RADIO · TELECOMMS · COMPUTERS · AUDIO · TEST GEAR

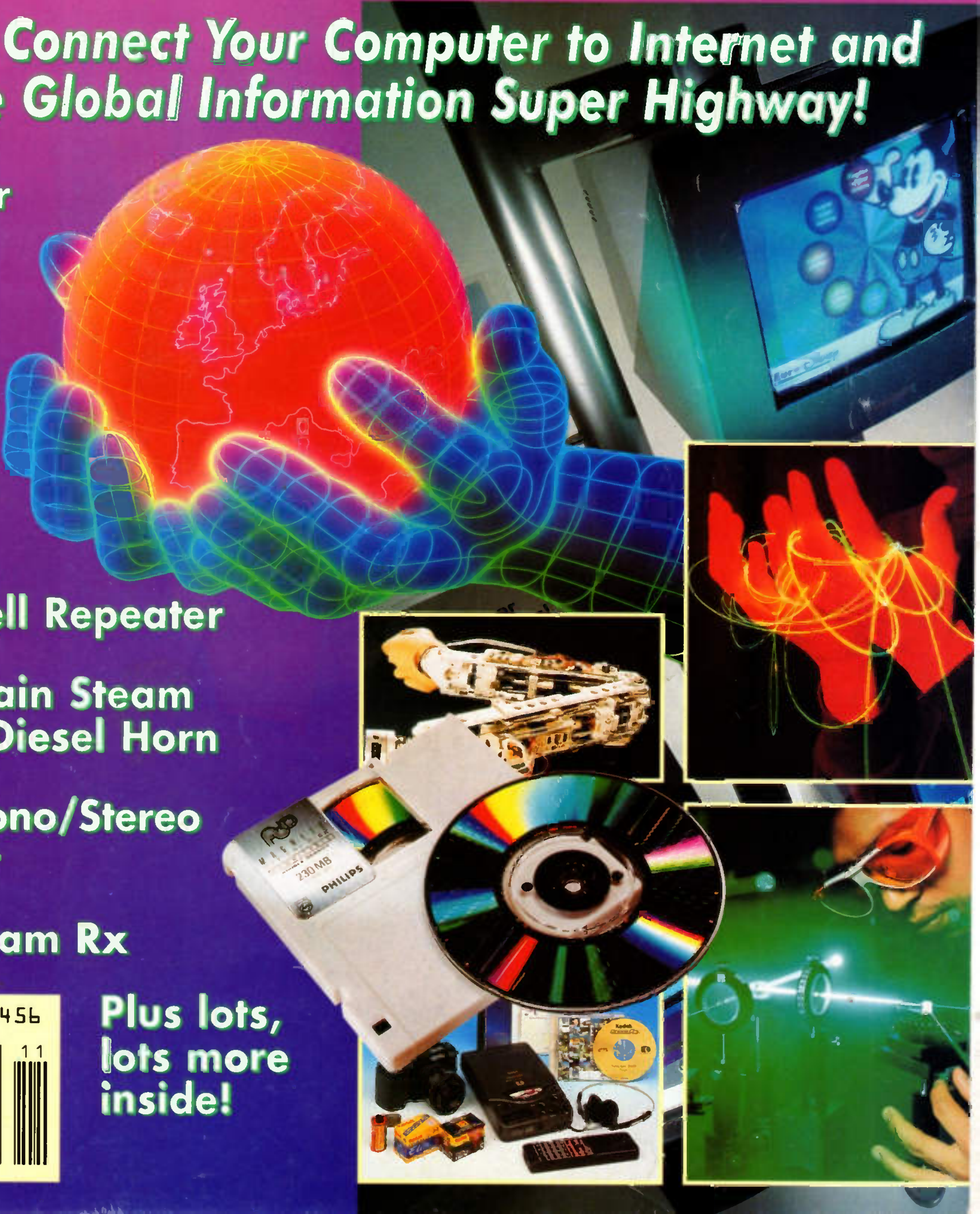
No. 83
FULL
SOR
NOVEMBER 1994 · £2.10
Printed in the United Kingdom

ELECTRONICS

The Maplin Magazine

Britain's Best Selling Electronics Magazine

How to Connect Your Computer to Internet and Join the Global Information Super Highway!



Six Super Projects in this Issue:

418MHz Encoded FM Tx and Rx

Phone Bell Repeater

Model Train Steam Whistle/Diesel Horn

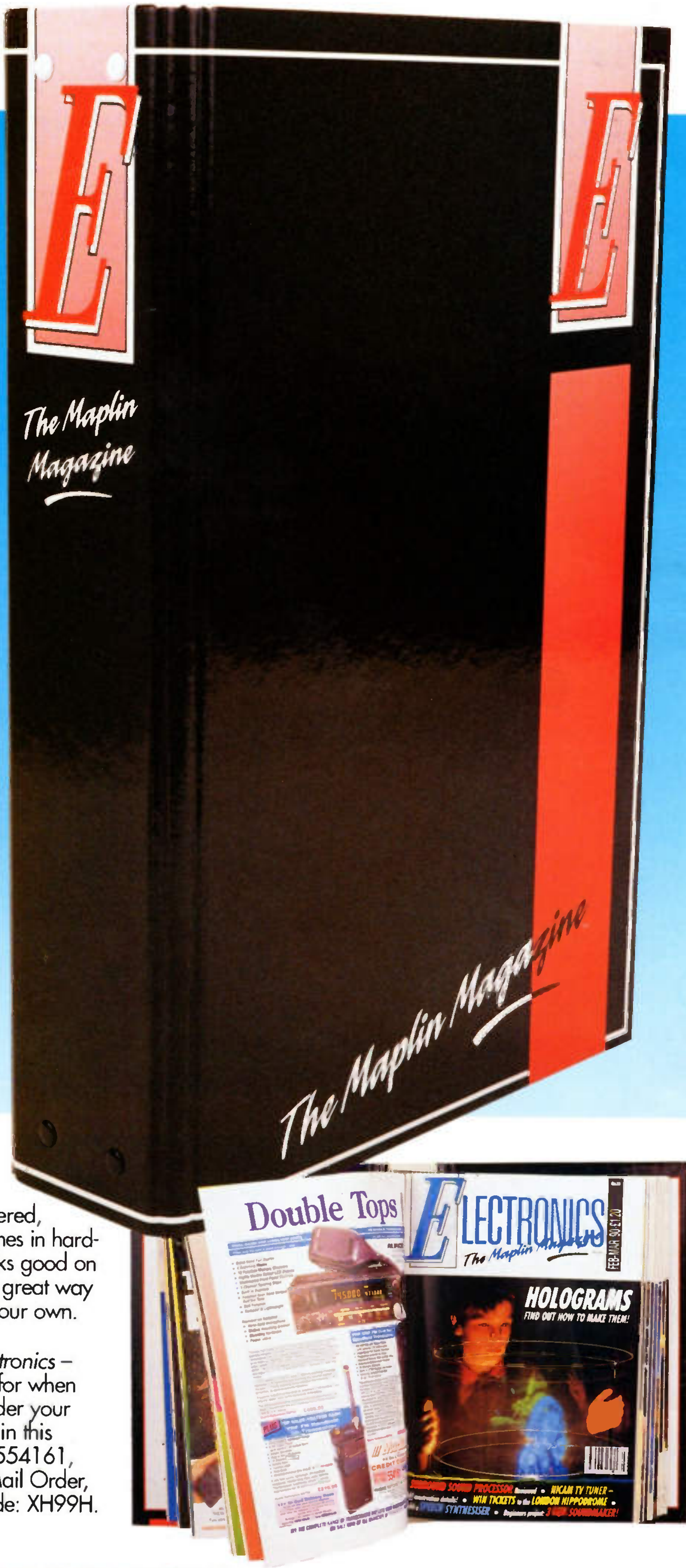
400W Mono/Stereo Amplifier

2m FM Ham Rx

Plus lots, lots more inside!

ISSN 0957-5456
11
9 770957 545077

Twelve great reasons to get Electronics under cover...



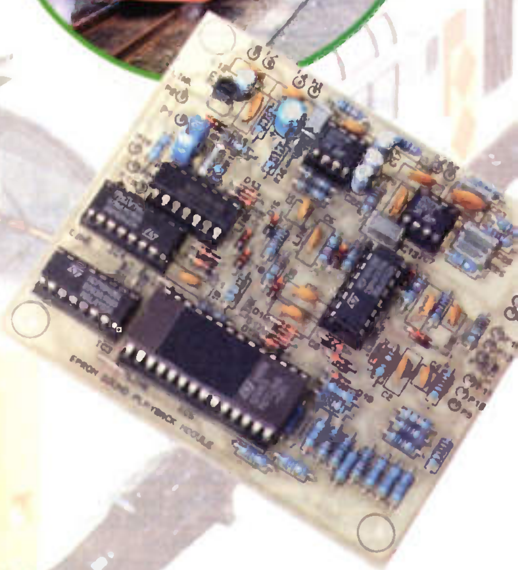
The Maplin magazine binder holds twelve issues of *Electronics – The Maplin Magazine*. If you have not got the world of electronics covered, now's your chance! This great quality binder comes in hard-wearing laminated art board, that not only looks good on your bookshelf or workshop desk, but is also a great way to build up an electronics reference library of your own.

Now you can keep all of your copies of *Electronics – The Maplin Magazine*, together and on hand, for when you need that extra piece of information. To order your binder simply fill in the order coupon provided in this issue, or call the Credit Card Hotline on 0702 554161, or visit your local Maplin Store. Only £5.99. (Mail Order, please add £1.50 Handling charge.) Order code: XH99H.

THE NEW MAPLIN MAGAZINE BINDER...
A GREAT WAY TO GET THE WORLD OF ELECTRONICS COVERED!

NOVEMBER 1994
VOL 13. No. 83

IN THIS ISSUE...



REGULARS *NOT TO BE MISSED!*

ABOUT THIS ISSUE . . .

Hello and welcome to this month's exciting, jam-packed Issue of *Electronics*!

Hello Who's Calling?

In an *Electronics* News Report story a few Issues back, it was mentioned that a Calling Line Identification (CLI) service was on trial In Perth, Edinburgh and Bristol. BT has now announced that it will introduce a CLI service on 5th November this year. The CLI service allows the recipient of a telephone call to see the telephone number of the caller shown on a display, prior to answering the call. A similar system is already in operation in the USA. The implementation of such a system has only recently become possible with the digitalisation of the, previously analogue, public switched telephone network (PSTN).

It is hoped that such a service will dramatically reduce the amount of nuisance calls received and provide additional benefits to both private and business telephone users alike. Users who wish to make use of this service will need to ask for the service to be 'switched on' (charges to be announced) and also get a CLI display unit or a telephone with a CLI display built in. Following the publication of Oftel's (the telecomms industry regulatory body) CLI consultative document last year, much discussion took place to identify the needs for such a service and what safeguards over privacy Issues needed to be put in place.

A policy paper on the introduction of CLI has now been published. Here is a summary of the main points of interest extracted from the document:

Although there will be some customers who do object to the introduction of CLI based services in any form . . . these services can be introduced in a way that, on balance, benefits consumers.

CLI based services should only be allowed in the UK if the caller has the option of inhibiting the display of their CLI on a call by call basis. The prefix 141 should be used as the Call Blocking [CLI block on a call by call basis] *inhibiting mechanism on all public telephone networks in the UK.*

. . . Line Blocking [CLI block on all calls] *should be made available by all telecomms operators, but that the decision to opt for line blocking should be an informed one.*

The CLI service must distinguish between calls where CLI is 'withheld' (i.e. blocked by the caller) and where it Is 'unavailable', and that this distinction must be made available at the called customers line [i.e. on their CLI display].

. . . telecomms operators should be encouraged [but not required] *to provide a service that rejects calls where the CLI has been 'withheld'.*

. . . 'call trace' services, where the CLI information is trapped by the telecomms operator upon instruction from the receiver of a call, and can then be given to the Police, should be permitted, but not required.

CLI data should only be used for purposes which are directly connected with the original call.

The use of CLI data for other purposes should only happen if the caller has given express permission [the use of such data, without permission, to create commercially available 'call lists' would breach the Data Protection Act].

. . . CLI based services [will not be subject] *to any retail price control* [but customers not using the CLI service should not pay any costs In providing the service to others].

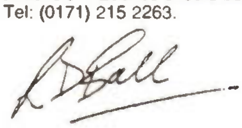
Additionally, Oftel Is strongly encouraging telecomms operators to work together to provide a system that is intercompatible (i.e. a call originating from the Mercury network should correctly pass its CLI to a number dialled on the BT network). It is interesting to note that the Integrated Services Digital Network (ISDN) had CLI built in from the ground up, but only calls from within the ISDN network currently pass on the CLI Information to the recipient of the call. The emergency services can already gain access to CLI information, e.g., if a call for help is received but the caller Is unable to give the address; the call can be traced quickly and responded to. CLI information has already enabled malicious callers to be traced and prosecuted. Copies of the full CLI policy paper can be obtained from Oftel, Tel: (0171) 634 8700. Details of BT's CLI service will included with future telephone bills!

Boost for Good Buddies

Previous restrictions over certain types of Citizens' Band (CB) aerial have now been substantially relaxed by the Radiocommunications Agency (RA).

$\lambda/2$ and $5/8\lambda$ single vertical monopole (whip) aerials with a driven element up to 6·95m long and 55mm diameter (including loading coils, circuitry and casings, but excluding groundplane rods or plates) are now permitted. Additionally vertical $\lambda/2$ dipole aerials up to 5·55m in length are also now permitted. Not surprisingly such antennas are not recommended for mobile use! Loop, yagi and beam aerials remain prohibited and the requirement for a CB licence remains.

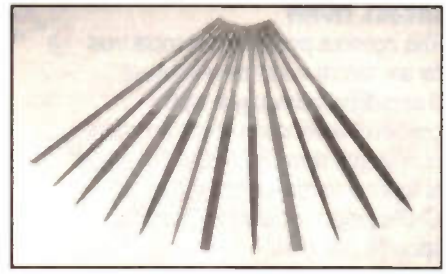
The changes have been brought about by the CB User Group Forum comprising representatives from the RA, CB Groups, CB Magazines, dealers and the Civil Aviation Authority (CAA) and is the culmination of several years of discussion. Queries should be directed to the RA, Tel: (0171) 215 2263.



New Maplin Regional Stores

Maplin opened two new regional stores recently in Belfast and Liverpool. The Belfast store is at 357-359 Lisburn Road, Belfast, Tel: (01232) 683929 and the Liverpool Store is at 354 Edge Lane, Fairfield, Liverpool, Tel: (0151) 230 0366. For the location of your nearest Maplin Regional Store call Customer Services, Tel: (01702) 552911.

Exclusive Subscribers' Club Special Offer



On offer this month, to subscribers only, is a 12-piece Needle File Set (pictured above) it is available for just £3.99, a saving of over 20%! If you are a subscriber, full details of how to order this file set are Included on the special offer leaflet in this issue – if the leaflet is missing contact Customer Services on (01702) 552911. If you are not a subscriber and would like take advantage of future special offers and other benefits of subscribing, turn to page 45 of this Issue to find out more.

ABC CONSUMER PRESS

Front Cover Pictures: *Magneto optical discs:* PDO Media, Wiesbaden, Germany. *Laser optics:* University College, London. *Optical fibre in hands:* Mr S. Shrimpton, University of Southampton. *Multi-media background:* IN.form. *Photo-CD:* Kodak. *Globe in hands:* Pictor International. All pictures © Copyright 1994, All rights reserved, used by permission.

EDITORIAL

Editor Robert Ball AMIPRE
Technical Authors Robin Hall FBIS, G4DVJ, Mike Holmes
Print Co-ordinators John Craddock, Len Carpenter
News Editor Stephen Waddington BEng (Hons)
Technical Illustrators Ross Nisbet, Paul Evans, Nicola Hull, Kevin Kirwan
Project Development Chris Barlow, Dennis Butcher, Alan Williamson, Nigel Skeels

PRODUCTION

Art Director Peter Blackmore
Production Controller Steve Drake
Designers Jim Bowler, Matt Buhler
Layout Artists Tracey Walker, Adrian Dulwich, Paul Andrews, David Holt, Daniel Drake
Published by Maplin Electronics plc., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Tel: (01702) 554155. Fax: (01702) 553935.
Lithographic Reproduction by Planagraphic Studios, 18 Sirdar Road, Brook Road Ind. Estate, Rayleigh, Essex SS6 7UY.
Printed in the United Kingdom by St Ives (Caerphilly) Ltd., Caerphilly, Mid-Glamorgan, CF8 3SU.

ADVERTISING

Jackson-Rudd & Associates Ltd., 2 Luke Street, London, EC21 4NT. Tel: (0171) 613 0717. Fax: (0171) 613 1108.
Advertisement Managers Eric Richardson, Jim Slater

UK NEWSTRADE DISTRIBUTION

United Magazine Distribution Ltd., 16-28 Tabernacle Street, London EC2A 4BN. Tel: (0171) 638 4666. Fax: (0171) 638 4665

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, refer to the advert in this issue or 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. Alternatively contact your nearest overseas Maplin Distributor see the advert is this Issue.

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 7th October 1994 and 28th February 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.

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 he 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.

TECHNOLOGY WATCH!

with Keith Brindley

Do you surf the Internet? Have you got direct access to e-mail facilities? Do you log on to bulletin boards? Are you connected?

If so, then you can help me with a survey of our readers. What I want to do is find out how many of our readers have direct access to the ethereal services, and which of those services in particular.

For the purposes of my little experiment, I've teamed up with the MacTel bulletin board to have an e-mail address which anyone with Internet access can send a message to.

All you need to do is drop me a line to the e-mail address:

keithtest@metro.mactel.org

Note that this is not my *real* e-mail address – just a temporary one for the purposes of this survey. Don't bother requesting a reply, and don't bother writing reams; I'm not going to answer any and I'm certainly not going to sit and read pages of text in the myriad of replies I'm expecting. All I'm trying to do is find out which of the readers of *Electronics – The Maplin Magazine* have Internet access, and what sort of numbers are involved. Also let me know what services you have access to, which you regularly use, and roughly how much time per month do you spend on the wires.

I'll let you all know what the survey brings up, in a future *Technology Watch.*

Board Member

MacTel is a bulletin board service which uses the First Class system. MacTel itself tends towards Macintosh computer users, although some limited IBM-compatible information is available. MacTel currently has two boards (one in London – MacTel Metro, and one in Nottingham at the MacTel headquarters – MacTel Iconex). On either board, subscribers have access to Fidonet, Usenet and OneNet worldwide news systems, and well over 100,000 files are available. Contact numbers:

MacTel HQ ('phone):	0602 455077
MacTel Iconex (modem):	0602 455444
MacTel Metro (modem):	081 543 8017

First Class is a bulletin board control and access system geared originally to Macintosh users. Well over five hundred other bulletin boards around the world (at the last count) use First Class also. Currently at least ten bulletin boards use it in the UK. It uses ordinary Mac-type windows and menus so in proper mode has none of the inelegant command-line prompts so often associated with bulletin boards. There is, however, a version of First Class available for those unfortunates who use Windows, as is a command-line interface for those without First Class software. Both the Mac and Windows versions of First Class can be downloaded from MacTel.

On Yer Bike . . .

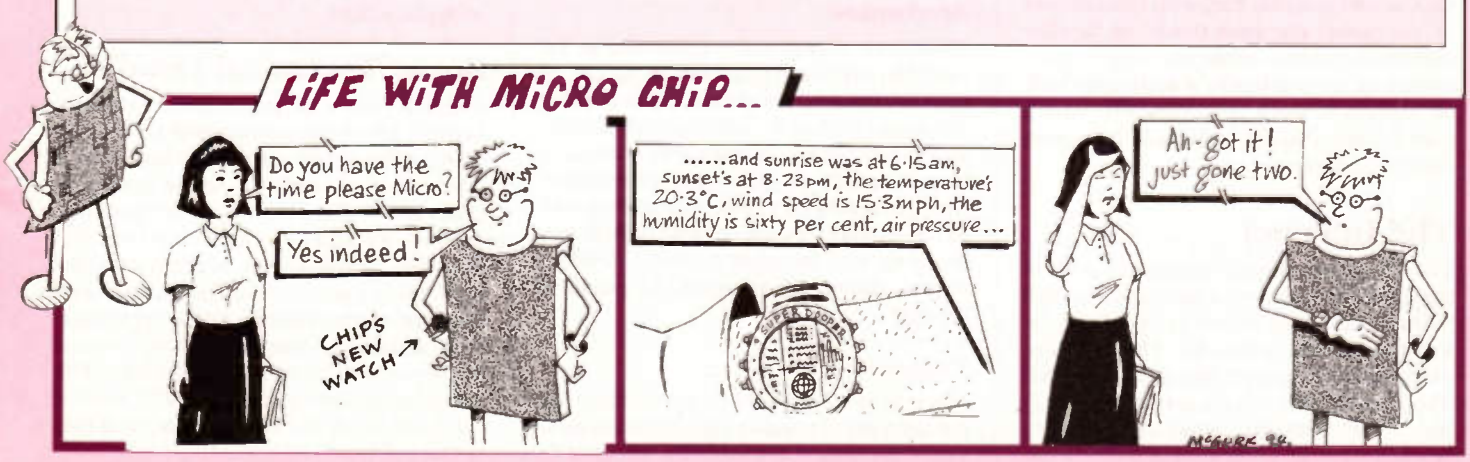
Don't ever tell my wife (it's all just a big joke dear, honestly!) but after my computer, my next best love is my mountain bike. I've been going through something of a fitness regime lately (in a vain attempt to claw back the years – I'm nearly . . . er . . . 21 . . . again – and recede the receding hairline) and my bike has been a welcome companion on several sessions a week.

However, apart from a swift calculation or two based on the old Ordnance Survey Pathfinder, I've never had any real idea of the miles I've covered (I say *miles* but the knowledgeable will read that as a euphemism for *yards* – still, we've all got to dream, haven't we?). Until now, that is. I've been trying out Maplin's own 12-function cycle computer which you may have seen in the *Money Saving Showcase* brochure, or in the Maplin Catalogue. For a limited period, until the end of February 1995, this little beauty is available for a fraction of the cost of many comparable bike computers you'll get from any bike dealer.

Now it never ceases to amaze me what technology is capable of; which is silly really because I get to see rather a lot of it in my work. I mean, some fifteen years ago when I was working as a general editorial dogsbody on a rival electronics magazine (oh, that's torn it, now you'll *know* I'm not 21) the first digital alarm watches in the UK turned up as a reader offer. I bought one then and – perhaps remarkably – it is today still working and on my wrist at this very moment. In *real* terms (no, I'm not a Government propagandist, honestly), the Maplin cycle computer costs much less than this watch did, yet of course manages to do much more (it'll give readouts of current speed, average speed, maximum speed, average speed alarm, current time, trip time, time alarm, countdown time, distance, trip distance, distance alarm and so on and so forth. Inside the computer is a 4-bit microcomputer controller, and a single lithium cell will give some two years' operation. To crown it all, the thing weighs less than an ounce (25g).

But will it make my bike go any faster or further? Does knowing what my top speed down my favourite break-back track do me any good? When *is* technology going to stop? And in the end, who cares? As long as we get out from technology what we want (not, I might add, necessarily what we *need*), then ain't technology wonderful? I think so.

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



by Dean P. Hodgkins BEng (Hons)

EVERYTHING YOU WANTED TO KNOW ABOUT 'THE NET'– BUT WERE TOO AFRAID TO ASK!

Did you realise that there are over 20 million people worldwide who are interconnected via the Internet? The Internet allows people to 'talk' to each other via computer terminals, and provides numerous other services, including access to a *vast* amount of information on just about any subject known to man. Whether you want to view the latest NASA space pictures, or just simply want to catch up with the plot of your favourite TV soap, it will be on the Internet!

Introduction

Recently, there has been a great deal of publicity given to something called the 'net'. Several quality papers have printed articles about it, and there is even (at the time of writing) a BBC television programme entitled 'The Net'. So, what exactly is all the fuss about?

'The Net' is a commonly used expression – it refers to a collection of over 13,000 interconnected networks, which link over 20 million people world-wide (present international connectivity is shown in Figure 1). One would imagine that, with this amount of 'net-users', everyone would be familiar with the term, but unless you happen to be a student, an academic, a computer-buff, or happen to work for a company which uses the net, you are unlikely to have even heard of Internet.

The Internet

The Internet simply connects people together; you can send someone a message (e-mail), talk to someone in 'real-time', or just send/receive a data file. The beauty of the Internet, however, lies in the fact that the person, with whom you are 'talking', may be in Australia, Japan, or anywhere else in the world! Geographical location has become irrelevant. As far as you are concerned, the other user may as well be logged on to a computer in the next room.

Who Uses the Internet?

The Internet has traditionally been used, in the main, by academics, large multinational corporations, and government organisations. However, this is all changing; anyone with a computer and a modem can connect to the net, and it appears that they frequently do!

Academics

Nowadays, almost every university in the world is connected to the net (in the UK, all universities have access to the Joint Academic Network – affectionately known as JANET – shown in Figure 2). It allows a free exchange of ideas and information between academics (and students!), as well as informing everyone of forthcoming conferences, and the latest scientific developments – this can be invaluable for research groups!

Corporations

Many large multinational companies use the Internet to transfer data between locations, or more commonly, to enable employees to keep in contact by using the 'e-mail' facility. Internet is not, however, 'secure', and so any confidential data *must* be encrypted.

Government Organisations

Government organisations often distribute all sorts of fascinating information. NASA, for example, circulates vast amounts of astronomical data, launch details, and even photographs from recent missions. Other organisations connected to the net include the military, and even the White House (Mr President receives several thousand 'e-mails' a day!).

Some Technical Details

There is now a large number of carriers (mainly telephone companies) worldwide which offer e-mail subscriptions, and so it became necessary to define an international standard to ensure compatibility. In 1984, the CCITT defined a set of MHS (Message Handling Systems) protocols in the X.400 recommendations. The ISO included these recommendations in the application layer of the OSI 7-layer model (they became known as MOTIS – Message-Orientated Text Interchange Systems). The CCITT further modified X.400, in 1988, to ensure that they remained in-line with MOTIS.

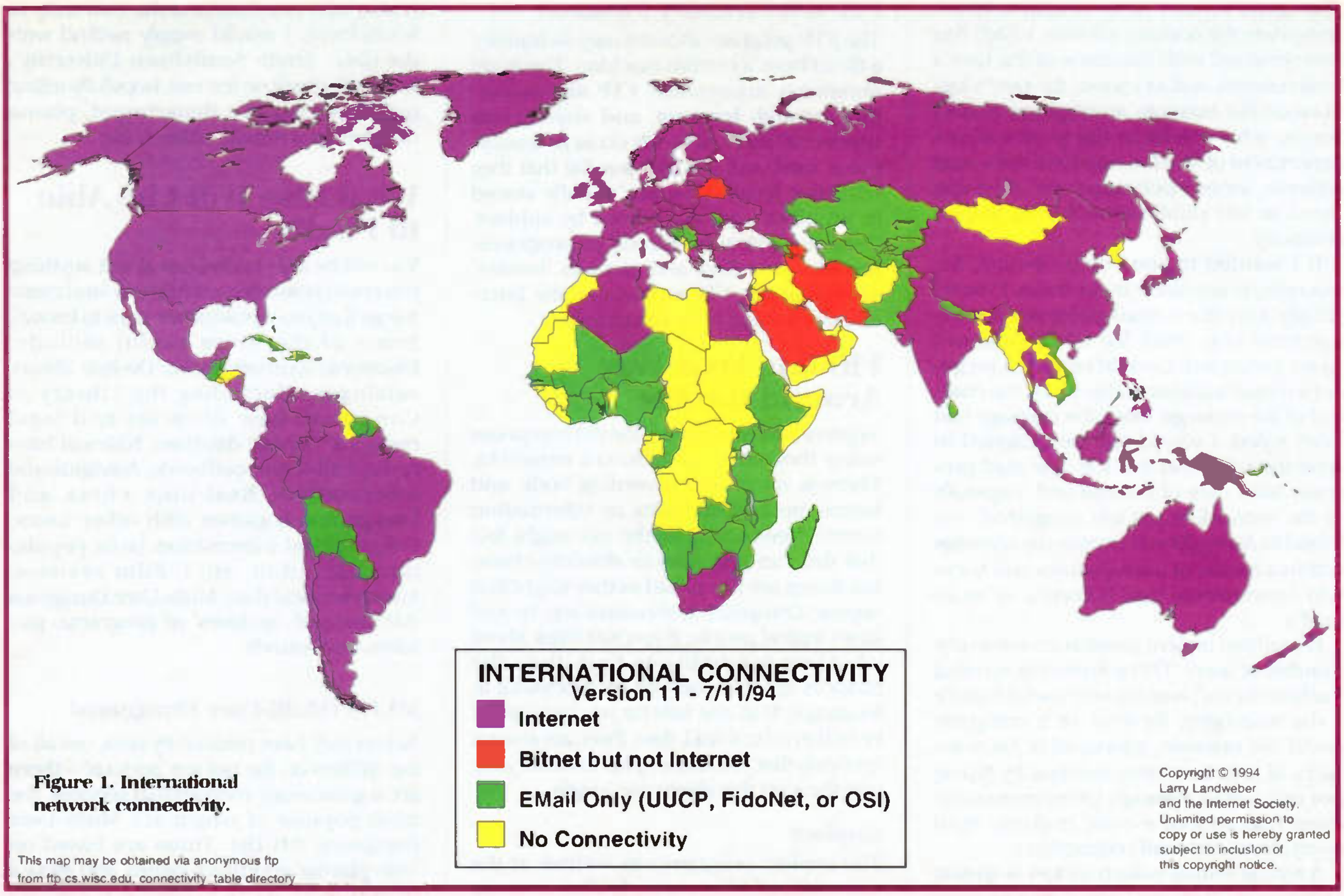


Figure 1. International network connectivity.

Internet Addresses

Rules concerning the definition of Internet addresses are specified within TCP/IP (Transmission Control Protocol and Internet Protocol). This is the protocol used by all computer systems connected to the Internet; it allows users to log on to remote machines, and then manipulate or transfer files by using the FTP (File Transfer Protocol) program.

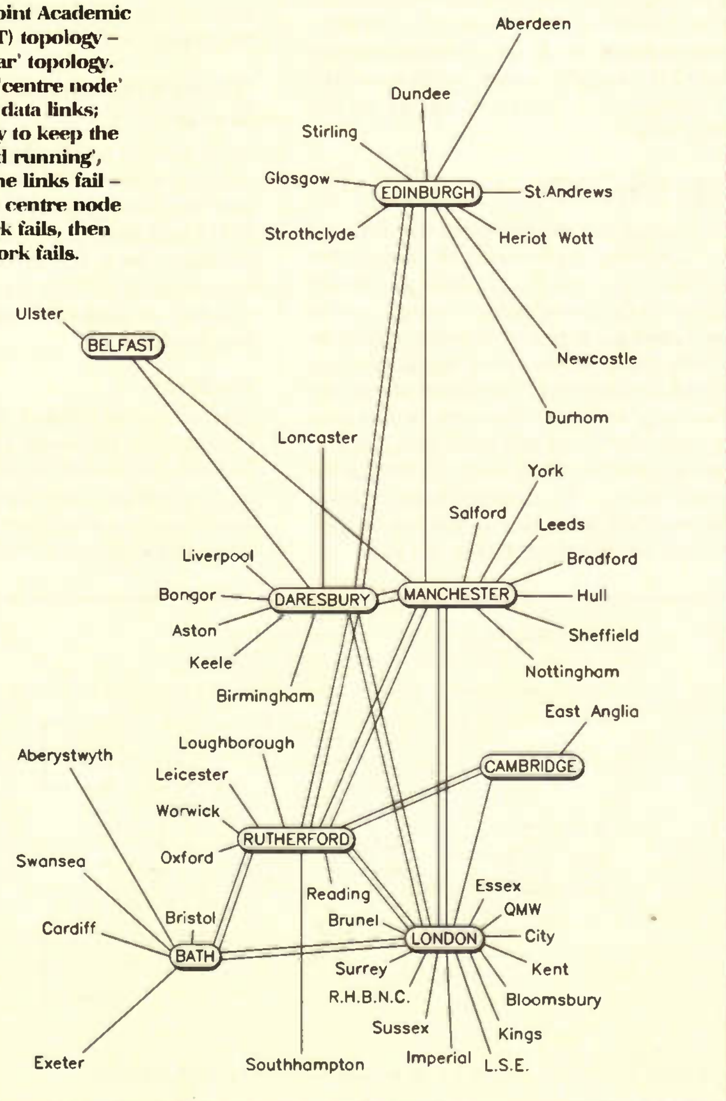
Every single machine which is connected to the net has a unique Internet address (IP address). The IP address is a 32-bit number, arranged in 4 sets of 8 bits, e.g., '192.144.3.1'. The first two 4-bit groups are used to identify the computer network, and the final two 4-bit groups specify the actual machine in question (analogous to the house-number in a conventional postal address).

Numerical addresses are difficult for humans to remember, and so 'Domain Names' are more commonly used. They are similar, in structure, to IP addresses, but they have a textual format, rather than numerical. So, for example, a computer belonging to NASA might have the domain name 'NASA.gov' – the 'gov' suffix indicating a government institution.

Electronic Mail (E-Mail)

Perhaps the single largest use of the Internet is the sending and receiving of e-mail. E-mail is exactly the same as normal letter-mail, except for one thing; there is not a postman in sight – the mail is delivered along a telephone line (or Ethernet connection). So, how does it work? Well, every user of the net will have a unique e-mail address, and this must be included within the 'electronic letter', just as conventional mail (known as 'snail-mail' to net-users) requires an address on the envelope.

Figure 2. The Joint Academic Network (JANET) topology – JANET has a 'star' topology. Note that every 'centre node' has at least two data links; this is necessary to keep the network 'up and running', should one of the links fail – obviously, if the centre node of a star network fails, then the whole network fails.



The usual format of an e-mail address comprises the domain address, which has been prefixed with the name of the user's local network and, of course, the user's log-in name. For example, an employee named Jones, who works in the publications department of Maplin, may have the e-mail address: 'jones@pub.map.com', meaning Jones at (@) publications in the Maplin company.

If I wanted to send some e-mail, for example, to someone in Australia, I would simply run the e-mail program for my machine (e.g., mail for UNIX systems); when prompted, I would enter the recipient's e-mail address, followed by the main text of the message. Once the message had been typed, I would tell the program to send the mail, and that's it! The mail program takes care of the rest and, hopefully (if the network is not too congested), my friend in Australia will receive my message within a matter of minutes (now you know why conventional mail is known as 'snail-mail'!).

E-mail can be sent simultaneously to any number of users. This is known as sending 'carbon copies', and is a very useful feature – the managing director of a company could, for example, inform all of his managers of a forthcoming meeting by typing just one e-mail message. Other commonly used features of e-mail include mail encryption, and mail redirection.

A typical e-mail system model is shown in Figure 3. The user 'posts' and receives his e-mail message by using a mail program (known as the 'user agent'). The user agent passes e-mail messages to a 'message transfer agent' (MTA); the message is routed from MTA to MTA until it reaches its final destination – the user agent of the 'addressee'.

File Transfer

Once you have connected to the net, you can download a plenitude of information and data. You can, for example, check the Library of Congress's index catalogue, view the latest pictures of Jupiter taken by NASA's space probes, read about the most recent discoveries in just about any scientific discipline known to man, or just simply make new 'net pen-pals' (and yes, you have guessed it – there is even a service for 'lonely hearts'). It is impossible to describe the wealth of information that is available, but you have to know where to look!

FTP (File Transfer Protocol)

The FTP program allows a user to transfer a file to/from a remote machine. There are numerous 'anonymous' FTP sites accessible through Internet, and anyone can connect to these sites, log on as an anonymous user, and transfer any file that they wish (for free!). Files are usually stored in archives, and are sorted by subject; there are many hundreds of programs, graphics, text files, and pictures 'hidden' away in public FTP archives on the Internet, just waiting to be discovered.

Finding Your Way Around the Net

As previously mentioned, the net comprises many thousands of different networks. There is no central governing body, and hence, no central index or information centre. Newcomers to the net might feel that this can only lead to absolute chaos, but things are not as bad as they might first appear. Computer enthusiasts are, by and large, logical people; if you just think about what you are trying to find, then the chances are that you will be successful in locating it. If all else fails (or you just cannot be bothered to think), then there are several methods that you can employ to locate your way through this electronic jungle.

Gopher

The gopher program was written at the University of Minnesota. It allows you to explore the Internet, usually by providing a menu of subject headings. Gopher is available for many platforms, including PCs and Macintoshes.

WAIS (Wide Area Information Server)

WAIS is a tool which allows a user to query databases for information. It is simple to use; the user inputs several keywords, and WAIS will search one or more Internet databases for articles which contain those keywords. WAIS can be accessed from a number of platforms (including PCs and Macintoshes).

Netfind

Netfind was developed at the University of Colorado by Professor Michael Schwartz. Netfind can usually locate any user with an account on the net if the user's name and some location details are known. Suppose, for example, that I am trying to locate John Smith, who is a student at the University of SouthTown; I would supply netfind with the data: 'Smith SouthTown University', and netfind will do the rest, hopefully telling me about Smith's department, phone number, and e-mail address, etc.

What Else Will I be Able to Find?

You will be able to find just about anything you could possibly want to know (and many things that you would *never* want to know!). Some of the more useful include: Electronic journals/books; On-line library catalogues (including the Library of Congress); Law libraries and legal research; Genetic database; National ham radio call-signs callbook; Navigational information; Real-time chess and backgammon games with other users; Geographical information (area population, elevation, etc.); Film reviews; Meteorological data; Multi-User Dungeons (MUDs); and 'archives' of programs, pictures, and sounds.

MUDs (Multi-User Dungeons)

As you may have realised by now, not all of the utilities on the net are 'serious' – there are a great many recreational services, the most popular of which are Multi-User Dungeons (MUDs). These are based on 'role-playing' adventure games, and allow a multitude of users to play and interact simultaneously, in real-time. Play takes place in a mythical world, and characters 'living' in this world usually have a number of tasks to fulfil, or puzzles to solve.

Talking

One of the many great attractions for new users of Internet is 'talk'. This service allows two or more users to communicate interactively (i.e. in real-time) by enabling them to view the other's typing. The geographical location of the users is irrelevant – they may be situated in the same room, or several thousand miles away. In practice, the 'conversation' is subject to 'net delays', especially if there is heavy traffic on the net. This causes a time-lag between typing a character, and the other user seeing the character on their screen.

'Newsgroups'

The USENET network was started at Duke University and the University of North Carolina, and it has become famous for its network news service. The 'news' service is basically the largest bulletin board in the world – subscribers to 'news' number in the millions. The service is divided into hundreds of newsgroups, each of which contain articles about one particular topic. There are newsgroups for almost every subject imaginable, including: science; the arts; politics; religion; TV programmes; careers advice; sports; hobbies; the list is endless!

If a user wishes to read an article, he simply 'subscribes' (this does not usually involve a fee!) to the particular newsgroup(s) that he is interested in. A user can also write an article 'to' a particular newsgroup – this is known as 'posting', and once posted to a newsgroup, any (and every)

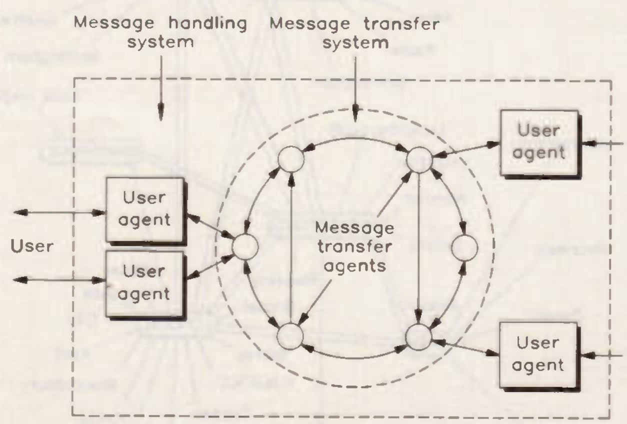


Figure 3. A typical model for an e-mail message handling system.

worldwide subscriber to that newsgroup will be able to read and reply to the posting. The potential of this service is amazing; Suppose, for example, that you have a technical query concerning your PC/Mac or whatever, you can post a help request which will be read (and hopefully answered) by several thousands of like-minded people.

