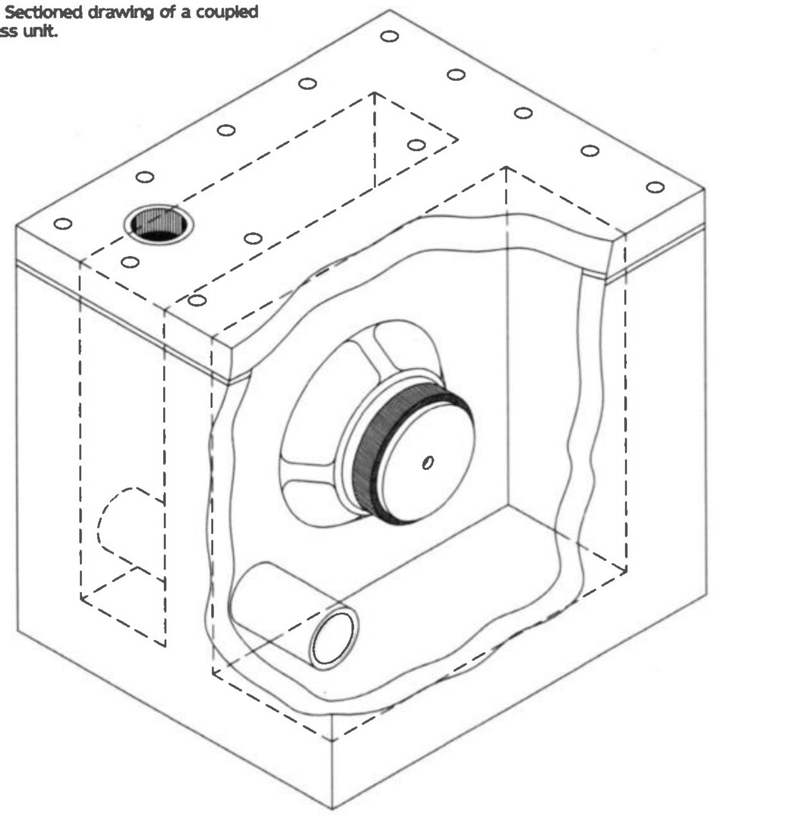
BP1 – Sealed back cavity.
BP2 – Back cavity vented to the outside.
BP3 – Back cavity vented to the front cavity.

The front cavity is always loaded to the outside, but it is the tuning of the whole assembly that produces the required response; a drive unit, that without crossovers, rolls its response off at both ends, unaided.

Summarising the Benefits

- The performance of the coupled cavity unit is achieved through tuning volumes of air and vent lengths, and not by the price of the driver.
- The drive unit is symmetrically loaded, thus reducing harmonic distortion.
- The bandwidth can be determined accurately, enabling better matching to your existing system.
- The cabinets are often much smaller than a normal speaker with the same (or worse) bass performance. Being in separate enclosures enables the listener to place them to maximum advantage in their listening room.
- If you do not intend to move house in the near future, you could even build them

Figure 2. Sectioned drawing of a coupled cavity bass unit.



Stock Code	Size (in.)	V1 (L)	V2 (L)	D1 (mm)	D2 (mm)	L1 (mm)	L2 (mm)	–3dB (Hz)	Eff (W/m)	A1	Poles (Hz)	Pwr (W)
XG43W	8	38	5	75	75	169	146	40/200	90	BP2	39·5/115	100
XG46A	10	35	18	75	75	160	54	32/190	89	BP3	42/82·5	100
XJ49D	12	28·5	18	75	100	222	132	35/180	89	BP3	41/80	200
XG53H	15	160	80	100	115	91	36	22/140	90	BP3	30/57	200
XG54J	18	300	195	100	195	184	35	28/90	94·5	BP3	17·5/51	400

Table 1. Specifications of speakers from Maplin's BIG CAT range.

under the floor, covered with small 5in. diameter grilles.

Because the units are connected in parallel, your system impedance drops to about 4Ω, but this should not prove to be a problem for most modern power amplifiers. You do have the option of driving the bass units separately with their own amplifier, and perhaps the keenest among you may choose to use one of the excellent Maplin kit amplifiers available.

Shown in Table 1 is a selection of five drivers from the Maplin range of Big Cat speakers, made by Eminence, and suited to coupled cavity loading. The 8in. and 10in. versions, working as a stereo pair, enable the domestic user to obtain state-of-the-art bass performance from relatively small cabinets. The larger versions would be suited to studio or large room applications. The biggest, fundamental bass PA driver design, of just under 500 litres (approximately 20 cubic feet!) would be suitable as a sub-bass unit in a large studio, and would not be out of place in a cinema application, with 120dB at 35Hz from a distance of 1m available! Although 20cu.ft. sounds immense, it is in fact a cube with sides of some 2·75 feet in length. One could conceivably mount it under the floor of a house.

In Part 2 of this series, we will build a coupled cavity speaker unit based around a 10in. diameter, 100W power driver (XG46A) with full constructional details, which will also be relevant to any model you choose to build. Don't miss it! E

References

High Power Loudspeaker Enclosure Design and Construction, Eminence (WM82D) Price £9.95 NV.

The Loudspeaker Design Cookbook – Fourth Edition, Vance Dickason (AA75S) Price £19.99 NV.

STEREO RIAA CORRECTION PREAMP – *Continued from page 54.*

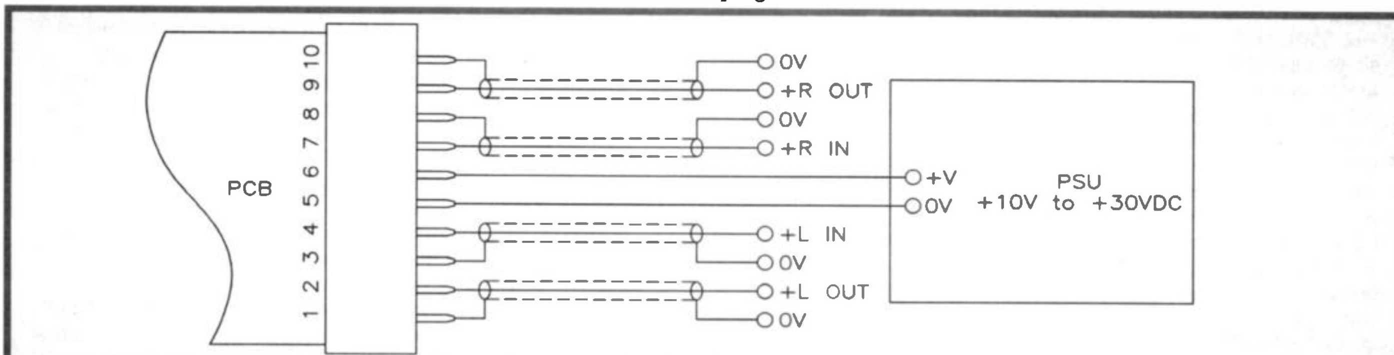


Figure 4. Wiring diagram, also showing the edge connector pinout.

Wiring Up

The wiring to the numbered connections (1 to 10) on the edge PCB is identical to the wiring of the K2572 Universal Stereo Preamplifier (90022). The connections are as follows:

1. Out left screen (0V).
2. Out left (+L OUT).
3. In left screen (0V).
4. In left (+L IN).
5. Ground (power supply) (0V).
6. +V (power supply) (+V).
7. In right (+R IN).
8. In right screen (0V).
9. Out right (+R OUT).
10. Out right screen (0V).

PSU Requirements

A low current PSU with an output voltage between 10 to 30V DC is suitable for the Stereo RIAA Preamplifier. However, the PSU MUST be well regulated and free from noise for trouble free operation. Keep the module well away from transformers, mains cable, and televisions, etc., this is in order to prevent hum pick-up.

Finally

With the Stereo RIAA Correction Preamplifier connected, relive your enjoyment from your record collection, that you thought you had lost forever. E

STEREO RIAA CORRECTION PREAMPLIFIER PARTS LIST

RESISTORS: All ⅓W 5%		
R1,R3	22k	2
R2,R4	100k	2
R5,R12	1M	2
R6,R11	2k2	2
R7,R10	47k	2
R8,R9	3k3	2
CAPACITORS		
C1	10µF 35V Electrolytic	1
C2,C5	3n3F Ceramic	2
C3,C4	680pF Ceramic	2
C6,C7,C8,C10	1µF Electrolytic	4
C9	100nF	1
SEMICONDUCTOR		
IC1	TL072CP	1
MISCELLANEOUS		
	8-pin IC Socket	1
	10-pin Edge Connector	1
	PCB	1

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

The above items are available in kit form only.
Order As 90014 (Stereo RIAA Correction Preamplifier) Price £7.99

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

Stray Signals

by Point Contact

How They Did it Then

PC was browsing through one of his recent acquisitions in the 'technical archaeology' section of his modest library the other day. The tome in question was the Admiralty Handbook of Wireless Telegraphy – but not the 1938 edition in two volumes, which you can find in almost any second-hand bookshop (and priced no doubt at considerably more than the six shillings at which it was originally published). No, this was the single-volume 1925 edition, which cost no less than five shillings, as reprinted in 1928. The book contains a wealth of fascinating material, from the Poulsen Arc as applied to transmitters, to the Bellini-Tosi DF System, from coherers to Menotti cells, etc., etc. On page 349, there is a circuit of the Armstrong receiver, which I reproduce here as this month's illustration. It is designed to operate in the shortwave bands – at 5MHz in the example shown. It is a single superhet with a BFO, for reception of Morse signals (CW), using an IF of 30kHz. With such a low IF, the rejection of the image frequency (known before the war as the 'second channel') at 4·94MHz, would have been very poor, especially with just a single tuned circuit at the incoming RF frequency. But in those days, there were so few transmissions about that this did not become apparent as a problem until a few years later. What a contrast to the problems encountered by the modern shortwave user or receiver designer! On the other hand, with a low IF such as 30kHz, there would have been no problem with instability in the three IF stages, and the gain achievable in each would have been large. Thus, the sensitivity of the receiver as a whole would probably, like a modern professional communications receiver, have been limited by external noise – unless using a very short or inefficient aerial.

How They Do it Now

Just like here in the UK, there is a problem in the United States with a growing prison population, currently over 1·4 million – a 100% rise over ten years. In the USA, they are always ready to apply advanced technology to a problem, and electronic 'home arrest' (electronic tagging) or 'curfew' systems were introduced in 1986, with nearly 70,000 such systems in use at present. In these 'first generation' systems, the offender is required to wear a bracelet or anklet which periodically signals its presence to a receiver connected to a phone line. If the offender is not where he or she should be (at home, or possibly at work) this fact is notified to the police. The offender could of course, cut the strap and abscond, but a cut strap sensor signals this, triggering steps for his/her arrest. In any case, there is a disincentive for such behaviour, in that a prison sentence is then likely to be substituted for home arrest. But nevertheless, not all would-be home-arrest/curfew breakers are deterred. So, with national funds, Westinghouse is developing a prototype 'second generation' system. Due for trials in 18 month's time, the 1W locator units would enable tracking and location of offenders over a city area. Later systems might use GPS or Loran C, for nationwide location of offenders. Third generation systems, which aim to discourage offenders from wandering – by, for example, zapping them with an electric shock – are under discussion. However, in addition to possible legal difficulties, there are practical ones; for instance, what happens if the offender is zapped whilst driving, and an accident results?

How They Might Do it Next Year

Readers may recall the publication in *Electronics* a few years ago, of a design for an audio noise generator, mounted in a loudspeaker cabinet and providing a choice of noise output – white, pink, breeze-in-the-trees or surf-on-the-shore. One of the suggested uses, was that one of the latter two types of noise might be used at night to help tinnitus sufferers sleep. Now here is an odd discovery, which might offer an alternative means of relief to tinnitus sufferers.