USENET has no central control, and is, therefore, open to abuse. Any user who 'misbehaves' (for example, by posting offensive articles) is likely to provoke an angry reaction from other subscribers (known as being 'flamed'). Unfortunately, flaming is usually only a 'verbal' reprimand.

To read news, you will need a news-reader program; these are freely available for file transfer from several anonymous FTP sites. Some of the more common ones include: tin (UNIX); Trumpet (IBM PC); NewsWatcher and HyperNews (Mac).

What Sort of Equipment Do I Need?

Traditionally, the main users of the net were large companies, and academic institutions. Hence, most people on the net will be using a mainframe, or a VAX which is running UNIX or VMS. However, nowadays there are a great number of 'private individuals' which connect to the net by using their Amiga, IBM PC, Macintosh or whatever, and the appropriate software (usually supplied free when you subscribe to the net!). You will, of course, also need a modem, and it is wisest to purchase a high-speed modem – they may be more expensive initially, but faster data transfer means shorter phone calls (and most net users transfer vast amounts of data!).

How Do I Connect?

In the USA, a dedicated telephone line link to the Internet will have a typical baud rate of 56K-bits/s. T1 phone lines are also in use, and they have a transfer rate of 1M-bits/s. Here in the UK, over 98% of British Telecom exchanges now offer ISDN lines. These lines were designed for the integration of voice and data transmission, and consequently allow higher transmission rates than normal phone lines. ISDN's Basic Rate Interface (BRI) provides a transmission rate of 192K-bits/s, and ISDN's Primary Rate Interface (PRI) provides a transmission rate of 2M-bits/s (1.5M-bits/s in the USA).

There are two main methods of connecting to the net: (1) A dedicated Internet Connection, or (2) Connection by using a modem and an ordinary phone line.

The Dedicated Connection

Most large institutions have a dedicated connection – it offers much faster (and more reliable) access to the net, but it is very expensive. A machine which has a dedicated connection (via an Ethernet cable) to the Internet becomes *part* of the Internet; it is allocated its very own unique address.

There is another method of connection which is becoming increasingly popular with smaller companies (because it is a great deal less expensive than having a dedicated connection), and this involves the use of SLIP (Serial Line Internet Protocol) or PPP (Point-to-Point Protocol) connections. The user's machine is linked, via a high-speed modem, and telephone line (preferably an ISDN line) to a host computer which has a dedicated connection to the net. The host machine acts as a gateway, allowing the user's machine to behave as though it had a dedicated connection to the net (i.e. it is allocated a unique address), but the rate of data transfer is much slower than with a dedicated connection.

Modem and Phone Line

A user can connect to the net by means of a 'subscription service'. The user pays a monthly connection fee (in addition to any phone charges) to a company which has a machine with a dedicated connection to the net – in the USA, for example, most of the telephone companies offer this service. In return for this monthly charge, the company will supply the subscriber with an account on its machine, a password, and any necessary software. To access the net, the user simply 'logs on' to the carrier's computer by using an ordinary modem and phone line. It is important to note that the subscriber's machine does not become part of the Internet – it has no net address – it is simply able to make use of the net by means of the company's machine.

Conclusions

The number of net users is expanding at a phenomenal rate – it is estimated that by the year 2000, world-wide users will have multiplied nearly tenfold, to well over 100 million. The range of services on offer will be unparalleled, for example, e-mail will expand from just simple ASCII textual messages, to include digitised voice message and digital facsimile transmissions.

This article has been written to give the reader a brief introduction to the world of the Internet; there really is no substitute for experience, so if you feel at all tempted or curious to discover more, then please do read one of the Internet books listed at the end of the article. Better still, connect-up and learn by experimenting for yourself! If you are a student at a major educational institution, it may be worth your while to ask the technicians at the computer science department; you should be able to access the net for free. For those that wish to learn more about the technical side of computer networking, I can recommend Tanenbaum's book – it is a very readable and thorough treatise on all aspects of networking.

I feel that I must give some words of warning for those of you tempted to connect; the Internet can be a very time-consuming and absorbing pastime – hours can (and frequently do) pass by unnoticed. The philosophy behind the Internet is one of sharing knowledge and expertise to help people – be careful not to use it as a substitute for people! Happy Netting!

Commonly Used Acronyms

ASCII	American Standard Code for Information Interchange.
CCITT	Comité Consultatif International de Télégraphique et Téléphonique.
E-Mail	Electronic Mail.
FTP	File Transfer Protocol.
ISDN	Integrated Services Digital Network.
ISO	International Standards Organisation.
JANET	Joint Academic Network.
MHS	Message Handling System.
MOTIS	Message-Orientated Text Interchange Systems.
MTA	Message Transfer Agent.
MUD	Multi-User Dungeon.
OSI	Open Systems Interconnection.
TCP/IP	Transmission Control Protocol/Internet Protocol.
WAIS	Wide Area Information Server.

Further Information

If you wish to explore *Cyberspace* (the world of the Internet), then you can obtain a connection to the net by contacting any of the service providers listed. Demon Internet Ltd, for example, are able to 'connect' most popular computers, including PCs, UNIX boxes, Amiga, Macintosh, Archie, and NeXT, etc. Data transfer speed depends, of course, on your modem – the minimum speed allowed is 2·4K-bits/s, and the maximum (with a 'standard dial-up connection') is 14·4K-bits/s with V.32bis/V.42bis modems. Demon Internet also offer connection via a 14·4K-bits/s or a 64K-bits/s leased line, if required (see 'The Dedicated Connection').

The average cost of a standard dial-up connection is about £10 per month + VAT.

CityScape Internet Services Ltd., Alexandra House, 9 Covent Garden, Cambridge, CB1 2HS.
Tel: 01223 566950

Demon Internet Ltd., 42 Hendon Lane, London, N3 1TT.
Tel: 0181 349 0063

The Direct Connection, P.O. Box 931, London, SE18 3PW.
Tel: 0181 317 0100

EUnet GB, Wilson House, John Wilson Business Park, Whitstable, Kent, CT5 3QY.
Tel: 01227 475497

PIPEX, 216 The Science Park, Cambridge, CB4 4WA.
Tel: 01223 250120

CIX, Suite 2, The Sanctuary, Oak Hill Grove, Surbiton, Surrey, KT6 6DU.
Tel: 0181 390 8446

Recommended Reading

Zen and the Art of the Internet: A Beginner's Guide (AA88V), Brendan P. Kehoe, Prentice-Hall, 1994.

The Instant Internet Guide,
Heslop and Angell, Addison-Wesley, 1994.

The Internet Navigator,
(AA97F), Paul Gilster, John Wiley & Sons, 1993.

Computer Networks,
Andrew S. Tanenbaum, Prentice-Hall, 1989.

*info*Highway, twice monthly newsletter giving latest news on The Internet:

*info*Highway, The Widford Old Rectory, Old London Road, Chelmsford, Essex, CM2 8TE.
Tel: 01245 495896

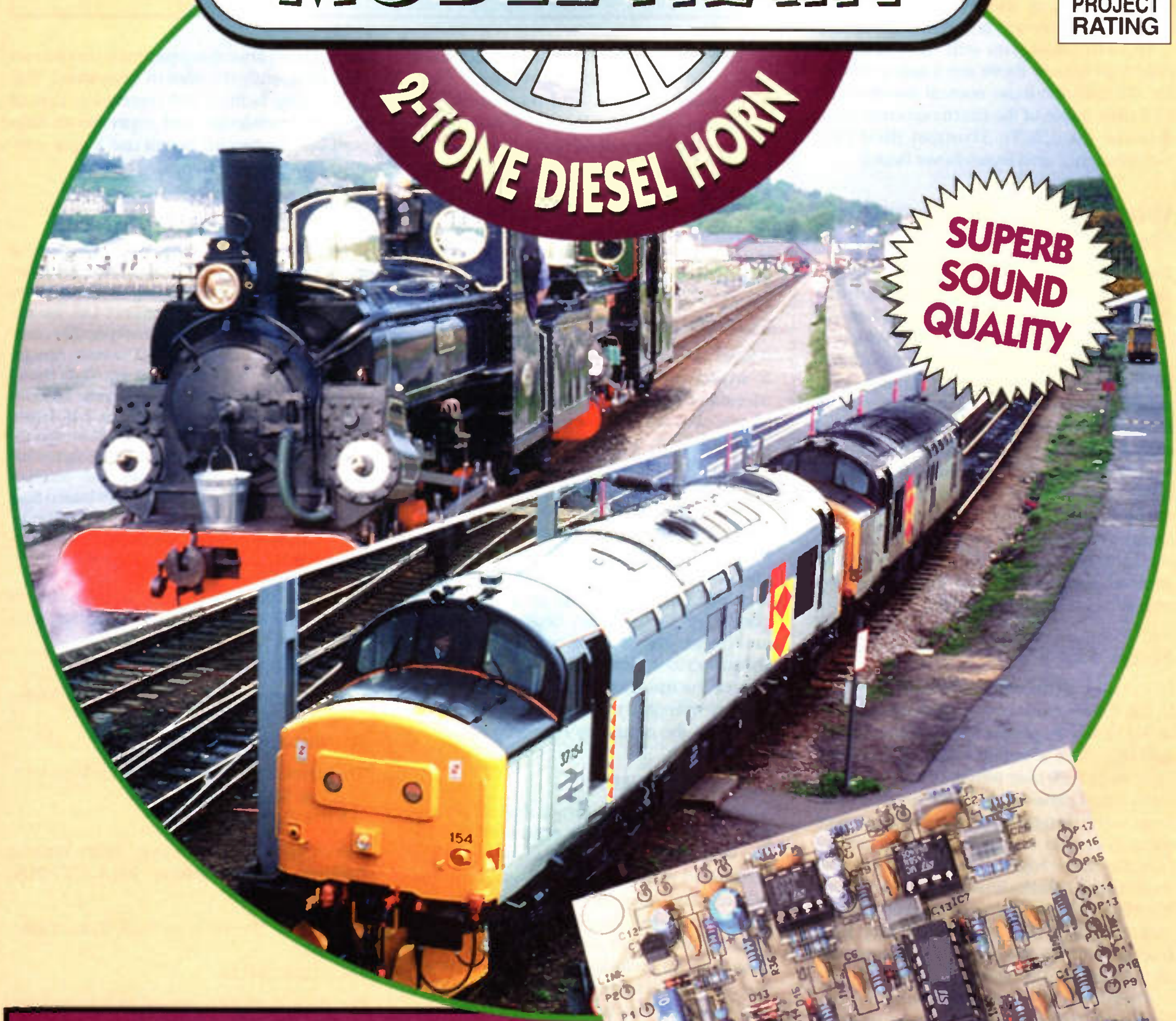
Design by Chris Barlow
Text by Chris Barlow and
Dean Hodgkins BEng (Hons)

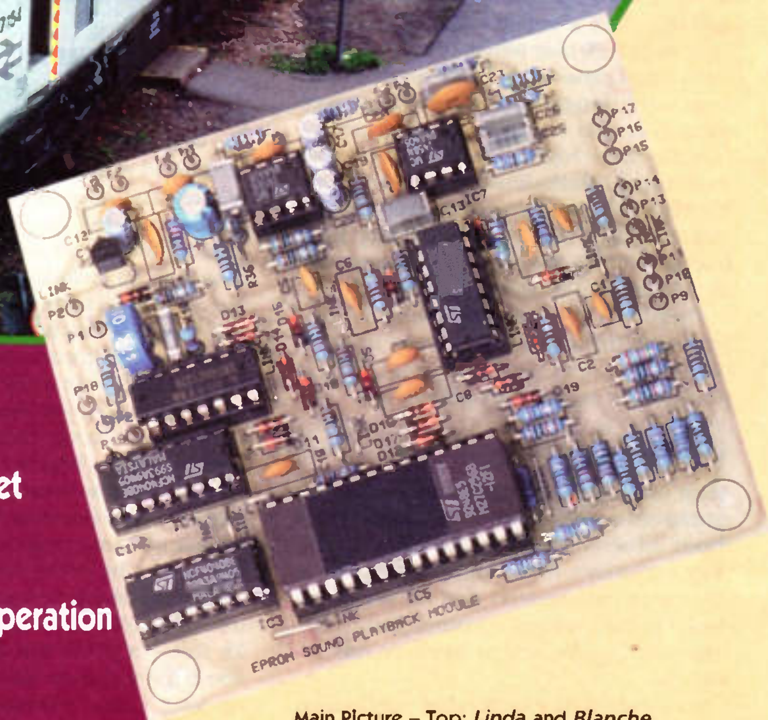
DIGITAL MODEL TRAIN
STEAM WHISTLE / 2-TONE DIESEL HORN

KIT AVAILABLE (LT61R)
PRICE £14.99
Includes pre-programmed EPROM!

2
PROJECT RATING

SUPERB SOUND QUALITY





FEATURES

* Three trigger inputs * Two trigger modes
* Two digital sound samples * Power on reset
* Playback LED * Variable playback speed
* High level and low impedance output
* Signal mixing for linked module playback operation

APPLICATIONS

* Authentic model train sound effects
* Novelty door bell * Alarm siren

Main Picture – Top: *Linda* and *Blanche*, Ffestiniog Railway, on the *Cob* at Porthmadog. Bottom: Two *Class 37* Diesels at Shoeburyness. ©Copyright 1994 Brian Meldon, all rights reserved, used by permission.
Above: The assembled PCB.

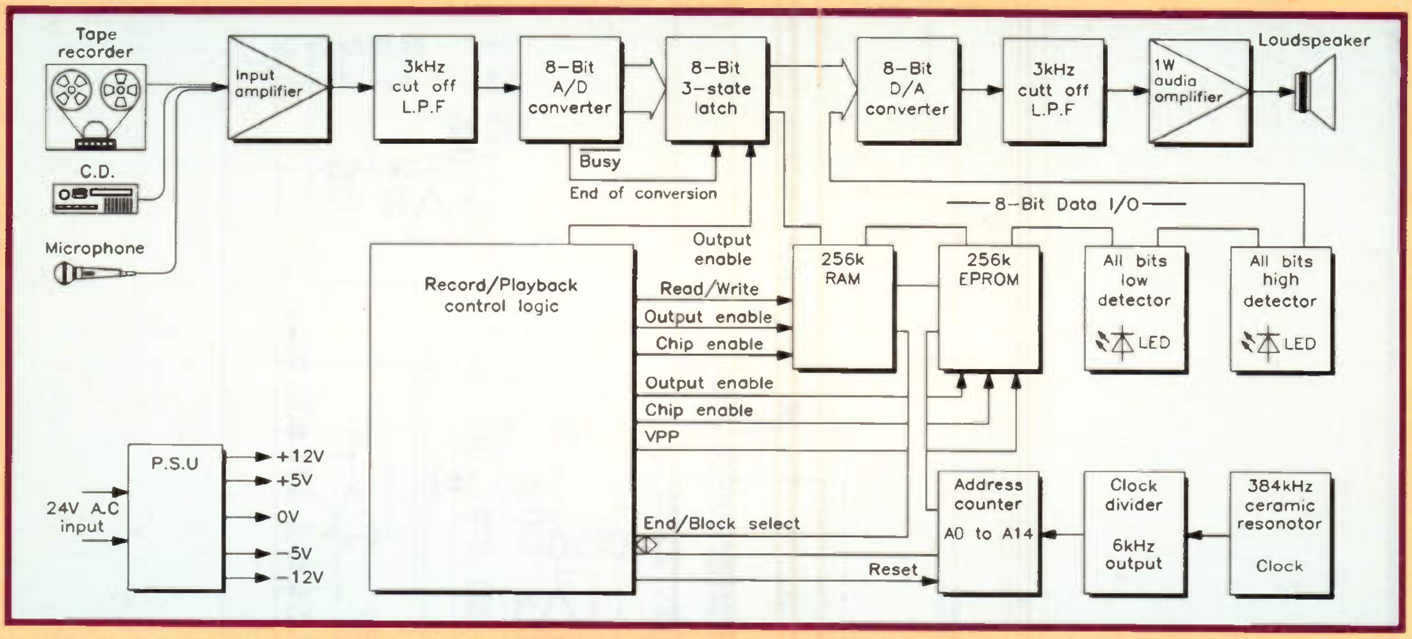


Figure 1. Block diagram of EPROM sound programmer used to record the sound samples used in this project; note it is not necessary to build this unit to use the horn/whistle project!

SOUND effects can be used to add an extra dimension of realism to any model train layout. This is not a new idea, as gramophone records and magnetic tape recordings have both been used for this purpose for many years. However, there are two main operational restraints associated with these electromechanical sound reproduction systems. First, the recording has to be 'cued up' in order to select the correct track before it can be played. Then, as each track is played over and over again the mechanical wear degrades the sound quality of the recording.

To overcome these short and long term difficulties, the world of electronics set about designing various analogue sound synthesis circuits. As each sound effect is constructed from many different elements, so each circuit becomes unique, and its complexity determines the degree of sound realism.

With the introduction of digital recording techniques, it is now possible to obtain good quality sound reproduction and overcome the long term wear of repeated plays. However, the cost of a digital sound system is still relatively high for a compact disc (CD) or digital audio tape (DAT). Since the sound samples for the train horn/whistle are of a relatively short duration, it is practical to store them in a non-volatile digital memory IC. The chip chosen for this purpose was a 256K Erasable Programmable Read Only Memory (EPROM); it offers a reasonably sized data store at a modest cost.

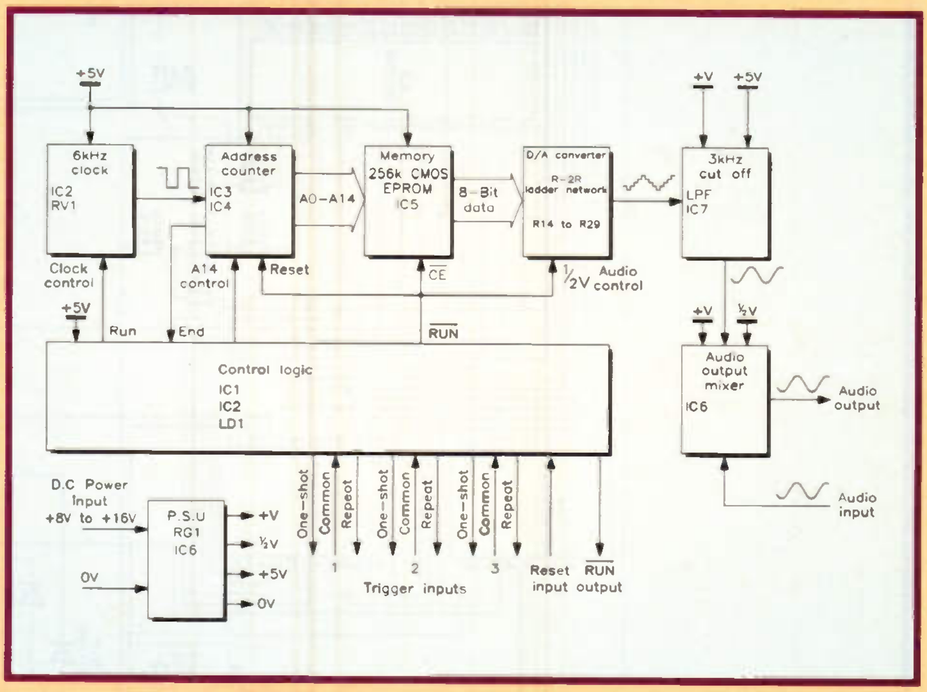


Figure 2. Block diagram of EPROM sound playback module.

The programming of the EPROM is the equivalent of the recording process, and is made on a custom-built digital sound programmer (see Figure 1). From this block diagram, you can see that it is made up from several signal processing stages, and one of the most important is the analogue to digital converter. The fidelity of the reproduced sound is determined, mainly, by the sample rate and conversion errors of this stage. A high sample rate will give a high frequency sound cut-off, but a short sound sample. To increase the duration of the sound sample, more memory must be added, or a slower

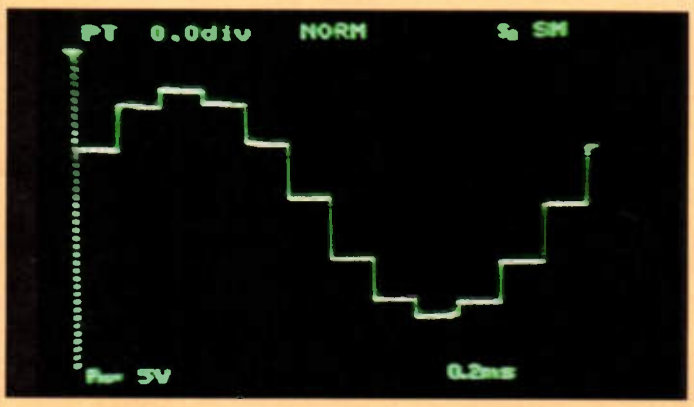


Photo 2. Shot of an oscilloscope screen, showing a digitally reconstructed audio waveform before filtering.

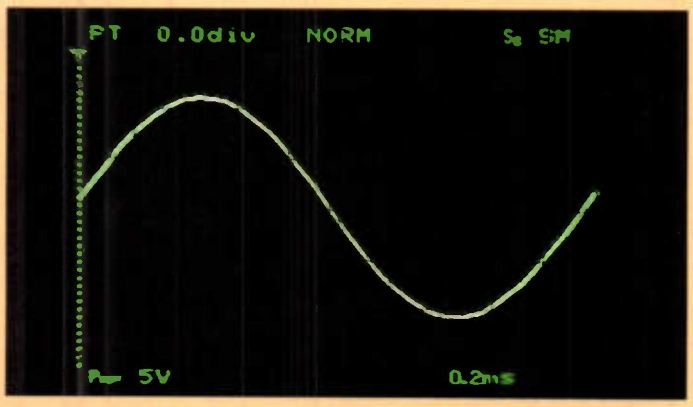


Photo 3. Shot of an oscilloscope screen, showing the final audio output after filtering.

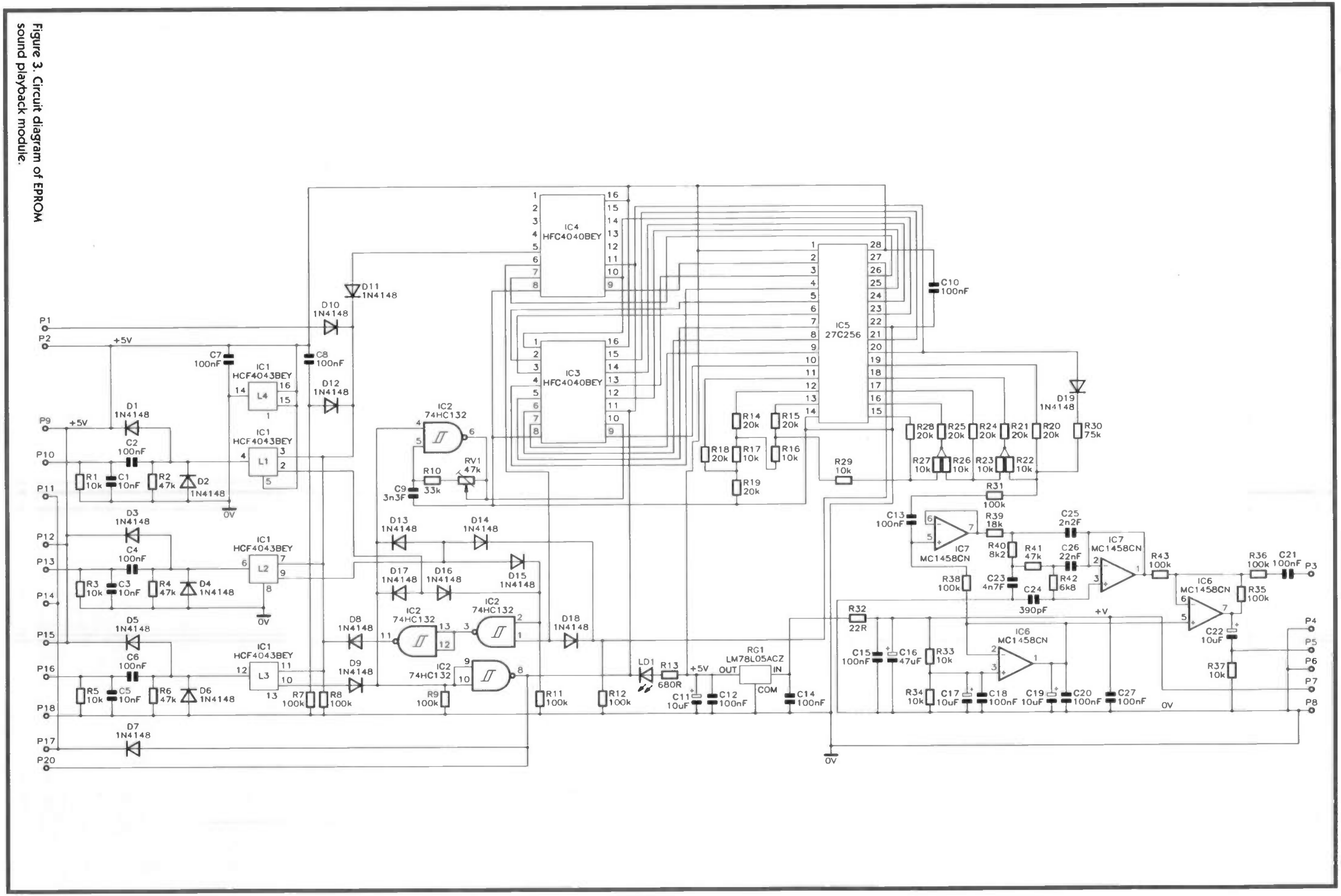


Figure 3. Circuit diagram of EPROM sound playback module.

sample rate must be used. A compromise must, therefore, be made which takes into account the type of sound to be sampled. From experimentation, it was discovered that 6kHz was the minimum practical sample rate for the diesel horn and steam whistle sounds. This is because the sample rate must be at least twice the maximum audio frequency in order to remove any aliasing products by using a low-pass filter, set to 3kHz.

The project presented in this article (see Photo 1) is concerned with the reading of the data held within the EPROM, which is equivalent to the playback process. This kit represents excellent value because the EPROM contains two sound effects; most commercially available units provide only one.

Circuit Description

In addition to the block diagram detailed in Figure 2, the circuit diagram is shown in Figure 3. This should assist in following the circuit description, or with fault-finding in the completed unit.

The positive DC power supply is applied to pin P7 and the negative, or 0V ground, to pin P8. This supply must be within the range of 8V to 15V DC, and have the correct polarity, or damage may occur to the components on the PCB.

The main supply rail decoupling is provided by C16, with additional high frequency decoupling provided by the 100nF ceramic capacitors C15 and C27. For the op amps in the audio circuits to function correctly, a half supply reference voltage is necessary. This is provided by IC6. The voltage reference applied to the input of this op amp is derived from the two resistors R33 and R34, which form a potential divider. This op-amp is merely used as a unity gain buffer to provide a low impedance 'half supply', with its input being decoupled by C17 & C18, and its output by C19 & C20.

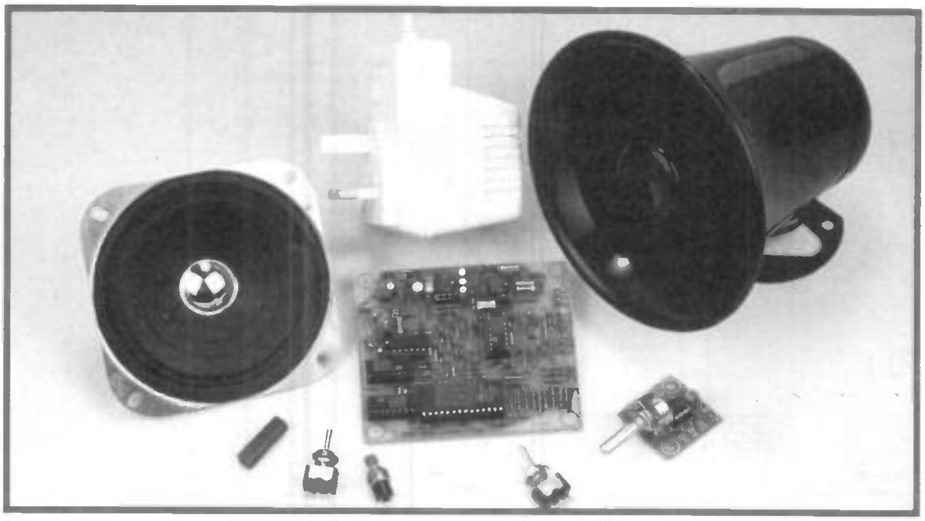


Photo 4. The EPROM Sound Playback Module, together with a suitable PSU, loudspeakers and switches.

Specification

Supply Voltage:	+8V to +15V DC
Supply Current at 12V	
Quiescent:	6mA
Operating:	19mA
Regulated Output Voltage:	+5V DC
+5V DC Output Current:	50mA Maximum
Output Signal Level:	1V rms (nominal)
Output Impedance Load:	1k
Mixer Input Level:	1V rms (nominal)
Mixer Input Impedance:	100k
D/A Sampling Rate:	6kHz
Playback Cut-off Frequency:	3kHz
Clock Frequency Range:	4kHz to 10kHz
Trigger Input 1:	Two-Tone Diesel Horn (2·73s)
Trigger Input 2:	Steam Whistle (2·73s)
Trigger Input 3:	Diesel Horn and Steam Whistle (5·46s)
Trigger Modes:	One-Shot or Repeat
External Reset Input:	+5V DC to Reset System
Playback Status Output:	+5V DC Low During Playback
Assembled Module Dimensions:	94 × 85 × 15mm

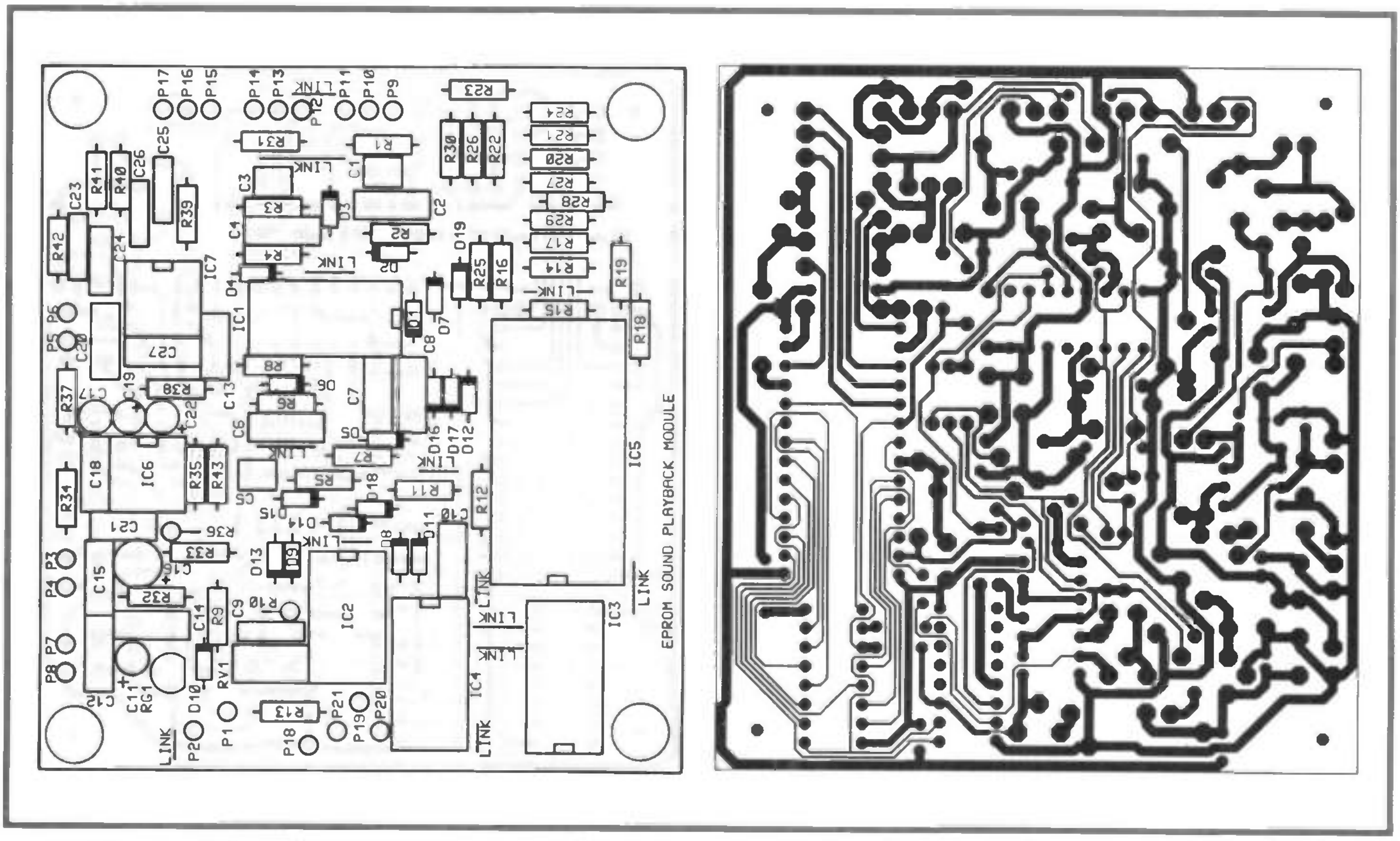


Figure 4. PCB legend and track.

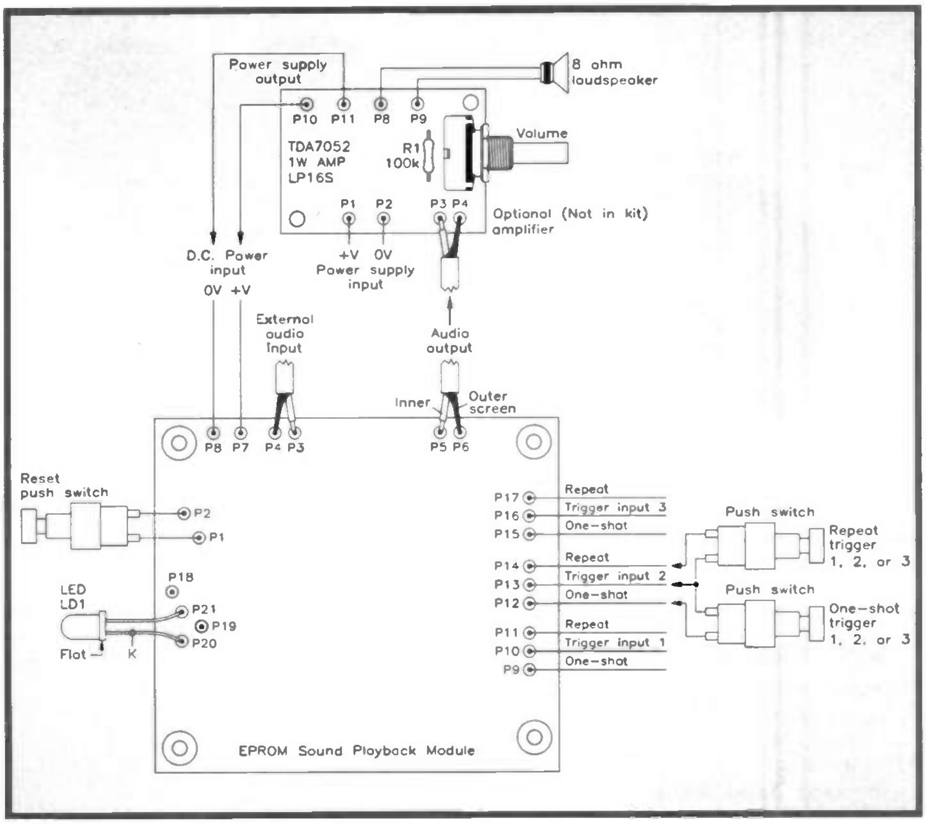


Figure 5. Wiring diagram showing connections to PSU, amplifier, and switches.

The other function of IC6 is as an audio buffer/mixer to provide a low impedance drive output on pin P5. It can be used to combine the filtered sound samples with an external audio signal which has been applied to the input pin (P3) – the Model Train Chuffer Kit (LT39N), for example, could be used in conjunction with this module since the audio signal levels are compatible!

The digital logic ICs (IC1 to IC5) require a +5V stabilised supply. This voltage is obtained by using a small 100mA regulator, RG1, with capacitors C7, C10, C11, C12 and C14 to provide the decoupling.

The circuit has three trigger inputs with two trigger modes. This function is controlled by IC1, a quad set/reset latch, and IC2, a quad Schmitt 2-input NAND gate. When trigger input 1 (on pin P10) is connected to pin P9, it will replay the diesel horn sound once only (one-shot mode). However, if it is connected to pin P11, it will repeat the playback in a continuous loop (repeat mode). This is the same for trigger input 2 (on pin P13), the steam whistle, with one-shot mode on pin P12 and repeat mode on pin P14. The third trigger input on pin P16 will replay both sound samples, one after the other, with one-shot mode on pin P15, and repeat mode on pin P17. An output on pin P19 is provided to indicate the status of the circuit: logic 1 (+5V) indicates that the circuit is ready to trigger, whilst logic 0 (0V) is present on the pin during playback. This is displayed visually by an LED (LD1), which lights up during playback.

The circuit has an automatic 'power-on reset' function (via components C8, R7 and D12). However, if you wish to inhibit or cancel the playback function at any time, simply connect +5V (logic 1) from pin P2 to the reset input on pin P1.

To replay the train horn/whistle sounds, the EPROM, IC5, must have each of its memory locations accessed sequentially. For the diesel horn, locations 0000h to 3FFFh are accessed, with locations 4000h to 7FFFh being used for the steam whistle. The sequential access is achieved by using two 12-stage ripple counters (IC3 and IC4), the count rate of which is governed by the frequency (6kHz) of the clock signal, generated by one section of IC2. This frequency is determined by the value of capacitor C9, and the combined value of the resistors R10 and RV1.

As IC5 steps through its memory locations, the digital recording is reproduced as a stream of eight-bit data patterns. These have to be converted back into the original analogue waveform before audio amplification can take place. This digital to analogue conversion is achieved by using a network of resistors (R14 to R29), with IC7 being used as a unity gain buffer to provide a low impedance output on pin 7. At this point, the audio signal contains a high level of digital aliasing noise, as can be seen from Photo 2. The audio signal is constructed from a series of 'steps' which follow the original analogue waveform. A low-pass filter (the other half of IC7) is used to smooth out these steps in order to remove the digital aliasing noise (see Photo 3). This filtered signal is now ready for use, and is passed to the input of the buffer/mixer (IC6).

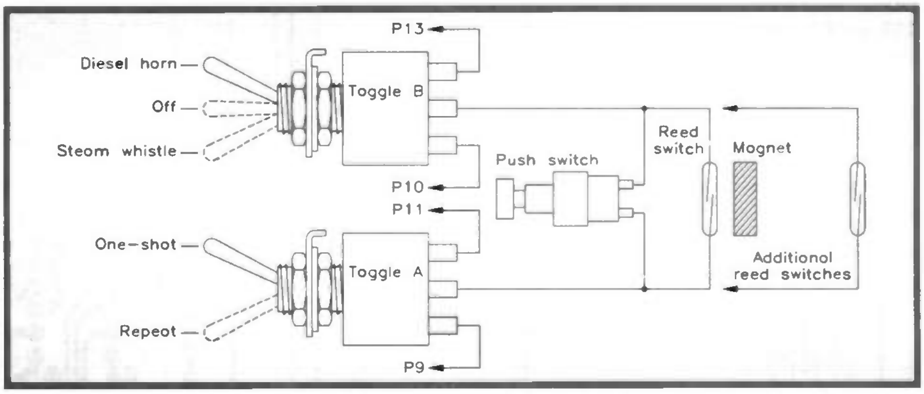


Figure 6. Wiring diagram showing how to connect a reed switch train trigger.

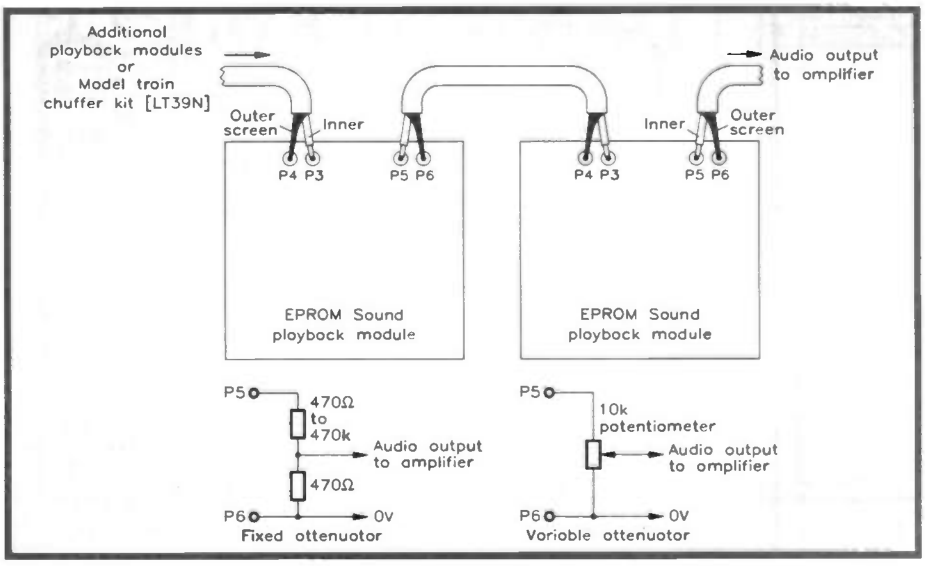


Figure 7. (a) The audio linking of modules; (b) output attenuation circuits.

Construction

The PCB is a single-sided fibreglass type, chosen for maximum reliability and stability. However, removal of a misplaced component is quite difficult, so double-check each component's type and value (and polarity where appropriate) before soldering! If you require additional information about soldering and assembly techniques, they can be found in the 'Constructors' Guide' (XH79L). The PCB has a printed legend (see Figure 4) to assist you in correctly positioning each item.

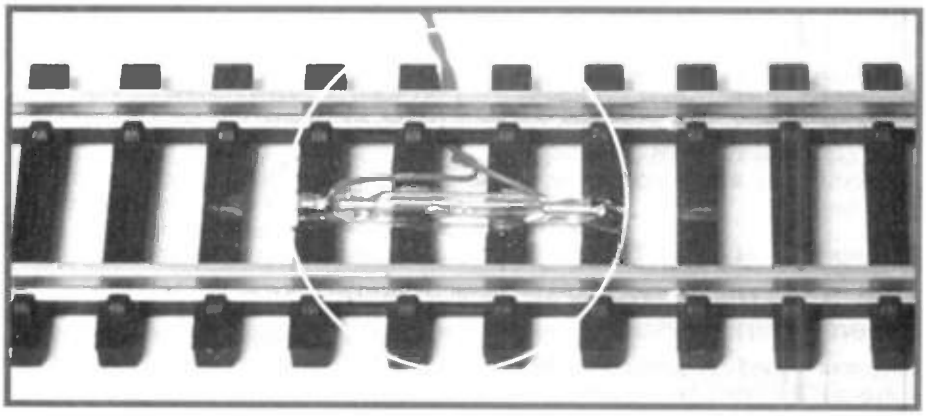


Photo 5. A reed switch fixed to a model train track.

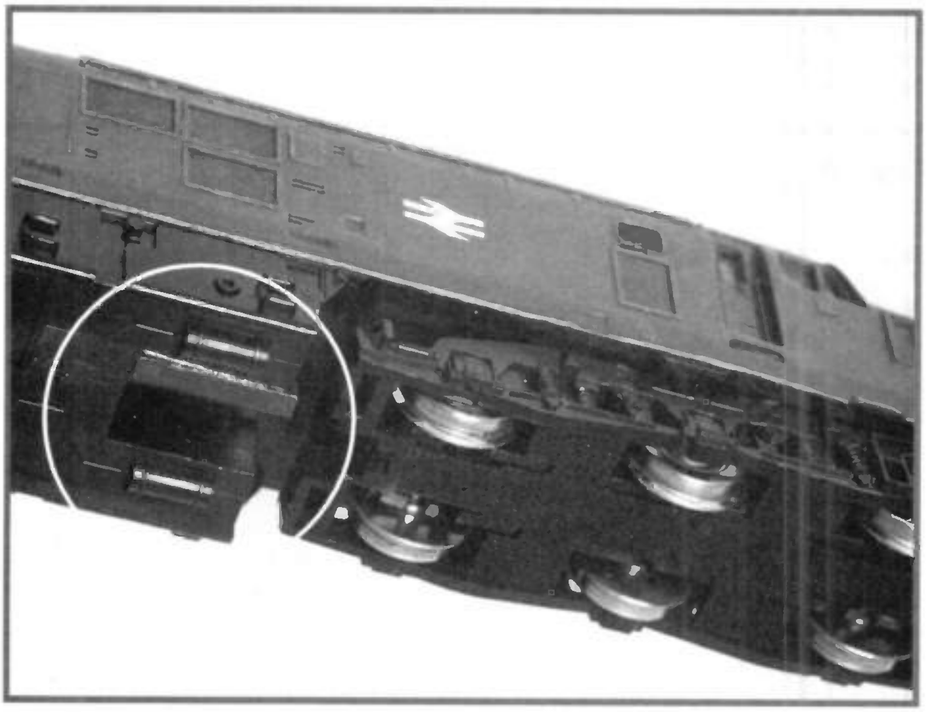


Photo 6. A magnet installed under a model train.

The sequence in which the components are placed is not critical, but it is easier to start with the smaller components such as resistors (R1 to R42 and RV1), followed by the ceramic, polyester layer and electrolytic capacitors. The polarity for the electrolytic capacitors is shown by a plus sign (+) on the PCB legend. However, the majority of electrolytic capacitors have the polarity designated by a negative symbol (−), in which case the lead nearest this symbol goes away from the positive sign on the legend. Note that any component offcuts can be used to form the wire links.

The diodes (D1 to D19) have a band at one end to identify the cathode (K) lead. The legend shows the diode positions with a symbol like a resistor, but with the prefix 'D'. The symbol also has a bar across one end, and this is where the cathode is placed. Now, install the 21 pins, marked P1 to P21, ensuring that you push them fully into the board.

Next, install the voltage regulator RG1, making sure that its outline conforms to the package outline on the legend. Next, fit the IC sockets, ensuring that you match the notch with the block on the legend. Install the ICs, making certain that all the pins go into the socket, and that the pin 1 marker is at the notched end. Remember to observe the standard antistatic precautions before you handle the ICs – ensure that you touch an 'earthed' conductor (domestic water pipes, for example) to remove any static charge which you may have accumulated.

Finally, set RV1 to its half-way position. This completes the assembly of the PCB. You should now check your work very carefully making sure that all the solder joints are sound; it is also very important that the solder side of the circuit board does not have any trimmed component leads standing proud by more than 2mm, as this may result in a short circuit. Remove any flux from the PCB by using a suitable solvent.

Testing

The initial DC testing procedure can be undertaken by using the minimum of test equipment; you will need a multimeter, and a power supply capable of providing +12V DC at up to 300mA (a suitable PSU is YB23A). All of the following readings were taken from the prototype, using a digital multimeter. The readings you obtain may vary slightly, depending upon the type of meter used!

With no wires connected to P1 to P21, carefully lay out the PCB assembly on a non-conductive surface, such as a piece of dry paper or plastic. The first test is to ensure that there are no short circuits before connecting the DC supply: Set your multimeter to read ohms on its resistance range, and connect its two test probes to P7 and P8; with the probes either way round, a reading greater than 15kΩ should be obtained. If a significantly lower reading is registered, check for solder joints and component leads shorting in between tracks.

In the following test, it will be assumed that the power supply used is the YB23A regulated AC-DC adaptor, set to its +12V output. Select a suitable range on your meter that will accommodate a 300mA DC current reading, and place it in line with the positive power output of the adaptor to P7. Connect the negative power line to P8, as shown in Figure 5, and solder the indicator LED (LD1) temporarily to pins P20 and P21 – its final location could be elsewhere in your completed system, mounted on your control console, for example. The LED has a long anode lead and a shorter cathode (K) lead; this is also denoted by a flat along one side of its package.

Now, plug the adaptor into the AC mains supply. Observe LD1 – it should not light. The meter should register a current of approximately 6mA. Unplug the adaptor from the mains, remove the test meter, and connect the positive line to P7.

Now, set your multimeter to read DC volts. The voltage readings are positive with respect to ground, so connect your negative lead to a convenient ground point, e.g. P8. When the PCB is powered up, the voltages present on the board should (approximately) be as shown below:

P1, 4, 6, 8, 10, 13, 16, 18	= 0V
P7	= 12V
P2, 9, 12, 15, 19, 20, 21	= 5V
P11, 14, 17	= 4·5V
IC6 pin 1 and 7	= 6V
IC7 pin 1 and 7	= 6V

When the circuit is activated by connecting one of its trigger inputs (P10, 13, 16) to the corresponding one-shot or repeat mode pins, LD1 should light; in the one-shot mode it should only stay lit for approximately 2·7 seconds, or 5·5 seconds for trigger input three (P16). In the repeat mode, LD1 should stay lit for as long as the connection between the pins is maintained. When the circuit is running, the voltages present on the board should (approximately) match the following:

P11, 14, 17, 19, 20	= 0V
P21	= 1·9V

If, at any time you wish to inhibit or cancel the playback function, simply connect the +5V (logic 1) level from pin P2 to the reset input on P1.

To fully test the audio output signal, you will require a sound amplification system and some additional test equipment, but you can perform most of the tests just 'by ear'. The audio output is taken (by screened cable) from pin P5 (inner screen) and P6 (outer screen) to your amplifier's signal input. Your amplifier must have a volume control so that the output can be adjusted to a comfortable level. Remember that the signal level from the circuit is 1V rms, which could be too high for some amplifiers – in which case, some additional input attenuation might be necessary.

If you only require a small low power amplifier, the TDA7052 one watt amplifier kit (LP16S) is well suited for this purpose. However, it will require a small modification to make it compatible with the rest of the system; this involves increasing the value of its input attenuator resistor R1 from 1kΩ to 100kΩ. It is also recommended that when using the amplifier with an 8Ω loudspeaker, the voltage output from your regulated PSU should be set to 9V.

When the circuit is triggered, LD1 will light, and the selected sound will be heard. In the one-shot mode, it should play for approximately 2·7 seconds (or 5·5 seconds for trigger input three), as previously mentioned. To set the playback speed, you simply adjust RV1 until it sounds correct to your own liking; as a rough guide, this should be when RV1 is set to approximately its midway position. For a more precise alignment, you will require a frequency counter to measure the output from the clock oscillator (IC2 pin 6); carefully adjust RV1 until a frequency of 6kHz is displayed on the counter.

This completes the testing of the model train horn/whistle, and the module is now ready for use.

Using the Model Train Two Tone Diesel Horn/ Steam Train Whistle

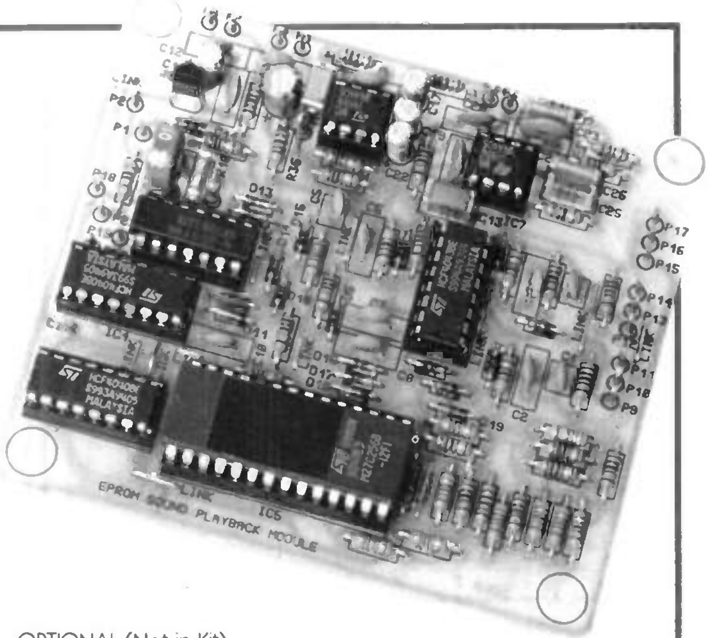
Since your finished unit could contain more than one PCB, it would be impossible to recommend a particular box for the project. However, an extensive range of plastic and metal boxes is available from Maplin and, as can be seen from Photo 4, there is also a wide range of speakers and switches which will be suitable for most applications.

Magnetically activated reed switches can be used within a model train system to provide automatic sound triggering. Figure 6 shows how reed and toggle switches can be wired to trigger the desired sound effect; the reed switch is installed on the model train track (see Photo 5), and a small magnet is mounted under the model train engine or carriage (see Photo 6). As the magnet passes over the reed switch, it closes, and the unit is triggered. The size of magnet required depends upon the vertical distance between the magnet and the track; the larger the distance, the larger the size of magnet required.

Two or more sound effects can be combined by using the external audio mixer input on pin P3 (see Figure 7a). In addition, the output can easily be attenuated (see Figure 7b) to provide a lower level signal input for your sound amplification system.

MODEL TRAIN HORN/WHISTLE PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1,3,5,16,17,22,23, 26,27,29,33,34,37	10k	13	(M10K)
R2,4,6,41	47k	4	(M47K)
R7-9,11,12,31,35, 36,38,43	100k	10	(M100K)
R10	33k	1	(M33K)
R13	680Ω	1	(M680R)
R14,15,18-21, 24,25,28	20k	9	(M20K)
R30	75k	1	(M75K)
R32	22Ω	1	(M22R)
R39	18k	1	(M18K)
R40	8k2	1	(M8K2)
R42	6k8	1	(M6K8)
RV1	47k Vertically Enclosed Preset	1	(UH18U)
CAPACITORS			
C1,3,5	10nF 50V Disc	3	(BX00A)
C2,4,6-8,10,12, 14,15,18,20,27	100nF 16V Minidisc	12	(YR75S)
C9	3n3F Polyester Layer	1	(WW25C)
C11,17,19,22	10μF 16V Miniature Radial Electrolytic	4	(YY34M)
C13,21	100nF Polyester Layer	2	(WW41U)
C16	47μF 16V Miniature Radial Electrolytic	1	(YY37S)
C23	4n7F Polyester Layer	1	(WW26D)
C24	390pF Ceramic	1	(WX63T)
C25	2n2F Polyester Layer	1	(WW24B)
C26	22nF Polyester Layer	1	(WW33L)
SEMICONDUCTORS			
D1-D19	1N4148	19	(QL80B)
LD1	2mA 5mm Red LED	1	(UK48C)
RG1	LM78L05ACZ	1	(QL26D)
IC1	HFC4043BEY	1	(QW29G)
IC2	SN74HC132N	1	(UB29G)
IC3,4	HFC4040BEY	2	(QW27E)
IC5	EPROM MS04 (27C256)	1	(ZC06G)
IC6,7	MC1458CN	2	(QH46A)
MISCELLANEOUS			
	Type 2145 PCB Pins	1 Pkt	(FL24B)
	8-Pin DIL IC Socket	2	(BL17T)
	14-Pin DIL IC Socket	1	(BL18U)
	16-Pin DIL IC Socket	3	(BL19V)
	28-Pin DIL IC Socket	1	(BL21X)
	PCB	1	(GH90X)
	Instruction Leaflet	1	(XU79L)
	Constructors' Guide	1	(XH79L)



OPTIONAL (Not in Kit)

Reed Switch	As Req.	(FX70M)
Small Magnet	As Req.	(FX71N)
Large Magnet	As Req.	(FX72P)
Push Switch	As Req.	(FH59P)
Sub-Miniature Push Switch	As Req.	(JM47B)
Sub-Miniature Toggle A Switch	As Req.	(FH00A)
Sub-Miniature Toggle B Switch	As Req.	(FH01B)
AC Adaptor Regulated	1	(YB23A)
Model Train Chuffer Kit	1	(LT39N)
TDA7052 Kit	1	(LP16S)
100k Miniature Resistor	1	(M100K)
1·5W Low Cost Speaker	1	(YT25C)
5in. Plastic Horn	1	(XQ73Q)
Single-Core Lapped Screen Cable	As Req.	(XR13P)

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 LT61R (Train Horn/Whistle Kit) Price £14.99

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

EPROM Sound Module PCB **Order As GH90X Price £3.99**

Pre-programmed EPROM MS04 **Order As ZC06G Price £4.99**

A readers forum for your views and comments. If you want to contribute, write to: The Editor, 'Electronics – The Maplin Magazine' P.O. Box 3, Rayleigh, Essex, SS6 8LR.

AIR YOUR VIEWS

Dear Editor

S·T·A·R L·E·T·T·E·R

In this issue, Mr R. Gosling, of Stoke-on-Trent, wins the Star Letter award of a Maplin £5 Gift Token for his letter about ultraviolet bank-note checkers.

Shocking Truth

Dear Sir,
Regarding the article 'Mains Safety in Hobby Projects' in *Electronics* Issue 82, October '94, I would like to suggest you might cover the following topics in the second part, Isolation transformers, full and half wave rectifying mains direct, live chassis, neutral half mains, earth: mainly in TV sets and switch mode supplies, and how you would connect an oscilloscope to monitor waveforms with a live chassis. Also thyristor or triacs connected via direct mains supply for power control etc. This has baffled me for some years now, I hope you will cover it with a theoretical and practical approach.
D. Lee, Claughton, Birkenhead, Merseyside.

I anticipated that this two part feature on mains safety would provoke a lot of interest and it certainly has! Your letter is one of several received raising specific questions about safety (that was one of the aims) apart from passing on some good advice – to get everyone thinking and generally more aware of the potential dangers of electricity. The areas you mention, and the ones mentioned in other letters, have not been covered in the second part (in this issue – if you missed part one, get a back issue!) quite simply because the second part of the article was already written long before the first part even got the first sniff of ink on magazine page. Anyway, the additional subject areas mentioned, which are more about servicing mains equipment than construction, would be best covered in a 'safety in fault-finding' feature – I'll discuss these ideas with the author, so watch this space.

Gimme Gimme Audio!

Dear Sir,
Firstly a word of congratulations on your excellent publication, which I have been reading for three years now – it is very user-friendly!
I have several suggestions for projects, which I believe may be of interest to the segment of your readership which like myself, is actively involved in operating a recording studio on a restricted budget.
To kick off, what about a Stereo Balance Meter? These devices connect in-line with a stereo line-level source and provide a continuous visual indication of the relative levels of right and left components.
Secondly, a Phase Meter. These incredibly useful devices, provide a visual indication of any phase-related anomalies in a stereo signal.
Finally, with the recent resurgence of interest in valve technology, what about a high quality valve mic/line level preamp? Any chance?
Thanks again for a great magazine and a great service all-round.
P. Leigh, Stokenchurch, Bucks.

Thanks for the ideas, one of them is already on the development list (but I'm not going to tell you which one, as that would spoil the fun!) – please keep the ideas coming!

Barred for Life

Dear Sir,
Whilst I was stuck in the slowest moving check-out at our local supermarket (as I inevitably am) I started to wonder how the automatic bar code reader actually worked. The principle of bar code reading with hand-held devices is not too difficult to understand, but the 'swipe-across-at-any-angle-or-direction' used in the reading cum weighing machines would appear to need a very complex scanning/reading system. I wonder if you could possibly find room for a small article on the subject in a future edition.
If you do (although it is not exactly an electronic subject) how are the bar codes allocated. Does each manufacturer allocate his own, with the possibility of duplication between manufacturers, or is there a central, worldwide organisation who issues them?
Another future project for your electronic wizards to produce would be a hand-held device with a range of about 20ft which would interrogate the check-out machine to see if it is about to run out of paper, or the operator is new to the job, and as a bonus, do a quick check of the goods in the trollies in front of you in the queue, to see if there are any unlabelled or unreadable bar codes which will bring that particular check-out to a halt very shortly – now that would be really useful!
E. W. Smith, Crowborough, E. Sussex.

I think just about everyone who does a Friday night or Saturday morning 'shop' at Safeburys will know exactly what you mean! Most bar codes are used to identify a product for supply, distribution and retail sale – such as a tin of baked beans you might buy from Safeburys. These are: the EAN/UPC (European Article Number/Uniform Product Code) bar code used to uniquely identify a product for retail sale (not the actual price charged) and the ITF (Interleaved Two of Five) Case Code bar code used to identify cases containing a number of units of a product (i.e. 48 bags of crisps). As you can imagine, avoidance of bar code duplication is very important, considering the same product could be on sale in many different countries. In the UK, the Article Numbering Association (ANA) looks after the administration of bar coding; internationally, numbers are issued by similar administration centres.
The EAN/UPC bar code identifies the country of origin, the manufacturer, the manufacturer's item number and provides a check digit for verification that the code has been read properly.
An introductory article on bar codes was published in Electronics Issue 37/April–May 1990 (XA37S). Further information can be obtained from the ANA, Tel: (0171) 836 3398.
I'll put the 'How Barcode Scanners Work' feature on the ideas list.

Dud Detective

Dear Sir,
Since there now seems to be a growing popularity for ultraviolet bank-note checkers in stores. I was wondering if it was possible for us consumers to be able to check the notes that we receive. After all we just assume that shops and banks give us genuine notes. But if we were to be given a counterfeit note and then try to use is elsewhere to make a purchase, it is us who are liable for prosecution.
Therefore, I was wondering if anyone made an LED or similar small device that emits UV light that could be easily mounted into a key-fob. Then we would have a pocket-sized checker that we could use to test every note as it comes into our possession.
On a slightly different note, I have recently purchased and installed a Fox Security Wireless Intruder Alarm for my in-laws. I have installed several different types of alarms for family and friends over the last few years, and I can honestly say that this system is a true value for money package, and I would recommend that anyone considering an alarm purchase should take a good look at the Fox system.
Finally, a note for Mr Gunner (Get it Taped, October issue), with reference to your problem of recording RS232 signals, there is a disk drive unit that used to be made by Canon called an AP86 which was designed as an 'add-on' for their AP350X electronic typewriters. The typewriter had an RS232 (CCITT V24 /EIA RS232C) interface on it and the disk drive used to record information via this format using its own RS232 decoder. As these units have now been obsolete for a few years, maybe you can find a Canon dealer who has one gathering dust, and is willing to donate it to a good experimental cause! I have not tried to interface one with a computer myself, I am sure that it would be possible, but try not to pay anything for the drive if you can help it, and then you will not lose anything if it does not work.

If you want a portable bank-note checker then try our UV Mini Lantern (ZC10L), it is pocket-sized (but not key-fob sized) costs under a tenner, so it could pay for itself on its first use. UV light is shorter in wavelength (around 320 to 380nm) than the visible parts of the spectrum (around 380 to 750nm), the nearest an 'off the shelf LED' can get to is 470nm (blue), which is not a lot of use. Fake or counterfeit notes will fluoresce under UV light whereas real ones will not. A UV bank-note checker should be used in conjunction with other methods of visually spotting counterfeit notes: make sure that there is a watermark (hold the note up to the light); check that there is a silver thread interwoven through the note; check the serial number is printed in two places; check the 'feel' of the paper; and look to see that there are no strange blemishes in the swirling patterns.

Wot No PCBs?

Dear Sir,
I feel I must put pen to paper and complain about your policy of not supplying Maplin project PCBs to your retail outlets. This must go down as one of the worst mistakes you are making. Does it not occur to the person who made this decision that constructors do not need to purchase a load of hardware when they can adapt, or already have a vast stock of parts? 'Tandy' is widely known as the 'One Stop Rubbish Shop!', but if this policy of yours carries on it may well apply to Maplin.
To be told "we can obtain it within a couple of days or so means not only a double journey, which results in people not spending out more money than what they have in mind, but raises the question – if you can get the PCB (etc.) in a couple of days, then why don't you stock it normally? Please change your policy A.S.A.P.
On another note, what about reducing the price on the out of date magazines in the retail shops instead of paying full price for a magazine that is months (or years!) out of date – they may sell a bit quicker.
Try thinking of us constructors for a change, and don't end up like Tandy, where they couldn't care less, because they are withdrawing, from the electronics side anyway (does anyone still use them?)
N. Page, Halesowen, West Midlands

Mrs Sandra Allen, Maplin's Operations Director replies:
Thank you for you letter regarding the non-stocking of PCBs in our retail stores. It seems that a misunderstanding has arisen: whilst we do not stock all of our PCBs throughout our thirty-three retail stores, the store can order any required item from our mail order distribution centre and have it sent directly to your home at no extra cost. The store would take the money for the item and put it through their till, and the ordered item would be classed as 'Free of charge' from the warehouse. 'Paid at store' items are received from the store by the distribution centre the next morning and then despatched that day by first-class post. The customer would therefore receive any item they had not been able to obtain within forty-eight hours of calling in at a Maplin store.
This service has been put into place to give all our customers a real benefit and to enhance our service at Maplin stores, and is used for a number of reasons:
1. Stock at an individual store may have run out and the next delivery has not yet arrived.
2. Sales at an individual store may be so low that keeping that particular item in stock is prohibited.
3. The item at an individual store has become discontinued and will never be replenished, but other stores may still have stock.
In all cases, we would either despatch the item the following day from our distribution centre, or recall the item from another store that did have stock to send to the customer as soon as possible.
I think you may well now agree that Maplin does try very hard to give the constructor what he needs. Whilst I agree that on the day that you visit a store we may not be in stock of every item, within forty-eight hours it can be at your home at no extra cost or inconvenience to you.
I hope this information will assist you in the future, and help to give you confidence in our company and in our ability to help the constructor at all times.
I am sure that you will also be interested to learn that during October, selected back issues of Electronics will be available from Maplin stores at substantially reduced prices.

Computers and Information

by Richard MacVean

THERE is about to be a revolution in Information Technology, and it will be brought about by new communications networks and high-power computers. Although the first computer was designed over a hundred years ago, we did not enter the computer age until the growth of electronics during the war years, and there has been a phenomenal growth in the power of computers since then. Cheap microprocessors made the personal computer feasible, and this, in turn, brought about the word processing revolution – this is an example of the interconnected nature of progress.

To predict the developments of the next ten or twenty years requires some knowledge of advanced electronic materials, communication networks and economics; new developments must be economical if they are to become widespread. An example of a technology with great potential, but which may become extinct, is space travel; it is prohibitively expensive.

Governments are reluctant to fund new technology if private companies can do so instead. But companies want to see a quick return on their investment, and the fruits of research may take a long time to materialise.

People may take the appearance of fax machines, CD players and videophones for granted, but the technology behind these machines will produce many more surprises. It has yet to take full effect on our lives, and threatens to change even the political nature of the world. So, let's see what is in store for the end of this century.

Micros, Minis and Mainframes

Mainframes are the largest and most powerful of computers, but each year personal computers grow in power. The biggest growth in sales has been for personal computers (PCs). Workstations are powerful PCs with large amounts of memory, and have high-resolution graphics which are often used for CAD, and the distinction between workstations and PCs will gradually disappear.

Laptop computers are a recent addition, and have been made possible by the advent of flat panel displays. It is predicted that, in 1995 alone, eight to nine million laptop computers will be sold, 75% of which will have LCD screens.

Smaller pocket computers act as personal organisers, taking telephone numbers and storing text. Some models recognise handwriting, which is then stored in memory. The trend is for them to become more of a personal assistant.

The increased ownership, and drop in prices, of personal cell phones may lead to the integration of a pocket computer with a communications device. This will have applications in the business world; bookings or orders could be made or received, and logged.

Displays

A display is possibly the most important component in a computer, and for many years, users have had to rely on the bulky cathode ray tube (CRT). Recently, flat panel displays have made laptop computers possible by reducing their weight to the level of portability.

The Liquid Crystal Display (LCD) is flat, lightweight, and has low power requirements. Within five years, the scales of LCDs will be greater than that for CRT displays. They will make High Definition Television (HDTV) affordable. Researchers are currently investigating different types of

LCD, and it is not yet clear which type will succeed as most suitable for computer displays.

LCD displays are being used in three-dimensional computer graphics; two screens are used, one for each eye. The display device takes the form of a pair of glasses that are worn on the head. This will have many serious as well as entertaining applications.

Storage Devices

Optical disc drives will supersede magnetic disk drives. Fully erasable magneto optical disc systems are currently available. These use a magnetic disc which is read from, and written to, using a laser beam. Bits are stored on the magnetic disc as magnetised regions. When reading, the laser light reflected from such a region has its properties changed, depending on the direction of magnetisation. Writing is performed at a higher laser power, which heats the region to be written above the material's Curie temperature. The direction of magnetisation can now easily be changed by the application of an external field.

A single 5in. optical disc, either CD-ROM or Magneto Optical, can store roughly 500M-bytes (on one side), but there is room for much improvement. The amount of information that can be stored and retrieved depends on how small a dot the laser beam can be focused into; this is proportional to the wavelength of the light. At present, only infra-red beams are used, but eventually, shorter wavelength (blue light, or ultraviolet) laser diodes will become available. This would give at least a fourfold increase in the storage capacity. Further into the ultraviolet, materials behave differently, and it becomes increasingly difficult to achieve laser action. The light emitted from conventional laser diodes is oval (see Figure 1a), but a new type of laser, called the Surface Emitting Laser Diode (SELD), emits a circular beam, which can be focused to a smaller spot, as shown in Figure 1b. If the SELD was combined with tighter tolerances in the design of the optical drive, a doubling in capacity could be achieved.

At present, a single CD can store the whole contents of the twenty volume Oxford English Dictionary. If new data compression techniques, shorter wavelength and SELDs were used, then enormous amounts of data could be stored on a single disc, perhaps as many as twenty music LPs, or over an hour of uncompressed video.

The Power Macintosh 8100/80 – the most powerful PC in the world, but not for long!

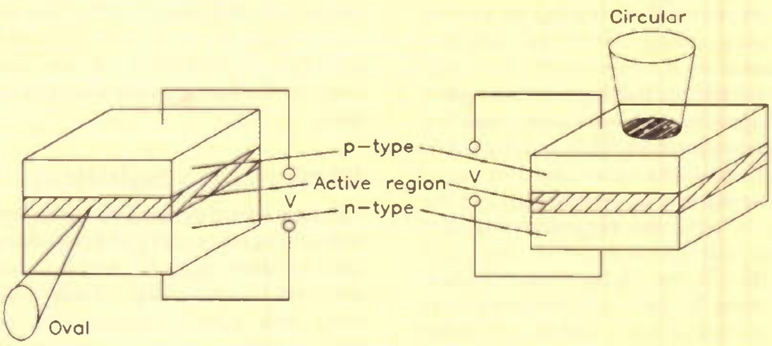
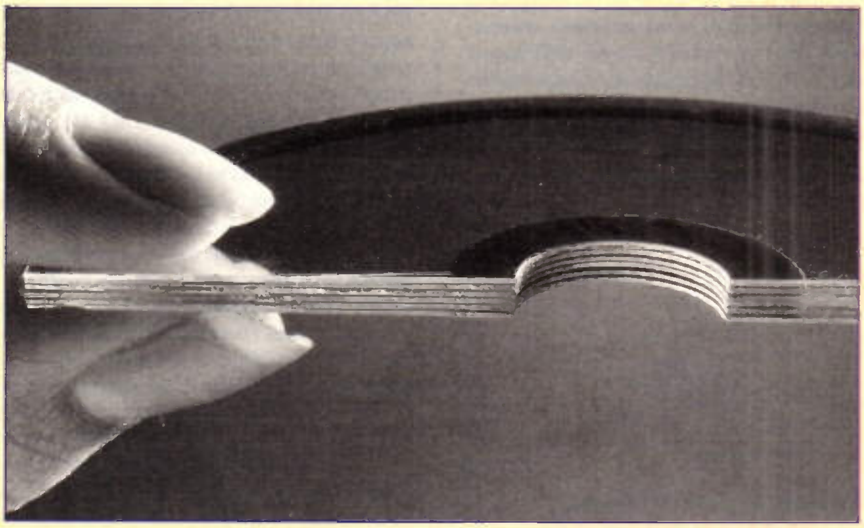


Figure 1. Comparison of a laser diode with a surface emitting diode: (a) a laser diode; (b) a surface emitting diode; note the circular beam.



IBM research Scientists predict that their new hard disc technology will enable a twenty-fold increase in data density by the turn of the century.

Integrated Circuits

The integrated circuit is fundamental to the success of the computer. It was developed to replace discrete components.

The advent of electronics made computers, as we know them, possible. Over the years, the circuits grew more complex until, by the 1960s, they were so complex that it was not feasible to make them from discrete components. The massive number of components and soldered joints increased the probability of an error. Integrated circuits, by putting many components into a single mass produced module, overcame this problem.

The ICs are made from thin discs, called wafers, of silicon. Each wafer is processed to form many ICs. Technology limits the size of the smallest features which can be fabricated on the wafer. The smaller the size, the greater the number of components that can be formed on the IC.

An important IC in desktop computers is the Dynamic Random Access Memory (DRAM). Currently, 4M-bit DRAMs are available, and eight of these give a computer 4M-bytes of RAM. A new generation of DRAM chip appears every three years, each generation having four times the capacity of the previous. 256M-bit DRAMs should be available before the end of the decade, making new applications feasible.

Magneto Optical discs. Photos courtesy of PDO Media, Wiesbaden, Germany.

WSI

A way of increasing the level of integration is to process the silicon wafer to form a single large IC – a kind of superchip. This Wafer Scale Integration (WSI) circuit could consist of banks of computer memory chips, or an entire computer. A difficulty to be overcome is the increased likelihood of faults in the crystalline structure of the wafer interfering with the circuit. This reduces the yield of the WSI process. To overcome this problem, redundant components are also formed on the wafer, which can be used as an alternative if faults are detected. This is known as Fault Tolerant Architecture. To make this possible, some way of reconfiguring the interconnections automatically needs to be found, in order to disconnect the faulty components and connect replacement ones.

If achieved, WSI promises to produce immensely powerful ICs, far superior to ones available today.

VLSI – The Problems

The number of components integrated onto a single piece of silicon has increased from just one, to over fifty million using Very Large Scale Integration (VLSI). This has been achieved by progressively reducing the size of the components formed on the chip.

The vast increase in complexity of ICs has caused problems for its designers. One factor is the power consumption. If the size of each component on a chip is halved, then so will the power consumption. But, there will be a fourfold increase in the numbers of components and, therefore, will be an overall doubling in power consumption. A large power consumption is unwanted, as it causes heat which can damage the circuit. Raising the clock speed in microprocessors also increases the power consumption. This is why some powerful computers are found in tower desk-side systems, to enable easy fan air cooling. A new microprocessor, the Pentium, consumes around 15W, over double that of the highest specification 486 processor. If more powerful computers are to be developed, a reduction in the power consumption needs to be made.

Figure 2. The effects of increasing integration in ICs. It becomes increasingly difficult to reach inner components without crossing wires, or removing outer components.

A vast number of interconnections have to be formed in a VLSI circuit; as much as 70% of the chip area is taken up by interconnections. It is also difficult to reach components on the chip that are far from the periphery (see Figure 2). As integrated components are progressively miniaturised, their switching speed decreases. However, the RC (Resistance × Capacitance) product of the interconnections remains constant, and the RC constant limits the rate at which data can be sent along the interconnections. It can be seen, therefore, that as miniaturisation progresses, the proportion of the time delay due to interconnections becomes greater – in fact, the speed of present VLSI circuits is almost entirely limited by this interconnection delay.

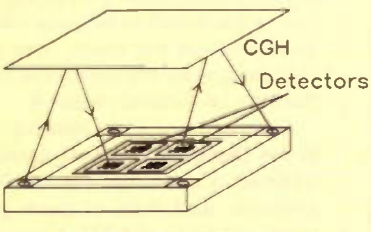


Figure 3. Examples of optical interconnection: (a) intra-chip; the laser sources are located on the periphery, which is GaAs. The detectors are within a conventional IC, which may be silicon; (b) inter-chip; the chips could be separate, or Wafer Scale Integration, as shown.

VLSI – The Solution

The number of interconnections could be reduced by eliminating the need for power lines to reach each IC, and this could be achieved by integrating a battery onto the chip itself. This is known as integrated micropower, and has been successfully achieved in simple circuits.

An almost infinite amount of information can be carried by a beam of light. Interconnection delays could be eliminated by using light instead of wires to carry signals in the circuit. Unlike electrons, two beams can cross without affecting the signals that each carries. Optical interconnections can be made by reflecting a laser beam, which carries the signal, off a computer generated hologram (CGH), shown in Figure 3. A beam incident on the CGH would be directed to locations on the chip's surface. Holograms, made from special materials, can be changed in real time. This means that the fault tolerant architecture, mentioned previously, can be realised. A more exotic application is for a microprocessor that reconfigures itself, depending on the problem that is to be solved. Any damage that accumulates during the lifetime of the device could be accommodated by disconnecting the damaged components from the circuit. A computer that is able to alter its own circuit may have interesting properties. One-to-many, and many-to-one interconnections could easily be achieved using CGHs, unlike electronic wiring.

Surface emitting lasers will be used as a light source, as they can be readily integrated into arrays (see Figure 4). They are also expected to be very efficient, and so will have low power consumption, which is important in an IC. The circular beam is also best for efficient coupling into optical fibres. Optical fibres may be used to form the interconnections, or to form a local area network between computers.

A problem is that lasers cannot be made out of silicon; Gallium Arsenide (GaAs) is the material used for laser diodes. If ICs are to be fabricated from GaAs, then lasers could be formed. Although this is more difficult, an advantage is that GaAs components can be operated at over double the speed of silicon based devices.

A prime candidate for optical interconnection is the microprocessor. Signals, such as the synchronising clock, could be broadcast simultaneously to all points of the chip, or to an entire circuit board. This will raise the maximum clock speed to over 1,000MHz. An IC that incorporates light sources and detectors would be known as an Optical Electronic IC (OEIC), see Figure 5.

An exciting possibility is to replace today's transistor based switches with an optical equivalent. An optical switch can be either

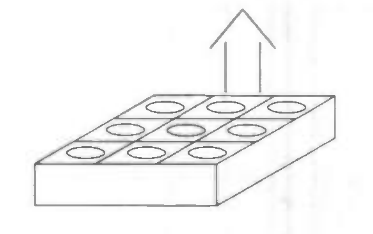


Figure 4. An Integrated Surface Emitting Laser Array for high-power, or 2-dimensional, signal communications.

hybrid optical electronic, or all-optical (see Figure 6). In an all-optical switch, a special material changes its optical properties, depending on the intensity of light that passes through it. When in the off state, a light beam would be prevented from passing through the device. Only when a second high-power beam is present would the device switch on, and allow the beams to pass. These devices have the potential to switch in the picosecond region, and could form massively parallel circuits. However, all-optical switching is still in its infancy when compared to hybrid optical electronic switching.