PC and some colleagues, were discussing the impending European electromagnetic compatibility (emc) directives which come into force next January, when one of them recounted this strange story. A firm, for whom he had previously worked, making switched mode power supplies (notorious generators of electromagnetic emissions), had invested in a do-it-yourself, but nonetheless, very effective screened room. This enabled them to check the conducted and radiated emissions from their products, without getting their measurements confused by the racket from the arc welder in the adjacent factory unit. It was not a conventional prefabricated screened room like you can buy, but just one of the rooms in their factory, with metallic sheeting covering the walls, floor and ceiling. Not that one could tell, as the sheeting was installed before adding ceiling tiles, wall coverings and a new floor. The aforementioned colleague was showing one of his in-laws (a completely non-technical gentleman, who also as it happened, suffered from tinnitus) around the factory one day. On entering the screened room, he exclaimed, unprompted and quite out of the blue, "It's gone!", only to find the ringing in his ears return as soon as he exited the screened room. If one wanted to treat a room in a domestic house, chicken-wire would probably suffice, rather than sheet metal, and it could be disguised with anaglypta and an additional hardboard floor, giving a modestly priced, do-it-yourself installation. So, will tinnitus sufferers in future sleep in a screened bedroom? Or wear a 'Ned Kelly' mask? It depends whether tinnitus is always caused by ambient electromagnetic radiation, as it apparently must have been in the case just described, or whether it is due to a variety of causes.

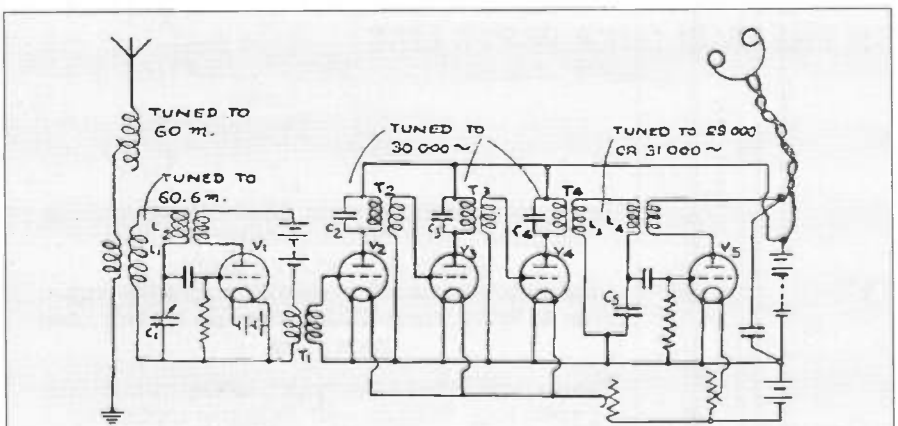
Tailpiece

A post-graduate student was investigating 1/f (flicker) noise, with a view to writing a thesis and getting his Ph.D. 1/f noise is an important phenomenon; furthermore, he was investigating it down to rather lower frequencies than usual – around 1mHz. Thus, he had been able to obtain special funding from somewhere. Unfortunately, the funding came to an end, long before he was anywhere near finishing his thesis. Measurements at this frequency being rather time-consuming, he turned to the Professor heading the electrical engineering department for advice. The Professor pointed out that one could not simply ask for more money for the same job, and after careful thought, suggested that the student apply for funds to cover an extension of the work down to 1μHz!

Yours sincerely,

Point Contact

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



TECHNOLOGY WATCH!

with Keith Brindley

Electronics manufacturers never seem to cotton on to life, do they? Whenever a new technology – or adaptation of an old technology – is developed, there is always at least two or three different methods of doing it. Manufacturers each develop their own processes, or do so in conjunction with a small group of others, so that there is always a scrum down on the playing field of electronics, until one system gets over the line by sheer volume of numbers, and the others fall down amidfield.

It happened with videocassette recorders. There was JVC's VHS, Sony's Beta, and Philips' V2000 systems, developed almost simultaneously. There was little doubt over the Beta's superiority over VHS, and little doubt over V2000's superiority over Beta, but in the end, VHS took over as the norm, and now not many of us even remember the other VCR technologies. It happened again (and the situation still isn't resolved) between Philips' digital compact cassette (DCC) and Sony's MiniDisc digital recording systems.

Just think of all the money wasted by these competing systems. Just think of all the confused consumers, some of whom remember the VCR battle (with singed pockets and burnt fingers) only too well. Just think of all the time spent battling it out at the consumers' expense, and you would think the manufacturers would learn to get it right the first time, wouldn't you? After all, potential users of the new technologies will automatically eschew them until an obvious leader has emerged.

Yes, I know that manufacturers have a lot at stake trying to make their system the winner. A great deal of money gets invested in research and development, and an even greater deal of money will be made by the winning technology in royalties. But, the whole process means that products take longer to become accepted by users en masse, so the proceeds of a *de facto* rather than an agreed standard simply take longer to come to fruition.

It is happening again with the latest technologies for disc-based video players, of which there are two competing formats. This time, Philips and Sony have got together to develop the compact disc format to be able to hold sufficient data (7·4G-bytes) to store over four hours of full motion video. Their format is known as *high density multi-media compact disc* (HDMMCD).

The other technology is backed by Toshiba, Matsushita, Pioneer, Hitachi, Thomson, Mitsubishi and others, and is called *digital video disk* (DVD). It is a technologically-advanced system over compact disc, but because of this, is more complex and potentially more expensive. However, Zenith (the leading TV maker in the USA) plans to have a reasonably-priced DVD player ready to sell next year. Sony and Philips do not expect to be in the same position for another year at least.

Philips' and Sony's HDMMCD looks like having a hard battle to become the standard which everyone chooses, but it does have the advantage of being compatible with existing CD-ROM technologies, so is easier to integrate into personal computer systems than DVD. This could be the ace up the sleeve, because it is the PC market into which most of these systems will eventually be integrated. Video disks for consumer use have been tried before and have always had a poor reception, simply because home users want to be able to record as well as replay films. This, of course, accounts for the popularity of VCRs in home use. Meanwhile compact discs are the norm in home audio use, even though they are non-recordable.

On the other hand, computer users have taken to CD-ROM technology a little better. The ability to store huge amounts of non-recordable data on a disc seems to suit computer users. HCDC, rather than DVD, could be the best bet for a PC user.

And that sums it up really. The whole process of new technologies *is* a gamble for the manufacturers. You don't know what the user wants until the products are there on the market, and you do not know how they will sell until you have developed them.

Amstrad on the Line

Toward the end of this year, and into next, there will be a new name in the UK mobile telephone market. Even the presence of this name is one which will expand the market significantly. Amstrad is set to produce and sell digital mobile 'phones, and if track record is anything to go by in Amstrad's other product lines, by doing this, the whole mobile telephone system will be rejuvenated with cheaper, more up-front handsets.

At the end of 1993, Amstrad bought a Danish company, called Dancall. Just under 500,000 mobile telephones will be made by the company, and sold to European network providers this year – the limits of current capacity. None of these handsets will bear the Amstrad name.

However, Amstrad is investing heavily in upgrading the Dancall manufacturing line, with the capability being expanded up to 1·5 million handsets by the end of the year. Amstrad aims this at making the company the fourth largest mobile handset manufacturer in the world.

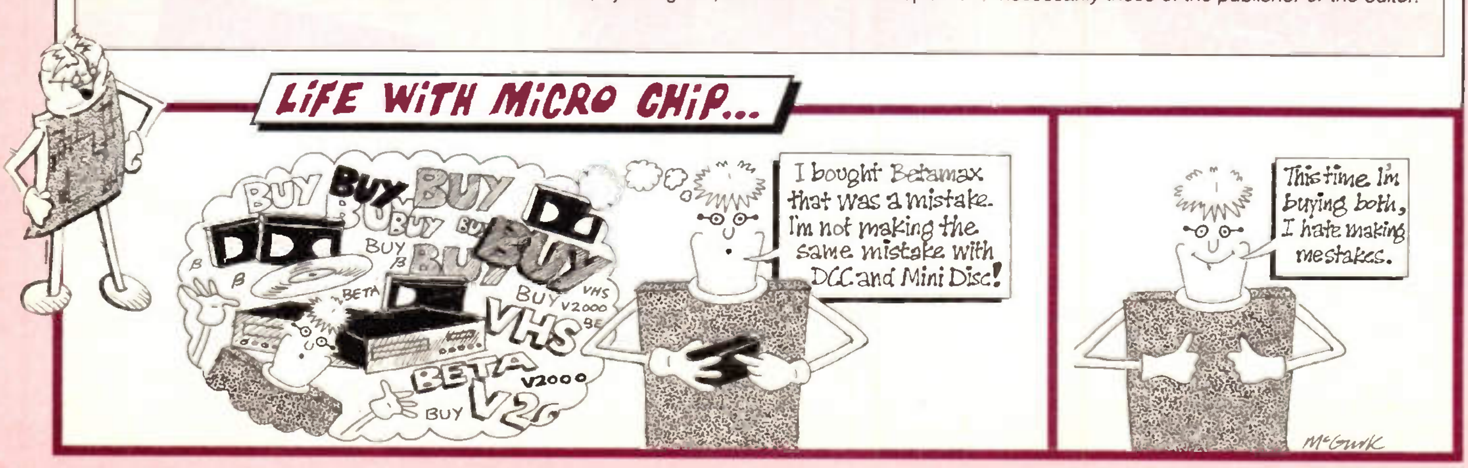
At this point, Amstrad will market the telephones under its own name in the UK, for GSM, PCN and DECT standards. Expect the market on all relevant mobile networks to grow accordingly.

RSI about Face

A significant legal battle has been won by IBM recently, in Minnesota, USA. A school secretary had brought a case against IBM (and Apple), suing for causing repetitive strain injury (RSI), saying that the companies had sold dangerous keyboards. Now, RSI, as anyone who has ever had the misfortune to suffer it will know, is a potentially disabling condition, in which users of equipment develop painful symptoms due to using the same movements and same working positions to use the equipment. Keyboard and computer users are particularly prone to such RSI conditions if they sit working, for long periods.

Computer manufacturers worldwide will be very happy with the outcome of the case, which rejected every claim against IBM (and indirectly against Apple) regarding unergonomic systems. In effect, the onus is now on the users to ensure they do not suffer from RSI due to using their computers. In a wider sense, any user who suffers RSI due to using any equipment at work, has little recourse against the equipment manufacturer.