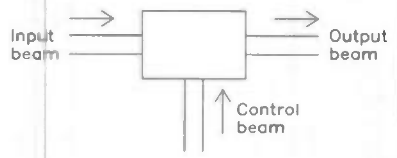


Figure 6. An all-optical switch; a high-power laser control beam is used to switch between states. These switches may replace transistor based components.

New Architectures

A way of making more powerful computers is to connect several processors together. Instead of a single processor, an array of processors work simultaneously on a problem, resulting in a tremendous computational speed. Such parallel computers require a massive number of interconnections, and so are ideal candidates for the use of optical interconnection techniques. Existing architectures will be questioned as completely new computer circuits will become possible. In Japan, there is a research project to develop the 'sixth generation' computer, which will have a massively parallel architecture – up to a million processors.

A fairly new type of computer that relies on a large number of processors is the Neural Network. Neural Networks contain large numbers of simple, interconnected processors, which learn to relate data and decisions from examples, rather than being programmed like conventional computers.

Neural computers are good at recognising patterns, and so could be used to recognise faces or make financial decisions. They are based on the structure of the brain, which is formed from many neurons. Each neuron has a series of weighted inputs, called dendrites. When the sum of the weighted inputs exceeds a threshold value, the neuron outputs a signal via a single output, called an axon. This is connected to other neuron inputs via a synapse. This structure (see Figure 7) has been successfully created artificially, using electronics, and optics.

A neural computer is trained to produce the appropriate response to a combination of inputs by being presented with many examples during a learning phase. The presentation of these examples causes the strength of the connections between neurons, that comprise the network, to be modified.

A potential application of neural networks is to recognise a three-dimensional object from any of its perspective views. This has been achieved for simplified wire frame objects.

No man-made neural computer comes anywhere near the brain in capability. This is surprising, since transistors can operate a million times faster than the nerve cells in the brain. But, there are roughly a hundred billion neurons in the brain, and each one is connected to ten thousand others. It is the massive number of neurons and interconnections that account for the brain's superiority. Electronic neural computers have been made with up to only a few thousand neurons.

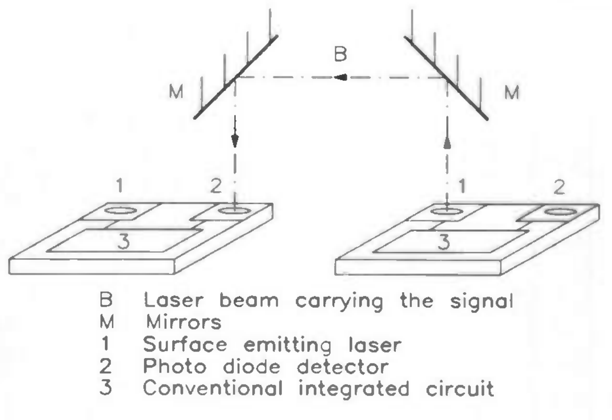
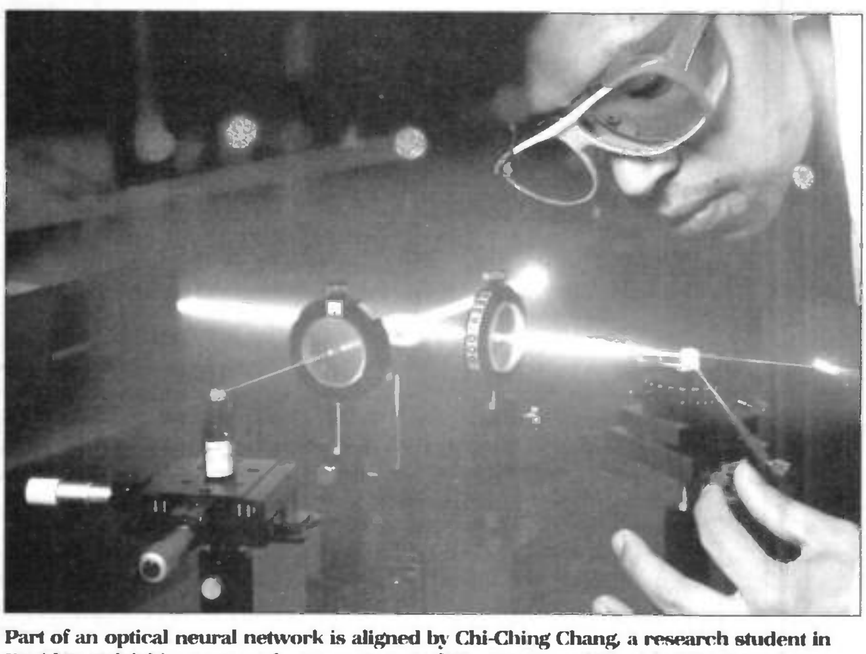
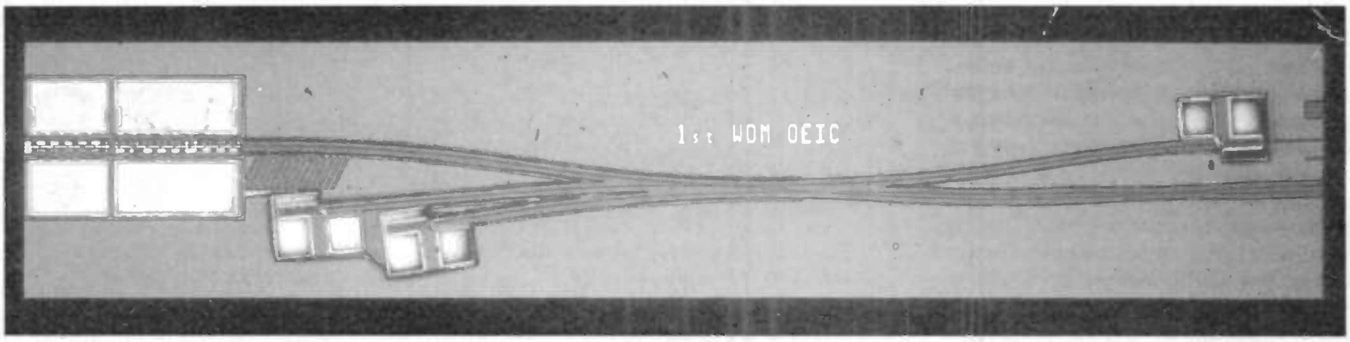


Figure 5. An OEIC chip with optical interconnection for use in advanced computers.



Part of an optical neural network is aligned by Chi-Ching Chang, a research student in David R. Selviah's group at the Department of Electronic and Electrical Engineering, University College, London.



OEICs integrate optoelectronic devices, e.g. lasers and detectors, with optical waveguide components, e.g. splitters and multiplexers and optical circuitry, to provide reliable, robust and low-cost components for optical fibre systems.
Photo courtesy of GEC-Marconi Materials Technology, Caswell.

Much of the research funding into neural computers came from Reagan's Star Wars programme. This has been cancelled, but even so, neural computers are expected to be the most important type of computer in the 21st century.

Networks

Networks enable desktop computers to become more powerful by exchanging files with other computers. One can access a large database, special programs, receive electronic mail, or use a powerful super-computer.

Scientists now, routinely, run the main part of their programs on a supercomputer. The results generated are then sent over a network to a PC. The PC is then used, merely, to display and analyse the data.

Today's networks are dominated by traffic to and from personal workstations of progressively increasing power. The distinction between workstations and PCs is gradually disappearing, and the number of computer users linked to a network is increasing.

Optical fibre has a massive information carrying potential, and will be used more in future networks. However, to send data at this high rate (Giga-bits/s), the optical signal has to be processed at this speed, both at the transmitting and receiving end of the fibre.

Conventionally, the incoming data from the network is converted to an electrical signal before processing, but electronics has difficulty coping with signals at this speed. A solution is to keep the signal in optical form, and use integrated opto-electronics or all-optical devices to process the signal. This is a reason for the development of OEICs, apart from their use for optical interconnection in computers.

Within ten years, the Local Area Network (LAN) will be fed by optical fibre, and will carry television, phone and computer data to our homes and offices. The new high-capacity networks will cause the distinction between these data types to blur.

There will be a drastically reduced cost for interconnected calls with the opening of the new all-optical repeater cables. The first one is due to open across the Pacific in 1995, and will have over ten times the capacity of current optical cable.

Hardware is being sold to enable a PC to act as a videophone. Teleconferencing is also a possibility. These devices will stimulate the demand for high-capacity networks.

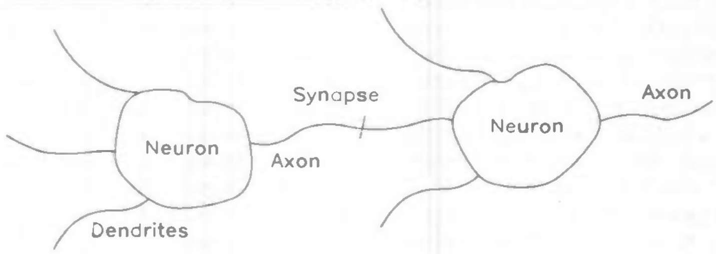
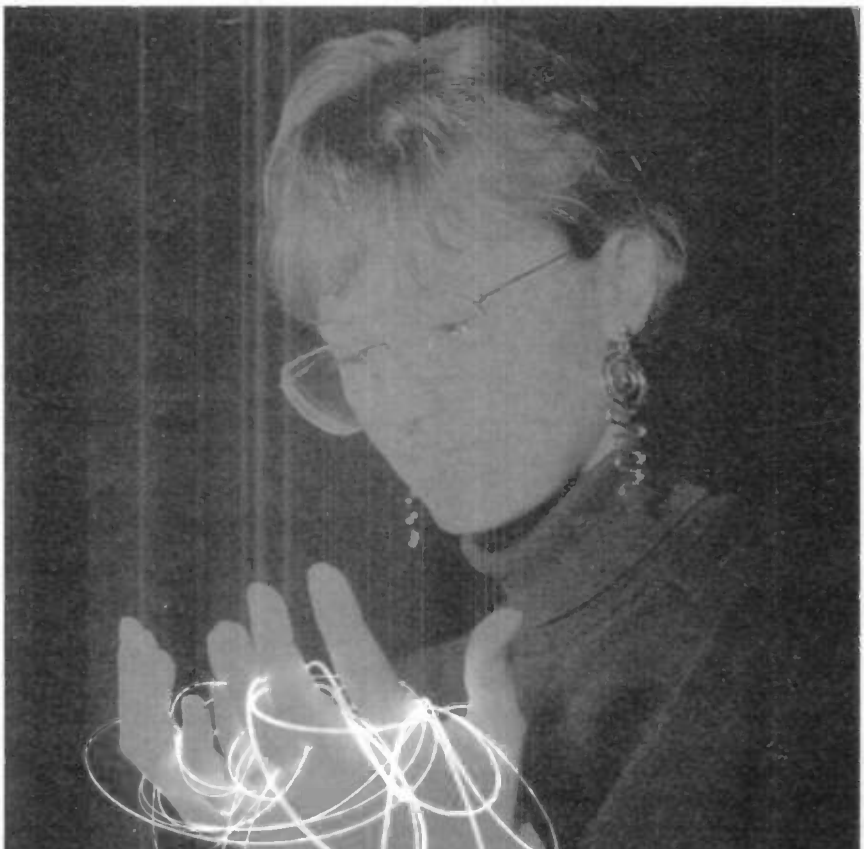
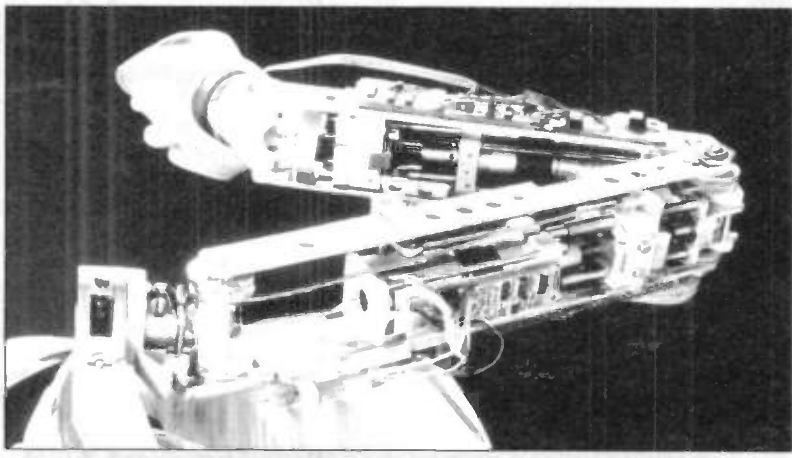


Figure 7. Neurons, such as might be found in the brain. Each neuron is typically connected to ten thousand others. Optical devices will be used to create artificial neural networks by utilising their massively parallel interconnection potential.



Dr Janet Townsend, Senior Research Fellow at the Optoelectronics Research Centre at the University of Southampton.
Photograph courtesy of Mr S. Shrimpton, Teaching Support and Media Services, University of Southampton.



Top Right: Kodak's portable Photo-CD player can also play ordinary CDs.

Above Left: Multi-media will become increasingly prevalent – shown is a touch screen, multi-lingual tourist information system created by IN.form.

Above Right: The realisation of cybernetics and artificial limb replacements is fast approaching.

General Applications

Entertainment

Virtual reality will become more popular when high-power computers fall in cost. Combined with high-capacity networks, it will be possible to play games with opponents anywhere in the world. Fully three-dimensional and high-resolution graphics will be possible. A kind of computer game Olympics may be held, but such absorbing entertainment may prove damaging to young people; there is already concern at the extended periods of time that children spend with computer games. The Government may have to legislate to prevent widespread addiction.

Transport

Computers are used to direct air traffic; as the amount of flights increases, more powerful traffic control computers will be used. They will also be used to manage the crowded shipping lanes in the Channel. Safety will be increased, and the number of collisions decreased.

Computer management will find its way into our cars; soon, drivers will know their positions thanks to in-car navigation systems. Street maps will be displayed on flat panel displays, and accurate up-to-date travel information will allow drivers to avoid congested routes. Car crime will also be reduced as stolen vehicles will be tracked down in a matter of minutes using radio communications. With the likely introduction of toll roads, computers will be required for the automatic debiting of the toll fee to the driver's account.

If British Rail is privatised, then a more sophisticated method of charging the customer may have to be found because different companies may operate for the different parts of the journey. There is, therefore, a demand for greater use of computing in this area.

Medicine

Medical images, such as those taken by scanners and X-ray machines, will be processed by computer to pick out relevant features such as tumours. Computers have been used recently to design an anti-flu drug. They will also be used to process the increasing amounts of sensor information obtained from patients, and aid in the diagnosis of ailments.

Science and Technology

Computers enable scientists to simulate experiments. They are used to perform the scientific 'shovel work', and so leave the scientist more time for creative thinking. Some mathematical problems cannot be solved by conventional techniques; a computer is required. Computation is now widely accepted as the third scientific technique, theory and experiment being the others. Scientists need high-power computers to model complicated systems, such as the weather. They were unable to predict the storms of October 1987 because their computers were not powerful enough.

Law and Order

A colossal number of financial transactions occur each day. Much crime could be detected if selected transactions were monitored, but vast computer systems would be required.

Card crime could be reduced if a Neural Network was used to recognise the card-holder's fingerprints at a cash machine.

There has been increased use of security cameras to monitor city centres. It is feasible that the signals from thousands of such cameras could be carried by a single optical fibre, making the centralised monitoring of banks, department stores, and streets possible. Centralised monitoring will enable an individual to be followed by cameras across a city and through buildings. Neural computers may eventually be used to monitor the video signals and select suspicious ones for recording. High-capacity recording would be based on high-capacity digital optical systems. Such systems could also recognise a vehicle's licence plates on roads.

Defence

For many years, the Soviet Union was a worthy opponent to the West. Its recent collapse has triggered defence spending cuts. Although there are other nations which could become hostile, these pose a relatively limited threat. Our defence will, therefore, probably be reduced to the role

Continued on page 29.

NEWS Report

AromaScan – Sensor Technology that Nose Best

The University of Manchester Institute of Science and Technology has developed a technology called AromaScan, that emulates the human nose.

Analysis of aromas in industry is already well established, particularly in the food, beverage, toiletries and perfume industries. AromaScan technology is already being sold into these markets.

AromaScan technology, however, has significant advantages over existing methods of aroma analysis. In particular, it characterises aromas in a digital format allowing them to be measured, recorded and analysed objectively. It is able to analyse a broad range of aromas with high levels of discrimination, sensitivity and reproducibility and can monitor these aromas continuously.

Innovative areas where AromaScan has been successfully tested include Withington Hospital, where an AromaScan instrument can detect infections in wounds at a very early stage and distinguish between certain types of infection.

Contact: Buchanan Communications, Tel: (0171) 489 1441.

Traffic Wardens Go Mobile

Traffic wardens in Croydon have gone hi-tech in their fight against wayward parkers. Using a mobile data network, the local army of wardens are able to cross-reference meter checks and ticket issues.

Vehicle removal trucks are also equipped to tap into the wireless network, allowing "illegally parked vehicles to be removed quicker", boasts Croydon Council. Isn't technology wonderful?

PhONE Day

As with most other phone numbers in Britain, central London's 071 area code is being extended to 0171 to expand the number of phone numbers available. A transitional overlap is now in place, with both STD codes valid until 16 April 1995. Why not start using the new numbers now in preparation for the changeover next year. Contact: British Telecom Operator, Tel: (0800) 010101.

Chicago in 1995?

Microsoft has confirmed that it does not expect Chicago, the latest version of its Windows operating system, to ship before January of next year. Rumours circulating on the Internet suggest that even this date is optimistic. Contact: Microsoft, Tel: (01734) 270001.

ISDN Problems

A frustrated *Electronics* reader wanting to set up a three-way international teleconference from a London-based hotel, called the editorial team last month for help.

Unable to locate a hotel equipped with ISDN lines essential for videoconferencing, Phil Tucker called directory enquiries for help. "What's ISDN?", came the bemused response. Call BT's ISDN helpline we advised.

Five minutes later Phil was back on the phone to the *Electronics* team: "You won't believe this, BT cannot tell me which hotels have ISDN installed."

Indeed we checked. It appears that BT do not have a directory of ISDN installations.

Mobile Theft

The Federation of Communication Services (FCS) has made a plea to Trade and Industry boss Michael Hesletine, for legislation to stamp out illegal mobile phone theft.

The move comes in the wake of recent figures which suggest that mobile phone related crime continues to increase. Crime in this area has soared by 50% during the last six months to an average 15,000 handset thefts every month.

The proposed legislation would outlaw the rechipping of the serial number within a mobile phone, making stolen phones easier to trace.

Contact: Federation of Communication Services, Tel: (0181) 778 5656.

Microchip Multichip Modules

Microchip's new multichip PICSEE modules use 50% less board space than conventional devices with similar functionality. The eight new 20-lead field-programmable modules combine a powerful 8-bit microcontroller with a serial EEPROM in a single SSOP package.

The modules extend Microchip's existing range of 28-lead multichip PICSEE modules to provide new solutions to many space-constrained applications, such as security, keyless entry, data acquisition and intelligent data buffering. The new PICSEE modules are smaller than Microchip's popular SOIC PICSEE devices and provide a low-cost serial-EEPROM based device to complement Microchip's popular parallel-EEPROM based PIC16C84 mid-range microcontrollers.

Four of the new 20-lead SSOP PICSEE MTA85XXX products include either a PIC16C58A or a PIC16C54A 8-bit static-EPROM based microcontroller with 128 or 256 byte serial EEPROM. The other four add the capability to directly control the U_{pp} pin of the EEPROM for the same microcontroller/EEPROM combinations as above, providing lower power consumption and improving portable application designs. Contact: Arizona Microchip Technology, Tel: (0628) 851077.

Rodent Recycling

We have seriously good news for ageing rodents – Logitech has stepped in to save pensioned-off mice from the big mousetrap in the sky.

Computer users are now able to use their old mouse as part exchange against a new Logitech Mouse Man, for a mere £29.99. That's a saving of almost 45% on the normal retail price.

The Mouse Man has three programmable buttons and is compatible with all DOS and Windows applications. The bundled MouseWare software helps users program resolution (up to 400dpi), cursor sensitivity and menu driven or keyboard short cuts.

Retired rodents, we are reassured, will be recycled in an environmentally-friendly manner by Logitech. Contact: Logitech, Tel: (01344) 894 300.

Amateur Radio Licences Revised

The Radiocommunications Agency has announced revisions to both the Full and Novice Amateur Radio Licences.

The revisions for both the Full and Novice Amateur Radio Licences include:

- a requirement to notify the Agency's Radio Investigation Service in advance of an intention to conduct unattended operation of digital communications;
- clarification of the requirements for keeping the Log on electronic storage medium.

The following revisions apply only to the Full Amateur Radio Licence:

- an increase in the power level permitted for 1·810 to 1·830MHz;
- an increase in the power level permitted for 50 to 51MHz antennas and maritime mobile operation;
- a relaxation of the regulations for operation at 51 to 52MHz with regard to height of antennas and maritime mobile operation; and
- provision of an updated list of Conference of European Posts and Telegraphs (CEPT) member countries and their associated country codes.

These revisions are the latest of a series in recent years and have been introduced in order to keep Amateur Radio Licences in step with the current needs of radio amateurs. This reflects the Agency's continued commitment to the amateur radio services. Contact: Radiocommunication Agency, Tel: (0171) 215 5000.

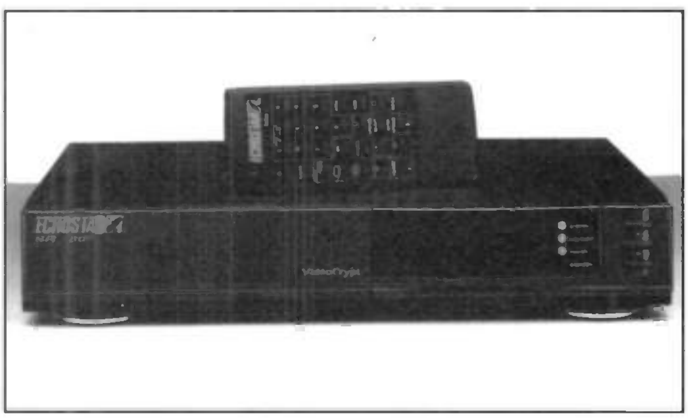
Pan-European Satellite Receiver

EchoStar International Corporation (EIC) has introduced a Pan-European satellite receiver, the EchoStar SR-800, with optional integrated Videocrypt I or Videocrypt II decoder.

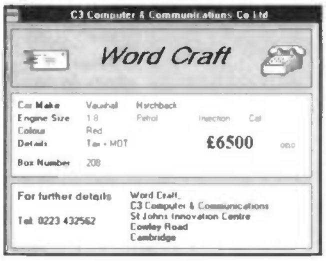
Designed in Europe, the EchoStar SR-800 is manufactured in response to the developing standards of the UK, Continental European and Scandinavian markets. This high-end fixed satellite receiver offers full Astra 1D compatibility and may be tailored for individual regions and program requirements.

Installation is simplified with on-screen graphics in English, French, German and Spanish and 200 pre-programmed audio and video frequencies. In addition to Videocrypt I and II decoder capabilities, the SR-800 also supports a variety of decoders such as DMac, D2Mac and SYSTER.

Contact: EchoStar International, Tel: (31) 546 814691.



Accents are Not a Problem



Until now, it has only been possible to build large vocabularies, involving hundreds or thousands of words using speaker-dependent speech recognition systems. The problem with these systems, is that they rely on users to train them to recognise specific voices, and hence have had relatively few widespread commercial applications.

By contrast, speaker-independent speech recognition systems, are much more widely used in telephone-based applications but are usually restricted to a vocabulary of fewer than half a dozen words.

WordCraft breaks this word barrier using an innovative and flexible vocabulary collection and storage technique. Traditionally, speech recognisers have operated by collecting vocabularies and then downloading them onto proprietary hardware, such as a PC speech recognition board. The problem is that this technique limits the scope of an application to the vocabulary on the hardware and prevents further expansion.

WordCraft does not require special speech recognition hardware. Customers simply need to install WordCraft software on a standard C3 TELi-LINK voice processing system, and then write an application to collect the required vocabulary using C3's application programming language '4Voice'.

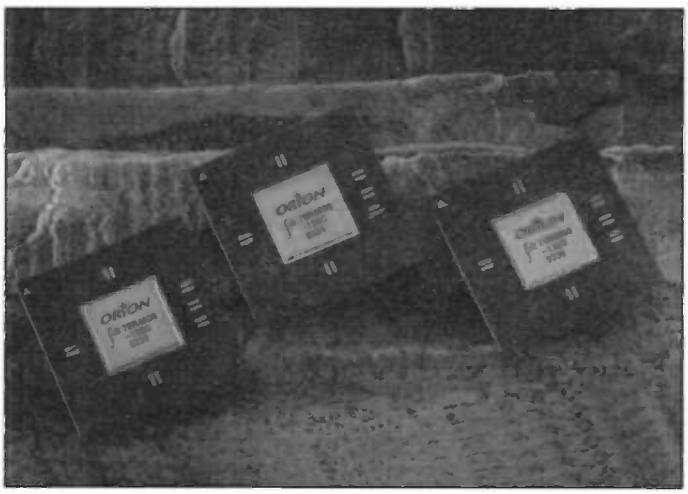
Once samples are collected, they are processed and ready to be used. And because WordCraft collects vocabularies using the TeliLink system memory, developers can theoretically collect an unlimited number of words in a dictionary. The constraint is not the number of words – but the size of the computer's memory.

When WordCraft is combined with C3's CTi-Link (a client Interface which allows a Microsoft Windows application program to access a C3 TELi-LINK voice processing system) information spoken over the phone can be transferred directly into a Windows application program created using Visual Basic. This technique effectively converts the spoken word into text used by the PC application. A typical example of this is where callers are asked to fill in a voice form over the phone, which will turn their spoken responses (to given prompts) into text which is stored on the PC. Contact: Computer & Communications Limited, Tel: (01223) 423562.

150MHz Orion

IDT has simultaneously released a 150MHz Orion MIPS RISC microprocessor and announced dramatic price reductions for their existing Orion microprocessor. The IDT R4600 Orion family combines high performance, dynamic power management and low price, making it ideal for high-end embedded, UNIX and Windows NT applications.

The new R4600-150 Orion outperforms the fastest Intel Pentium for about the price of a 486DX. For example, the new R4600-150 is up to 315% faster than the Intel Pentium-90 running native Windows NT benchmarks. Based on preliminary simulation numbers, the R4600-150 achieves 104 SPECint92 and 81 SPECfp92 running UNIX benchmarks. In addition the R4600 die is less than half the size of the Pentium. Contact: IDT Europe, Tel: (0732) 363734.



PC Radio Callbook

A UK Amateur Radio Callbook is now available for the PC. Produced by G0LOV & G4LUE Amateur Software, the callbook is based on comprehensive data from the Radio Authority.

Using pull-down menus, the user is able to source addresses from UK call signs with ease. Postcodes and towns can be identified as well as UK repeater data, node lists and packet mailboxes.

Priced £10 plus £1.50 postage and packaging the callbook comes on three 3·5in. disks and requires a PC running DOS 3.1 or above, with 15MB of hard disk space. Contact: G0LOV & G4LUE Amateur Software, 8 Hild Avenue, Cudworth, Barnsley, South Yorkshire S72 8RN.

Fax Mailbox

Winfax Pro publisher Delrina has opened a mailbox service for fax modem users who do not wish to leave their PCs switched on permanently. Faxes can be picked up using Winfax Pro or any Group III machines. Rental rates start from a flat fee of £9.95 per month. Contact: Delrina, Tel: (0181) 207 3163.

Timetable Strikes

Here's irony. While commuters struggle with random strikes, British Rail has announced that it is selling the summer version of its Electronic Rail Planner, in Windows (£45) or DOS (£41) versions.

A BR spokesperson reported that there are no plans to produce a special strike edition. Contact: British Rail Order Line, Tel: (0800) 526306.

OEM SCSI Adaptor

Shuttle Technology is replacing its highly successful Pocket Adaptor with the Pocket Demon and Integra parallel to SCSI adaptors. The launch of these new products meets the demand for low-cost, high-performance converters in the smallest size yet available.

Both the Integra and the Demon are based on Shuttle's new EPSA II ASIC, the first single chip solution for parallel to SCSI conversion. The adaptors support the Enhanced Parallel Port (EPP) allowing burst transfer rates of up to 1MByte per second. They are also fully compatible with Standard, Uni-Directional, Bi-Directional and PS/2 parallel ports.

The Demon adaptor offers the increasingly popular mini-centronics 'high density' format, reducing connector size by fifty per cent. The Integra maintains the popular 50-pin centronics SCSI connector. Both adaptors feature auto-configuring ASPI (Advanced SCSI Peripheral Interface) software for operation with CD-ROM, hard disk, SyQuest and Benouilli removable, WORM, magneto-optical, tape and floptical formats.

In seconds, the Demon and Integra provide parallel printer ports with full SCSI connectivity, while maintaining concurrent printing capability.

Shuttle's existing pocket adaptor has sold over 50,000 units since its introduction in March 1993. OEM customers include Fujitsu, Panasonic, NEC and Toshiba. Contact: Shuttle Technology, Tel: (0734) 770441.

WordPerfect 3.1 for Macintosh

WordPerfect Corporation is announcing the development of WordPerfect 3.1 for Macintosh, an upgrade that adds new features and offers increased support for Apple system software technologies. WordPerfect 3.1 for Macintosh is scheduled to ship this autumn in the UK and will include features and enhancements such as QuickCorrect, enhanced merge data options, and a fat binary installation option for network administration. The product will also include support for new Apple system technologies such as Quickdraw GX printing, Macintosh Drag and Drop, and Apple Guide. Contact: WordPerfect, Tel: (0932) 850 505.

Bigger Orange

The Orange GSM network is getting wider, now covering 35 million people in the UK – almost 60% of the population.

Since its launch in April, the Orange service has been growing rapidly and has now reached Leeds, Penistone, along the M50 to Ross-on-Wye, and Stansted Airport.

Orange expects this growth to continue, reaching 70% of the population by the end of the year. Contact: Orange, Tel: (0121) 606 6850.

The Hills are Alive with Mobiles

Two walkers, lost last month on a Lake District peak used a mobile telephone to summon the local mountain rescue team. The couple, from the Darlington area, dialled 999 when mist descended upon them as they walked above Easedale Tarn, Grasmere.

Stuart Hulse, leader of the Langdale and Ambleside Mountain Rescue Team, condemned the incident: "This is the second incident of its kind – it's all getting a bit silly, really."

Budget Notebook

Twinhead has launched a low-budget SlimNote Classic VESA local bus notebook bundled with a free Canon BJ10SX Bubblejet portable printer for £999.

The special offer is directed at users who want a low-cost notebook that gets back to simple basics delivering performance and portability without the added baggage of expensive technologies sometimes not required on a notebook.

The SlimNote Classic utilises an Intel 486SX processor running at 33MHz, 120MB hard disk drive and 4MB RAM user-expandable to 20MB. The system benefits from a sharp monochrome 10in. diagonal liquid crystal display (LCD) with 512KB video RAM. The screen displays a 64 shade VGA greyscale resolution of 640 × 480 pixels.

The SlimNote Classic weighing only 5·5lbs is powered by a removable Nickel Cadmium battery (Ni-Cd) which powers the system for around 3·5 hours. In order to increase battery life the system benefits from a suspend mode. Suspend mode turns the screen off, powers the hard disk drive down which reduces the computer's energy consumption to a minimum.

The system is supplied complete with internal 3·5in. floppy disk drive, MS DOS 6.2, MS Windows 3.1, mouse or an optional internal trackball, carry case and a one year on-site warranty. Contact: Twinhead, Tel: (0256) 811366.

Perfect Timing

Reluctant anoraks will love this one. Timex plans to launch a wristwatch that can download diary data from Microsoft Schedule Plus. The benefit? Well, you will be able to check messages to yourself while on the move.

Data is loaded via a bar-code system by holding the watch up to the desktop screen. By pushing minute buttons on the face of the watch, the user will be able to scroll through personal entries.

Called Data Link, the wristwatch will sell in computer stores in late-autumn from around US$130. Contact: Timex Corporation, Tel: (0181) 567 7733.

New Antenna Test Facility

A new type of antenna test facility has been commissioned by Siemens Plessey Systems at Cowes, Isle of Wight. The cylindrical near field test facility uses a probe in a 36m-high tower to measure the radiation pattern of the antenna under test.

Precise positioning of the probe is critical and a laser-controlled system is used to maintain alignment of the probe through its vertical travel. Contact: Siemens Plessey Systems, Tel: (0202) 404418.

Smart Card Information

Smart cards are the subject of a report recently published by the Institution of Electrical Engineers. Priced £40, the pack includes technical papers, book listings, reports and conference proceedings, International, European and British Standards, European smart card suppliers, market data and details of relevant European conferences.

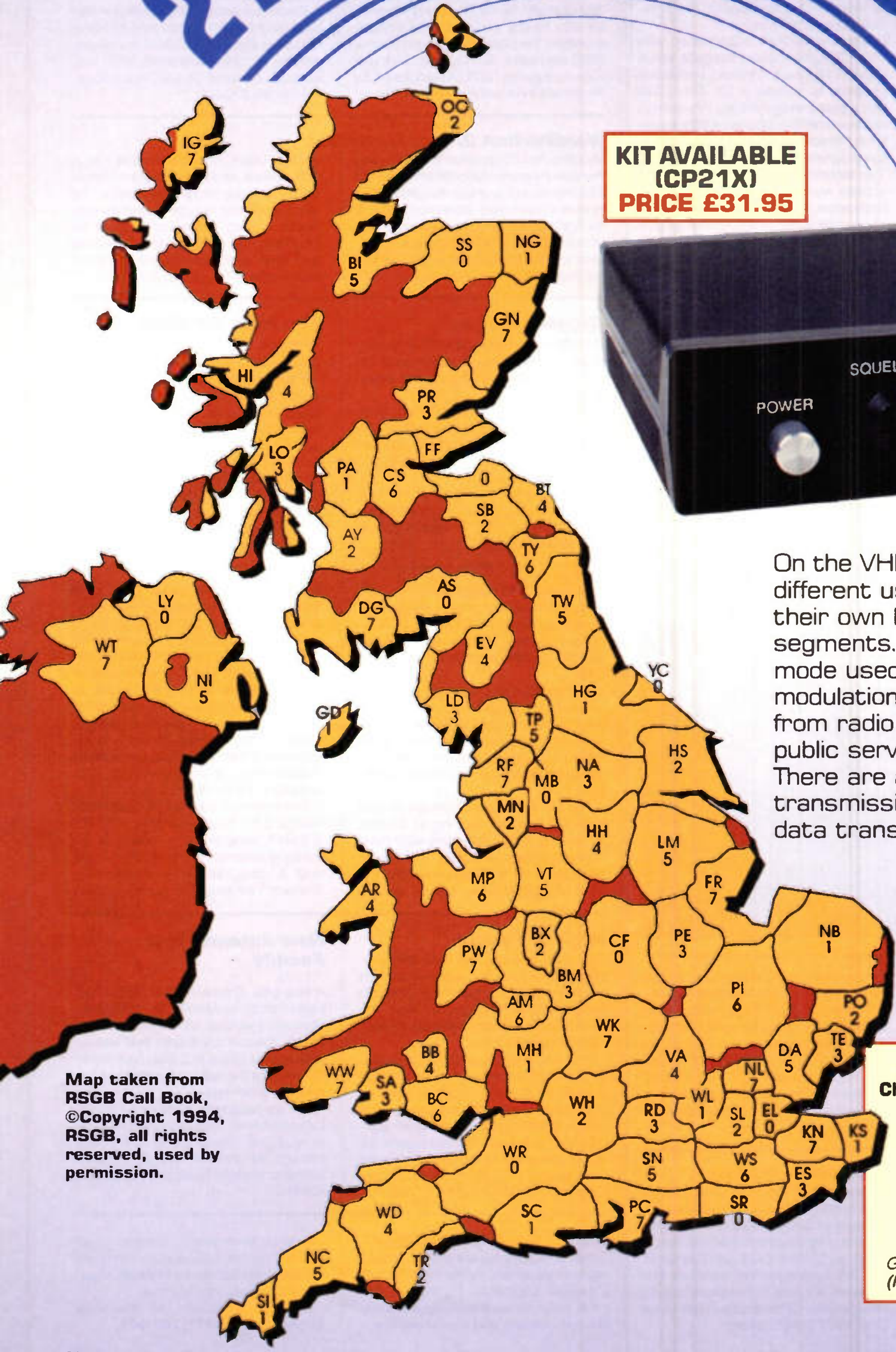
Contact: Institution of Electrical Engineers, Tel: (0171) 240 1871.

Text by Robin Hall G4DVJ

PROJECT RATING 2

2 Metre FM Receiver

* EASY TO BUILD * VARICAP DIODE TUNED * SQUELCH CONTROL



KIT AVAILABLE (CP21X) PRICE £31.95

On the VHF band there are many different users, and each have their own band segment, or segments. The most common mode used on VHF is frequency modulation (FM). The users range from radio amateurs, shipping, public services, and the police. There are a whole host of voice transmissions, and these days, data transmissions as well.

Please note the case shown above is not included in the kit and must be purchased separately.

Map taken from RSGB Call Book, ©Copyright 1994, RSGB, all rights reserved, used by permission.