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



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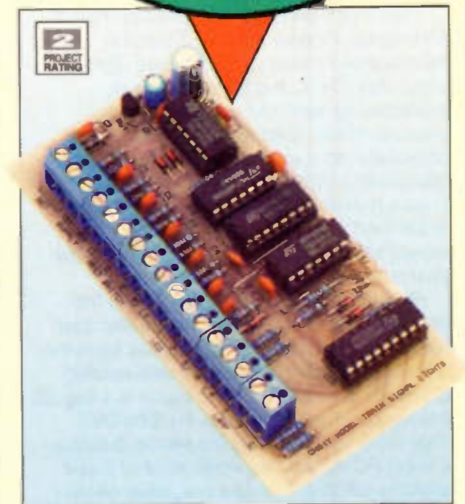

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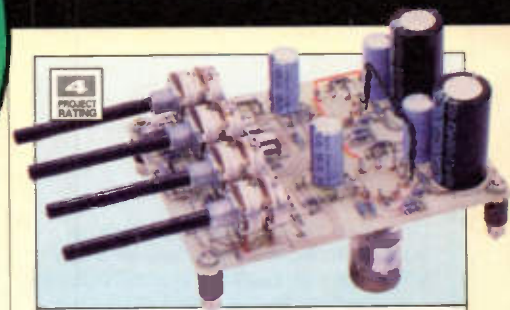

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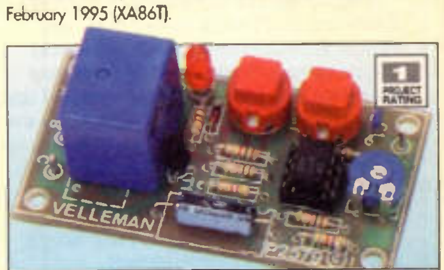

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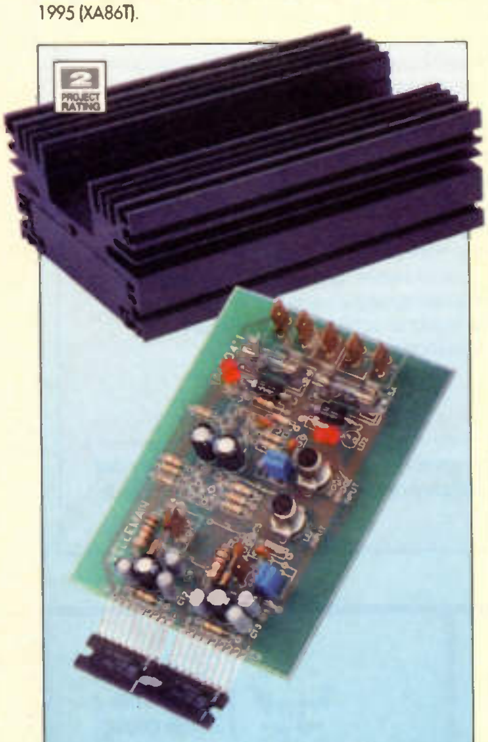

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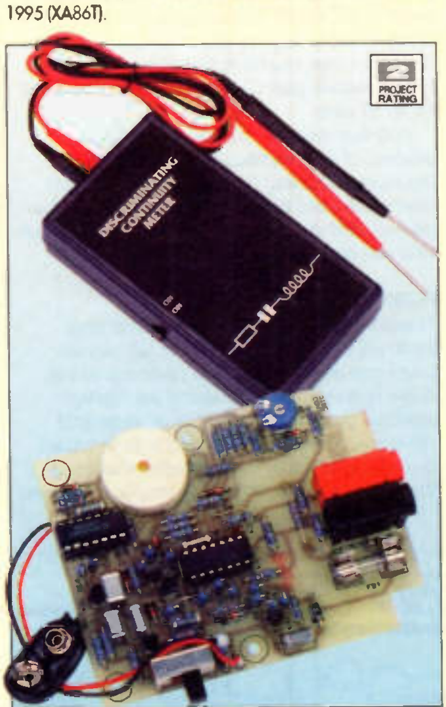

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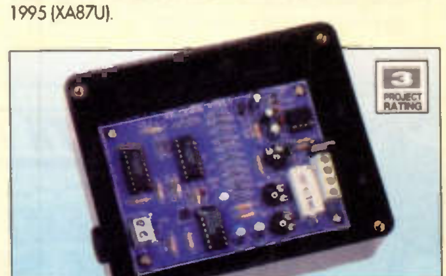

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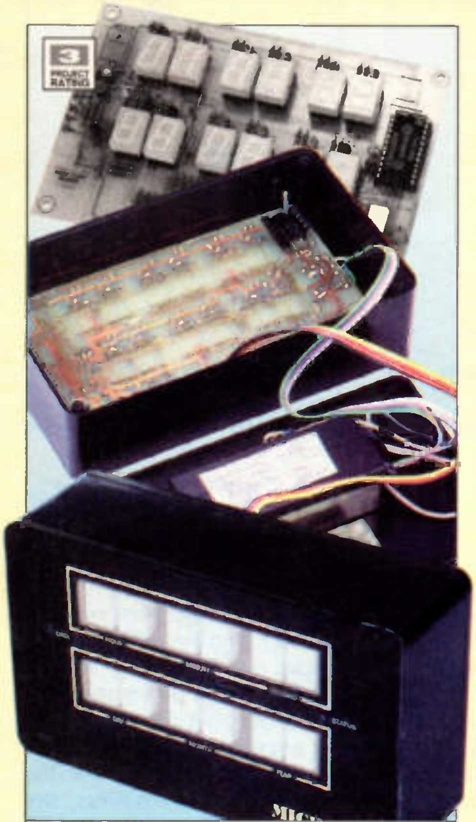

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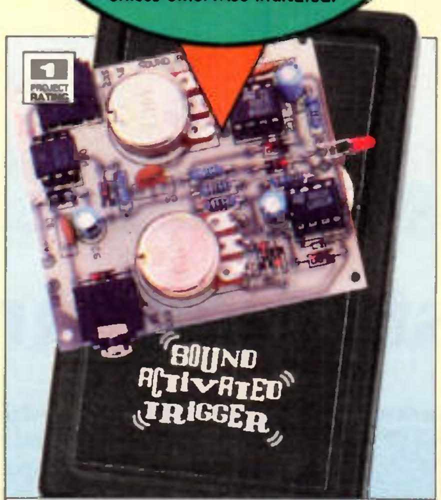

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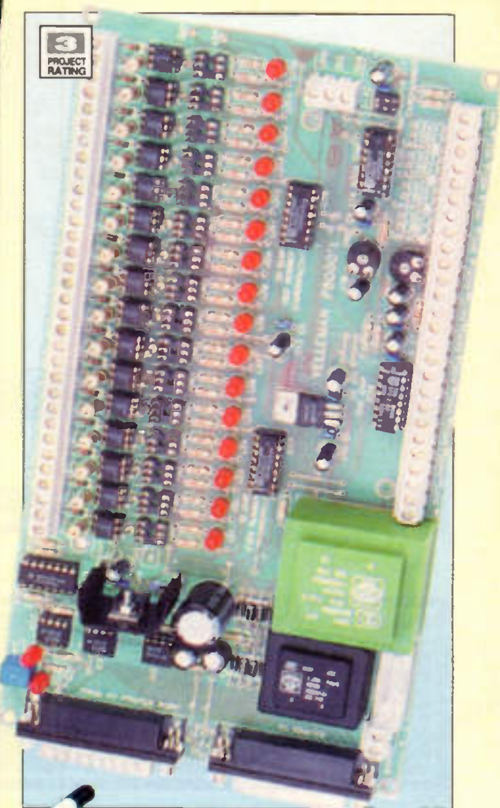

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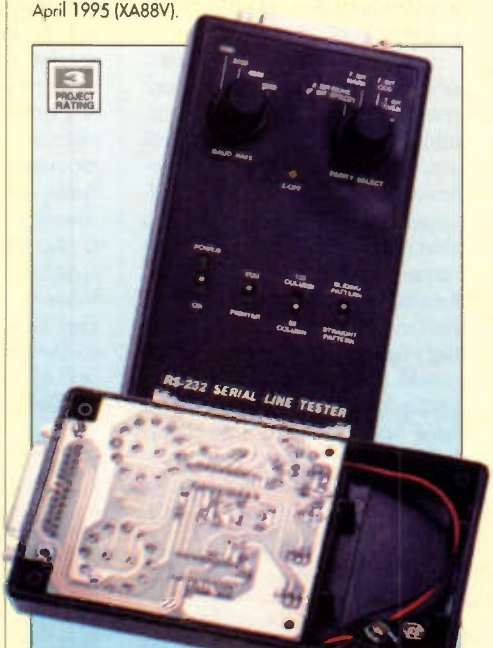

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MS Stereo

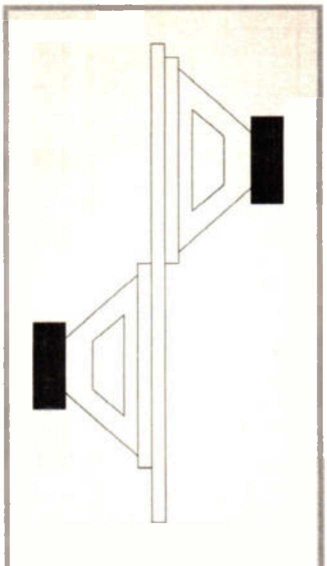


Figure 9. Flat baffle dipole loudspeaker.

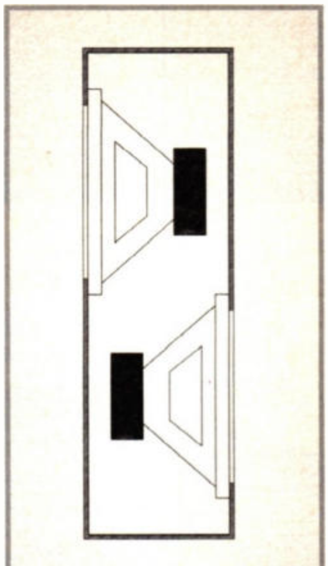


Figure 10. Dipole cabinet loudspeaker system.

New Harvests from an Old Field?

Part 2: Experiments

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

LAST month, in Part 1, we looked at the basic theory of MS (mid-side or mono/stereo) stereo, and investigated the theory of MS microphone techniques in some depth. This month, we look at loudspeakers and signal-processing circuits for direct MS reproduction, mainly at the practical level.

For these experiments, we shall need a number of identical loudspeaker drive units and enclosures, and a number of 'power' or final amplifiers. The loudspeaker systems should consist of single full-range drivers, because separated drivers and variations of directional response with frequency will confuse the results of the experiments. Furthermore, the cost of several high fidelity multi-driver systems would be too high for most experimenters. When good results have been obtained with simple systems, the ideas can then be extended to more ambitious systems.

Drive Units

To cover most of the audio range with a single driver that does not become too directional at high frequencies, we should look at 100mm or 120mm units, and low-cost units such as Maplin's YJ16S and GL12N are extremely suitable. We shall see later that the higher sensitivity of GL12N is useful in some applications, as is its rather brighter sound, not very obvious from the measured frequency response. These drivers work quite well in closed boxes of 5L volume, and I happened to have a number of these, with internal dimensions of 200 × 300 × 100mm deep. For the experiments, we also need a loudspeaker system with a lemniscate ('figure of eight') directional response, to reproduce the S-channel. This can be made by mounting two drive units on a flat baffle about 300mm square, as shown in Figure 9. Such a device is also known as a dipole loudspeaker. The two cones must move in the same direction, but they face in opposite directions, so the voice-coils must be connected in *opposite* polarity, and parallel connection is appropriate in this case. The drive unit which has its (+) terminal connected to the 'hot' signal input, should face to the left when in use. Another possible construction has the drive units mounted on the 'front' and 'back' of a 5L enclosure, and again connected in parallel with opposite polarity, as you can see in Figure 10. Because one cone moves out of the box as the other moves in, there is no net change in box volume and it should not be necessary to separate the drive units by an internal partition: if it is, a 10L box is required to preserve the same low-frequency response. However, in several of my experiments, I found the flat baffle system gave better results. A larger baffle could give an increase in low-frequency response, but the two drive units must be mounted close together, preferably asymmetrically placed with respect to the centre of the baffle.