2m repeater frequencies

Channel	Input	Output
R0	145·000	145·600
R1	145·025	145·625
R2	145·050	145·650
R3	145·075	145·675
R4	145·100	145·600
R5	145·125	145·625
R6	145·150	145·650
R7	145·175	145·675
GB3SF (PSSB)	*145·185*	*145·785*

Specification of 2m FM Receiver

DC power supply source:	+9V PP3 battery
Supply current min to max:	20mA to 125mA
Frequency range:	135MHz to 175MHz
High Intermediate Frequency:	10·7MHz
Low Intermediate Frequency:	455kHz
Reception mode:	Frequency Modulation
Rated loudspeaker load impedance:	8Ω
Audio output power:	200mW into 8Ω
PCB size:	120 × 102mm

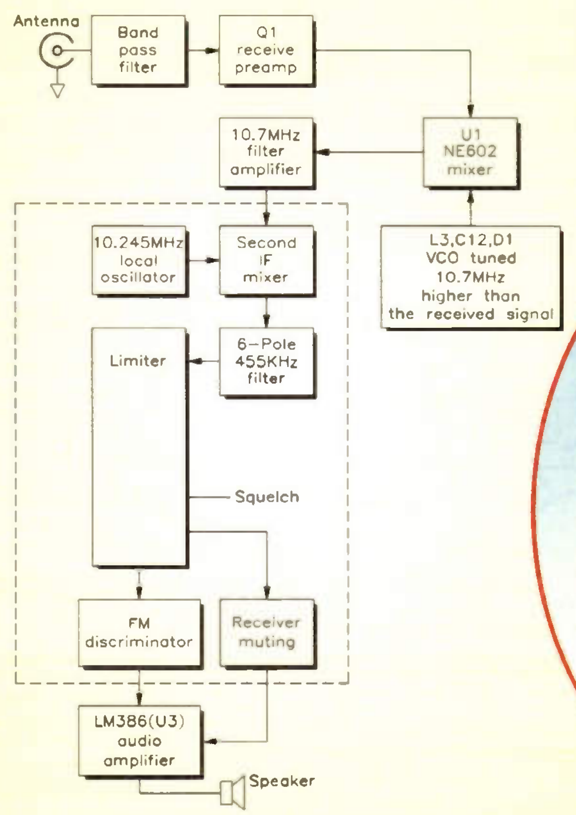
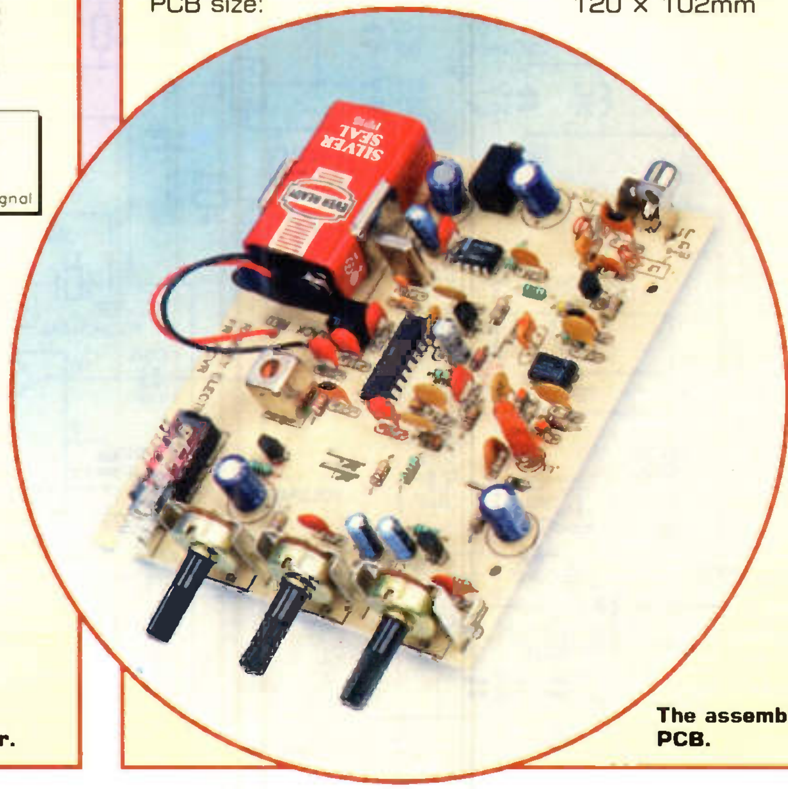


Figure 1. Block diagram of the 2m FM Receiver.



The assembled PCB.

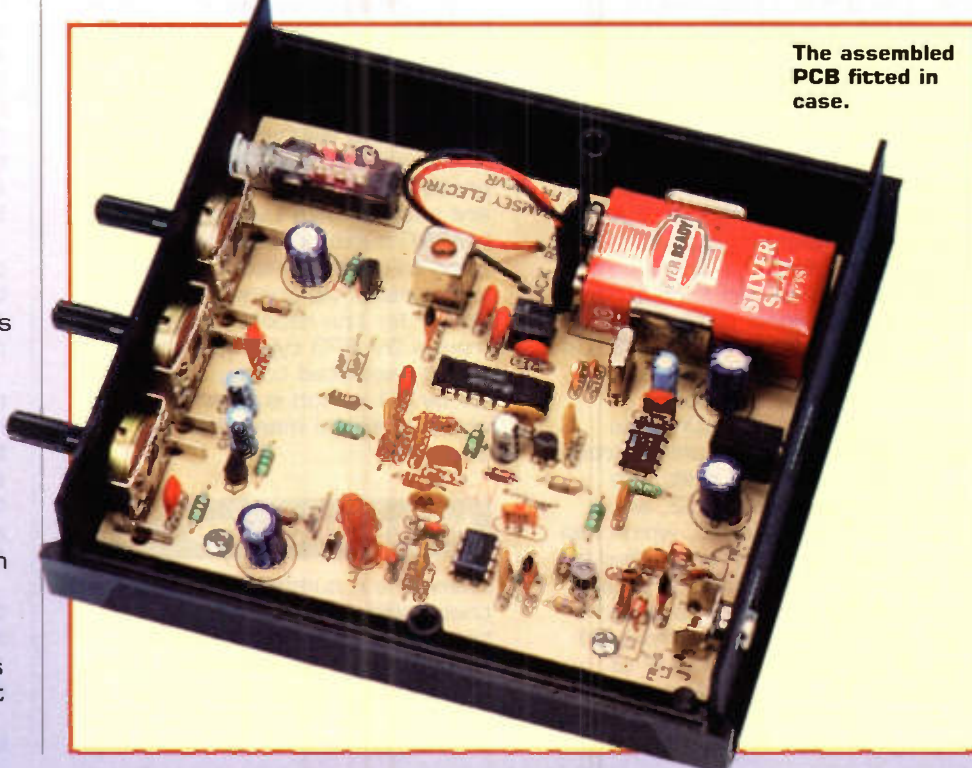
Generally, reception of just one of these groups, such as by radio amateurs is a complete hobby in itself, but in these days of wideband coverage receivers and scanners, it has meant that reception of other band users is possible, whether deliberately intended or not.

There are a variety of receivers available for the radio enthusiast, and as stated there are a number of modes used on the VHF band, with FM the most common. Receivers and scanning type receivers intended for use on these bands must be capable of demodulating these modes. Advancement in microchip technology has made a big impact on receivers as elsewhere. There are some very sophisticated pieces of equipment available, some of which can scan outside the band, and use other modes, such as amplitude modulation (AM), or single sideband (SSB). In fact one does not require an expensive scanning receiver in order to pick up FM transmissions, and a dedicated receiver such as the 2m FM Receiver (CP21X) presented here, can be used, either by a hobbyist just starting out, or by a dedicated enthusiast who wants to monitor a local frequency whilst keeping a scanning receiver or transceiver free.

Circuit Description

Figure 1 shows the block diagram for the 2m FM Receiver and Figure 2 shows the circuit diagram. These diagrams and the following circuit description will assist the reader in understanding the operation of the receiver. In the unlikely event of the receiver failing to operate as expected, this information will also assist fault-finding.

The antenna connects to J1 and the RF signal passes through the tuned input circuit L1, C3 and L2, C4 via C1, C2 and C5 to Q1, a 2SC2498 NPN bipolar transistor,



The assembled PCB fitted in case.

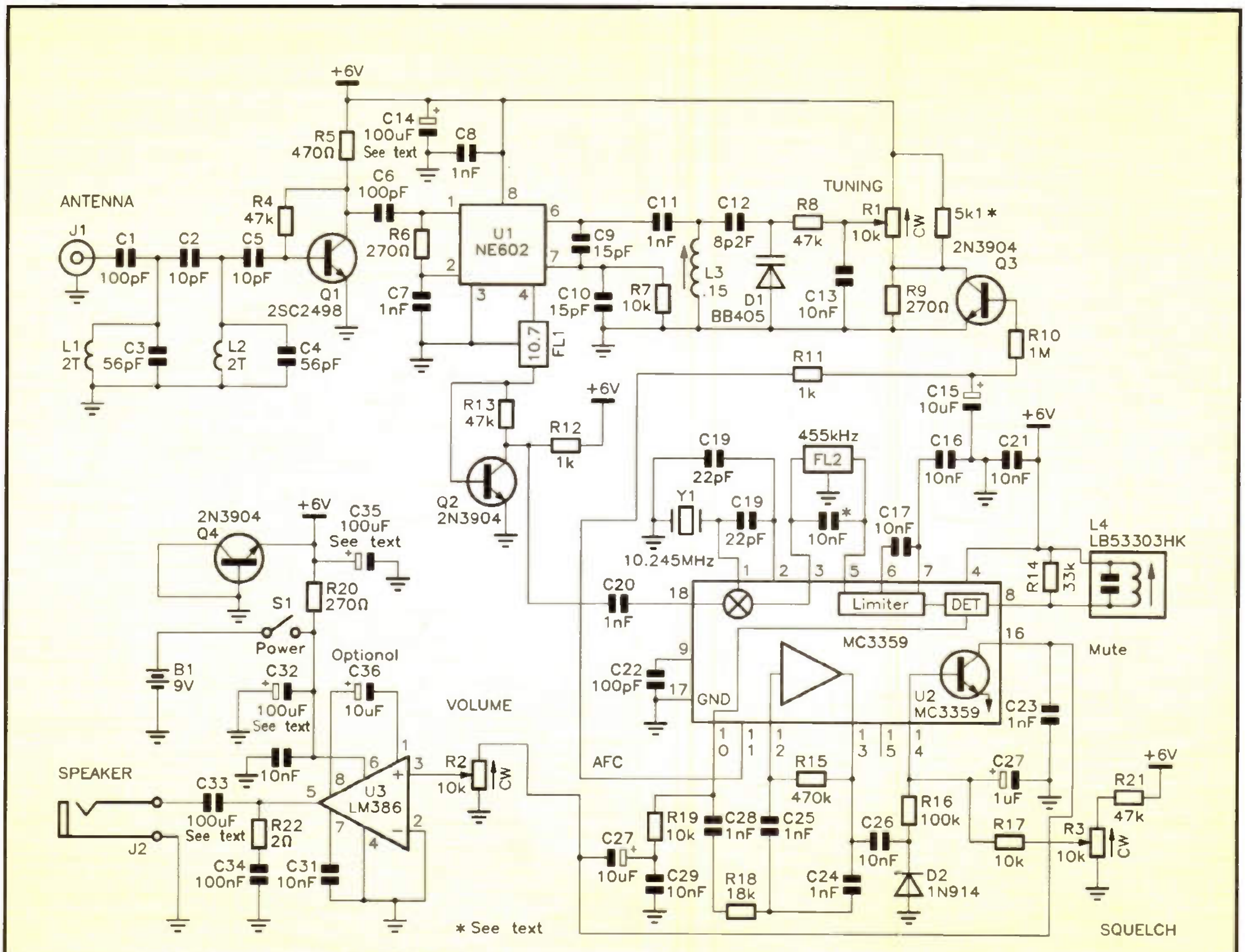


Figure 2. Circuit diagram of the 2m FM Receiver.

where the RF signal is amplified. The RF signal now passes via C6 to U1, an NE602 mixer-product detector-oscillator IC. L3 and associated components form the local oscillator, the frequency of which is set at 10·7MHz *higher* than the desired incoming RF signal. D1 is a BB405 or BB505 varicap diode, and is tuned by the voltage taken from R1, a 10k potentiometer. The local oscillator tuning range being over 5MHz. FL1 is a 10·7MHz ceramic filter and the *difference* signal (obtained by mixing the local oscillator and incoming RF signals) passes through this filter to Q2, a 2N3904 NPN bipolar transistor, where the IF signal is amplified.

Transistor Q3, another 2N3904, provides automatic frequency control (AFC) for the local oscillator U1, by adjusting the tuning of the varicap tuning circuit to oppose any signal drift. The signal then passes to U2, an MC3359 IF amplifier IC, which has an internal oscillator controlled by an external 10·245MHz crystal. The 10·245MHz signal is mixed with the 10·7MHz input from U1 and converted to the low IF of 455kHz. The 455kHz IF is filtered by FL2 and then amplified by a limiting amplifier in U2. Audio demodulation takes place in the quadrature detector, with L4 adjusting the detector. Audio modulation is detected in U2, and is used to control the mute circuit to eliminate background noise. R3, the squelch control sets the mute level. The audio output is amplified by U3 to a suitable level to drive a loudspeaker or headphones. Pin 16 of U2 grounds the input of U3 when the squelch is closed. R2 acts as the volume control.

The audio signals, after being processed by the various stages, are passed onto U3, which is an LM386 audio power amplifier IC used to drive the external 8Ω loudspeaker via connector J2. Power for the receiver is supplied from a 9V PP3 type battery and shunt regulated to approximately 6V by Q4, which is used in an unconventional manner as a Zener diode.

Hints and Tips

There are a number of suggestions that could enhance the use of the receiver preferably before completion of construction. Using IC sockets is generally a good practice but not essential. They are not provided in the kit, and if they were to be used, would require two DIL 8-pin sockets (BL17T), and one DIL 18-pin socket (HQ76H).

The audio output is via a mono 2·5mm jack socket, and an external 8Ω loudspeaker or 8Ω headset with a 2·5mm jack plug is required. Again, a recommended modification is to change the 2·5mm jack socket to the more common 3·5mm jack socket. It may be found that it is necessary to hard-wire the connector since the PCB pin spacing will probably be different.

It is desirable to add a 10nF capacitor across the supply pins to U3, the audio amplifier IC; connect it to pins 6 and 4 on the underside of the PCB.

If the tuning range is found to be rather wide for the frequency covered required, then the voltage to the varicap should be limited such as by a resistor. One way to limit this voltage is by putting a 5k1 resistor in parallel with the 10k tuning potentiometer.

Another tip, is that if it is found that the bandwidth is too narrow for your reception, is to place a 10nF capacitor across the 455kHz FL2 filter.

Optional extras not included: 8Ω loudspeaker (RU73Q) and 2·5mm jack plug (JK00A), which would have to be fitted instead of the moulded 3·5mm jack plug (or alternatively an 8Ω earpiece (LB23A) with fitted 2·5mm jack plug); PP3 type 9V battery (JY60Q).

The aerial connector, although adequate for a single dedicated aerial, may not be useful if one wanted to change aerials, especially if there was another aerial available using the BNC or PL259 type of connector. Adaptors such as a BNC Female to Phono Plug Adaptor (FE88V) or a UHF Female to Phono Plug Adaptor (FE89W) are ideal for this purpose. The receiver can operate using an indoor aerial, but better performance will be obtained from a suitable outside aerial, such as a discone (CM09K) and 50Ω coaxial cable (XS51F) – length as required.

There are a number of aerials available that are intended for the VHF/UHF amateur bands but are also ideal for wideband reception on other portions of the VHF/UHF bands, such as the Diamond X-30 Base Co-Linear Aerial (CP00A).

To finish off, there is a pre-drilled case available (CP20W) for the kit, which includes knobs, feet and fixing screws; it is very easy to fit the receiver PCB into this case so it is the ideal choice if you have limited workshop facilities. There are a number of other boxes available from Maplin that are equally suitable with some drilling.

Construction

The 2m FM Receiver kit includes all the components required to build the receiver PCB. It is a good idea to sort out and identify the components before soldering them in place. This way one gets to know the values and check to see if any are missing, or identify the components before soldering them in position. Figure 3, which shows the PCB legend, will assist PCB assembly. It is best to start off by fitting and soldering the *larger* components first, such as switches, jack sockets and potentiometers. Note that this is contrary to our normal recommendation and is based on Ramsey's recommended assembly sequence and check-list.

Next identify and fit the coils and transformers, also the ceramic filter which has three leads. Identify the different types of diodes and fit these on the board making sure that they are orientated correctly. With wire offcuts, shape and solder in the jumpers. Next fit the resistors, preshaping the leads before fitting and soldering them in place. Identify and fit the capacitors, starting off with the ceramic and

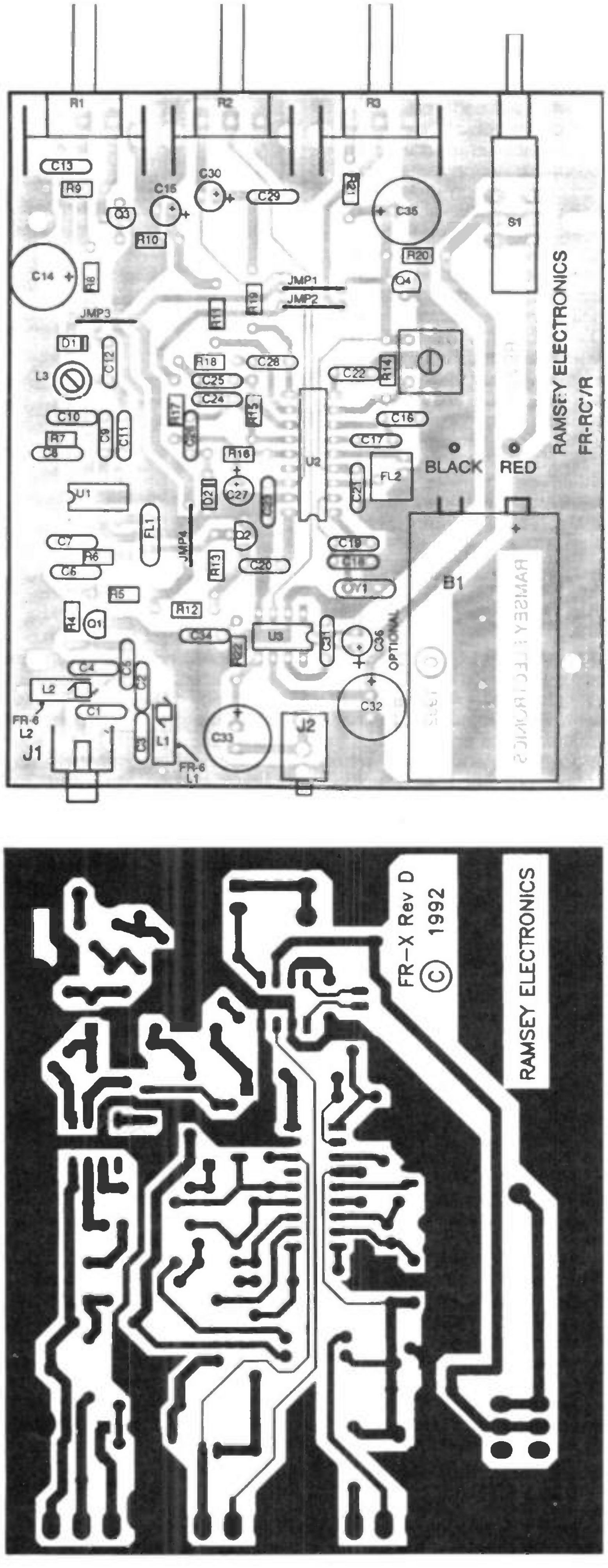
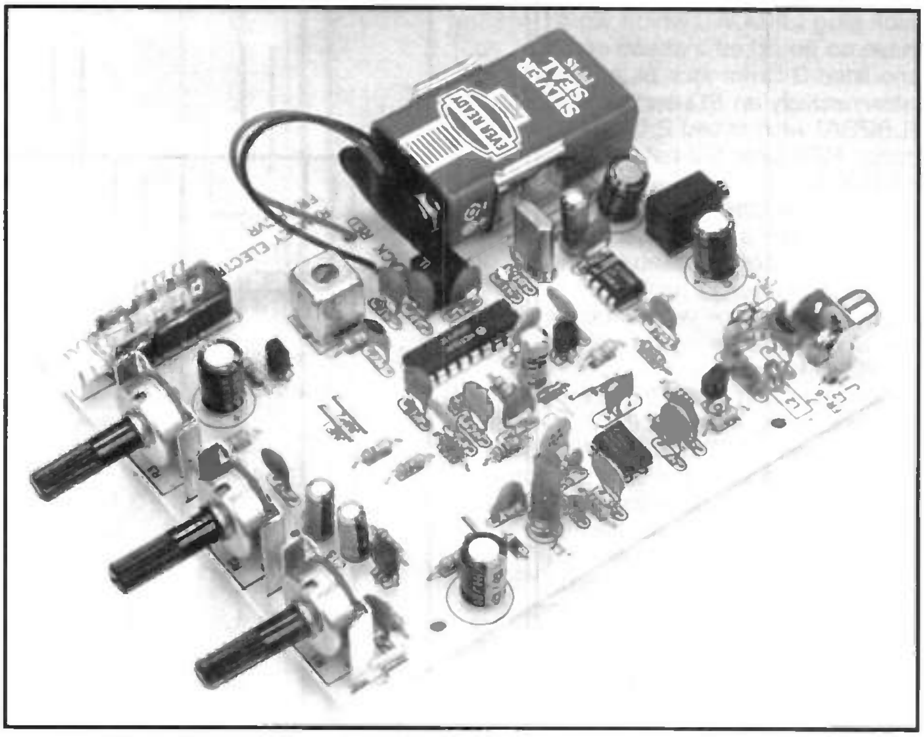


Figure 3. PCB legend and track.

then the electrolytic types which are polarised; these should be correctly orientated on the board – refer to the legend. Identify the ICs and solder them in position, or if sockets are being used, solder these in place instead, making sure that the notch at the top is correctly orientated on the board. The battery clip connector should be soldered in position making sure that the red wire goes to the (+) side as shown on the PCB drawings. Finally with another off-cut of wire, solder in position the PP3 battery holder; do not use too much solder on the holder or the battery will not fit properly.

There are very good instructions for the kit, and they show a logical path to follow. If you are new to project building, then refer to the Constructors' Guide (order separately as XH79L) for helpful practical advice and hints on how to solder, component identification and the like.



Setting Up and Operation

Setting up the 2m FM Receiver is fairly straightforward and can be done with the minimum of test equipment. After making sure that all the components are in their correct positions, and that there are no shorts or whiskers of solder on the board, connect a suitable aerial to the aerial socket, an 8Ω speaker or headphones to the 2·5mm audio socket and finally a PP3 type 9V battery to the power connector, making sure that the switch S1 is off at this point.

The desired tuning range is determined by L3 and adjustment must be made using a non-magnetic trimming tool – *not* a screwdriver. When adjusting cores make sure that not too much force is used as it is easy to crack the cores. Using the trimming tool, turn the core within L3 until it is at the top of the coil former, then turn the core 7 turns clockwise into the coil former. Next turn the core within L4 until it is at the top of the former, turn the core 2 turns into the former. Set the tuning control R1, the volume control R2 and the squelch control R3 fully anti-clockwise at this stage.

Now switch on S1 and advance the volume control R2 until background noise is heard in the loudspeaker or headset. If the receiver does not produce noise then immediately switch off and recheck the circuit. If all is well adjust L4 for maximum noise in the speaker, and now tune the receiver by rotating R1, which will produce signals up and down the band.

If by these procedures you fail to locate the signals you require, such as radio amateur transmissions, then carefully tune L3 fully clockwise; at some point aircraft band signals will be heard. The signals will sound distorted as are AM not FM! Having found the aircraft band stations in the frequency range 118MHz to 135MHz, rotate L3 gently anti-clockwise; depending on where you are located you may hear amateur packet stations on 144·625 to 144·675MHz. If all is correct then the tuning range can now be set up as desired.

If a frequency counter is available, then with the tuning control fully anti-clockwise the local oscillator can be set 10·7MHz higher than the desired lowest signal frequency. A signal generator or transceiver on low power can then confirm that the receiver aligned correctly.

Now using the main tuning control rotate R1 over its range to see if there are any stations. Once stations are found then the quadrature coil L4 can be used to peak up the signals. It is better to find a station at the centre of travel of the main tuning control, and peak up on that, rather than on the band edge. It should be noted that radio traffic on the amateur band is likely to be spasmodic, and it might take a number of transmissions in order to get this right.

The 2m amateur radio band in the UK is between 144 to 146MHz; there are of course other types of transmissions outside this band. The marine FM band is from 156 to 163MHz. Once the frequency range has been decided and set up on the receiver, to assist in frequency selection, it is advisable to make up a suitable logging scale and stick it in position, showing where the stations are on the dial.

Further Reading

There are of course many books to read on radio and amateur radio in particular. Other books on all aspects of the hobby such as typical receivers, scanners and suitable aerials, frequency allocations and stations are available. As a start some books that could be useful for the enthusiast are:

The VHF/UHF Scanning Frequency Guide by Bill Laver (WT70M).

Radio Amateur and Listener's Pocket Book by Steve Money (WP91Y).

An Introduction to VHF/UHF for Radio Amateurs by Ian Poole (WS93B).

Marine UK Radio Frequency Guide by Bill Laver (WT71N).

In Issue 76 of *Electronics* an article entitled 'What are Scanners?', by Ian Poole covered many aspects of VHF and UHF reception, and provided general information, such as details of frequency spectrum, aerials and feeders.

Contacts

There are many clubs and societies for the radio enthusiast, ranging from the broad field of amateur radio, to the more dedicated clubs devoted to one type of mode or particular band. For the general radio amateur or listener, there is the Radio Society of Great Britain (RSGB), which publishes *RadCom*.

Acknowledgment

Thanks to Waters & Stanton Electronics of Hockley for supplying the 2m FM Receiver.

2m FM RECEIVER PARTS LIST

RESISTORS: All 5% Metal Film (Unless specified)

R1-3	10k Potentiometers	3
R22	2Ω	1
R6,9,20	270Ω	3
R5	470Ω	1
R11,12	1k	2
R7,17,19	10k	3
R18	18k	1
R14	33k	1
R4,8,13,21	47k	4
R16	100k	1
R15	470k	1
R10	1M	1

CAPACITORS

C12	8p2F Metallised Ceramic	1
C2,5	10pF Metallised Ceramic	2
C9,10	15pF Metallised Ceramic	2
C19	22pF Metallised Ceramic	1
C3,4	56pF Metallised Ceramic	2
C1,6,22	100pF Metallised Ceramic	3
C18	220pF Metallised Ceramic	1
C7,8,11,20, 23-25	1nF	7
C13,16,17, 21, 26,28,29,31	10nF	8
C34	100nF	1
C27	1µF 50V Electrolytic	1
C15,30,36	10µF 25V Electrolytic	3
C14,32,33,35	100µF 35V Electrolytic	4*

* This value may be changed, i.e. 100µF to 220µF

SEMICONDUCTORS

Q1	2SC2498	1
Q2,3,4	2N3904	3
U1	NE602	1
U2	MC3359	1
U3	LM386	1
D1	BB405 Varicap Diode	1
D2	1N418/1N914 Silicon Diode	1

INDUCTORS AND FILTERS

L1,2	Pre-wound 1½-turn Wire Coils	2
L3	3½-turn Iron Dust Core Tuned Coil	1
L4	Shielded 10·7MHz Transformer	1
FL1	10·7MHz Ceramic Filter	1
FL2	455kHz Ceramic Filter	1

MISCELLANEOUS

	PCB	1
	10·245MHz Crystal	1
S1	PCB Mounting Latchswitch DPDT	1
J1	PCB Mounting Phono Socket	1
J2	PCB Mounting Mono 2·5mm Jack Socket	1
	PP3 Battery Clip Connector	1
	PP3 Battery Mount	1

OPTIONAL (Not in Kit)

RESISTOR	5k1 (See text)	1	(M5K1)
CAPACITOR	10nF (See text)	2	(BX00A)

MISCELLANEOUS

2m FM Receiver Plastic Case (Includes Knobs, Feet and Screws)	1	(CP22Y)
Discone Aerial	1	(CM09K)
Diamond X-30 Base Aerial Co-Linear	1	(CP00A)
50Ω Coaxial Cable	As Req.	(XS51F)
Phono Plug	1	(HQ54J)
SP-140 Mobile Speaker 8Ω	1	(RU73Q)
2·5mm Mono Jack Plug	1	(JK00A)
Non-magnetic Trimming Tool	1	(BR51F)
8Ω Magnetic Earpiece	1	(LB23A)
9V PP3 Battery	1	(JY60Q)
DIL Socket 8-pin	2	(BL17T)
DIL Socket 18-pin	1	(HQ76H)
Constructors' Guide	1	(XH79L)

The Maplin 'Get-You-Working' Service is available for this project.
The above items (excluding Optional) are available in kit form only.
Order As CP21X (2m FM Receiver) Price £31.95
Order As CP22Y (Case CRF) Price £14.95
Please Note: Some parts, which are specific to this project (e.g., PCB), are not available separately.

QUO VADIS? Computers and Information – *Continued from page 21.*

of monitoring and peace keeping. Computers are used to process intelligence information and so will continue to be required.

There will be increased emphasis on smaller, highly mobile units. These will use advanced electronics for communications and be able to handle the large amounts of sensor data.

Future tactical aircraft will only have one seat. The pilots will not have time to evaluate the incoming sensor data, and so neural computers will be used to aid in this task. Computers are already used to aid in the control of modern aircraft.

Conclusion

Soon, beams of laser light will carry information across oceans and into local area networks, even into the integrated circuits of our computers. Laser diodes, holograms, and optical switches will be the building blocks of tomorrow's computers. So far, progress in optical electronics may be compared to the history of electronics up to the early 1960s. A factor holding back change is the relatively high cost of these devices. Mass production by the semiconductor industry will lower cost, and stimulate consumer demand.

Much of this technology originated in Britain; the first computer was designed by a Londoner. But, it has been exploited commercially by other countries. Japan is investing in every area of computing technology.

There is no doubt that technology has contributed to unemployment. We could cease further development, but our neighbouring countries will not do likewise. As it stands, by the end of the decade we may still have to buy all our telephones and computers from Japan. Technology should be used to help business by achieving greater efficiency. Global networks enable small firms to communicate effectively with customers on the other side of the world; many high-technology firms rely on orders from abroad for their survival.

Information technology may lead to a situation where our daily actions are open to scrutiny by strangers; movements could be tracked and purchases recorded. George Orwell created a nightmare vision of a totally controlled society, but this could only occur if all communications were controlled by the government – an increasingly unlikely event. Public access to computing and communications devices is greater than it has ever been. To monitor is not the same as to control.

One drawback of this technology is the potential for abuse in the form of pornography, junk mail, and invasion of privacy. Public use of communications networks may result in an explosion of software piracy. Digital techniques may mean that music and films can be copied without loss of quality, and distributed anywhere in the world.

A balance will have to be struck when deciding how the new technology is to be used, but it seems that the benefits far outweigh the problems that may be caused.

What's On?

NoteStation Strikes the Right Chord at British Music Fair

Music and machine in perfect harmony is an ideal way to describe NoteStation, a user-friendly kiosk which allows you to browse through an electronic library of songs at the touch of a display screen.

From Bach to Led Zeppelin, NoteStation contains thousands of song titles stored on CD-ROM to bring music to your ears and high-quality sheet music to your hands.

As well as printing sheet music, NoteStation can also provide songs in the general MIDI format, compatible with personal computers and a variety of MIDI equipment.

This year saw NoteStation's birthday launch at the BMF as a fully European system. It now supports five languages: English, French, German, Italian and Spanish. Store owners can choose to show all languages or any combination.

International Music Publications, the UK agent for NoteStation, is also committing 250 of its best-selling songs to be included on NoteStation at its BMF birthday bash. Two hundred more titles will follow every month.

NoteStation is an innovative creation which will allow you to choose a song by title, artiste, composer or music style. The first page of sheet music is displayed on screen and NoteStation will also play the most familiar bars of the arrangement in the original key.

To change the key, you simply touch the screen and NoteStation will transpose the song into the new key and play it back to confirm your choice.

When you have selected a song, and customised it as desired, NoteStation prints it out as high-quality sheet music or provides it on MIDI format – eliminating the need for shops to carry vast quantities of sheet music. Contact: International Music Publications, Tel: (0181) 551 6131.

Get Online for '94

The Online/CD-ROM Information 94 Exhibition taking place at Olympia 2, London, from 6 to 8 December, is claimed to be the largest presentation of electronically available information products in the world. An alliance that sees authors, musicians, directors and producers joining together with engineers, to exploit the technological creativity of both parties.

As last year, an integral part of the exhibition will be the Internet Village. This is a state-of-the-art collection of products and services presented by some of the Internet's key suppliers such as Pipex and ORBIT. Situated in the main exhibition hall, the Internet Village will provide an insight into what's currently available on the Internet, and how to secure access. Contact: Online 94 Information, Tel: (01865) 730275.

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.

4 October. Talk on Electrical Safety and Regulations, Sudbury and District Radio Amateurs. Tel: (01787) 313212.

4 to 6 October. EDI 94, ICC, Birmingham. Tel: (0181) 742 2828.

10 October. Inside your PC by Martin Rhodes G3XZO, Stratford-upon-Avon and District Radio Society. Tel: (01789) 740073.

11 to 13 October. Voice 94, Olympia, London. Tel: (01733) 575 020.

15 to 16 October. Warley National Model Railway Exhibition, National Exhibition Centre, Birmingham. Tel: (0121) 558 8851.

24 October. QRP by Norman Field G4LQF, Stratford-upon-Avon and District Radio Society. Tel: (01789) 740073.

26 to 27 October. Instrumentation, Sandown Exhibition Centre, Sandown. Tel: (01822) 614671.

26 to 28 October. PEVD '94, Power Electronics & Variable Speed Drives Conference, Institution of Electrical Engineers, London. Tel: (0171) 240 1871.

1 November. Talk & Demonstration on First Aid by St. Johns Ambulance, Sudbury and District Radio Amateurs. Tel: (01787) 313212.

1 to 3 November. Windows Expo, Olympia, London. Tel: (01256) 381 456.

5 to 6 November. Eighth North Wales Radio and Electronics Show, Aberconwy Conference Centre & The New Theatre, Llandudno. Tel: (01745) 591704.

14 November. 'Operation Raleigh' by John Leyton G4AAL, Stratford-upon-Avon and District Radio Society. Tel: (01789) 740073.

28 November. 'Microphones' by Jack Cluley G4YIG, Stratford-upon-Avon and District Radio Society. Tel: (01789) 740073.

1 to 4 December. Christmas Computer Shopper Show, Grand Hall, Olympia, London. Tel: (0181) 742 2828.

6 December. Open Forum – Questions & Answers on Anything Related to Amateur Radio, Sudbury and District Radio Amateurs. Tel: (01787) 313212.

6 to 8 December. Online/CD-ROM 94 Exhibition, Olympia 2, London. Tel: Online 94 Information. Tel: (01865) 730275.

12 December. Open house/Night-on-the-air – Visitors most welcome, Stratford-upon-Avon and District Radio Society. Tel: (01789) 740073.

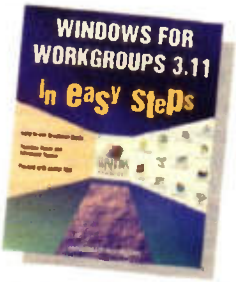
Please send details of events for inclusion in 'Diary Dates' to: The News Editor, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex SS6 8LR.

NEW BOOKS

Windows for Workgroups 3.11 In Easy Steps

by Harshad Kotecha

Windows is the most popular graphical environment being used on personal computers (PCs) and Windows for Workgroups 3.11 is the latest version of Windows. It provides an easy to use networking facility as well as much improved performance for Windows users. Like other titles in the 'Easy Steps' series, the book is enjoyable to read and provides a cost-effective training guide. By combining stunning Windows screen shots, exactly as they appear in the software, with simple, clear instructions on how to perform specific tasks, the book is easy to follow and understand. Text is clear and concise with no unnecessary long-winded explanations.



The book starts from basics and guides the reader through to the more advanced topics such as network drives, sharing printers, using Mail and Schedule, customising Windows for workgroups and object linking/embedding. An attractively priced book and a must for all those upgrading or using Windows for Workgroups 3.11.

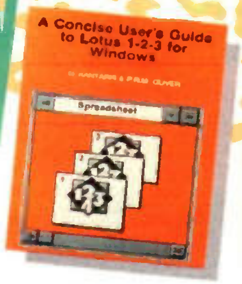
1994. 200 pages. 227 x 186mm, illustrated.

Order As AA94C
(Win For Wkgroups3.11) £14.95 NV

A Concise User's Guide to Lotus 1-2-3 for Windows

by N. Kantaris & P. R. M. Oliver

Written for the newcomer to spreadsheets, as well as the experienced spreadsheet user, this book aims to cover all the basics necessary to get the most out of Lotus. The material in this book is helpfully arranged so that the novice can start using Lotus right from the onset. Once the beginner understands the basics, along with the more experienced user, he can scan back and forth through the different sections and topics as required. The experienced user will know what they are looking for and can use the book as a tutorial and reference for the more complex spreadsheet problems. For the beginner the book starts in a very basic way, with tasks like how to enter data and edit formulae. As you progress, the tasks get harder and more complicated. You may feel that you cannot cope with the graphing features to start with, but as the



book guides and encourages you, you will feel more able to approach such obstacles. If you should find you do come unstuck, the book can help to show you where you went wrong. Detailed screen dumps act as a guide to help you through the basics as well as the complex operations of a spreadsheet. You will have no problems in understanding concepts as the reasons behind them are always explained. The book always builds on what you already know, so you don't keep going over the same explanations repeatedly. Topics covered by the book include all the basic aspects of a spreadsheet; 3-D worksheets and applications, linking sheets and punching data through from one sheet to another, and graphing facilities. Being an efficient user of Lotus is also important. Understanding how to get the most out of your spreadsheet covers a number of advanced sections: efficient use; printing exactly what you wanted, as opposed to what you got; use of SmartIcons; building, maintaining and debugging databases; macro building, editing and debugging; and using Auditor, Backsolver, What-if Tables, Solver and Version Manager. Even if you already know how to create spreadsheets and use them effectively, with the aid of this book you will be able to increase your productivity, and enhance your spreadsheet's usefulness and versatility.

1994. 159 pages. 198 x 130mm, illustrated.

Order As AN01B
(Concise Lotus123 Win) £5.95 NV

Electronic Board Games

by R. Bebbington

A selection of 20 of the most popular novelty electronic board games. The nature of the electronic components means anybody from young to old can enjoy constructing circuits, testing and finally using them to play games. Simple components like LEDs, resistors, transistors and integrated circuits can be linked together either on strip or breadboard to produce working circuits in just minutes. By using safe components and voltages these projects are suitable and safe for the young; the only possible danger being IC pins. When using breadboard you don't even need a soldering iron. If you use breadboard then you can reuse the parts and build other projects when you wish to move on to the next game. This means that from a small selection of components, all the 20 games could be constructed. Quite a few of the games have variations; that means they can either be configured differently or used in a different manner, so in practice there are more than 20 games. Some of the games involve skill while others involve decision making and leadership. As well as home use, these projects could be adapted for use in schools and colleges, where groups or teams could work together in building and testing them. The book is easy to read, and each separate game project is in a different chapter to keep all the relevant information together. Each project starts with a description of the game and the ideas behind it and describes the way in which the circuit is used to play the game. Circuit construction explains how to assemble the circuit, and describes any tools required. Quite often there are useful hints and ideas that will help with construction. A clear circuit diagram shows how to connect up the circuit, and is clearly labelled with pin numbers, component values and circuit symbols. Connection of items like switched and external LEDs is made much simpler as the terminals have been labelled with

a letter and a number indicating to which hole in the strip or breadboard they must be connected. A full component listing details all the required components, their values and circuit references. A great book for introducing first-timers to electronics, and providing fun for other constructors.

1994. 132 pages. 178 x 110mm, illustrated.

Order As AN05F
(Elec Board Games) £4.95 NV

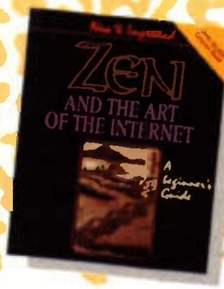
ZEN and the Art of the Internet

by Brendan P. Kehoe

Did you realise that there are over 15 million people worldwide who are interconnected via the Internet? The Internet allows people to 'talk' to each other via computer terminals, and provides numerous other services, including access to a VAST amount of information on just about any subject known to man (including: almost every branch of science; computing; engineering; the arts; and even the latest NASA space pictures!). Internet has joined the ranks of the telephone and television as a technological breakthrough that has fundamentally altered the way people live and work.

This book serves as a very comprehensive and readable introduction to the fascinating world of the Internet. It was the first book to be published for newcomers to Internet.

Subjects covered include: Network basics; Electronic mail (e-mail); Anonymous FTP; Usenet News; Telnet; Commercial Services; Data retrieval tools (including: Gopher; the 'WHOIS' Database; and the 'Wide Area Information Server');



Internet bulletin boards; and many others.

At the back of the book, there is a comprehensive glossary of networking terminology. Also included are detailed appendices, which give information about connection to other networks, retrieving files via e-mail, news-group creation, country codes, and services available via Telnet.

Entertainingly written and well organised, this book will be referred to again and again. Suitable for anyone with basic computer knowledge.