Power Amplifiers

While we can use just two power amplifiers and some switching to compare some MS arrangements with LR stereo, for one of the most interesting arrangements we need a power amplifier with balanced output, and in this case we also need two extra power amplifiers for the LR system, because switching amplifiers is rather too complicated for comfort. For the conventional amplifiers, the LW36P amplifier kit is very suitable, or you could use just the PC board (BY73Q) with either the LM383T (WQ33L) or the rather cheaper TDA2003H (AH53H). For the balanced-output amplifier, a bridge-tied load (BTL) configuration is ideal, and much cheaper than a 1:1 loudspeaker transformer if the TDA2005M device (YY70M) is used. The manufacturer's data sheet for the TDA2003 also shows BTL circuits which are suitable for these experiments, and one example is shown in Figure 11. Actually, the data sheet also says that the TDA2003 will accept a transformer load, unlike some ICs (and some discrete amplifiers, too!), so if you have a 1:1 loudspeaker transformer, you could use it. These amplifiers will work quite happily from a single 12V to 15V unregulated supply, and this can also be used, with a complemen-

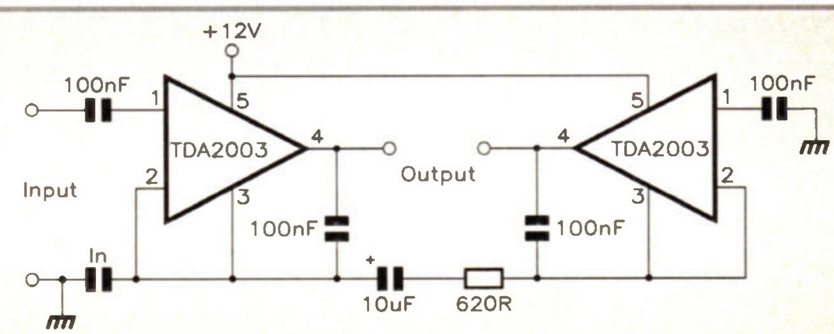
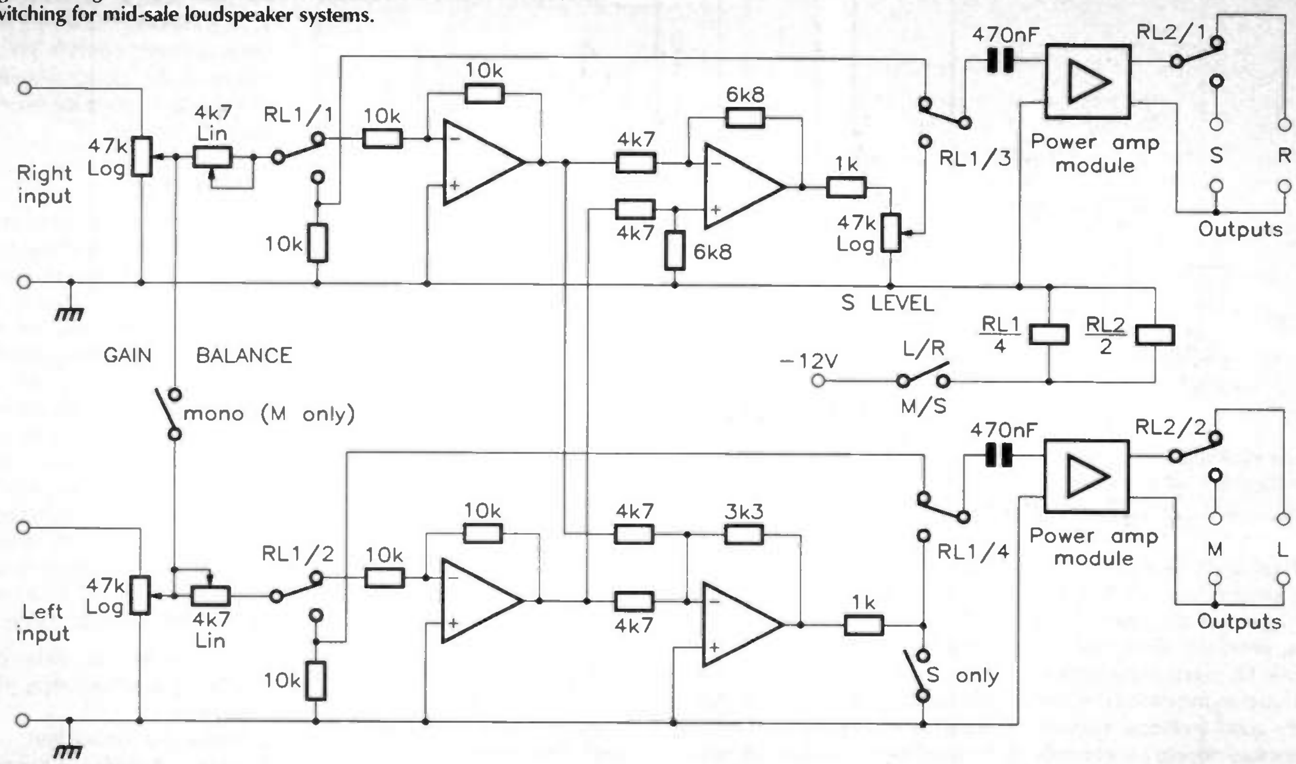


Figure 11. Bridge-tied load amplifier, using TDA2003 (derived from manufacturer's data sheet).

Figure 12. Sigma-delta matrix with S-channel level control and LR/MS switching for mid-sale loudspeaker systems.



tary −12V or −15V supply, for the low-level processing circuits which we will look at next.

The Σ-Δ (Sum-and-Difference) Matrix

Because we are likely to want to switch between ordinary LR stereo and MS, the sigma-delta matrix should include the 3dB gain loss, that we saw was necessary in Part 1, in order to get LR and MS signals with the same total energy. During the experiments, I found that it was necessary to provide some extra gain, about 6dB in fact, in the S-channel, i.e., 3dB gain instead of 3dB loss, and to have a control for this gain. I found that it was never useful to turn the S-channel gain quite to maximum, because the stereo effect 'falls apart' if there is too much S signal, but I needed all but about 1dB of the extra gain on some programme material. The complete circuit diagram, including switching from LR to one of the MS loudspeaker arrangements, is shown in Figure 12. While the low-level signal switching would be done at lowest cost with CMOS switches (two 74HC4066 ICs, UF10L), the loudspeaker circuits can only be switched with relays, so I have used relays throughout. One JG69A 4-pole changeover is required, and one JG66W 2-pole changeover, and both are operated from the negative supply, which does not feed the amplifiers, so as to partly equalise the current drains.

The 47kΩ dual log potentiometer is, of course, for gain control. The matching of the track resistances is much more critical for MS signals than for LR, because a 1dB (12%) mismatch in the attenuations of identical L and R signals, which is about the best that can be obtained with standard dual pots, results in a spurious S signal at a level of 12% of the input signal, i.e., only 18·4dB down. With the extra S-channel gain of 6dB mentioned previously, the spurious signal could be only 12·4dB down and then would confuse the results. For this reason, the dual 4·7kΩ linear balance control is included. It provides 3dB of differential gain adjustment in conjunction with the 10kΩ load resistors, and can be set for zero S signal with identical L and R inputs, i.e., a dual-mono signal input, at any setting of the gain control.

The Mid-Side Loudspeaker Configuration

This is shown in Figure 13, and is the arrangement which promises stereo from what at least appears to be *one box*. The part of the 'box' which encloses the dipole assembly has to be acoustically transparent, such as fabric on a wire frame or perforated metal with perforations no smaller in diameter than four times the metal thickness. This configuration does not require a balanced-output S-channel power amplifier and can be driven from the Figure 12 circuit. We have taken some care to make an S-channel loudspeaker with the correct figure of eight directional response, so it seems odd to use a conventional closed-box system for the M-channel, because this only has the required omnidirectional characteristic at low frequencies. At higher frequencies, its response tends towards a cardioid, or even narrower. This can be overcome by laying the enclosure on its back, so that the drive unit faces upwards. Clearly, apart from some diffraction effects due to the enclosure edges, this must give an omnidirectional response in the horizontal plane. Such an arrangement was used by the now legendary Gilbert Briggs, for mono, in his pioneering demonstrations in the Royal Festival Hall over forty years ago. A conical diffuser was arranged over the driver so as to spread out the high-frequency energy. This was necessary because the drive units were 200mm or 250mm diameter devices, necessary to handle the 20W or so that was even sufficient for the RFH in those days! This principle was revived in the USA in the 1970s, and appeared in this country in the form of the ITT-KB

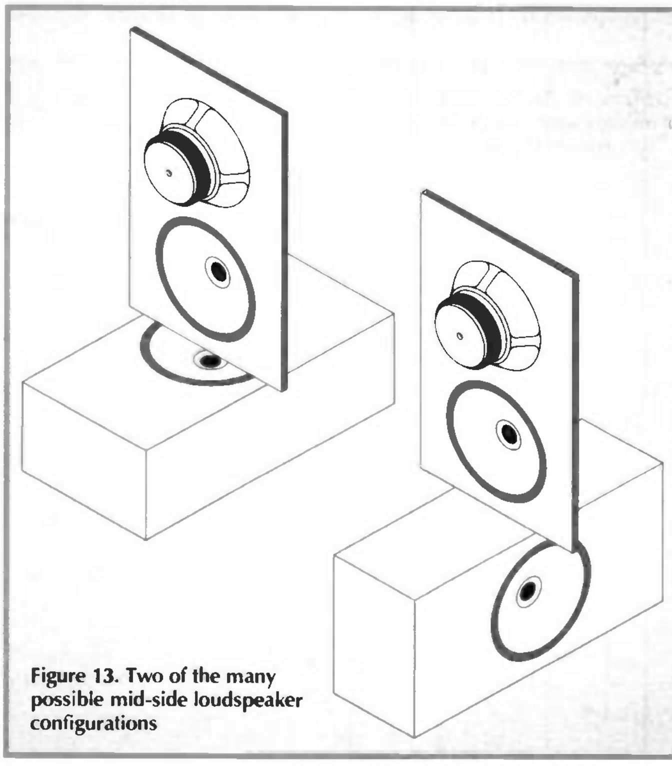


Figure 13. Two of the many possible mid-side loudspeaker configurations

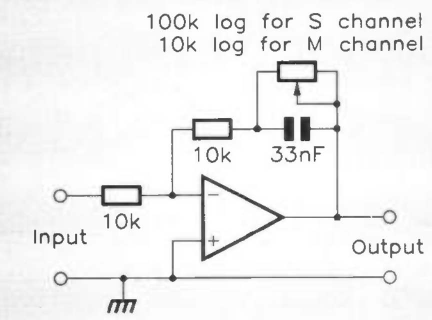


Figure 14. Bass boost circuits to compensate for S loudspeaker low-frequency characteristic.

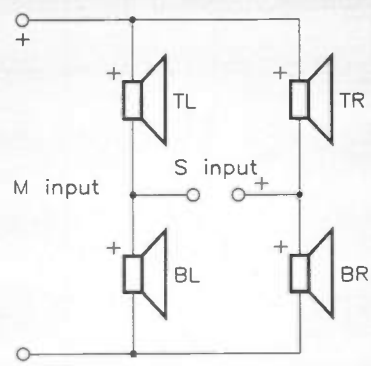


Figure 15. Bridge feed circuit for the MS four-driver configuration. Either the S signal or the M signal must be balanced (i.e. neither side earthed). The M and S polarity markings correspond to a left-channel only signal.

KS651, using a 175mm drive unit with a whizzer cone. It has surfaced again in the very costly Canon products designed for improved LR stereo reproduction, which have asymmetrical diffusers for very good technical reasons. Such unusual devices could hardly be exploited in the earlier days due to conservatism in design matters.