1994. 193 pages. 228 x 152mm, illustrated. American book.

Order As AA88V
(Zen:Art Of Internet) £18.25 NV

Antennas for VHF and UHF

by I. D. Poole

Covers installing and setting up of TV and FM aerials, to multi-aerial arrays for shortwave listening. This book gives all the essential information required in order to obtain the best possible results from an aerial. All the explanations are in easy to read terminology, enabling the reader to understand the technical reasons for installation practices and selection of a particular aerial without the clutter of theory. Advantages of different types of aerial are discussed to ensure you never buy the wrong aerial for the job. The book begins by explaining some basic ideas about aerials and feeders, and why some are better for VHF reception and others more suited to UHF. In addition, specialised aerials for hi-fi enthusiasts are covered. Users of scanning receivers and radio amateurs will also find this book useful, as there is also information covering specific aerial types designed for communications equipment. Practical and helpful hints on erecting an aerial will help you to get the most from your set-up, with the minimum of trouble. In addition to

helping with the positioning, selection and optimisation of aerials the book contains enough detail to enable the enthusiast to start building their own aerials. Information on frequency allocations, how to work out the wavelength, and how this applies to aerials in practice will allow you to make dipole, folded dipole, Yagi, and numerous vertical mobile communication antennas.

1994. 104 pages. 198 x 130mm, illustrated.

Order As AN06G
(Antennas For UHF\VHF) £4.95 NV

by Andrew Chadwick B.A., C.Eng., M.I.E.E.

A Guide to MAINS SAFETY

PART TWO

This series concludes with a look at fire hazards, adopting general precautions, fuses & maintenance

Fire Hazards

The other hazard of mains operated equipment is that of fire (see Photo 6), due to the great amount of heat that can be generated, particularly if a fault occurs. Incidentally, this can also be true of equipment powered by nickel cadmium, lead-acid, or lithium batteries, which have the potential to supply a very large current due to their extremely low internal resistance.

The types of fault likely to cause abnormal heating are: short circuits; component failures; overloads; and high-resistance contacts. The design of equipment should ensure that shock protection is not affected by these faults, and that any heating is minimised. If combustion does occur, then it should be prevented from spreading. The standards prescribe a mixture of good design and suitable protection, such as fusing, in order to achieve this aim (some of the recommendations are described in the following paragraphs). One specific requirement which is applicable to home constructors is that transformers must be protected against short circuits of the secondary windings by means of a conventional fuse in the primary, or a thermal fuse in the windings.

General Precautions

Under normal use, no part of the equipment should reach an excessive temperature. This is tested by running the equipment until temperatures have stabilised, and then checking whether the temperature rise of any part exceeds values defined in the standards.

There should be no risk of parts that naturally run hot causing combustion of surrounding materials. Suitable precautions may have to be taken, such as standing off high-wattage resistors from a PCB. PCB tracks should be capable of carrying their normal current without overheating (suitable minimum widths are shown in Table 4).

Components conforming to British or European standards should be used wherever possible, as these provide a high level of safety and reliability. Components should be operated within their ratings to minimise the risk of failure. When selecting the voltage rating of a component, allow for the worst case value that may arise due, for instance, to variation of the mains supply, or the rise in the secondary voltage of a transformer when off load. Note that the RMS AC voltage rating of a capacitor is only about 70% of its DC rating, so make sure you know which is specified.

Capacitors connected directly between the live and neutral of the mains supply must be of 'Type X' construction. They are designed to withstand the high-voltage spikes that may occur on the mains; if a fault does occur, a Type X capacitor will not overheat or catch fire. Capacitors of 'Type Y' construction may be connected between the live conductor and earth. They are even more robust than Type X, as it is essential that there is no risk of the capacitor becoming a short circuit under fault conditions, because this would create a shock hazard. Type X and Type Y capacitors are often used in filter circuits.

Current (A)	Minimum track width (mm)
<0·5	0·6
0·5 - 1·5	1·6
1·5 - 3·0	3·0
3·0 - 6·0	6·0

Table 4. Minimum widths for PCB tracks.

Short Circuits

There should be adequate insulation between conductors (at different potentials) in order to reduce the chance of a short circuit. As previously mentioned, this is known as operational insulation to distinguish it from insulation providing protection against shock. It should have minimum creepage and clearance distances as shown in Table 2 in Part One.

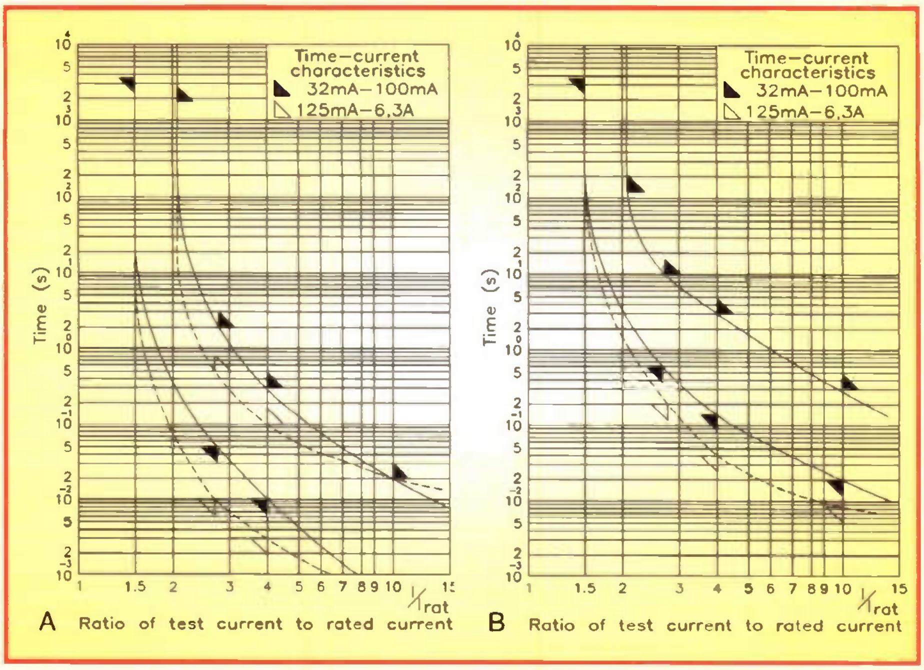
Short circuits normally cause a very high fault current, and so effective protection can be provided by conventional fuses.

Fuses

The rated current of a fuse is the current that it can carry indefinitely. If the current exceeds this value the fuse will not blow immediately, but in a time determined by the magnitude of the current and the type of fuse. Figure 5

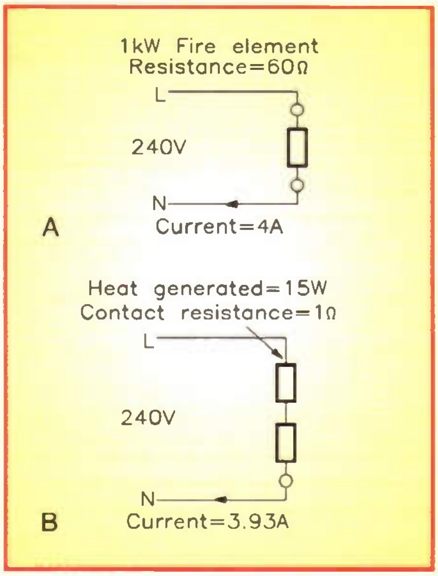
Right: Electrical faults can cause fires.

shows the characteristic curves for two common types of 20 × 5mm fuses. There is considerable tolerance, and the curve for a particular fuse may lie anywhere between the two limits plotted. At low values of overload, it can be seen that the delay before the fuse blows can be considerable. In the time-lag (Type T) fuse, this delay is deliberately increased so that the fuse can cope with circuits in which there is a surge of current at turn-on; transformers are a good example. For normal circuits, quick-acting (Type F) fuses offer better protection. A fuse, whose rating is just greater than the normal current in the circuit, should be used for the best protection. In the case of a mains transformer, the normal current will probably have to be measured, as it is not easily calculated.



Right: Figure 5. Time-current curves for 20 × 5mm fuses (to IEC 127): (a) Type F; (b) Type T.

Below: Figure 6. Calculation of heat generated by a high-resistance contact: (a) Normal operation; (b) With high-resistance contact.



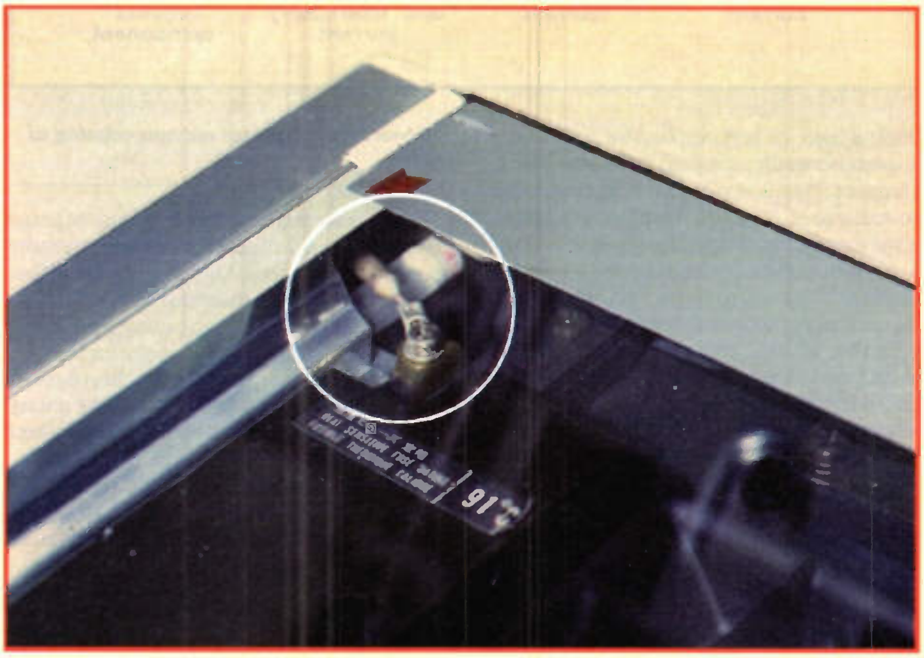
The other important characteristic of a fuse is its breaking capacity. This is the fault current that the fuse can safely interrupt. For the common 20mm fuse, this is typically 35A for the low-breaking capacity 'glass' fuse, and 1500A for the high-breaking capacity 'HRC' or 'ceramic' fuse. The breaking capacity must be more than the prospective fault current; it is the current that would flow into a dead short if no fuse were present, and is therefore the maximum supply voltage divided by the supply impedance. For a typical socket outlet, this could easily be a few hundred amps.

If the above principle is followed, the high-breaking capacity fuse should be used when protecting circuits that are connected directly to the mains. In practice, the standards do permit wiring and components, such as an RFI filter or switch, which are in series with the mains supply, to be protected against short circuit by the building supply or plug-top fuses (which will have the necessary high-breaking capacity).

Overloads

In the case of overloads which do not cause a large increase in current, conventional fuses may not be very effective; thermal fuses can give better protection. These are located where heat is likely to be generated under overload conditions (see Photo 7), a common example being in the windings of mains transformers. Note, however, that thermal overload devices do not normally provide adequate short circuit protection, as their breaking capacity is limited.

Fusible resistors are designed to go open circuit under overload, without risk of fire. They are cheap and can be very useful for the protection of low-voltage circuits, often being used in series with power supply rails.



Above: Photo 7. A thermal fuse in a photocopier.

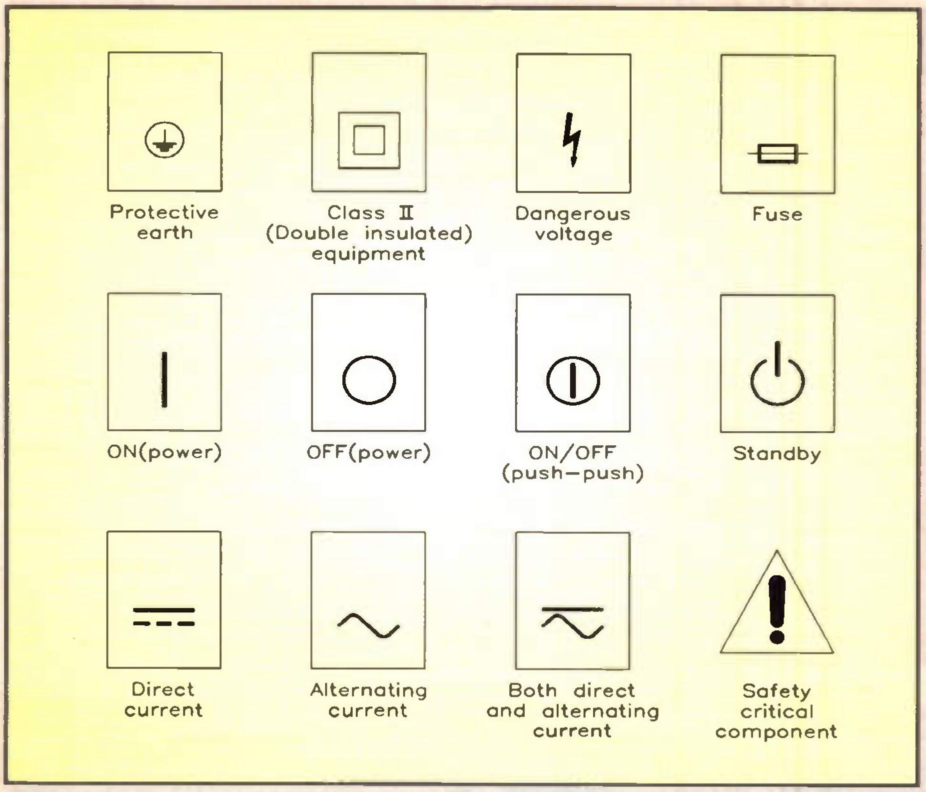
High-Resistance Contacts

A high-resistance contact may not, initially, seem to be a safety hazard, but if it is carrying a heavy current, considerable heat can be generated with a consequent risk of fire. Figure 6 shows how this can occur.

Unlike short circuits and overloads, high-resistance contacts do not result in any increase in supply current, and so conventional fuses are ineffective. The best defence is to take precautions against a high resistance developing in the first place. Connections and terminals should be reliably fastened so that they will not work loose. Consolidating the strands of flexible cable by soft solder before inserting in a terminal is officially banned, as cold flow of the solder can lead to loose connection and the development of a high resistance. Crimp terminals are also a risk if the correct size crimp, or tool, is not used. It is recommended that insulation supporting parts that may develop a high resistance, such as switch contacts, fuseholders and screw terminals, should have a softening temperature of more than 150°C.

Mechanical Construction

It is only commonsense that the case protecting the user from contact with the mains should be of sound construction, so that it can withstand rough handling. BS EN 60950 describes three tests to be applied: The



Above: **Figure 7. Some symbols relating to safety.**

first is a force of 30N, applied for 5 seconds, on parts normally protected by a cover. Then, a force of 250N is applied for 5 seconds over a circular area, 30mm in diameter, to all parts of the external enclosure. Finally, a 500g steel ball is dropped or swung through a vertical height of 1300mm, to impact on any area of the enclosure protecting hazardous parts.

Hand-held equipment must, in addition, be dropped three times from a height of 1m onto a hardwood floor.

None of these tests should cause significant damage, such as exposing live parts or reducing clearance distances due, for example, to denting the case. However, the equipment need not be operational after the tests!

Rated Current I (A)	Normal cross-section (mm²)
I ≤ 3	0·5 *
3 < I ≤ 6	0·75
6 < I ≤ 10	1·0
10 < I ≤ 13	1·25
13 < I ≤ 16	1·5

* Only if length <2m, otherwise 0·75mm² (not allowed at all according to BS 415).

Mains Cords

The standards are very particular about mains cords because of the abuse that they may suffer, and the importance of maintaining the earth connection in Class I equipment.

The cord should have a minimum cross-section as shown in Table 5. It must be anchored by a clamp which relieves strain on the conductors, protects the outer sheath from abrasion, and prevents the cable from being rotated or pushed into the equipment.

Above: Table 5. Cross-sectional areas of power supply cords.
Right: Figure 8. Example of Class I construction.

These requirements preclude the use of knots or string, and clamps that use a screw bearing on the cord. The clamp must incorporate insulating material equivalent to supplementary insulation between the outer surface of the cord and the enclosure. Finally, for hand-held equipment, protection against bending is required where the cord enters the clamp, either by means of a bell-mouthed opening, or a flexible cable protector.

Terminals for the connection of mains cords must ensure that an 8mm strand of wire, not inserted correctly in the terminal, would not reduce the required clearances.

Isolation

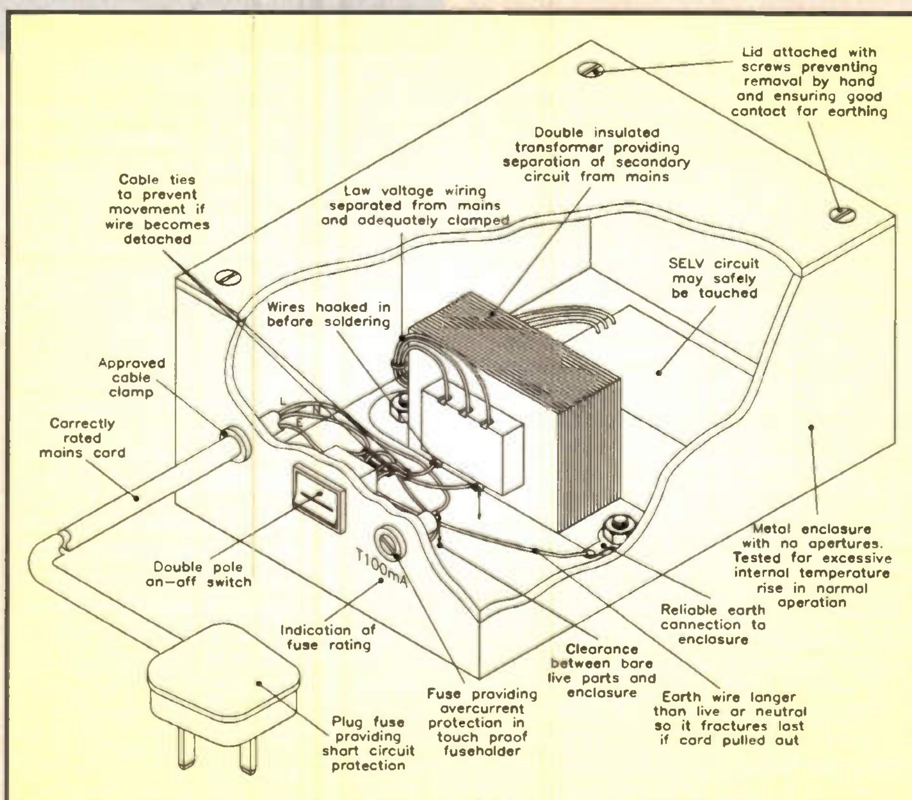
A means for isolating the power, when servicing the equipment, must be provided. This should interrupt both live and neutral conductors, with a contact gap of at least 3mm, and should be as near to the incoming supply as possible. A suitable double pole switch may be used, but a plug on the mains cord, or an appliance coupler, is also acceptable. However, its design must ensure that the earth connection is made first and broken last, as is the case with domestic 13A plugs to BS 1363.

Stored charge may also be a hazard when removing the mains plug from the socket. The standards require that any voltage on the plug pins must have decayed to a safe level within 2 seconds of its removal.

Switching

Isolation is concerned with interrupting the supply in order to avoid shock when working on the equipment. As already explained, this does not necessarily require a switch to be fitted. However, a switch may be required so that the user can remove power from the equipment whilst it is unattended, to reduce, for example, the risk of a fault leading to a fire.

The standards on this issue are fairly complicated, but a double pole switch, fitted as near to the incoming supply as possible, is acceptable in all circumstances. Items, such as fuses and filter capacitors, need not be disconnected by the switch. If the equipment is fed from a mains transformer, then a single pole switch is allowed. If the equipment consumes less than 10W, then no switch is necessary. A functional switch is one that controls the normal operation of the equipment. This includes the main on-off switch, and if this directly disconnects the mains, then no further switch is necessary. However, in



modern equipment the on-off switch often only controls some part of the low-voltage circuitry, leaving the mains wiring live. In this case, a separate switch is necessary unless either the parts that remain live are fed from a transformer and consume less than 10W, or an audible or visual indication shows that the equipment is still live with the on-off switch in the off position. This is the function of the 'standby' indicator frequently fitted to audio and video equipment.

Limited Current Circuits

Certain components are permitted to bridge safety insulation, but they must obviously satisfy stringent requirements of reliability, and must restrict the current that can flow. One common example where this principle is used is in the aerial connection to a TV receiver. The only time this is likely to be of interest to the hobbyist is in the case of a capacitor connected between live or neutral, and earth, which must meet the test requirements for a Type Y capacitor.

Marking and Symbols

There are a number of requirements for marking commercial equipment with basic safety information, such as the supply voltage and current. The only one really relevant to the home constructor is that the rating and type of fuse (e.g. T1A) should be marked near any fuseholders. Figure 7 shows some of the symbols relating to safety which may be seen on commercial equipment.

Examples

The above discussion may seem rather theoretical to some readers, and so I have included two examples showing how the principles might be applied to hobby projects:

Figure 8 shows an example of a typical project built in accordance with the principles of Class I construction. Basic insulation between the case and the mains wiring is provided, mostly, by the PVC insulation. At terminals where bare metal is exposed, the basic insulation is the air gap. This must be at least 2mm, according to Table 2 in Part One, provided it will not be reduced by, for example, bending of the case.

It is debatable whether the fuse should be placed before or after the mains switch. Placing the fuse first means that there will be less damage in the case of a short circuit in the switch. This is because it will be protected by the low-value equipment fuse, rather than the plug fuse. The fuseholder will remain live when the mains switch is off, but this should not be a hazard with a touchproof fuseholder.

Placing all the mains connections at one end of the enclosure, behind the mains transformer, reduces the risk of accidental contact when fault-finding. Rubber boots might also be used on the switch and fuseholder.

Figure 9 follows the requirements of Class II construction using a PCB mounted mains transformer. Mains wiring is all on the PCB, and the clearance between the PCB and the case forms the basic insulation. Table 2 in

Above: Photo 8. Correctly wired mains plug. Below: Figure 9. Example of Class II construction.

Part One suggests this clearance need only be 2mm, but 6mm is a more sensible choice. This allows for the stubs of components, and for the possibility of a loose nut or piece of wire reducing the gap. The plastic enclosure is the supplementary insulation required for Class II construction.

The double insulation, between mains and low-voltage circuits, provided by the transformer will be ineffective unless the PCB provides an equivalent standard of insulation. This means that the creepage and clearance between the mains and the low-voltage tracks must be that of reinforced insulation; a minimum of 5mm. In practice, a far larger distance of 15mm or 20mm would be better.

The plastic PCB mounting pillars are assumed to be fixed by a single screw from below. As the screw will be accessible, it is separated from the mains by, firstly, a distance on the PCB equivalent to basic insulation, and secondly, by the material of the pillar forming supplementary insulation.

Other distances between mains tracks are set by the requirement of 2.5mm for operational insulation in Table 2 in Part One. Note the use of a 5mm pitch terminal block with the centre terminal removed so that the clearance and creepage distances can be readily obtained.

Unsafe design is, sad to say, fairly common in the hobby press. Recently, a project was published, in another magazine, that interfaced to a computer. Since most of the circuit was powered directly from the mains, two isolated circuits were needed to interface the 'live' and 'safe' parts of the circuit. The designer, very sensibly, decided to use optoisolators to isolate these circuits; unfortunately the rules on clearance and creepage were not followed.

Although optoisolators have not been specifically mentioned, the safety principles already described can readily be applied. The isolated 'safe' circuit was accessible to the user, and so must conform to the require-

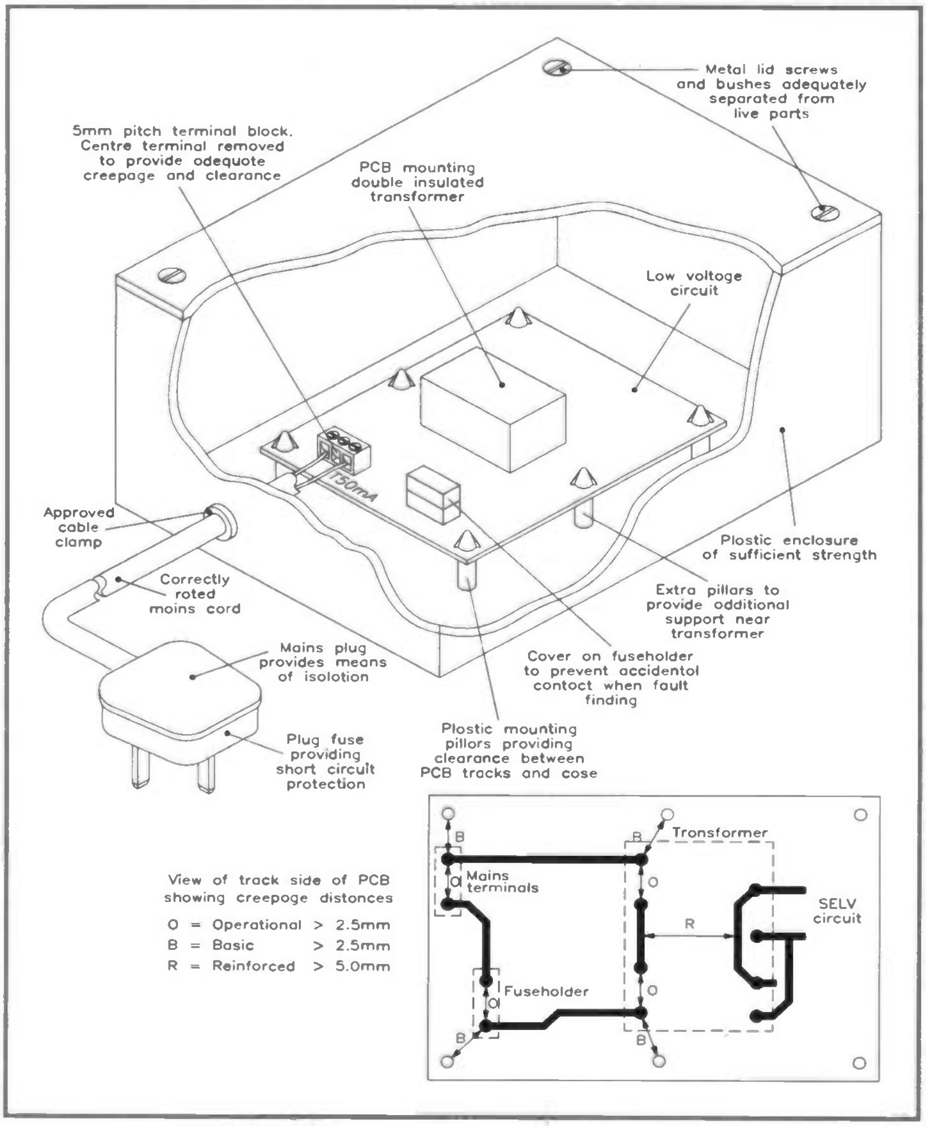


Photo 9. Portable Appliance Tester (PAT), used to check for earthing continuity between appliance and plug, live/neutral shorting to case, and plug/appliance fuse testing.

ments for low-voltage circuits in terms of maximum voltage, and separation from hazardous 'live' circuits. The input to the optoisolators was only be 5V, and well within the 60V DC maximum for shock protection.

The low-voltage circuits must also have protective separation from circuits at mains voltage which, in the project, meant any part of the rest of the circuit. The required separation is achieved by the insulation of the optoisolator and the PCB. Both of these can only be considered as single insulating 'layers', and so they must conform to the requirements for reinforced insulation. The creepage distance between the 'safe' circuit tracks and the other tracks should, therefore, be at least 5mm, as shown in Table 2 in Part One. However, in the PCB layout published, some distances were as low as 2mm! Furthermore, Table 3 in Part One shows that reinforced insulation must withstand 3000V, yet the specified 4N27 optoisolator only had an isolation voltage of 1500V!

Maintenance

Hopefully, this article will help you to design and build mains-powered equipment that is safe to use. However, it is important that you take the trouble to keep it that way. Do not forget that a very high proportion of house fires are caused by faulty electrical equipment and wiring. Ideally, the following routine checks should be made on all electrical equipment, not just items built by yourself. If you do find something wrong, put it right straight away. Do not leave it until after the accident!

Check the state of the wiring, and the tightness of the terminal screws and flex grip, in mains plugs (see Photo 8). Make sure the fuse has a sensible rating.

In Class I equipment, check the security of the earth connections both at the plug, and in the equipment itself (if possible). The earth connection could be the only defence against shock in the event of a fault. The continuity of the earth should also be checked electrically by measuring the resistance from the earth pin in the plug to all exposed metal parts (see Photo 9). Ideally, a special test instrument that delivers a high current should be used, but a multimeter may have to do. The resistance should be a fraction of an ohm.

Check for any physical damage to insulation or the equipment case. Remember that shock protection in Class II equipment relies totally on the integrity of the insulation. In both classes of equipment, a damaged case could allow live parts to be touched, or might reduce critical clearances.

Residual current devices (RCDs) provide extra protection against shock, but must be tested regularly. This is normally done simply by pressing a test button and ensuring that the device operates.

References

As there are no standards dealing specifically with hobby projects, it is necessary to decide which of the available equipment standards are applicable. From its title, BS 415 would appear to be the most relevant but, unfortunately, the way in which it is written makes it very difficult to grasp. This is particularly evident when trying to apply it to a typical hobby project.

Although BS EN 60950 applies to information technology equipment, such as computers and modems, it also covers less complex business equipment, such as telephone answering machines, typewriters and calculators. It is a more modern standard, is written in a far more accessible style, and deals extensively with low-voltage circuits powered from the mains. It has, therefore, been used as the basis of this article, and any significant differences to BS 415 have been noted.

BS 3456 applies, mainly, to domestic appliances. It has a large number of parts, each relevant to a particular kind of appliance. These are in the process of being replaced by parts of BS EN 60335, which will eventually be the new standard in this area.

Standards Dealing with the Safety of Specific Types of Equipment

BS EN 60950:1992 (also known as BS 7002) – Safety of information technology equipment, including electrical business equipment.

BS 415:1990 (soon to be replaced by BS EN 60065) – Safety requirements for mains-operated electronic and related apparatus for household and similar general use.

BS 3456 – Safety of household and similar electrical appliances.

BS EN 60335 – Specifications for safety of household and similar electrical appliances.

Standards Dealing with the General Principles of Safety

BS 2754:1976 (Memorandum) – Construction of electrical equipment for protection against electric shock.

IEC 536:1992 – Classification of electrical and electronic equipment with regard to protection against electric shock. Part 2: Guidelines to requirements for protection against electric shock (similar to BS 2754).

PD 6535:1993 – Guide to common aspects for installation and equipment for protection against electric shock.

PD 6536:1993 – Extra-low voltage (ELV) – Limit values.

Other Standards and References

BS 7671:1992 – *Requirements for Electrical Installations* (IEE Wiring Regulations WZ90X Price £34.00 NV).

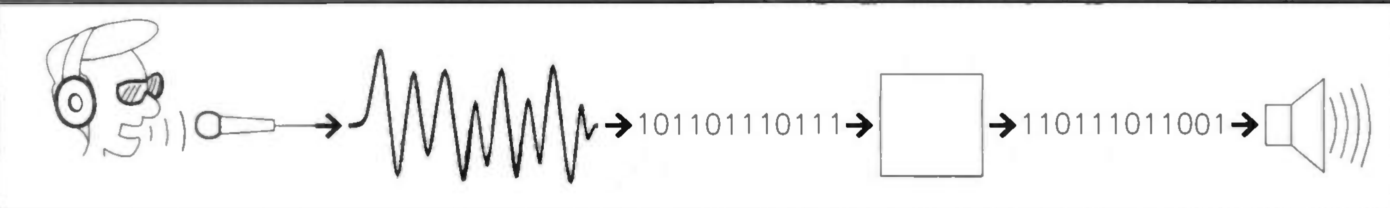
Electrical Safety Engineering – W. Fordham Cooper.

Electrical Safety and the Law – Ken Oldham Smith. AA66W Price £22.50 NV.

BS 6217:1981 – *Graphical symbols for use on electrical equipment.*

British and European Standards are available from HMSO book shops and direct from HMSO Publications Centre, 51 Nine Elms Lane, Holburn, London SW8 5DR. Sales, Tel: 0171 873 9090; Enquiries, Tel: 0171 873 0011. Most public libraries hold British and European Standards, or can obtain them on request.

Part One by Jason Sharpe **AN INTRODUCTION TO**



DIGITAL SIGNAL PROCESSING

SIGNAL processing is a vast subject; this article is an introduction to simple filters, including high-pass, band-pass, and low-pass. Most signal processing books include complicated mathematics, but this has been kept to a minimum to enable most readers to gain at least some understanding of the theory involved. Example programs have been written in Microsoft QBASIC.

Signals

What are signals, and why process them? The signals we are concerned with are those that are, or can be turned into, electrical waveforms. Examples of such signals are radio and audio signals (both of which may be naturally occurring or man made), outputs of sensors (pressure, temperature, etc.), etc.

Signals contain information, which may or may not be useful. Often extra 'information' that is not required is included in the signal. One example of this is the hiss produced by low quality audio systems. To make use of the signal, the extra information may have to be removed. This is where signal processing comes in.

The brain is a very versatile signal processing system, enabling us to extract information from even very noisy speech signals. The signals mentioned above are mainly one dimensional. When we see an object we are able to identify features such as edges, texture, and depth. Signal processing can be applied to pictures to enhance or detect certain features.

Figure 1 shows a signal that we may wish to process. It could have been created by connecting a light-level sensor to a chart recorder. The slow change of light level is caused by time of day, and motion of clouds covering the sun. The sharp dip at time 2 was caused by a bird flying very close to the sensor!

If we are monitoring the variation of light-level during the day, the dip is an error in the readings. The sensor output could be filtered to remove transient events – a low-pass filter reduces the amplitude of high frequency components of signals.

Fourier and the Frequency Domain

In 1807, Fourier presented a theory to the French Academy in Paris that practically created the entire discipline of signal processing. Fourier stated that any arbitrary real valued function (or signal), f(x), defined over the interval [−L,+L] could be represented as an infinite series of pure sine and cosine functions.

'Even functions' (see Figure 2a) can be represented by using only cosine terms. 'Odd functions' (see Figure 2b) can be represented by using only sine terms.

Program 1 shows how the square and triangular waveforms shown in Figure 2 can be created by adding sine and cosine terms of different frequencies and amplitudes. The program also allows you to try some of your own coefficients. The more terms you use, the closer the waveform will be to the original.

You may notice peaks at the edges of the square wave. This phenomenon is known as the 'Gibbs effect'.

Figure 3 shows the amplitudes of sine waves used to make up a square wave (when using 10 sine waves). If all of these values are made positive, the resulting graph is known as the frequency spectrum. The frequency spectrum shows the amplitudes of various frequencies of sine and cosine waves required to create a particular waveform – more about this later.

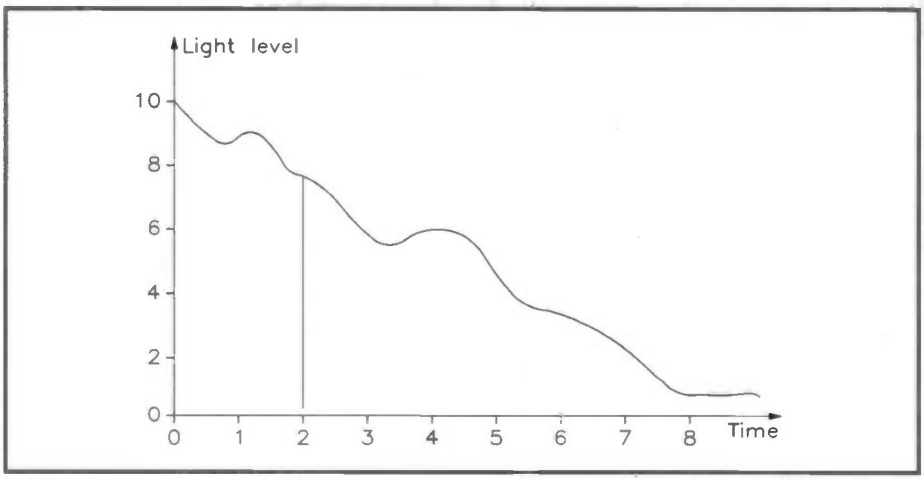


Figure 1. An example signal.

The Fourier Series

This is optional reading for those who can integrate, and wish to try their own coefficients. The following method can be used on real periodic signals, f(x), with period 2L. The Fourier series is defined as:

$$f(x) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty} a_n \cos\frac{n\pi x}{L} + \sum_{n=1}^{\infty} a_n \sin\frac{n\pi x}{L}$$

where a_n and b_n are the Fourier cosine and sine coefficients respectively. They are defined as follows:

$$a_n = \frac{1}{L}\int_{-L}^{L} \cos\frac{n\pi x}{L}\,dx \qquad n = 0, 1, 2, \ldots..$$

$$b_n = \frac{1}{L}\int_{-L}^{L} f(x)\sin\frac{n\pi x}{L}\,dx \qquad n = 0, 1, 2, \ldots..$$

The following example shows how the square wave coefficients were found for L=1. As sine is an odd function, integrating over the range −y to +y will produce zero, thus b_n will be zero for all n.

$$a_0 = \frac{1}{1}\int_{-1}^{1} f(x)\cos 0\,dx = \int_{-0.5}^{0.5} dx = 1$$

$$a_n = \frac{1}{1}\int_{-1}^{1} f(x)\cos\frac{n\pi x}{1}\,dx = 2\int_{0}^{0.5}\cos n\pi x\,dx = \frac{2}{n\pi}\sin\frac{n\pi}{2} \quad (\text{for } n > 0)$$

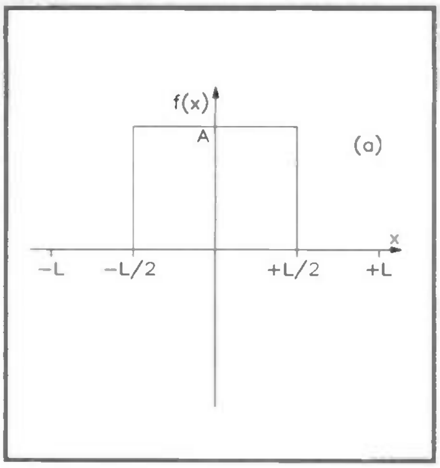


Figure 2a. An example of an 'Even' waveform (i.e. F(x) = F(−x)).

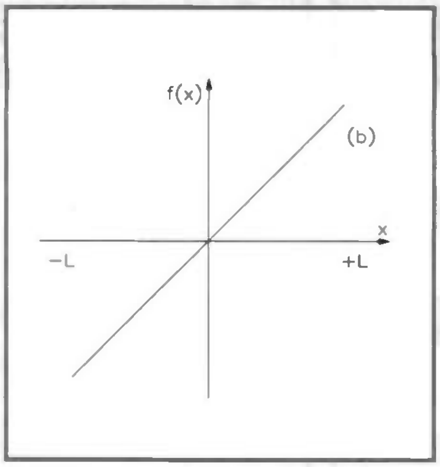


Figure 2b. An example of an 'Odd' waveform (i.e. F(x) = −F(−x))

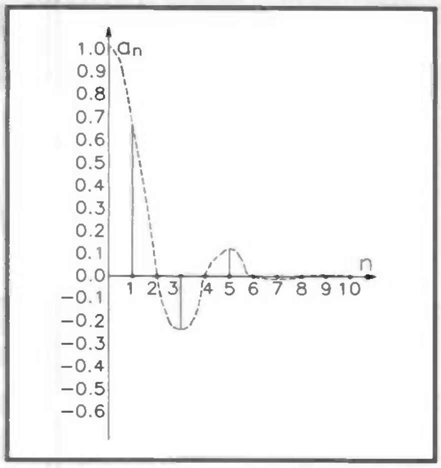


Figure 3. Fourier coefficients for a 'square' wave.