Frequency Response Correction

Both of the dipole loudspeakers described above have falling low-frequency responses. In order to prevent this, much larger structures would be required. The alternative is to provide some compensating bass lift in the amplifying chain, and Figure 14 shows two versions of a suitable circuit. The amount of lift required in the S-channel is rather more than 10dB (any more would certainly overdrive the loudspeakers without producing any useful bass extension), but it is also possible to compensate some programme material by providing a much smaller amount of lift, less than 3dB, in the M-channel instead. This will not work well for multi-track CD mixes which contain high-amplitude S-channel signals at low frequencies, a situation which does not normally occur when you are listening to live programmes. This bass compensation is not essential, and is a matter of preference, also depending on the drive unit characteristics.

The Four-Driver Bridge

This interesting loudspeaker configuration is one of the arrangements investigated by Holger Lauridsen at Danish State Radio in the 1950s. Four identical drive units are arranged in a horizontal line in a single enclosure, divided into four closed compartments. These are connected in a bridge circuit, as shown in Figure 15. For this application, the S-channel amplifier must be of the balanced output type mentioned previously. Alternatively, if the BTL amplifier has a higher output power, it could be used in the M-channel, which mostly handles higher signal levels, but if so, *the circuit shown in Figure 15 must still be used, i.e. do NOT swap over the M and S connections to the drive units.*

This configuration drives all of the loudspeakers with the M signal in the same polarity. The top left and bottom right drive units are driven with the S signal in the same polarity as the M signal, while the top right and bottom left receive the S signal current in opposition to the M signal current. Now, M plus S is the left channel signal in LR stereo, while M minus S is the right channel signal. Thus the drive units in the enclosure should be connected as shown in Figure 16. With the extra S-channel gain provided in the matrix circuit, it is quite possible to get stable sound images well beyond the ends of the enclosure, provided that you listen fairly close to the system, say within 2 metres. The results are much more interesting that those from a similarly-sized 'ghetto-blaster'.

For the M signal, the four drive units represent a column loudspeaker with its long axis horizontal. A column loudspeaker has a fan-like directional response (or like a car fog-light), and with the axis horizontal, the wide spread is in the *vertical* direction, while the horizontal spread is narrower. This contributes to the improved stereo performance at small listening distances.

Comparing 'MS Bridge' and LR Stereo

It is quite difficult to switch amplifiers and loudspeakers between these two modes, and it is more practicable to provide separate amplifiers and loudspeakers for the LR system, as shown in Figure 17. It is important to set the sound levels as nearly equal as possible, otherwise the louder system will sound better (unless it is overloading and clipping!).

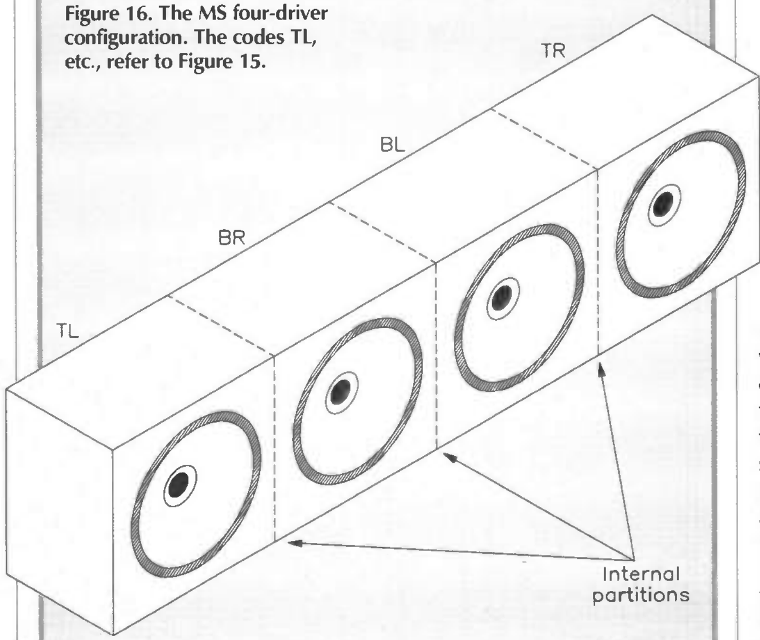


Figure 16. The MS four-driver configuration. The codes TL, etc., refer to Figure 15.

Listening

I have spent a considerable amount of time listening to the two basic loudspeaker arrangements described above, with many minor variations and much twiddling of the various controls. It is very noticeable that MS stereo works much better with some programme material: with other material the S-channel contains very little signal, or very little *useful* signal, as can be verified by disconnecting the M-channel loudspeaker. A refinement of the matrix circuit would be to add a three-position switch, giving:

1. Mono (or M only): sliders of the 47kΩ potentiometers joined together.
2. Stereo: no connections.
3. S only: M output of the matrix earthed.

This possibility is shown as separate switches in Figures 12 and 17.

These signals with little useful S information are, *ipso facto*, almost mono, so it is not surprising that they do not give much stereo effect, either in MS or LR mode. I have found, indeed, that some music output from local radio stations (FM, of course!) is *truly* mono, with no S signal at all! Because radio stations insert the stereo pilot-tone at the transmitter rather than at the studio (which is impracticable), the stereo light on the tuner stays on all the time, even if the station admits to sending a mono programme.

On the other hand, some programme material, from radio or recordings of all types, is good stereo, and the change in the sound image when switched to mono is very marked. This particularly applies to recordings you make yourself with one of the MS microphone configurations discussed in Part 1, provided you have everything set up correctly. These MS signals should, of course be fed directly into the power amplifiers, not through the MS matrix, which will convert them to LR signals! In other words, with MS input, the functions of the switch controlling the relays are reversed. On good stereo material, MS reproduction places much less emphasis on the actual loudspeaker positions (which is actually a defect in LR reproduction due to the directional responses of the LR loudspeakers not being correct, unless they are costly Canons, anyway!).

Continued on page 67.

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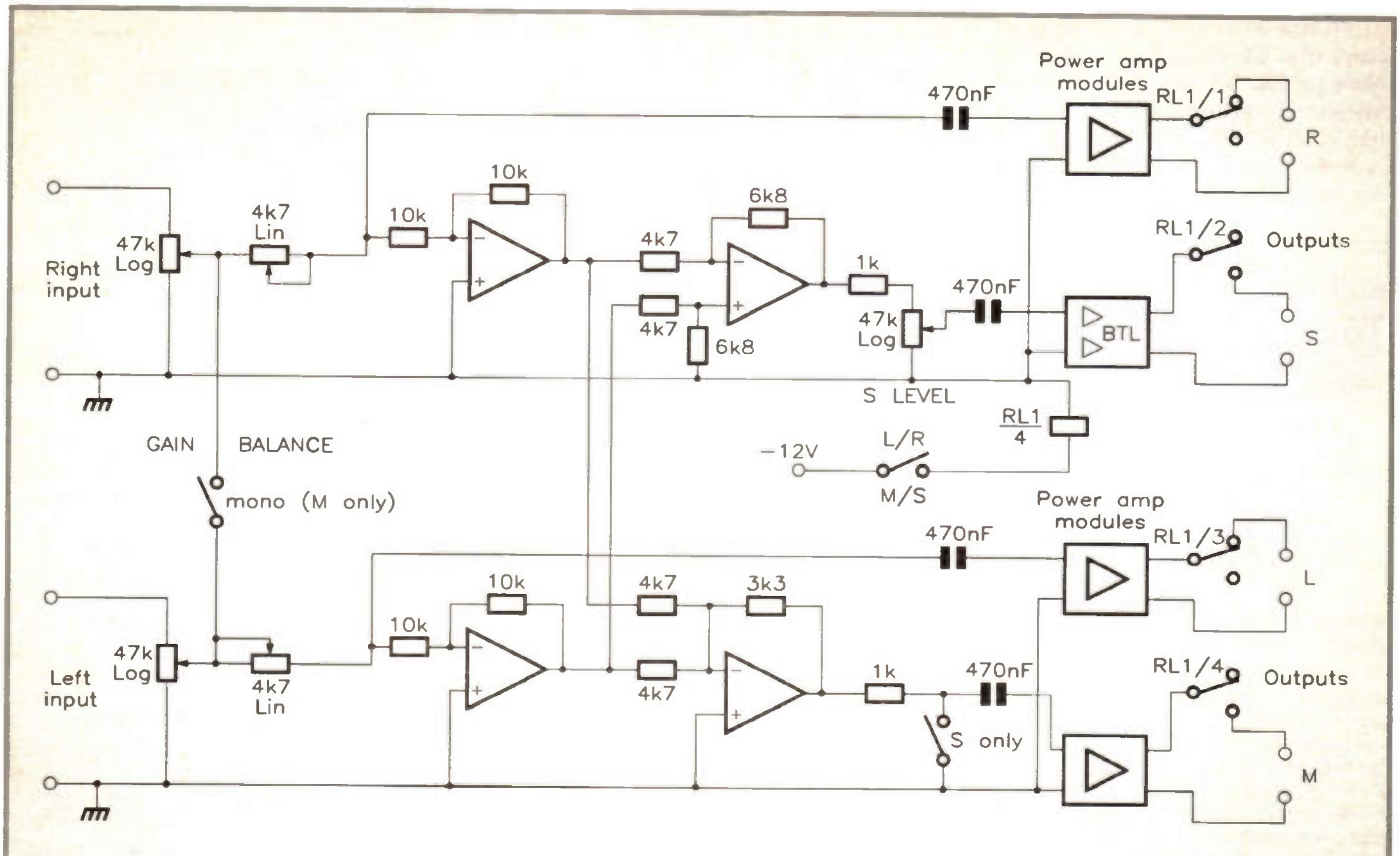


Figure 17. Sigma-delta matrix with S-channel level control and LR/MS switching for MS four-driver loudspeaker experiments. The BTL amplifier could be used in the M-channel instead.

Initially, MS may sound lacking in 'stereo effect', but this is largely because of the absence of localisation on the loudspeaker positions. In particular, if the loudspeaker system is placed symmetrically in a corner position in the room (and it is naturally much easier to find one free location than the two required for LR stereo), very satisfactory stereo reproduction can be obtained.

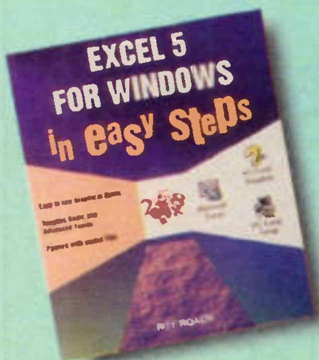
More Experiments

There is ample scope for further experiments, among which the following questions require investigation:

- What is the difference between the effect of the flat-baffle dipole and the enclosed dipole and why?
- How large does the flat baffle really have to be?
- Should the two drive units of the flat-baffle dipole be in a vertical or a horizontal line?
- What is the difference between the effect of the M loudspeaker facing forward and facing upward?
- Does the upward-facing loudspeaker benefit from a conical diffuser (made of plaster, perhaps?) mounted above it?
- Should the diffuser be symmetrical or asymmetrical?
- Should the S-channel dipole be above, below, behind or in front of the M loudspeaker?
- Should the MS bridge enclosure have a flat, concave or convex front panel?
- Granted that in theory the four drive units should be in separate compartments, how necessary is this in practice? Perhaps only the outer two need to be partitioned off?

All of the books featured on this page are available from Maplin Regional Stores and by Maplin Mail Order. To find your nearest Maplin Regional Store Tel: (01702) 552911 or to order call the Credit Card Hotline on Tel: (01702) 554161

NEW BOOKS



Excel 5 For Windows In Easy Steps

by Roy Roach

Microsoft's Excel 5 For Windows has become one of the leading spreadsheets available and is part of the Microsoft suite of business programs for the PC, which includes Word For Windows and Access. The 'Easy Steps' series from this British publisher offers a clear, concise graphical guide to popular business software that uses simple instructions to teach all the essential techniques of the software covered. This book can be further used as a cost-effective training guide and as quick reference guide.

This book is ideally suited to the absolute beginner as it starts with the very basics of spreadsheets and progresses to the more advanced features of spreadsheets, charts and graphics. By using very clear and concise graphical representations, the book covers Tip, Function and Chart Wizards; Workbook file management and Security; Formulas and troubleshooting; What-If analysis techniques and Scenarios; Linking Worksheets and Naming cells; Formatting and Printing; Charts and Graphic objects; Macros, Customising and Visual Basic.

354

1994. 225 × 186mm. ***Order As** 90003 (Excel 5 For Windows) £14.95 NV*

NETWORKING ILLUSTRATED

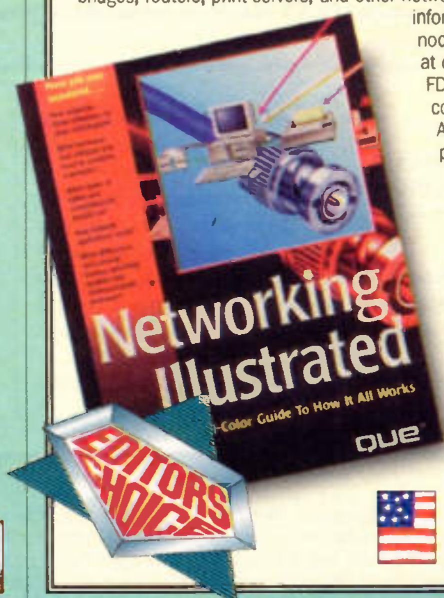
by Eddie Kee

Computer networks are becoming increasingly common, with few offices that do not have at least one network that interconnects personal computers and printers. With the advance of the superhighway, life outside the office will involve sophisticated communications. Understanding network components will help to understand the technologies that will soon dominate the way we live and work.

This book provides a highly illustrated tour of computer networks covering all the necessary topics to help the reader to gain a full and detailed understanding of networks. Topics covered include; what is a network and network concepts; the OSI model; network topology; cabling and connections; communication protocols; operating systems; network-to-network connections; MANs and WANs; protecting network data. You will learn how bridges, routers, print servers, and other network components work; how information is shared between nodes, plus an in-depth look at data transfer, token passing, FDDI, cabling, workgroup computing and a lot more.

A handy glossary of terms is provided at the end of the book.

The book is packed with hundreds of full-colour drawings that are reinforced with concise explanations and numerous technical tips. The layout makes each topic easy to find and understand. Highly recommended.



1994. 279 × 215mm.
***Order As** 90002 (Network Illustrated) £22.99 NV*

223

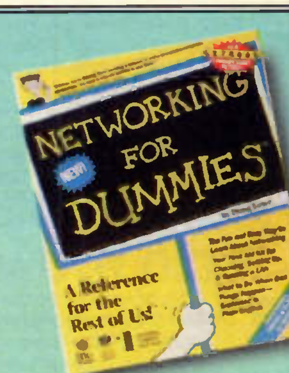
Networking For Dummies

by Doug Lowe

Not that long ago computers and computer management was something of a fine art, reserved for people who worked in special air-conditioned rooms. Today, things have changed drastically, with PCs on virtually every desk and as indispensable as telephones. A new breed of words has appeared, such as LAN (local-area networking), WAN (wide-area networking) and MAN (metropolitan-area networking). The term network has become an everyday phrase in office use, but networks are simply a way to speed up the rate at which we exchange ideas and information.

This book breaks down all the excessively technical language and helps the reader to really understand what networks are all about. Those mysterious phrases such as print queues, queuing, redirection, as well as software selection and management are tackled in an enjoyable and friendly way.

The book does not specialise in any one system and deals with Novell's NetWare, NetWare Lite, LANtastic and Windows for Workgroups. There is also coverage of Macintosh networking basics. Explanations of printer networking, Ethernet, types of network cable, coaxial cable, twisted pair cables, installation adapter cards and other networking paraphernalia are all covered in detail. In fact everything you need to know to select, set up, use and manage a small computer network, in a plain English style.



382

1994. 232 × 188mm. ***Order As** 90000 (Network For Dummies) £17.99 NV*

Practical Opto-Electronics Projects

by R. A. Penfold

Opto-electronics represents one of the most fascinating aspects of modern electronics and in recent years the range of opto devices available to the electronics enthusiast has expanded and changed considerably. You only have to look at the Opto-Electrical section of the Maplin Catalogue to see the diverse range of components – from LEDs to elaborate sensors. Compare this to the sixties, when all you would probably find was the odd CdS (cadmium sulphide) cell, a photo-resistor or photo-transistor. Many of the latest devices are worth trying for there interest value, however, they do have as much practical application as play value. This book provides practical designs which use a wide range of opto-electric devices, from the old cadmium sulphide cells and torch bulbs to modern high power infra-red emitters, fibre-optic devices and pyro sensors. The designs are all within the capabilities of the average electronic project constructor, with a few designs suitable for the absolute beginner. The projects are divided into three main types – photographic, those that use infra-red devices, and those that are based on modulated light transmission. Each project includes a circuit description, parts list and construction details where applicable.

158

1994. 188 × 112mm. ***Order As** 90001 (Pract Opto-Elec Prjct) £4.95 NV*

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DIARY DATES

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

2 May. Starting in Contesting, Sunbury & District Radio Amateurs, Wells Hall Old School, Great Cornard. Tel: (01787) 313212.

2 May. Embedded Systems Engineering Show, Barbican Exhibition Centre, London. Tel: (0171) 404 0564.

5 May. 'Caught in the Net', Arts Theatre, 6-7 Great Newport Street, London WC2. Tel: (0171) 836 2132.

8 May. Working wartime CW shortwave station to celebrate VE-Day, Puckpool Park Wireless Museum, IOW. Tel: (01983) 567665.

8 May. Digital Broadcasting, Stratford-upon-Avon and District Radio Society, Stratford-upon-Avon. Tel: (01789) 740073.

16 to 18 May. Internet World, Wembley Centre, London. Tel: (0171) 976 0405.

16 to 18 May. Control and Instrumentation Exhibition, NEC, Birmingham. Tel: (0181) 302 8585.

16 to 18 May. European Convention on Security, Brighton. Tel: (0171) 344 8403.

17 May. Visit to RAF Waddington, Lincoln Short Wave Club, Lincoln. Tel: (01427) 788356.

17 to 18 May. Mobile Communications Trade Exhibition, NEC, Birmingham. Tel: (01822) 614671.

21 May. Waters & Stanton Open Day, Special Offers and bargains. Refreshment provided free of charge for visitors. Tel: (01702) 206835

22 May. 2-metre Foxhunt, Stratford-upon-Avon and District Radio Society, Stratford-upon-Avon. Tel: (01789) 740073.

6 June. Using Thermionic Valves, Sunbury & District Radio Amateurs, Wells Hall Old School, Great Cornard. Tel:(01787) 313212.

12 June. Open House/Night-on-the-Air, Stratford-upon-Avon and District Radio Society, Stratford-upon-Avon. Tel: (01789) 740 073.

14 to 15 June. Government Computing & Information Management, Royal Horticultural Halls, London. Tel: (0171) 587 1551.

20 to 22 June. Multimedia Interactive Information Forum, Business Design Centre, London. Tel: (0171) 359 3535.

26 June. Top Band Foxhunt, Stratford-upon-Avon and District Radio Society, Stratford-upon-Avon. Tel: (01789) 740073.

27 to 29 June. Networks Exhibition, NEC, Birmingham. Tel: (0181) 742 2828.

28 June. 'The Man who was Q', Lincoln Short Wave Club, Lincoln. Tel: (01427) 788 356.

4 July. Operating QRP, Sunbury & District Radio Amateurs, Wells Hall Old School, Great Cornard. Tel: (01787) 313212.

10 July. Summer Social, Stratford-upon-Avon and District Radio Society, Stratford-upon-Avon. Tel: (01789) 740073.

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

NEWS Report

Solar-Powered Camera

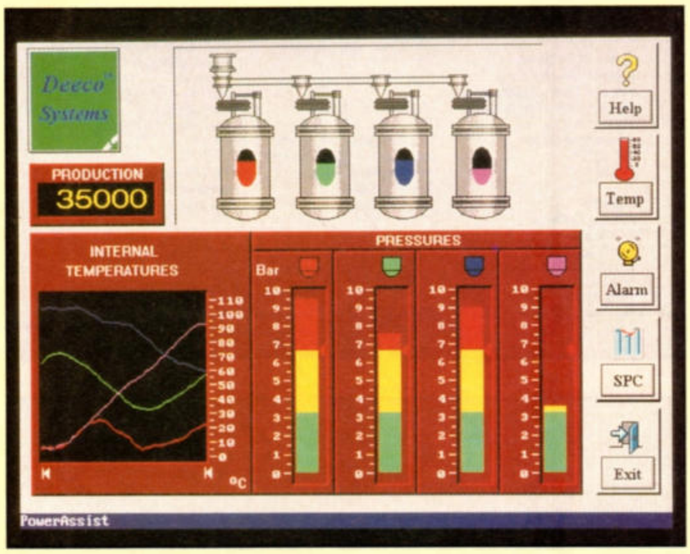
Canon has launched what it claims to be the first solar-powered compact camera, for those with an eye to ecology and economy in the run up to the summer holiday season. The Canon Sureshot Del Sol is a slimline and stylish, fully-automatic camera with a wide 32mm lens, ideal for panoramic holiday shots. While you soak up the sun, so does the camera. At the same time, an in-built rechargeable lithium ion battery stores enough power to shoot up to four 24-exposure films – or two if using flash at night. The Del Sol charges itself through solar cells on the front cover, which is operational even without sunlight. Artificial or normal light will suffice, similar to most other solar-powered devices, such as calculators. Power level can be checked on the camera's LCD panel, by pressing an illumination/battery check button. The solar panel cover acts as an on/off switch for the camera. When shut, power is off and it will absorb energy from various light sources, to continually charge the reserve battery. If exposure in direct sunlight causes the temperature of internal components to get too hot, the solar panel automatically opens to allow them to cool down.

Contact: Canon, Tel: (0181) 773 3173.

Software for Process Monitoring and Control

Lucas Control Systems Products has launched a software program for monitoring and controlling batch or continuous process production. Called Power Assist, the software is capable of running on high-performance PCs similar to the Deeco 486DX-2, or lower-performance 386SX systems, with as little as 2M-byte of RAM. The software is described as a Programmable Logic Controller Graphic User Interface program, and comes in two parts, a Developers package and a Runtime package, which are available separately or together.

Contact: Lucas, Tel: (01535) 661 144.



Hitachi 32-bit Embedded Processor

Hitachi's new SH-3 series of 32-bit RISC microcontrollers addresses the needs of portable computer, consumer and wireless OEMs by combining what it claims is the industry's highest MIPS/Watt figure with exceptionally low cost per MIPS. The SH-3 is the latest in the SH range, based on the SuperH RISC engine, which has already been designed into over four hundred products, including the Saturn, Sega's new-generation entertainment console. The SH-3 architecture can achieve 100 Dhrystone MIPS at 100MHz, yet consumes less than 1W at 3V. Under the same conditions, the SH-3 achieves excellent SpecInt of 42. Power consumption is reduced further by the three on-chip, power-down modes, and a low-power cache memory design. These flexible, low-power modes, allow power dissipation to be dynamically modified to match system operation modes. This type of power management is vital for the emerging generation of battery-operated systems. Typical applications include PDAs, set-top boxes and digital cellular devices. The high-performance of the SH-3 architecture and hardware multiply/accumulate (MAC) block, allows DSP functions to be carried out in software, reducing external chip count. On-chip peripherals include: a timer, a separately-powered real-time clock, PLL-controlled oscillator, 32-bit multiplier, barrel shifter, and serial interface. SH-3 silicon integrates an extremely low power, 4-way set associative cache memory, and a memory management unit (MMU). The MMU provides the memory partitioning required for complex operating systems. A memory access support function enables direct connection to DRAM, SDRAM and PSRAM, further reducing external chip count. This bus controller supports a PCMCIA interface, an increasingly important feature for portable products.