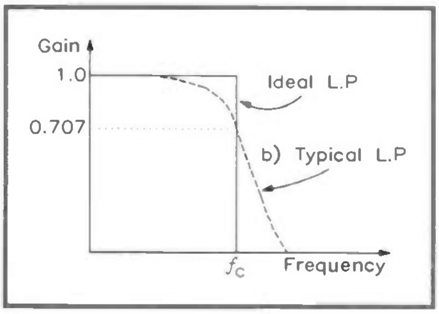


Figure 4. Frequency response of an ideal, and a typical low-pass filter.

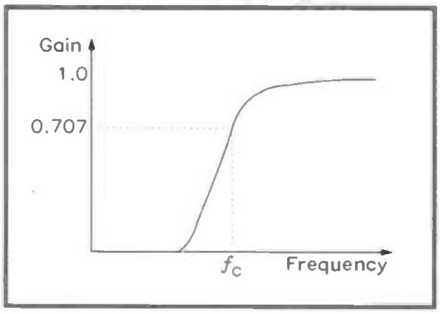


Figure 5. Frequency response of a high-pass filter.

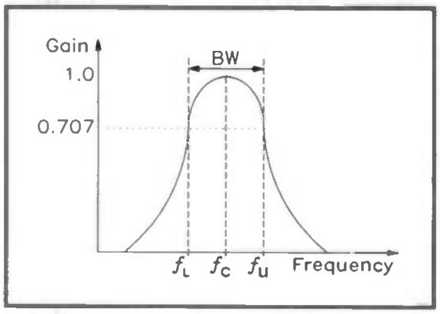


Figure 6. Frequency response of a band-pass filter.

Filtering

So how can we use filtering to help us remove the error? You will notice that the dip is very sharp, and varies far more quickly than any data that we are interested in. If we reduce the high frequency components of the sensor output, the dip would also be reduced. This can be done with a low-pass (i.e. passes low frequencies) filter.

The frequency response of an ideal low-pass filter is shown in Figure 4. Frequencies below f_c are unchanged by the filter. Frequencies greater than f_c are removed. It is not possible to make an ideal filter; the response of a typical low-pass filter is also shown in Figure 4. The cut-off frequency, f_c, is the final point at which the filter response falls to 0·707 (or 3dB) of its peak value. The rate at which the gain falls is determined by the order of the filter. A number of filters can be placed in series to increase this – the ideal filter has an infinite fall off, and this would require an infinite number of filter stages.

A typical high-pass filter response, as shown in Figure 5, attenuates low frequencies, and can be used to remove DC components of signals.

Figure 6 shows a band-pass filter response. This sort of filter is used when a certain range of frequencies is of interest – for example, in the receiving of radio signals.

Filter Implementation

There are three ways to implement filters:

Analogue Passive

These are the most basic type. They are made using resistors, inductors and capacitors, and as there are no active components, they always have a maximum gain of 1. Figure 7a shows a simple passive low-pass filter.

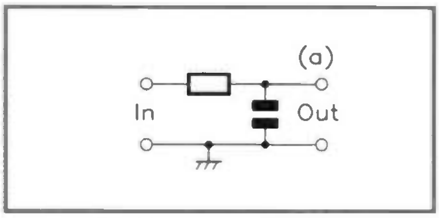


Figure 7a. Simple passive analogue low-pass filter.

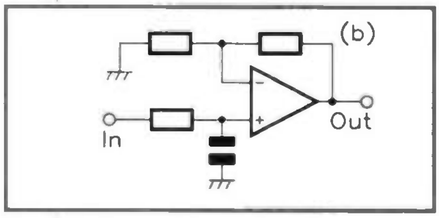


Figure 7b. Simple active analogue low-pass filter.

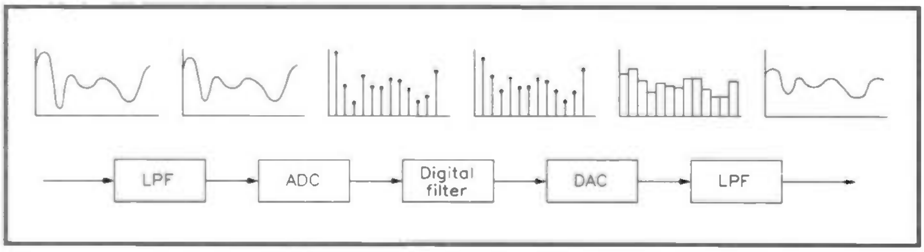


Figure 8. Block diagram of a digital filter system.

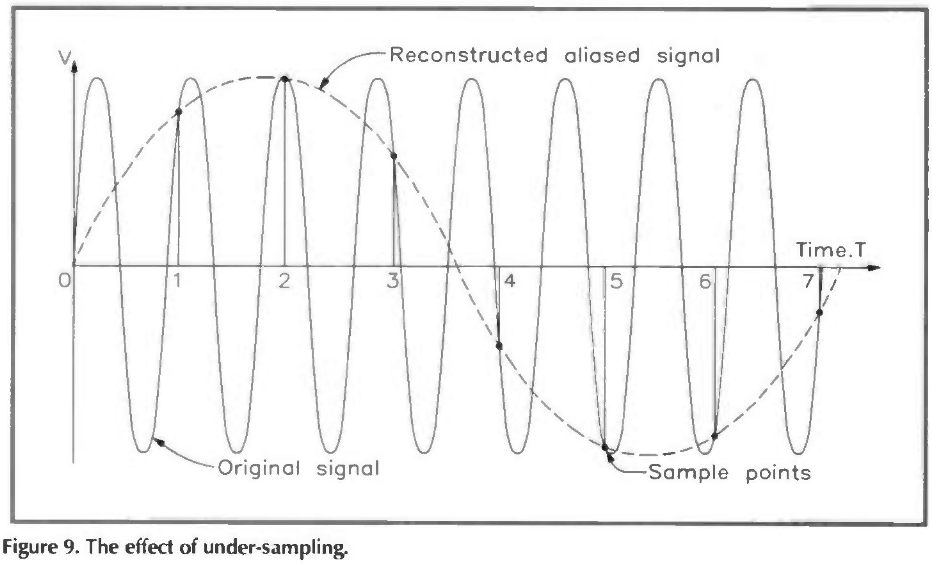


Figure 9. The effect of under-sampling.

Analogue Active

Inductors are not available in a wide range of values, and are awkward to make. Active filters only require resistors, capacitors and op amps. They may have gains of more than 1, and are easy to tune. However, the range of frequencies over which they are useful is limited to the bandwidth of the op amp. Figure 7b shows a simple low-pass active filter.

Digital

An analogue signal can be converted into a stream of digits by using an analogue to digital converter (ADC). A processor or logic circuit can then perform additions, multiplication, and delay operations to transform the sequences of digits. The sequence may then be converted back to an analogue signal using a digital to analogue converter (DAC), or may be left in digital form and processed further– for example, presented to the user as a graph. Figure 8 shows a block diagram of a typical digital filter, and associated waveforms.

The two conversions may seem pointless – why not just keep it analogue? Digital filters are normally very rugged; the frequency response is hardly affected by temperature. The main advantage is, however, programmability; designing an analogue filter that could be switched from band-pass to high-pass, with variable cut-off frequencies, would be near impossible. A digital design can perform the task easily. As the order of an analogue filter increases, the component count increases linearly. Digital filters just require a few more memory locations, and are easier to tune than similar analogue filters.

```
REM /----------------------------------------------------------\
REM  Shows creation of (even) square wave and (odd) triangle wave
REM  by addition of sine and cosine waves.     J.M.Sharpe
REM \----------------------------------------------------------/

DECLARE SUB PlotGraph (L, terms%)
DECLARE SUB Triangle (terms%)
DECLARE SUB Square (terms%)
DECLARE SUB UserInput (terms%)

CONST PI = 3.141592654#                                 'PI
CONST RES% = 100                                        'Graph step size

REM $DYNAMIC
DIM SHARED a(0 TO 10), b(1 TO 10), y(1 TO RES%)
nl$ = CHR$(10) + SPACE$(5)
DO
  CLS : PRINT : PRINT "Press...."; nl$; "1.  For Square wave"
  PRINT TAB(6); "2.  For Triangle wave"; nl$; "3.  For user defined terms"
  PRINT TAB(6); "4.  To Exit": INPUT i%: PRINT
  IF i% > 0 AND i% < 4 THEN
    DO: INPUT "Input number of terms to use: ", terms%: LOOP UNTIL terms% > 0
    REDIM a(0 TO terms%), b(1 TO terms%)
  END IF
  SELECT CASE i%
    CASE 1: CALL Square(terms%)
    CASE 2: CALL Triangle(terms%)
    CASE 3: CALL UserInput(terms%)
  END SELECT
LOOP UNTIL i% = 4

REM $STATIC
SUB PlotGraph (L, terms%)                               'L=period/2
CLS : PRINT "Working ";
max = 0                                                 'Maximum Y value
x = -L + 1 / RES%                                       'first x coord
FOR xl% = 1 TO RES%: y(xl%) = a(0) / 2                  'y=DC term
  FOR n% = 1 TO terms%                                  'Sum of series
    y(xl%) = y(xl%) + a(n%) * COS(n% * PI * x / L) - b(n%) * SIN(n% * PI * x / L)
  NEXT: PRINT ".";
  IF ABS(y(xl%)) > max THEN max = ABS(y(xl%))           'keep track of max Y
  x = x + 2 * L / RES%                                  'next x coord
NEXT

SCREEN 12                                               'Graphics screen
YSCALE = 240 / max                                      'Y axis scaling
XSCALE = 640 / RES%                                     'X axis scaling
LINE (0, 240)-(639, 240): LINE (320, 0)-(320, 479)      'Draw axis
PSET (0, 240 - YSCALE * y(1))                           'Move to first point
FOR xl% = 2 TO RES%: LINE -(XSCALE * (xl% - 1), 240 - YSCALE * y(xl%)): NEXT
PRINT "Press a key to continue": DO WHILE INKEY$ = "": LOOP: SCREEN 0
END SUB

SUB Square (terms%)
a(0) = 1: FOR n% = 1 TO terms%
a(n%) = 2 * SIN(PI * n% / 2) / (PI * n%): b(n%) = 0: NEXT
CALL PlotGraph(1, terms%)
END SUB

SUB Triangle (terms%)
a(0) = 0
FOR n% = 1 TO terms%: a(n%) = 0: b(n%) = -2 * COS(PI * n%) / (n% * PI): NEXT
CALL PlotGraph(1, terms%)
END SUB

SUB UserInput (terms%)
CLS : INPUT "Input L (period of wave/2): ", L
INPUT "Input DC term, a0: ", a(0)
FOR n% = 1 TO terms%: PRINT "Coefs a"; n%; ", b"; n%; " :";
INPUT a(n%), b(n%): NEXT: CALL PlotGraph(L, terms%)
END SUB
```

Program 1.

Analogue to Digital Conversion

The signal to be processed may be in digital form already, though it is often a continuous analogue signal that must be converted into a discrete stream of numbers. The output may have to be converted back to a continuous analogue signal. This is accomplished using an ADC/DAC. Workings of the many types of ADC/DAC and various conversion errors incurred will not be discussed here. Such details can be found from the books listed in the reference section.

The signal being sampled must not have any frequency components higher than half of the sampling frequency, f_s. Figure 9 highlights this problem. If the signal being sampled contains frequency components greater than one half of the sampling frequency, they will be 'aliased' back to lower frequencies, appearing as noise. Analogue low-pass filtering the signal, before sampling, prevents this problem. As 'ideal' low-pass filters are unrealisable, the signal is normally attenuated before $f_s/2$. This means that an ADC capable of sampling at four or five times the maximum frequency to be processed may be required. The greater the sampling rate, the closer the discrete approximation is to the continuous original.

Over-sampling is an approach often used in high quality audio applications. The signal is sampled at around 100 times the required frequency (e.g., approximately 5MHz for an audio signal). A high order digital low-pass filter is then used, and the data rate reduced, leading to increased accuracy.

The DAC output will probably be 'stepped' as shown in Figure 8. Analogue low-pass filtering of the output reduces this problem. Digital interpolation can be used to create a data stream with a higher data rate, to pass to a DAC. This reduces the complexity of analogue filter circuitry required for high quality applications.

If the ADC produces an output every T seconds, then we represent the output at time T=0 by x[0], at T=1 by x[1], and the nth sample as x[n] (this is similar to the way arrays are indexed in BASIC). A sequence of numbers is represented by {x[0],x[1],...,x[n],...}. We will use this notation next month to look at the 'impulse' and 'step' responses of filters.

REFERENCES

Computers in the real world, Dixey, G., *Electronics* Issue 35, pp. 35-39.

The Art of Electronics (2nd ed.), Horowitz P. and Hill W., Cambridge University Press, 1989, pp. 612-640 (ADC/DAC), pp. 263-284, 776 (Active Filters).

TELEPHONE BELL REPEATER

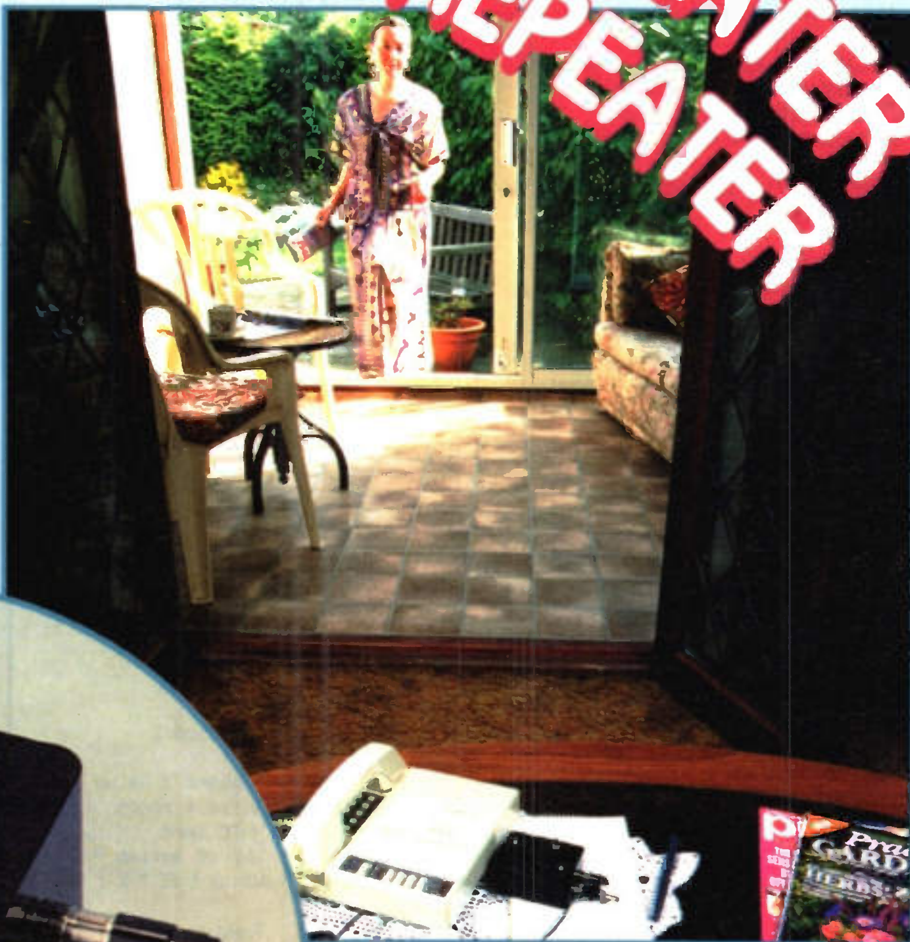
TELEPHONE BELL REPEATER

2
PROJECT RATING

Quite often, the telephone cannot be heard in other parts of the house, or in the garden, shed or garage. This is where this simple Phone Repeater presented here is very useful, to those people with only a single phone socket (or even a hard-wired phone).

Designed by Alan Williamson

Text by Alan Williamson and Robin Hall



The assembled unit

FEATURES

* Easy to build and install
* No direct connections to the telephone
* LED/sound annunciators
* Can be used with 418MHz Encoded Radio Tx/Rx

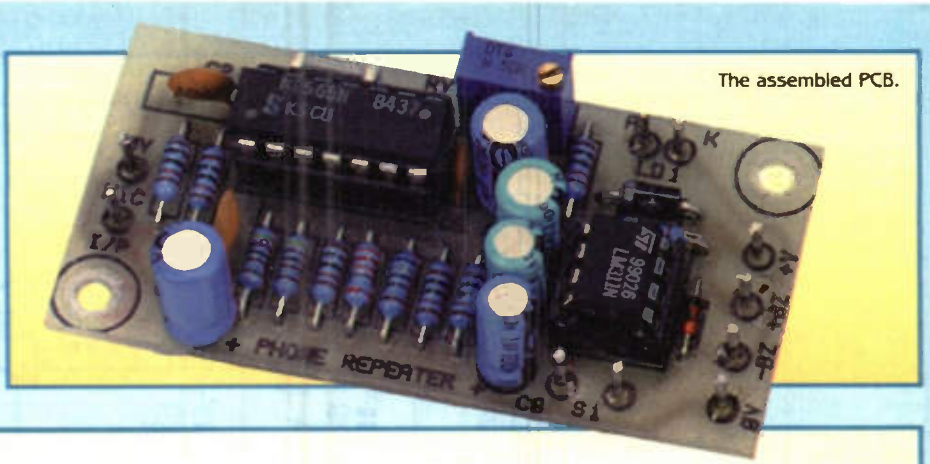
KIT AVAILABLE (LT67X)
PRICE
£10.99

The Telephone Bell Repeater 'sits' beside the telephone, and a piezo buzzer is remotely wired from the Telephone Bell Repeater (using zip wire) to the required 'repeat' position. When the telephone rings, the LED illuminates and the buzzer beeps in time with the ringing pattern. A purely audible connection is all that is required since direct connection of non-approved apparatus to the public telephone network is strictly prohibited.

A wireless Telephone Bell Repeater is also practical using the 418MHz Encoded Transmitter and Receiver system, which is also to be found within this issue!

The applications are not limited to this sole purpose, as it can be used equally well as a whistle switch, or possibly a baby alarm! (Sorry, we haven't tried it out as a baby alarm – the Lab stores do not stock crying infants, thankfully!) Interestingly enough, during the design and development of this project, it was nicknamed The Raddish! Why? Well, think about it, what do raddishes do when you eat them? [Groan! What an awful pun Alan, your jokes get worse! – Ed.]

Due to the narrow capture range around the preset centre frequency, the Telephone Bell Repeater is discriminating enough to 'tell' the difference between different telephones. So every time a 'phone on the telly' rings, the Telephone Bell Repeater will not trigger, unless it has an exact fundamental or harmonic of your phone!


The assembled PCB.

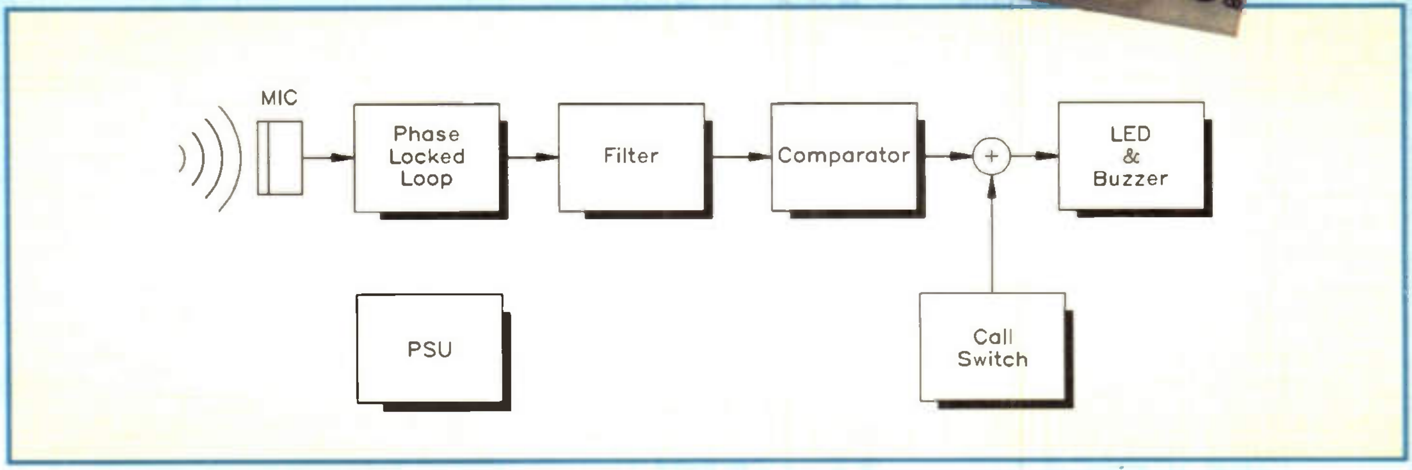


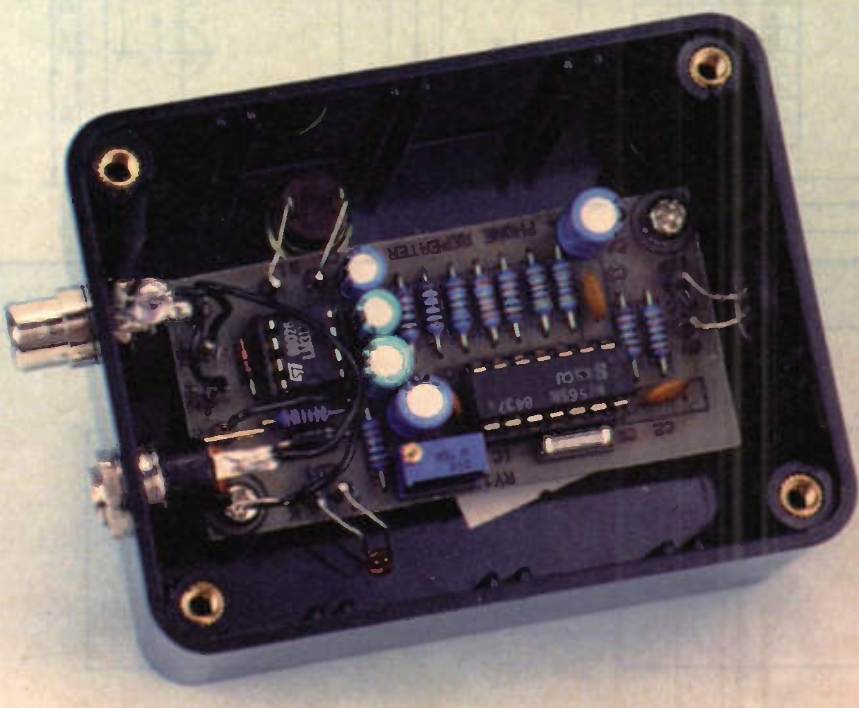
Figure 1.Block diagram of the Telephone Bell Repeater.

It must be pointed out that the Telephone Bell Repeater does have its limitations, mainly because of its simple design, as can be demonstrated by using it as a whistle switch. But, human interpretation can easily tell the difference between a false triggered single beep, and a real 'phone' call triggered multiple beep, which should follow the same timing as the telephone ring.

The other limitation of the unit is that a stabilised supply (preferably regulated) must be used. A 12V battery pack will not suffice, as a change in supply voltage *will cause variations* in the oscillator frequency.

Specification

Power supply voltage:	12 to 24V DC
Current Consumption	
Quiescent current @ 12V:	10·5mA
Operating current @ 12V:	19·4mA
Operating current @ 24V:	39mA
Input nominal frequency measured at 12V:	240Hz to 1400Hz


PCB in its optional box showing internal wiring.

Incidentally, a fairly sophisticated telephone 'ring and pause' detection system was originally developed for the Telephone Bell Repeater, which triggered only when the telephone rang one complete 'ring-ring-pause-ring-ring' cycle. However, the system would have been prohibitively expensive and, therefore, would not have been a viable economic proposition as a kit – it would have been cheaper to get another phone installed!

Circuit Description

The block diagram is shown in Figure 1, and the circuit diagram is detailed in Figure 2; this should assist you in following the circuit description.

The diode D1 prevents damage to the circuit from accidental reverse polarity connections. The capacitor C1 provides the main low-frequency reservoir function, and capacitor C2 provides the high-frequency decoupling.

Resistor R1 provides a bias voltage to the microphone insert, since it is of the electret variety. The microphone picks up the audible telephone ring, the electrical signal produced is ac coupled, via C3, to the phase comparator input of IC1, which is a phase locked loop (PLL for short). Resistors R2 to 5 and capacitor C4 are the biasing components. The PLL contains a voltage controlled oscillator (VCO), the frequency of which is determined by R6, RV1 & C5. Resistor R7, and capacitors C6 and C7 are the 'loop filter' components that determine the capture range deviation from the oscillator centre frequency.

The PLL compares the input signal with the reference frequency. If a good match is obtained, the voltage level on pin 7 decreases and this is detected by IC2, a voltage comparator.

The resistors R8 to R10, and capacitors C8 and C9 provide (very) low-pass filtering

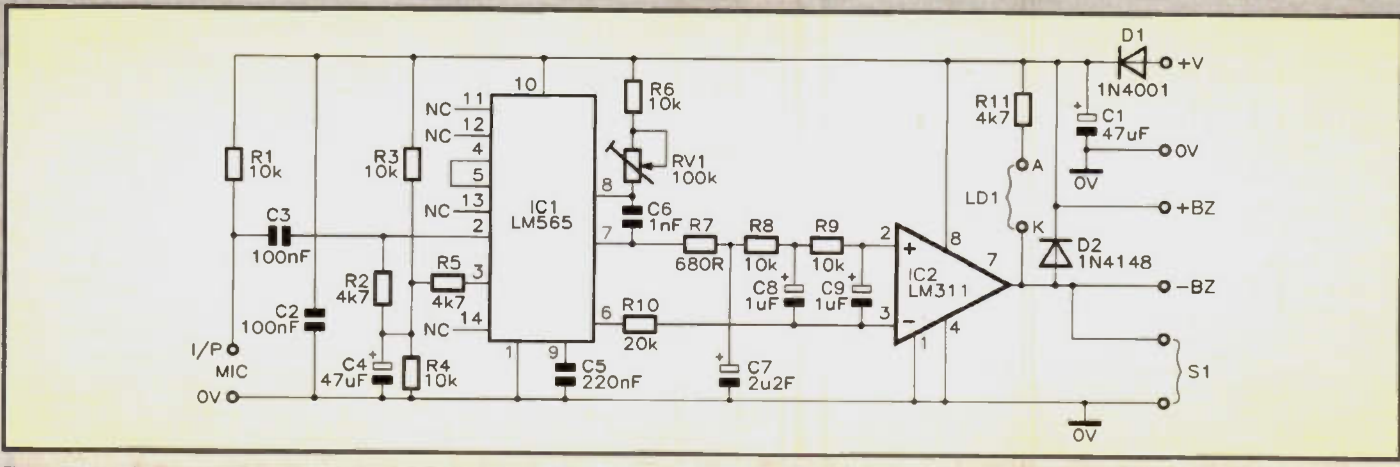


Figure 2. Circuit diagram of the Telephone Bell Repeater.

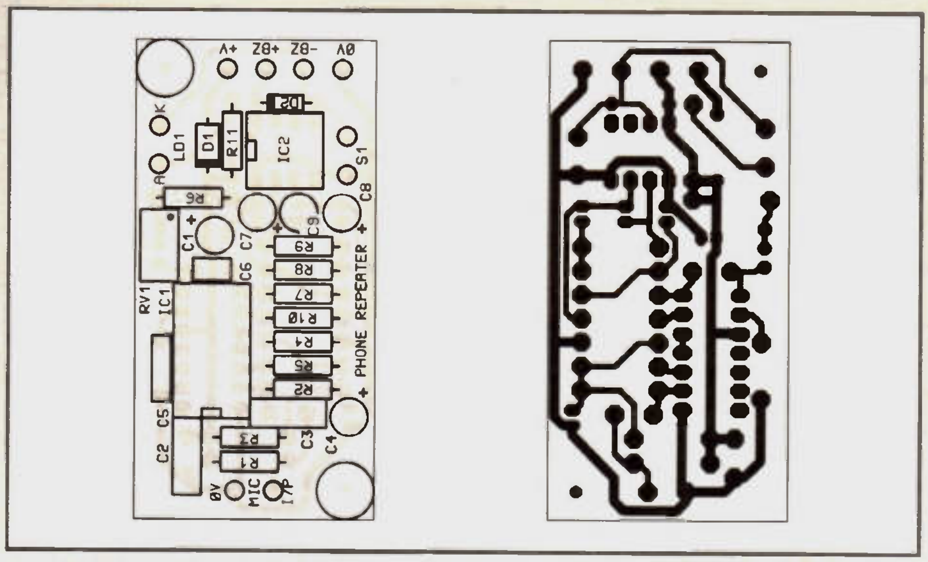
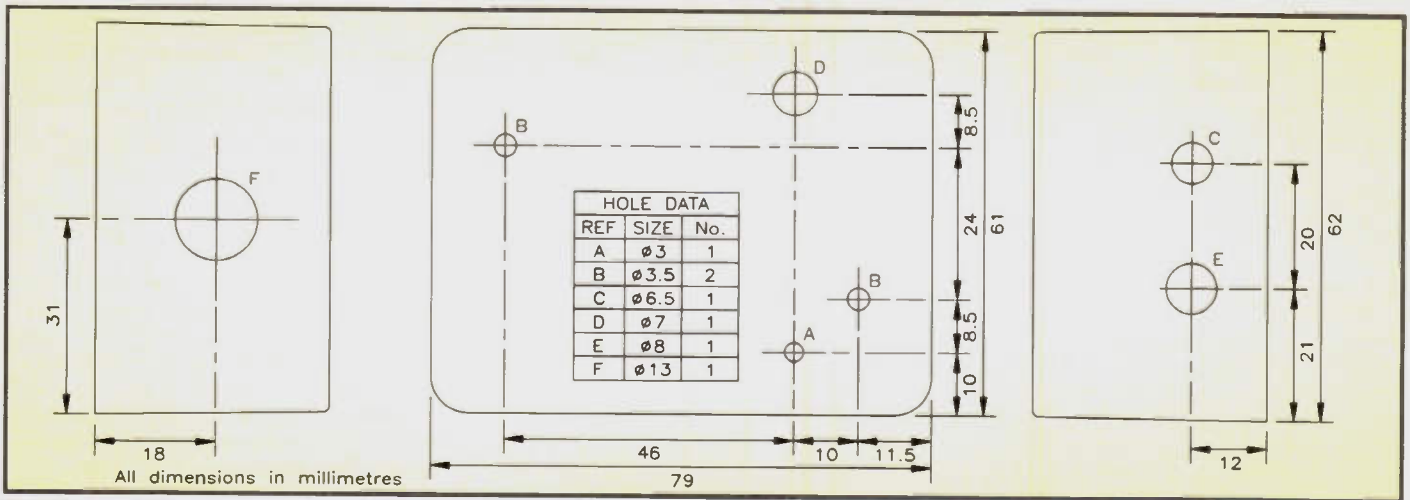


Figure 3. PCB legend and track.

to decrease the possibility of spurious operation from short-term locking, caused by environmental noise pollution (e.g. television, music, pets, kids shouting at the pets, mum screaming at the kids for shouting at the pets, dad bellowing at mum for . . . [okay Alan, I think we've got the general idea! – Ed.]

The output stage of the voltage comparator is configured as an open collector and therefore can only 'sink' current (maximum 50mA, including LD1 and BZ1 current). The LED (LD1) illuminates and the buzzer (BZ1) produces a loud piercing tone when the output of the comparator becomes active (low). Resistor R11 limits the current through the LED to around 2mA, and diode D2 is the 'load dump' diode preventing damage to the output of the comparator from reactive loads. S1 is included as a remote 'call' switch.



HOLE DATA

REF	SIZE	No.
A	ø3	1
B	ø3.5	2
C	ø6.5	1
D	ø7	1
E	ø8	1
F	ø13	1

Figure 4. Box drilling.

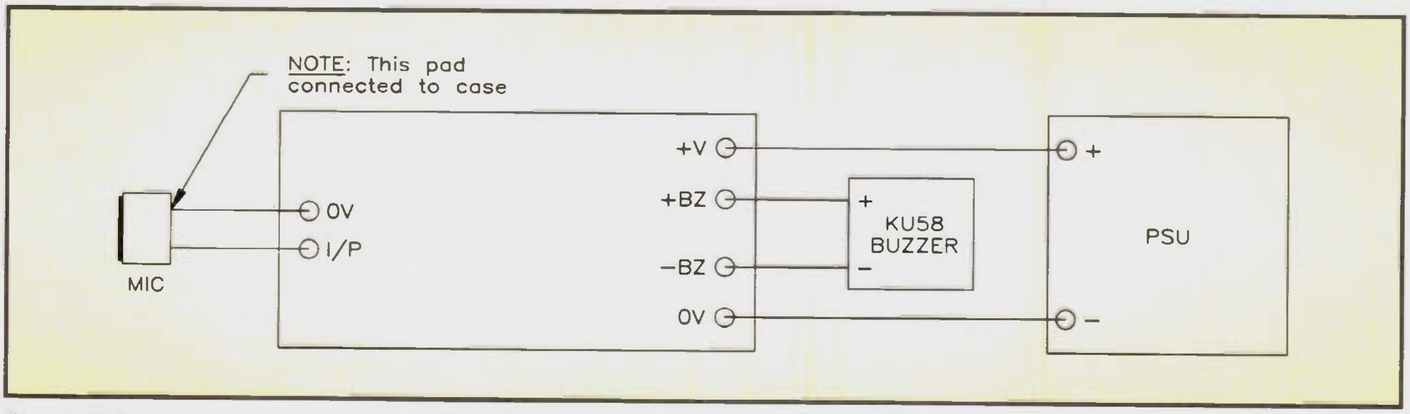


Figure 5. Wiring diagram.

Construction

The PCB legend and track are shown in Figure 3, and will assist in the construction of the PCB. A ready made PCB is included in the kit and is also available separately. Construction of the Telephone Bell Repeater is fairly straightforward and the following general advice applies; begin with the smallest components first, working up in size to the largest. Insert the PCB pins from the track side; be careful to orientate correctly the polarised devices, i.e. electrolytic capacitors, diodes and ICs. The ICs should be inserted into their sockets last of all. A more detailed explanation of component recognition and construction techniques may be found in the Constructors' Guide, which is included in the kit (available separately, XH79L).

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

Case Study

Drilling details of the optional box are shown in Figure 4; mark out, then drill, cut, and file all the holes as required. When the box is prepared, the project can be installed and wired up; refer to the assembly diagrams in Figures 5 and 6, also for fitting the LED and microphone. Attach the 1N4001 lead off cuts to the solder pads of the microphone (note which one of the solder pads is connected to the case; this is the 0V pad), then fit to the box and connect to the PCB.

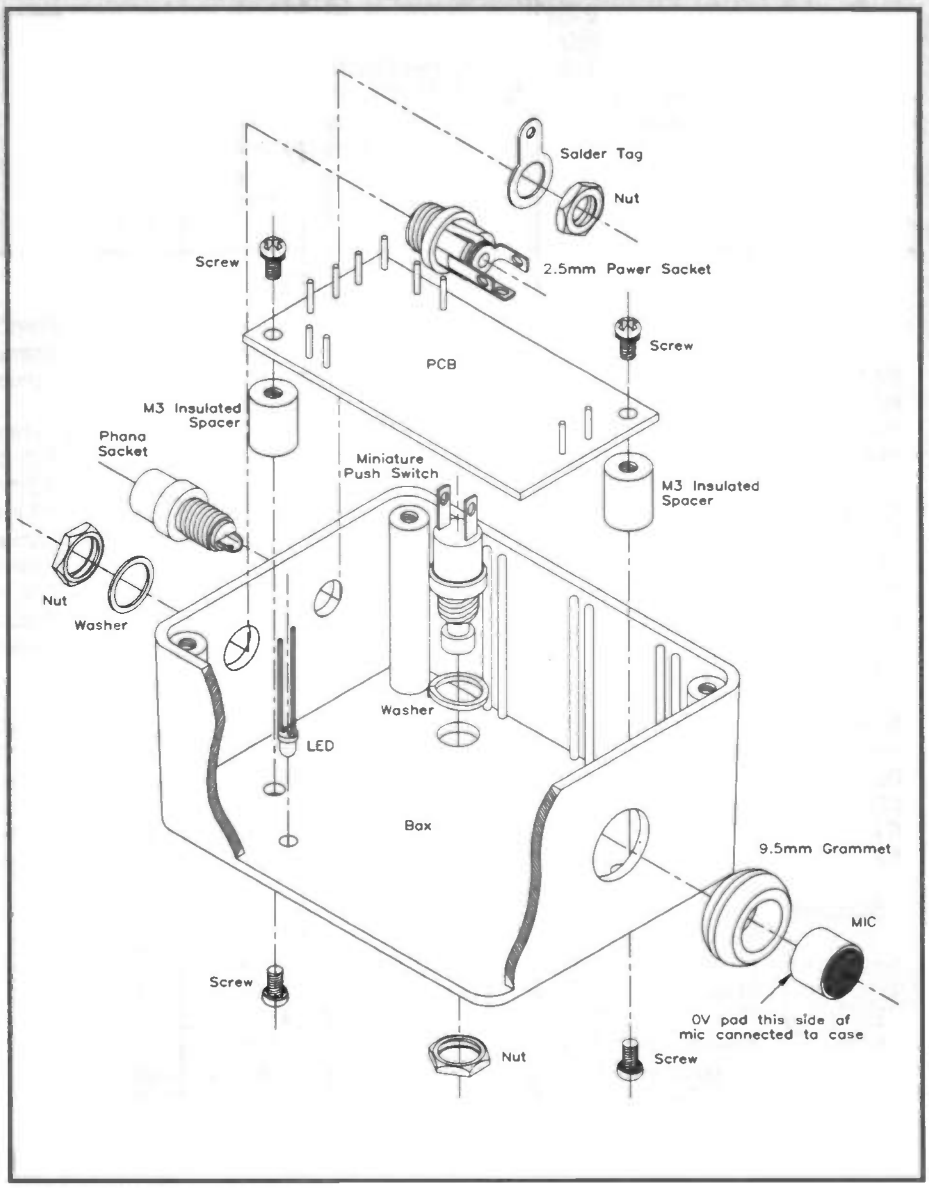


Figure 6. Exploded assembly diagram.

Testing

The audible ringer output from a modern push-button telephone is a fairly complex pattern which contains at least three tones (not including harmonics), two of which are high frequency, the third is a low frequency which is used to toggle between the two higher tones. Traditional dial telephones with mechanical bells also have three main tones, but with differing harmonic content.

Therefore there are at least two tones the Telephone Bell Repeater can lock to.

Turn the 22-turn preset fully clockwise. Apply power to the circuit (+12 to +24V DC); it is normal for the circuit to trigger briefly whilst setting.

You will need to telephone a friend and ask to be phoned back, but explain that you will not be picking the phone up to answer it for a minute or two.

Place the Telephone Bell Repeater close to the ringing phone, adjust the preset in an anti-clockwise direction (only when the phone is ringing, stop during the pauses) until the 'lock' is achieved (this is the higher tone of the phone ring); carry on turning anti-clockwise and count the number of turns until the 'lock' is lost. This determines the 'locking range'; set the preset in the centre of the 'lock range'. Fine adjustment is then made by moving the Repeater a couple of feet away from the phone, and then finding the best 'lock' position.