Contact: Hitachi, Tel: (01628) 585 163.

IEE Launches Mobile Communication Prize

A £2,000 prize for engineers working in the fields of mobile radio and data has been launched by the Institution of Electrical Engineers (IEE). The prize, which will be administered by the IEE, will be awarded in the first year to a practising engineer embarking on a post-graduate course in mobile radio, and on alternate years, to an undergraduate.

Contact: IEE, Tel: (0171) 344 5454.

Fuji Launches Digital Card SLR Camera

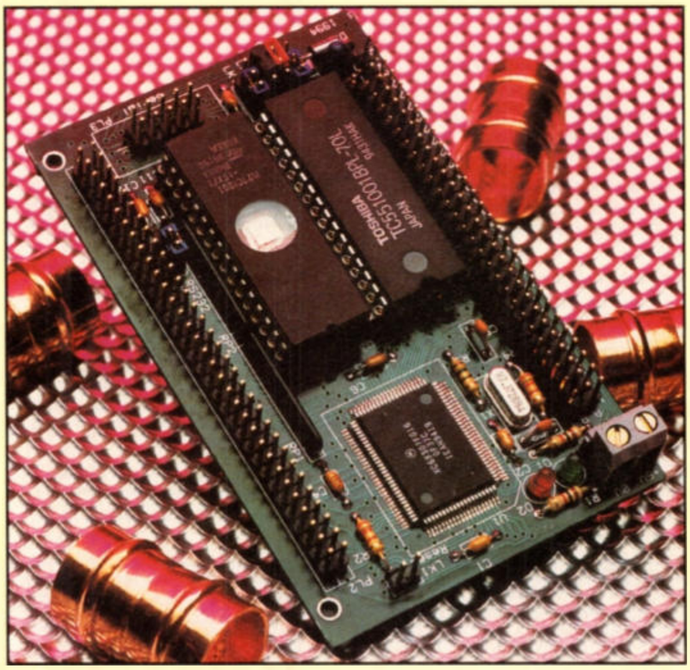
The much heralded, high image quality, digital SLR camera, developed by Fuji Film in collaboration with the Nikon Corporation, will be available in the UK from April. The Fujix DS-505/DS-515 is tailored to electronic imaging in applications such as reportage, portrait and commercial photography and health care, where the need is for computer readable multimedia information available for transmission via communications networks. The camera uses a Vacancy Transfer based, 1·3 million-pixel CCD to capture images and a high-speed industry standard PC card for storage. A single reusable Fujix HG-15 Image Memory Card, with a capacity of 15Mb, can store up to 84 compressed images. With the familiarity many photographers will have with Nikon F mount lenses, and Nikon accessories such as flash a macro equipment, which can be used unmodified on the standard Fujix DS505 camera and the Fujix DS515 continuous exposure model, the transition between the worlds of photography and digital imaging becomes even more straightforward.

Contact: Fuji, Tel: (0171) 586 5900.

Complete CPU Engine with a PC Starter Pack

The new Micro-Midget from CMS is a small (3·8in. × 2in. approx.) 16/32 bit controller. It is ideal as a component in intelligent control systems, incorporating a real-time operating system and full support for high level languages, including C. The controller has up to 22 digital I/O lines, which can be configured for input or output as required, a single serial port operating at up to 38,400 baud with RS-232 or R-485 driver options, and two 16-bit timer/counters. The peripheral expansion bus can be used with 68,000-type or 8051-type devices. Applications are developed on a PC, down-loaded to the Micro-Midget, and tested in RAM. Up to 1M-byte of program space is available on board, with up to 512K-byte of Static RAM. The PC utilities are provided to allow the application code to be downloaded and stored on EPROM, enabling the controller to run from power up. The board is priced at £95, with a PC starter pack containing all the software support, operating system, C compiler, PC utilities and Micro-Midget, from £295.

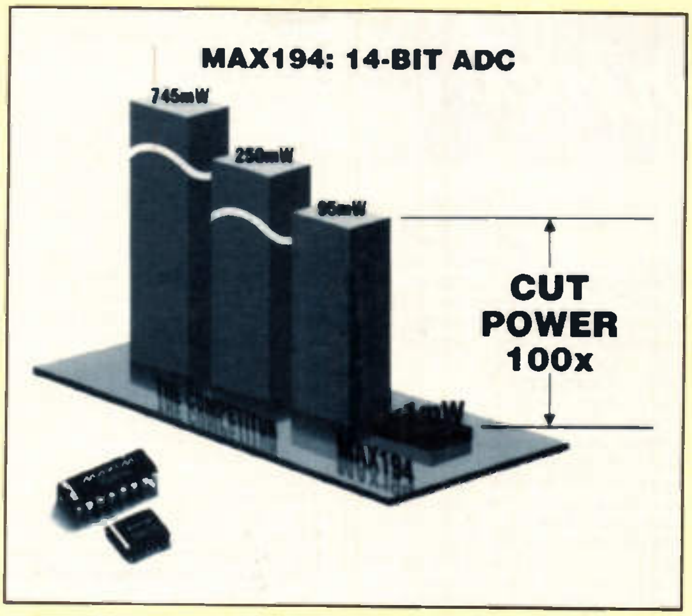
Contact: Cambridge Microprocessor, Tel: (01371) 875 644.



Low Power ADC

The MAX194 from Maxim is a 14-bit, successive approximation, analogue-to-digital converter (ADC) which combines high speed, high accuracy, low power consumption, and a 10µA shutdown mode. Internal calibration circuitry corrects linearity and offset errors, to maintain the full rated performance over the operating temperature range, without external adjustment. The capacitive DAC architecture provides an inherent 85ksps track/hold function. The MAX194, with an external reference (up to +5V) offers a unipolar or bipolar pin-selectable input/out range. Separate analogue and digital supplies minimize digital-noise coupling. Applications include portable instruments, industrial controls and medical signal acquisition. The MAX194 is available in 16-pin DIP, SO and ceramic sidebraze packages, screened for the commercial (0°C to +70°C), extended-industrial (–40°C to +85°C) and military (–55°C to +125°C) temperature ranges.

Contact: Maxim (UK), Tel: (01734) 303 388.



Philips and IBM Form New Company

Philips Electronics of the Netherlands and IBM, which last October announced their intent to join forces in specific semiconductor areas, has agreed to form a new company to operate IBM's facility in Boeblingen Hulb, near Stuttgart, Germany. Under the terms of the agreement Philips becomes the majority owner with 51% of the company, while IBM retains a 49% stake. The joint venture is expected to start operations by the beginning of April. The people currently employed by IBM will work for the new company to make products soles for Philips and IBM. For IBM, it will make four-megabit DRAM chips, the most commonly used memory product today, which are produced on eight-inch wafers. For Philips, the joint venture plans to manufacture 0·8µm linewidth CMOS logic products. The companies plan in time to upgrade the facility for production of integrated circuits for the next generation of technology.

Contact: Philips Semiconductors, Tel: (+31) 40 72 20 91

UK Industry Must Innovate and Invest to Win Globally

Delivering a strong message to a high level business audience at the 1995 UK Innovation Lecture, Peter Williams, Chairman and CEO of Oxford Instruments, declared that UK industry will continue to under-achieve in world markets unless it is prepared to exploit one of the UK's national assets, its science and technology base, and that industry, shareholders and the financial world must be prepared to invest in the whole process of innovation, in order to bring UK scientific development to market profitability. Maintaining that the origins of UK under-investment in research and subsequent development could be traced as much to the boardroom as to the City, Peter Williams stressed the central role of shareholders and the financial world in the whole process of innovation. "How can UK companies expect to compete in technologically sophisticated sectors internationally, if they handicap themselves in the provision of very necessary investment for the long-term development of new products and services?" asked Williams. He continued, "Industry must also pit its wits against the best that international competition has to offer, not merely to defend positions within these shores, but more importantly, in the export markets of the world". Emphasising that the science base is a vital UK national asset, Williams stressed that industry must be swifter in turning scientific prowess into hard cash. A major step forward, according to Williams, would lie in industry and the science base creating a joint vision that they would like to move towards in the future. "We must not fall into the trap of believing that the science base can bale out industry and compensate for its deficiencies", added Williams.

It's Not all Hard Work for Laptop User

Portable Add-ons, has just launched the Game PC·Card, claimed to be the UK's first PC Card game port. Notebook PCs are now just as powerful as their desktop equivalents, and some top-end models feature built-in sound cards capable of livening up any game. For those that don't, PC Card sound cards, such as the NewMedia .WAVjammer will add this facility. Despite this new-found games potential, off-duty notebook users still have to grapple with a miniature keyboard or trackball when playing games. With the Game PC Card, this limitation is blasted into oblivion. The £69 Game PC Card will add the industry-standard 15-pin connector to any PCMCIA-equipped computer, with a running speed of between 8 and 200MHz. Any IBM-compatible joystick or joypad can be plugged into this port.

Contact: Portable Add-ons, Tel: (01483) 440 777.

IC Encodes Digital Video Data into NTSC and PAL Analogue Signal

Philips Semiconductors' digital MPEG-compatible video encoder, the SAA7185, encodes digital YUV data to an NTSC or PAL CVBS and S-video analogue signal, to be displayed on consumer TVs or recorded on VCRs. The SAA185 is designed for use in video processing equipment such as computers, video servers, video CD players and video games. Because the device accepts 16-bit YUV data or 8-bit CCIR 656-compatible YUV data in MPEG format, it is ideal for CD playback in PCs and games.

Contact: Philips Semiconductors, Tel: (+31) 40 72 20 91.

AT&T Announces New 40,000 Gate ORCA FPGA

AT&T Microelectronics has announced the availability of a 40,000-gate FPGA, designed to match the speed performance of conventional gate arrays, while narrowing the cost-per-gate gap between FPGAs and gate arrays. The new ATT2C40 is claimed to be the highest density FPGA available in today's market.

Contact: AT&T, Tel: (01344) 865 927.

Novell Sponsors Local Hospital Radio

Novell UK has donated £8,000 worth of equipment to St. Peter's Hospital, Chertsey, Surrey, for use in its radio station, Hospital Radio Wey. The station, broadcasting to over 1,000 patients daily in three hospitals in Chertsey, Weybridge and Ashford, is a registered charity, staffed entirely by volunteers.

Contact: Novell, Tel: (01344) 724 460.

ATM – Huge Growth Rates Now in Sight

"ATM will really take off in 1996, both in Europe and the US, and after 1996, growth rates will boom", says Iain Stevenson, lead author of the fourth and final update of ATM: Market Strategies, just published by Ovum. The update contains a completely new set of forecasts for the period 1994 to 2000, projecting uptake of ATM both in Europe and the US.

Contact: Ovum, Tel: (0171) 255 2670.

New RSGB Call Book for Windows

Skyview Communications has produced a UK Call Book on computer disk for the RSGB. SkyCall comes on four 3·5in. diskettes, and will run on any IBM-compatible PC, with an 80386 or better processor running Microsoft Windows 3.1 or 3.11, and a minimum of 4M-byte RAM and 8M-byte spare hard disk space. All 55,000 UK callsigns are included, and records can be accessed by callsign, name or postcode. In addition to these rapid searches, the use of the standard language SQL (Structured Query Language) allows much more complex searches to be made. Names and addresses may be exported in a neat multi-line format for use on QSL cards or club mailing lists. Three more databases are included: packet radio BBSs, 2m repeaters and 70cm repeaters. These may be amended by the user to keep them right up to date. SykCall is available exclusively from RSGB Sales.

Contact: RGSB, Tel: (01707) 659 015.

Storage System

DIY enthusiasts, hobbyists and others who dabble in electronics, will find the Caretaker answers many of their storage problems. The Caretaker will hold aerosol cans, nuts, bolts, screws, washers, and other numerous bits and pieces that collect around the workshop. The 2m storage system has been designed to create a lot more usable space in the garage or shed, for the DIY enthusiast, by using a carousel disc system, which takes up very little space, and is fully adjustable in height.

Contact: Caretaker Storage Systems, Tel: (01202) 822 712.

CD – Check on Multimedia Standards

Eurosoft has developed a new product to support anyone installing or upgrading PCs. The CD-Check Diagnostic Disc is a dedicated multimedia hardware diagnostic product with unique, independent test data. When you install or upgrade PCs with new multimedia hardware, the most commonly asked questions include, "Does it meet MPC (Multimedia PC Council) standards?" and, "What is the CD-ROMs access time?" These questions can now be avoided with the new CD-Check Diagnostic Disc available from Eurosoft. The CD-Check Diagnostic Disc is provided on a CD-ROM disc to immediately begin testing the MPC system CD-ROM drive. It confirms reliable operation by testing each sector of a CD-ROM drive and goes on to measure real-time data access with manufacturers' access times. This ensures that a CD-ROM drive is installed correctly and that an entire CD-ROM can be read reliably. A special manufacturer's database shows available CD-ROM specification data to compare CD-ROM access times.

Contact: Eurosoft, Tel: (01202) 297 315.

@Internet

Last month, we looked at Internet addressing, in the form of the four sets of numbers which identify any computer connected to the Internet. These numbers identify each machine in much the same way a telephone number identifies any particular telephone user. But, while the computers themselves are whizz-bang at remembering and calling a numbered identity (Internet or telephone addressing), numbers are not the ideal way for us users to remember and call. Yes, we *can* cope with a few friends' and relatives' telephone numbers (*and* Internet addresses at a push), but after that, things become a little tricky unless you have a photographic memory. So, Internet addresses are usually given in a domain naming system, where domain names are given to users rather than numbers. A *domain* name server (a dedicated computer on the Internet) automatically translates between the domain names which users have, into the numbered addresses used by the computers themselves in the Internet. The domain names used can help to make a user's address easy to remember (though, if names are awkward ones – which can be the case when you register through some Internet providers – this is not necessarily true). Domain names are usually split into three, sometimes more, levels, along the lines of: *computer.network.country* and, of course, the full stops between domain names are universally called *dots*. Top-level domains (the last one given in an Internet address) are most usually country codes: *uk* is the United Kingdom, *au* is Australia, and so on. Other examples of top-level domains are com (commercial providers), *org* (non-commercial organisations), *gov* (governments), etc. Middle-level domains usually specify the organisation or computer network (*compuserve, demon*, and so on). Finally, the last domain (the first part of the address) signifies the actual computer a user is connected to. If you are interested in contacting a particular user at the computer in question, then in front of the whole address goes the user's very own ID, followed by the *at* symbol (@). We can take as an example, the address if you are trying to contact this very column with a startling piece of information about the Internet which you think deserves to be mentioned in next month's issue. The domain-based Internet e-mail address is: **site_survey@maplin.demon.co.uk** which illustrates the whole thing pretty well. If I was giving this address to someone else over the telephone, say, I would refer to is as: "site underscore survey at maplin dot demon dot co dot uk", but I would need to make sure that whoever I was giving it to recognised the convention. A new user of the Internet might not know what *at* and *dot* signifies. If you are only trying to get onto a computer for, say, download purposes via FTP or the like, no user ID needs to be tagged on at the beginning – you are effectively logging onto a computer, not a user. This is a subtle difference which can confuse a new user, but, when you think about it, it is pretty obvious.

IBM Research to Develop NASA Data Over 'Net

Amateur and professional environmentalists, geologists and others who have a need or use for earth science data from outer space, may gain easier access to this information in a few years. IBM researchers are developing a system that will enable wider public access to NASA earth and space science data over the Internet. This project has been launched, thanks to a £2 million grant that NASA awarded to scientists at the IBM Research Division's Thomas J. Watson Research Centre in Yorktown Heights, New York. The IBM grant, and 14 other awards, totalling £20 million, are intended to fund projects that accelerate the creation of a National Information Infrastructure (NII). NII is a governmental initiative to provide greatly improved access to electronic information, and to promote the exchange of information.

For IBM, the NII is part of network-centric computing, a strategic effort focused on an emerging market in which customers can subscribe to application services delivered on high-speed voice and data networks. This enables the sharing of voice, video and other forms of information for business, research or entertainment, and facilitates anytime, anywhere access to these forms of information. The IBM project will use a combination of existing and to-be-developed technology, to enable multiple users to concurrently and interactively retrieve NASA digital satellite data from a large digital library with greater ease and efficiency than is currently possible.

The researchers will be developing algorithms (a set of computer instructions) that will perform the retrieval by image content, rather than requiring the users to extract large volumes of data for later selection as is the focus of current retrieval methods. This project will be carried out by the systems analysis and systems applications group, at the Watson research facility. Commenting on the significance of the grant, Steve Lavenberg, senior manager for the group said, "This is an exciting opportunity for IBM Research to apply its technology leadership in algorithms, database technology, image and signal processing, user interfaces and visualisation, to help NASA achieve its objectives. The complexity and scale of NASA's data make this a particularly challenging project."

IBM will incorporate the new algorithms into a test-bed system that will be installed, along with a high-performance server based on IBM's line of wordstations, at NASA's Remote Sensing Public Access Centre (RSPAC) in West Virginia. The researchers will work with user groups to test and evaluate the test-bed retrieval system, which will be available to users over the Internet. The initial database will be focused on one class of data, such as images for environmental analysis and land use studies.

For example, a scientist who is attempting to ascertain the total acreage of crops being irrigated in Nebraska, may issue the following query, "Show me the most recent satellite image of Nebraska". In the image that is recovered, the area is obscured by clouds. The user issues a second query, "Show me the most recent cloud-free satellite image of Nebraska". In order to obtain satellite images of Nebraska from the last 12 months, the next query issued may be, "Show me the weekly history of this region for the last year".

At this point, the user is interested in discovering the distribution of water usage for crop irrigation across the Midwestern states. The user issues one last query, "Find me all regions in the Midwestern United States that contain the signature identified in recent satellite images". This will provide the user with a view of the total acreage of irrigated crops across all the Midwestern states.

While some aspects of these queries could be satisfied by current methods, most could not. The ability to conduct this type of search and retrieve of the images over the Internet, is a primary objective of the IBM research.

"The IBM work will draw on software previously developed by IBM Research, including IBM's Visualisation Data Explorer, an application and toolkit that allows the visualisation and analysis of large amounts of complex and multi-variate data, independent of discipline; and IBM's Query by Image Content (QBIC) technology, which enables retrieval of images by colour, texture, shape and layout", said Lavenberg.

Contact: IBM, Tel: (01705) 561 781.

Philips Semiconductors Sets Up Home Page

Philips Semiconductors has established a presence on the world wide web with a home page on the Internet. The company's Internet address is: **http://www.semiconductors.philips.com/ps/**. The information available via Philips Semiconductors' home page includes a company overview, information about the company's core competencies (multimedia, wirelesscommunications, audio and video and microcontrollers), job openings (currently only for North America), and product and technology news. Over time, the firm plans to expand the scope and quantity of company information and technical documentation available at the site.

Contact: Philips Semiconductor, Tel: (+31) 40 72 20 91.

UK Construction Research on Information Super Highway

Information on the Building Research Establishment (BRE) and its construction research, ranging from energy efficiency, environmental engineering and fire to geotechnics and buildings economics, will soon be made available on the worldwide information superhighway. BRE is the UK's principal construction research organisation. Information from the Energy Efficiency Office's Best Practice programme for buildings is already available, and it will be followed shortly by all BRE news releases and BRE news of construction research. Information on the Best Practice programme for buildings provides independent guidance on energy efficiency to technical/non-technical buildings professionals, and is also available at: **http://www.bre.co.uk/bre/otherprg/eeobp/**.

Contact: BRE, Tel: (01923) 664 083.

Site Survey
– the month's destination

With what amounts to a cool public relations exercise (there is actually not that much *real* information available), the UK Government's Open Government pages deserve a critical look. The home page is sited at: **http://www.open.gov.uk/** and contains hyperlinks to several areas which you might find relevant. The screenshot shows the British National Space Centre (BNSC) information page, at: **http://www.open.gov.uk/bnsc/bnschome/htm** which tells us that "Britain is very active in space". Hmm. Still, if we read it often enough, we'll start to believe it. There is a bit of information about a new CD-ROM published by BNSC, titled *Britain's Place in Space* (ISBN 0 11 701975 5), which is available from HMSO and bookshops, price £70.50, or £40 to schools. I hope to look at the CD-ROM in a future @Internet. The government site as a whole, is pretty dis-

ingenuous, but if you look at it with a few pinches of salt in mind, you can glean a little of the political incorrectness not intended by the politically correct providers. There are also a few snippets of worthy information and readable text available, such as the complete *Frameworks for the Future of Northern Ireland*, which you can down-load and printout for your own later diges-tion.

CORRIGENDA
Newton Valve Preamplifier

The following is a summary of documentation and other errors published in *Electronics* Issue 85, January 1995, and early kit literature.

Input (Phono) Module Kit LT76H

On the phono PCB, wiring points P103 & 104, and P106 & 107 are complementary or other-channel equivalents to P3 & P4, and P6, P7. There is no P105 because P5 is the HT supply pin, which is common. This should have been a bit clearer in the instructions.

The C13 reference in the instructions has obviously been overlooked and is a mistake, but you can deduce its placement according to the PCB legend and the parts list.

Component values for the RIAA equalisation network were based on original findings by Richard Brice, first published in his amplifier circuit in Wireless World, 1985. It has been pointed out that these were subsequently found to be slightly inaccurate compared with the correct RIAA response. This can be easily rectified, if desired, using recalculated component values as follows:

With reference to the Phono Module circuit diagram, Figure 2:

R4 = 33kΩ in parallel with
1MΩ (= 32·1k)
R11 = 100kΩ
C5 = 56nF
C8 = 820pF
C9 = 9n1F
(C8 + C9 = 9·91nF)

At least one customer has experienced what appeared to be LF instability (described as 'motor-boating'). In reality this was a symptom of *RF instability*, in the V2a and/or V2b line driver stages. In certain conditions, these can behave as RF oscillators, each valve using the short connecting tracks and wire on the PCB as small RF coils.

To prevent RF instability, add a 'grid stopper' resistor in series with each input, i.e. to pins P10, P110, and then connect the signal leads to these. Values could be 4k7Ω, for example.

PSU Module Kit LT75S

The 100mA DC fuse, F2, is reported to have a tendency to 'flash' on power-up, but survives due to supply electrolytics having resistors in series; the final surge current is probably close to 100mA. A 'time delay' type can be used if preferred, e.g., UJ92A (100mA Time Delay Fuse 20mm).

The mains fuse rating is 500mA for European use and 1A for US use, but *only* if there are no euro outlet sockets added to the chassis. If there are, then the fuse will have to be uprated to whatever the total power consumption is likely to be. The maximum is 6A, because the inlet filtered socket is rated to 6·3A. The fuse must be a ceramic bodied type.