Once the adjustments have been made, answer the phone, say thank you to your friend and that the drinks are on you!

If false triggering becomes a problem, repeat the adjustment procedure but this time start the preset fully anti-clockwise and adjust in a clockwise direction.

The Telephone Bell Repeater is now fully tested and adjusted; permanently install and supply power to the device in the vicinity of the selected telephone.

Use of the Telephone Bell Repeater

The Telephone Bell Repeater can be used as a standalone unit, or with the 418MHz Encoded Transmitter (LT87U) and the 418MHz Encoded Receiver (LT88V) projects.

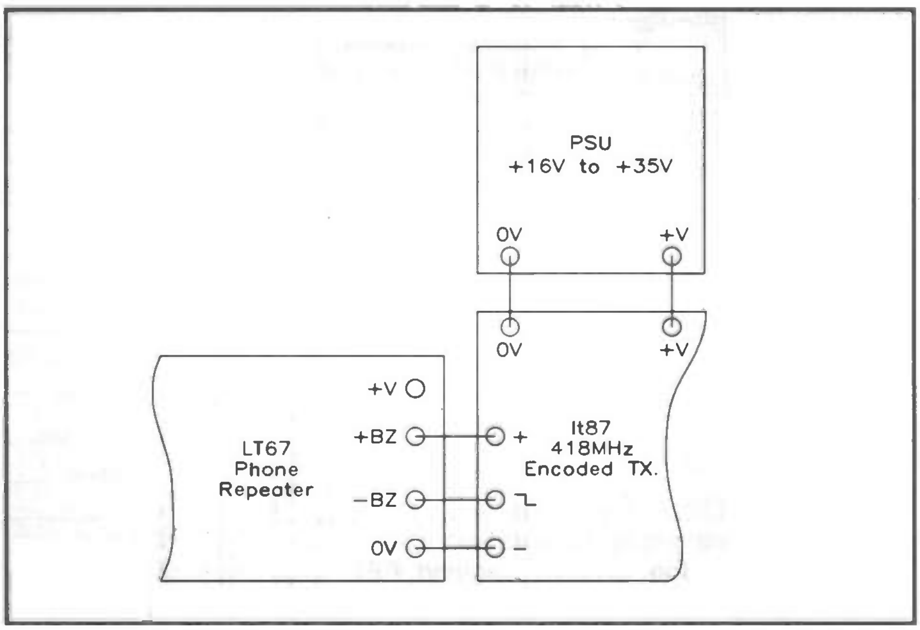


Figure 7. Interconnecting with the 418MHz Encoded Transmitter (LT87U).

Figure 7 shows how the Telephone Bell Repeater is interfaced to the 418MHz Encoded Transmitter if this option is to be used, so that when the telephone rings, the Telephone Bell Repeater activates and 'keys' the transmitter. This transmits an digitally encoded FM signal on 418MHz, and is received by the 418MHz receiver. The signal is demodulated and decoded, if the transmitter and receiver codes match a piezo buzzer and LED then operate on the 418MHz receiver, informing the person with the receiver that the telephone is ringing. The use of digital encoding ensures that only the correct transmitter triggers the piezo buzzer on the receiver.

There are many other applications for the Telephone Bell Repeater, limited only by your own ideas, where tones emitted are in the audio capture range of the unit. It is a very useful device especially since low-level tones can be used to activate other equipment such as the 418MHz transmitter.

TELEPHONE BELL REPEATER PARTS LIST

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

R1,3,4,6,8,9	10k	6	(M10K)
R2,5,11	4k7	3	(M4K7)
R7	680Ω	1	(M680R)
R10	20k	1	(M20K)
RV1	50k 22-turn Cermet	1	(UH26D)

CAPACITORS

C1,4	47µF 25V Radial Electrolytic	2	(FF08J)
C2,3	100nF 50V Disc Ceramic	2	(BX03D)
C5	22nF Polyester Layer	1	(WW33L)
C6	1nF Metallised Ceramic	1	(WX68Y)
C7	2µ2F 100V Radial Electrolytic	1	(FF02C)
C8,9	1µF 100V Radial Electrolytic	2	(FF01B)

SEMICONDUCTORS

D1	1N4001	1	(QL73Q)
D2	1N4148	1	(QL80B)
LD1	3mm 2mA Red LED	1	(CZ28F)
IC1	LM565N	1	(WQ56L)
IC2	LM311N	1	(QY09K)

MISCELLANEOUS

8-pin DIL IC Socket	1	(BL17T)
14-pin DIL IC Socket	1	(BL18U)
Single-ended PCB Pin 1mm (0·4in.)	1 Pkt	(FL24B)
PCB	1	(GH93B)
Piezo Buzzer PCB	1	(KU58N)
Microphone Insert	1	(FS43W)
Push Switch	1	(FH59P)
Instruction Leaflet	1	(XU91Y)
Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

ABS Box Type MB1	1	(LH20W)
9·5mm Grommet	1	(JX63T)
M3 Insulated Spacer	1	(FS36P)
Chassis Phono Socket	1	(YW06G)
Phono Plug Black Screw Cap	1	(HQ54J)
2·5mm Panel Mount Power Socket	1	(JK10L)
Regulated AC Adaptor	1	(YB23A)
Zip Wire	As Req.	(XR39N)

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 LT67X (Telephone Bell Repeater) Price £10.99
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 items (which are included in the kit) are also available separately, but are not shown in the 1995 Maplin Catalogue
Telephone Bell Repeater PCB **Order As GH93B Price £2.49**

SUBSCRIBE TO ELECTRONICS

✻ BRITAIN'S BEST SELLING ✻
ELECTRONICS MAGAZINE!

ELECTRONICS *The Maplin Magazine*

* **2 FREE ISSUES** if you agree to subscribe by Direct Debit or Continuous Credit Card, saving you £5.82!
* **FREE DELIVERY TO YOUR DOOR,** and there are no additional carriage charges.
* **YES, SAVE MONEY** by taking a subscription, it's cheaper than buying each individual copy.
* **REGULAR SUBSCRIBERS' SPECIAL OFFERS** Super savings on selected products!
* ***PLUS*** – News, reviews, readers letters, competitions and lots, lots more besides!

To subscribe just send a cheque/postal order for £10.98 made payable to Maplin Electronics, P.O. Box 3, Rayleigh, Essex SS6 8LR. **OR** you can take advantage of our offer of two free issues by completing the coupon below and agreeing to pay by Credit Card or Direct Debit. The two free issues offer only applies if you use one of these two methods of payment. Simply fill in the 'Payment by Credit' or 'Payment by Direct Debiting Mandate' and return it to Maplin. Every time, about 1 month before your subscription is due, we will send you a letter giving details of the subscription rate and telling you the date on which we will charge your Credit Card or debit your bank account. If you do not wish to continue your subscription, you have until that date to let us know, and we will then cancel your authority to bill your Credit Card or cancel your mandate. Otherwise, if you do nothing, your subscription will continue. The authority or mandate you give us does not allow us to charge anything other than the Maplin Magazine subscription. The benefit to you is that you no longer need to remember to renew your subscription or send off any more cheques or postal orders. Payment is made automatically.

OVERSEAS READERS – *SUBSCRIBE NOW!* – Phone Maplin Export: +44 1702 554155 Ext. 326 or 351. Full details on request.
Subscription rates for 6 issues are: £15.00 (or 37 IRCs) in Eire, Europe and surface mail outside Europe; £22.50 (or 55 IRCs) Air Mail outside Europe.
Subscription rates for 12 issues are: £30.00 (or 73 IRCs) in Eire, Europe and surface mail outside Europe; £45.00 (or 110 IRCs) Air Mail outside Europe.
AFRICAN READERS – SUBSCRIBE NOW! – Phone Maplin South Africa: +27 24 51 5124.
Subscription rate for 6 issues is: R114,00; Subscription rate for 12 issues is: R215,00.

TAKE THE NEXT 2 ISSUES OF THIS MAGAZINE FREE!!

Because we're so certain that now you've seen the Maplin Magazine you'll want to receive it regularly, we're offering to send you the next two issues free of charge with absolutely no obligation to continue. Just fill in the details below and if after receiving two issues you do not wish to continue, just let us know at least one month before the next issue is due and we will cancel your subscription. The two free issues will be yours to keep whatever you decide. If you already have a subscription, fill in the details below and we'll add two issues free of charge to your current subscription. SEND NO MONEY NOW. About 2 weeks before the third issue is due, we will charge you £10.98 for the next six issues, unless you have cancelled. This offer is not available to those already paying by Direct Debit or Continuous Credit Card or those who have stopped payment by either method within the last year. **THIS OFFER IS OPEN TO RESIDENTS WITH U.K. ADDRESSES ONLY.**

PLEASE START MY SUBSCRIPTION WITH ISSUE ☐ (If left blank subscription will start from next issue.)

EITHER

★ PLEASE ADD YOUR ADDRESS, SEE BOTTOM RIGHT ★

PAYMENT BY CREDIT CARD. Please charge my Credit Card Account

I authorise you until further notice in writing to debit my CREDIT CARD account by £10.98 and in future, with any amounts which, after notification, MAPLIN ELECTRONICS plc may debit thereto in respect of my subscription to the Maplin Magazine.

Customer Number (if known) ....

Access ☐ Visa ☐ American Express ☐

Account No.

Signature | Date

OR

PAYMENT BY DIRECT DEBITING MANDATE in favour of Maplin Electronics plc, P.O. Box 3, Rayleigh, Essex SS6 8LR.
Direct Debit payment option is only open to customers with bank accounts in the U.K. Including Channel Isles, Isle of Man and N. Ireland.
Please note: Instructions cannot be accepted to charge Direct Debits to a Deposit or Savings Account.

DIRECT Debit

Bank Sort Code

Bank Account Number

Name of account to be debited

Bank Address

I authorise you until further notice in writing to charge my account, with you, any amounts which MAPLIN ELECTRONICS plc may debit thereto by Direct Debit in respect of my subscription to the Maplin Magazine.

I will inform the bank in writing if I wish to cancel this instruction.

I understand that if any direct debit is paid which breaks the terms of this instruction, the bank will make a refund.

Signature | Date

Enter your address and Maplin customer number, if known.

Postcode

Put this form in an envelope and address it to: Maplin Electronics, Freepost, P.O. Box 3, Rayleigh, Essex, SS6 2BR.

ORDER COUPON

Maplin ELECTRONICS

P.O. Box 3, Rayleigh, Essex SS6 8LR.
Telephone, Credit Card Sales (01702) 554161; Enquiries (01702) 552911.

A different postal code is correctly shown on the reply paid envelopes.

Please make cheques payable to 'Maplin Electronics plc'.

On occasion Maplin Electronics may permit other reputable companies to make offers of products or services which we believe will be of interest to our customers. If you do not wish to receive this information please write no in the box. ☐

In any correspondence please quote your customer number. Date ....

Customer No. ....

Name ....

Address ....

....

Post Code.......................... Phone No. ....

IT IS MOST IMPORTANT THAT YOU INCLUDE YOUR POSTCODE

Block capital letters please. Keep a copy of your order.

*Please enter catalogue page no. where item appears. If not in catalogue, write Mag for Magazine or SO for Special Offers etc. If not using 1995 catalogue, enter date of catalogue here: 19..............

Description (for your information only)	Page*	Order Code					Quantity	Price Each	£ Total	p	£ Carriage Charge	p
Price Change Leaflet (Please write 1 in quantity, if required)		C	A	9	9	H		FREE	0	00	0	00
1995 Maplin Catalogue		C	A	1	2	N		£3.95			0	00
Maplin Magazine Subscription (UK 6 Issues)		X	A	0	0	A		£10.98			0	00
Maplin Magazine Subscription (UK 12 Issues)		X	A	0	0	A		£21.96			0	00

Form ME58 Issue 5

Access | VISA | AMERICAN EXPRESS

PHONE BEFORE 5pm FOR SAME DAY DESPATCH

Overseas customers including Channel Isles and Eire, please deduct VAT where applicable and tick this box.

Export Order ☐

Office Use Only			
DOR	CQ	CA	PO
CNC	Total		
CNM			

I authorise you to debit my credit card account for the cost of goods despatched.

Credit Card Number ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Access/American Express/Visa .... Delete as required.

Note. Goods will be despatched only if the address above is the cardholder's address.
If ordering by credit card please sign:

....

Expiry date of Credit Card..

		£	p
Total this sheet	£		
Total other sheet(s)	£		
Total for goods	**£**		
Carriage charges for large, fragile, or heavy items as shown in catalogue. If total in this box exceeds £6.00 you need only pay £6.00 (Max. Carr. Charge per order £6.00)			
Deduct value of Credit Note No .... Enclose the numbered Credit Note with this order.			
Deduct value of Gift Token No. .... (Enclose Gift Token with order.)			
Please add £1.50 Handling Charge. This amount must be added to each order placed.*		1	50
*Except if only ordering a Catalogue or Magazine Subscription	Total £		

Carriage Charges
- A £1.55
- B £2.20
- C £2.80
- D £3.30
- E £3.90
- F £4.45
- G £5.35
- H £6.00

418MHz ENCODED TX

The 418MHz Encoded Transmitter project presented here and its companion, the 418MHz Encoded Receiver project (LT88V) are a boon for security and other applications. Using these projects means that standalone or wire-interconnected equipment can now be linked to good effect by totally wireless means. The Telephone Bell Repeater project (LT67X) is an ideal candidate for wireless operation, but many more applications are possible.

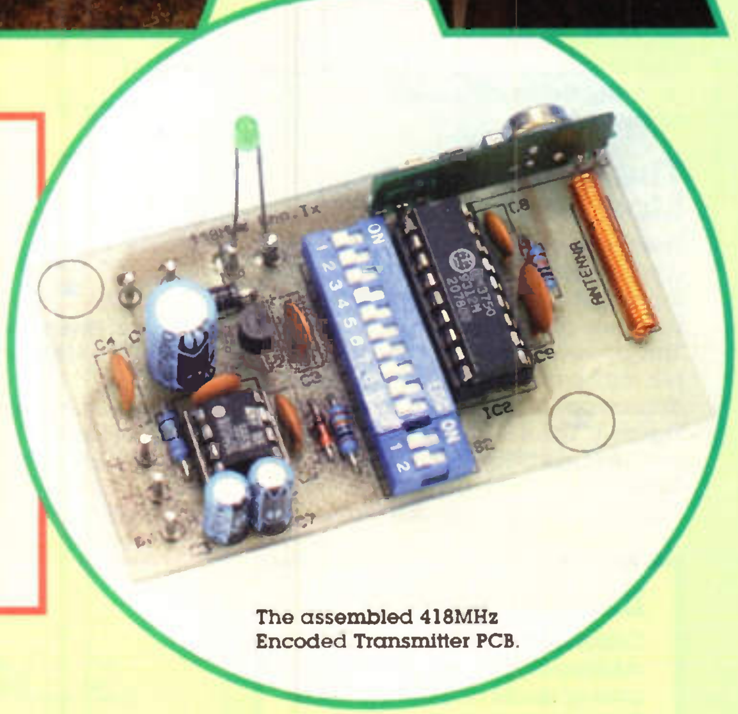
FEATURES

* Wide supply range
* Easy to build and use
* Low current consumption
* DTI approved to MPT 1340
* Ready-made/aligned RF module
* 4,096 codes
* FM operation

1 PROJECT RATING

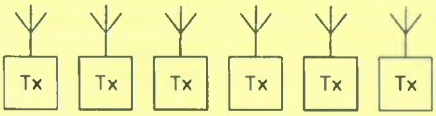
APPLICATIONS

* Domestic/commercial security
* Guard patrol protection
* Lone worker protection
* Medical alert
* Nurse call systems
* Site paging systems
* Door bell
* Paging car alarms
* Fire alarms
* Remote control systems



The assembled 418MHz Encoded Transmitter PCB.

Designed by Chris Barlow and Alan Williamson
Text by Chris Barlow, Alan Williamson and Robin Hall



KIT AVAILABLE (LT87U) PRICE £26.99

Specification

Power supply voltage: 16 to 35V DC
Current consumption
Quiescent current: 3·8mA
Operating current: 14·5mA

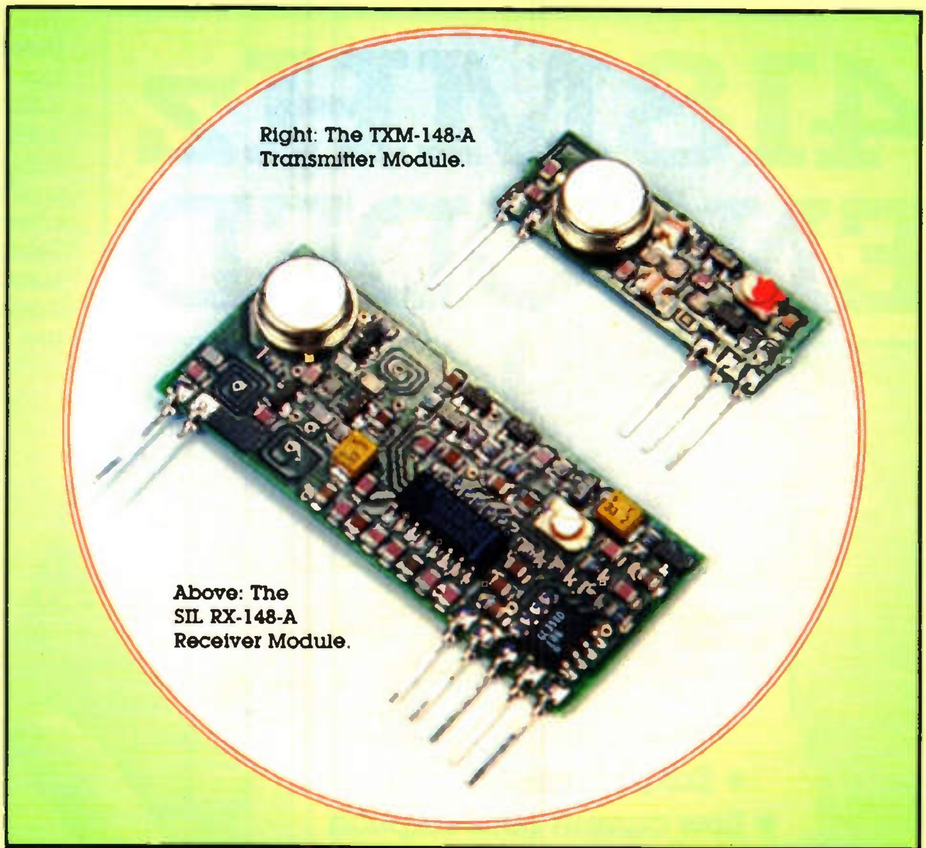
PREVIOUSLY, it has been difficult for the electronics enthusiast to build, and legally use, UHF radio transmitters and receivers. However, this project uses a ready-built and aligned radio transmitter module TMX-418-A (AM27E), similarly the Encoded Receiver project, similarly, uses a ready-built and aligned radio receiver module SILRX-418-A (AM28F). With ideal antennae, these modules are capable of transferring data reliably up to a distance 50m in buildings and over 200m under open field conditions. The transmitter is type approved to Department of Trade and Industry (DTI) Radio Communications Agency (RA) specification MPT 1340, thus avoiding the need to submit the finished project for further approval. The modules have been optimised for battery powered operation and both are designed for reliability and performance in the field. They perform well with very small antennas and require no alignment whatsoever.

The Transmitter Module

The transmitter module requires only a power supply, data modulation input and an antenna. The module operates over the range +6 to 12V DC. This power is applied to the V_{cc} input pin (pin 3) of the module, the physical dimensions of which are given in Figure 1. The 418MHz transmitter module's specification is given in Table 1.

As seen in the block diagram, Figure 2, the raw data is applied to pin 5 of the module (Table 2 shows the 418MHz transmitter module's pinout details), this is the input to a simple R/C low-pass filter (LPF) which restricts the modulation bandwidth to 10kHz at the −3db point. The data input is normally driven directly by CMOS logic, which is run from the same power supply as the transmitter module.

The filtered data is then passed to a wide band frequency modulator (WBFM) stage which will accept analogue AFSK or digital data from DC to the 10kHz upper limit. Although the modulation bandwidth of the transmitter extends down to DC as does the audio output of the receiver module, it is not possible to pass data with a DC component due to frequency errors and drifts between the transmitter and receiver. The WBFM modulator drives a Varicap diode, and its changing capacitance is used to modify the frequency of the



Right: The TXM-148-A Transmitter Module.

Above: The SIL RX-148-A Receiver Module.

Operating supply range (Vcc):	6 to 12V DC
Supply current:	6mA (6V) to 14mA (12V)
Effective Radiated Power (ERP):	−10dBm (6V) to −6dBm (12V)
Initial frequency accuracy:	±50kHz
Overall frequency accuracy:	±80kHz
Spurious radiation:	To MPT 1340
FM deviation:	±25kHz
Modulation bandwidth (analogue):	DC to 10kHz (−3dB)
Minimum pulse width (digital modulation):	100μs

Table 1. Typical TXM-418-A 418MHz transmitter module specification.

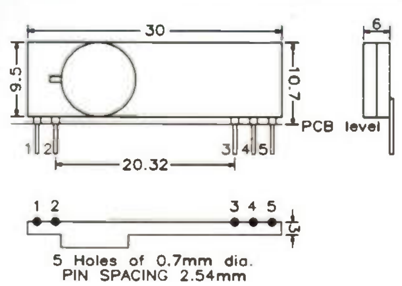


Figure 1. Physical dimensions of the TXM-418-A 418MHz transmitter module.

Important Note:

Commercial use may require additional type approval; in case of doubt contact the Radio Communications Agency at the Department of Trade and Industry, contact details are given at the end of this article.

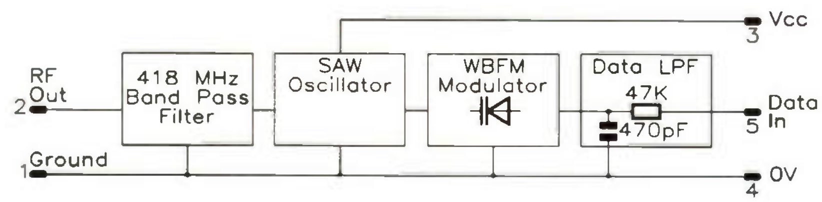


Figure 2. TXM-418-A 418MHz transmitter module block diagram.

Pin 1: RF Ground – internal connected to pin 4.
Pin 2: RF out – connects to the integral antenna (50Ω).
Pin 3. Positive power supply input.
Pin 4. 0V connection for power and modulation ground.
Pin 5. Data input – CMOS logic driven.

Table 2. TXM-418-A 418MHz transmitter module pinout.

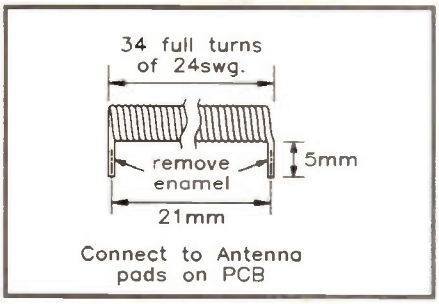


Figure 3a. Winding details for a helical antenna.

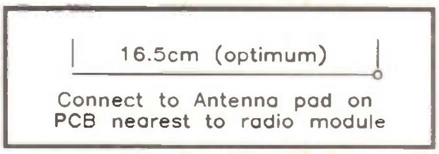


Figure 3b. Fitting a length of wire as an antenna.

next stage, a radio frequency (RF) oscillator. The centre working frequency of the RF oscillator is accurately set by a surface acoustic wave (SAW) resonator to be within the 418MHz band (417·90 to 418·1MHz). In addition to this the RF oscillator has a 418MHz band pass filter (BPF) to ensure that any spurious out of band emissions are within the limits set by the DTI RA performance specification MPT 1340. The final filtered RF output appears on pin 2 of the module.

Antenna Choice

MPT 1340 requires that the transmitter *shall* use an integral antenna only. In this specification, an integral antenna is defined as one which is designed to be connected permanently to the transmitter without the use of an external feeder. Three types of integral antenna are recommended and approved for use with the TXM-418-A transmitter module, however only two types are suitable for use with Encoded Transmitter project, these are listed below, see Table 3 for their various merits.

Helical

A wire coil, connected directly to pin 2 of the module, open circuit at other end (Figure 3a). This antenna is very efficient given its small size (20 × 4mm diameter). The helical is a high-Q antenna, trim the wire length or expand the coil for optimum results.

Whip

This is a wire connected directly to pin 2 of the module. Optimum total length is 165mm (¼ wave at 418MHz). Keep the open circuit (hot) end well away from metal components to prevent serious detuning (Figure 3b).

The choice of antenna and its position directly controls the effective range of the transmitter. The best position by far, is for the antenna to stick out the top of the finished boxed unit. This is often not desirable for practical or ergonomic reasons so a good compromise is the helical antenna.

The equipment in which the transmitter module is fitted must carry an inspection mark located on the outside of the unit and be clearly visible. The minimum dimensions of this inspection mark should be 10 × 15mm and the letter and figure height must be not less than 2mm. The wording shall read 'MPT 1340 W.T. LICENCE EXEMPT'. A suitable label, complying with these requirements, is included in the Encoded Transmitter kit (and is also available separately).

IMPORTANT! The trimmer control on the transmitter module is factory set to comply with the DTI (RA) specification MPT 1340, and therefore must *never* be altered.

418MHz Encoded Transmitter

Circuit Description

Figure 4 shows the block diagram of the Encoded Transmitter project, and Figure 5 shows the circuit diagram.

The circuit could not be simpler;

Antenna selection		
Characteristics	**Helical**	**Whip**
Ultimate performance	Good	Excellent
Ease of design set up	Good	Excellent
Size	Excellent	Fair
Immunity to proximity detuning	Good	Fair

Table 3. Antenna selection for use with the 418MHz Encoded Transmitter.

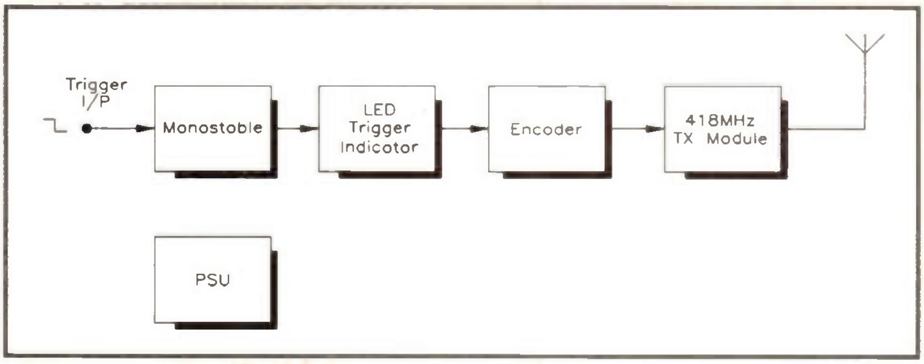


Figure 4. Block diagram of the 418MHz Encoded Transmitter.

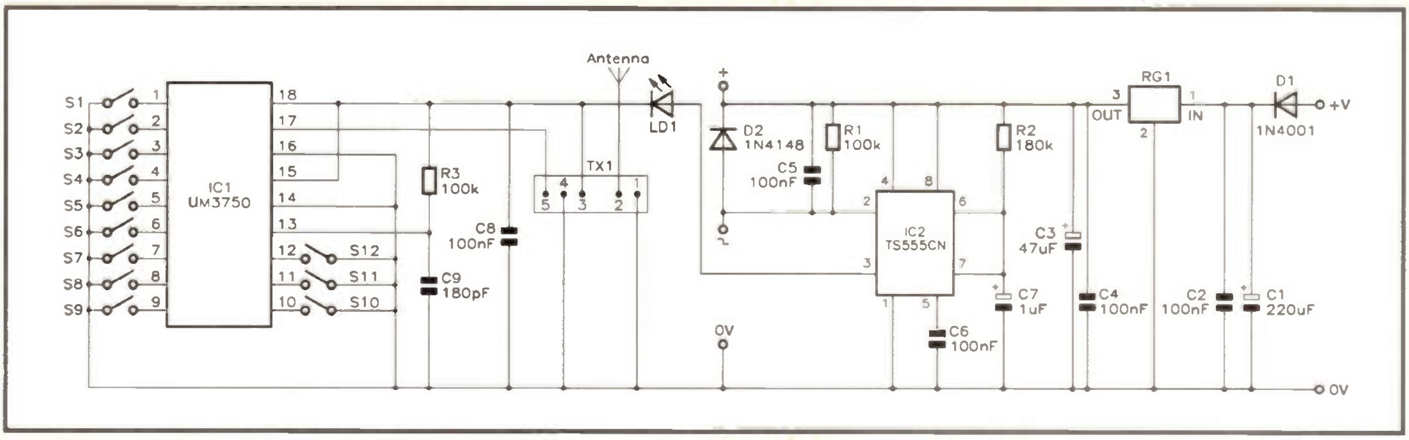


Figure 5. Circuit diagram of the 418MHz Encoded Transmitter.

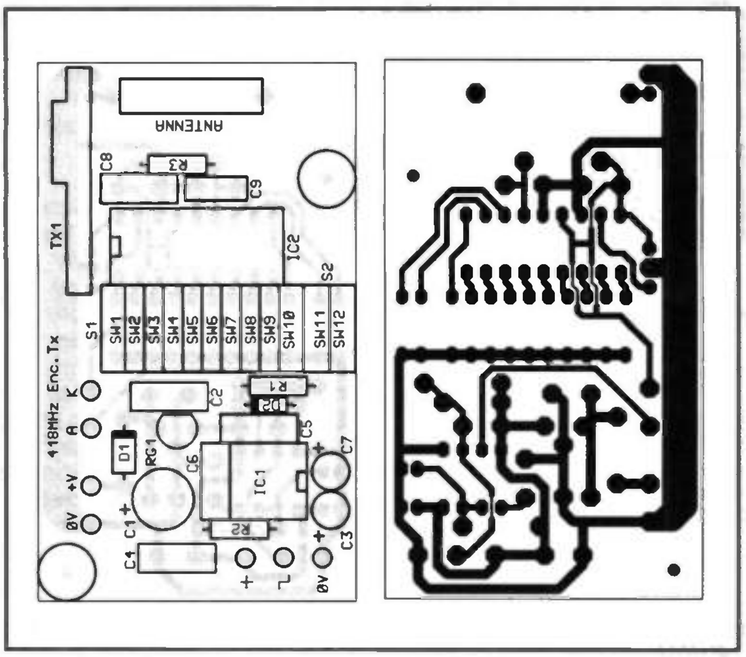


Figure 6. PCB legend and track.

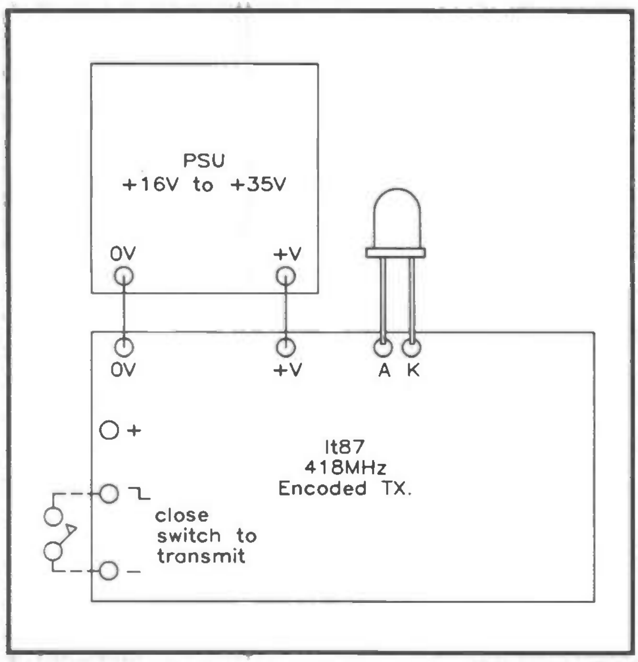


Figure 7. Wiring diagram.

diode D1 prevents damage to the circuit from accidental reverse polarity connection; capacitor C1 provides the reservoir function, and capacitor C2 provides high frequency decoupling. RG1 is a 12V regulator preventing supply variations from affecting operation of the unit, capacitor C3 is the output decoupling capacitor for the regulator and C4 provides high frequency decoupling as well as aiding stability.

IC2 is the ever popular TS555 timer in a monostable configuration; resistor R2 and capacitor C7 set the monostable period at approximately 200ms. R1 is the input pull-up resistor, capacitor C5 helps to prevent false triggering in a noisy environment and diode D2 prevents the input from going more than 0·6V above $+V_{CC}$. C6 decouples the internal divider chain, promoting stability in a noisy environment.

IC1 and Tx1 are powered from the output of IC2 (other lower power types of 555 such as the TLC555 and ICM7555 are not a suitable replacement due to the limited output source current) via the LED (LD1), which has a twofold use; the obvious one being a visual indicator showing transmit duration. The second and more important function is to reduce the output voltage of IC2 by 2V to bring it within the safe operating voltage range for IC2 (the absolute maximum being 11V).

The encoder and transmitter circuits are activated each time the input of the IC2 is triggered by a negative going input on IC2 pin 2.

Code Setting

IC1 is a UM3750 single chip encoder/decoder and is put into its encode (transmit) mode by connecting pin 15 to $+V_{CC}$. The code pattern is set by switches S1 to S12 on pins 1 to 12 of IC1, and a total of 4,096 different codes are possible; with the timing of the system set by the R/C network R1, C1. The resulting digital code appearing on pin 17 is fed to the modulation input pin 5 of the transmitter module TX1.

Construction

The PCB legend and track are shown in Figure 6, and will assist in the construction of the PCB. A ready made PCB is included in the kit and is also available separately (GH94B). Construction is fairly straightforward and the following general advice applies; begin with the smallest components first, working up in size to the largest, insert the PCB pins from the track side; be careful to orientate correctly the polarised devices, i.e. electrolytic capacitors, diodes, LEDs, regulator and ICs. Do not fit the 418MHz transmitter module Tx1 at this stage.

Fit the LED (LD1), with the shortest lead to the cathode (K) or the flat side of the legend. Next correctly orientate and insert the ICs into their sockets.

A more detailed explanation of component recognition and construction techniques may be found in the Constructors' Guide, which is included in the kit (available separately, XH79L).

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

The choice of a suitable enclosure is left entirely to the constructor, but it is important to point out that a metal enclosure should not be used as will act as an RF shield around the project!

Antenna Types

Decide upon the antenna type as previously discussed and then follow the relevant instructions to construct and then fit onto the PCB. It is recommended that either a helical or whip antenna is employed. A whip antenna is preferable if this can be accommodated inside or outside the enclosure.

Helical

Use the shank of a 2·5mm drill as the former for the antenna; tightly and closely wind 34 full turns of the 24SWG enamelled copper wire onto the drill bit shank; remove the antenna from the drill bit. Then preform it as shown in Figure 3a, crop to 5mm and remove the enamel from the antenna lead ends; fit and solder to the PCB.

Whip

Straighten out the enamelled copper wire; then cut off a 170mm length. Scrape the enamel off one end of the antenna and solder to the PCB, refer to Figure 3b; trim the antenna to the correct length (165mm including PCB track).

Testing

Refer to Figure 7, showing the wiring diagram and PSU. Connect a PSU (+16V to +35V DC) to the +V and 0V pins respectively and power up the module.

Using a test lead, connect the trigger (⅂) pin to 0V; the LED should illuminate continuously; upon removal of the link, the should LED extinguish.

Disconnect the PSU then very carefully fit the 418MHz transmitter module into the PCB and solder it in position.

To test the 418MHz Encoded Transmitter; a matching 418MHz Encoded Receiver is required. Ensure that both the transmitter and receiver have been set up to use the same code. Turn on the receiver; the receiver module's green LED should illuminate and the buzzer should sound when the transmitter is powered up and the trigger (⅂) pin is connected to 0V.

If you possess any RF test equipment this will enable you to test the transmitter output power level; and

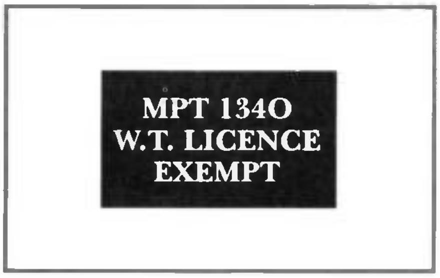


Figure 8. Front panel label.

to assist you to fine tune the antenna using the appropriate techniques to achieve maximum range in difficult locations. Even without RF test equipment, range tests can still be easily carried out, by gradually increasing the distance between transmitter and receiver, noting the point at which reception becomes unreliable. Such experiments will allow optimisation of transmitter site and antenna configuration. Avoid the temptation to adjust the trimmer on the transmitter, it has already been set correctly during manufacture!

A front panel label has been included in the kit in order to comply with the requirements of MPT1340, see Figure 8, it is also available separately (KP72P). The wording reads 'MPT 1340 W.T. LICENCE EXEMPT' and this should be fitted on the outside of any box or case that the transmitter module is incorporated into.

Use of the Transmitter

One of the many applications of the 418MHz Encoded Transmitter is using it with the Telephone Bell Repeater project, when the telephone rings, the Telephone Bell Repeater activates and keys the transmitter, this then transmits an encoded signal on 418MHz, and is received by the 418MHz receiver. The signal is decoded and a piezo buzzer and LED then operate on the receiver, informing the person with the receiver that the telephone is ringing.

Other applications for the 418MHz transmitter, are security related. Interfacing the transmitter to a sensor or to an alarm system, so that when the sensor or alarm is activated the transmitter is then triggered as well. As long as the range is not exceeded it is possible to use it on a boat, caravan, garage, shed at the bottom of the garden (protect your tools and ladders – burglars love 'em).

The 418MHz low-power transmitter module used in this project was covered in a DATA FILE in Issue 73 of *Electronics*, which contains additional applications information.

Contacts

Radiocommunications Agency,
Waterloo Bridge House,
Waterloo Road,
London, SE1 8UA.
Switchboard, Tel: 0171 215 5000

Copies of MPT1340 are available from the Radiocommunications Agency.

418MHz ENCODED TRANSMITTER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1	180k	1	(M180K)
R2,3	100k	2	(M100K)
CAPACITORS			
C1	220μF 35V Radial Electrolytic	1	(JL22Y)
C2,4-6,8	100nF 50V Disc Ceramic	5	(BX03D)
C3	47μF 25V Radial Electrolytic	1	(FF08J)
C7	1μF 100V Radial Electrolytic	1	(FF01B)
C9	180pF Metallised Ceramic	1	(WX59X)
SEMICONDUCTORS			
D1	1N4001	1	(QL73Q)
D2	1N4148	1	(QL80B)
LD1	3mm 2mA Green LED	1	(CZ30H)
RG1	LM78L12ACZ	1	(WQ77J)
IC1	NE555N	1	(QH66W)
IC2	UM3750	1	(UK77J)
MISCELLANEOUS			
S1	SPST 10-way DIL Switch	1	(FV45Y)
S2	SPST 2-way DIL Switch	1	(XX26D)
TX1	418MHz Transmitter Module	1	(AM27E)
	Enamelled Copper Wire 0·56mm 24SWG	1 Reel	(BL28F)
	8-pin DIL IC Socket	1	(BL17T)
	18-pin DIL IC Socket	1	(HQ76H)
	Single-ended PCB Pin 1mm (0·04in.)	1 Pkt	(FL24B)
	Front Panel Label	1	(KP72P)
	PCB	1	(GH94B)
	Instruction Leaflet	1	(XU96E)
	Constructors' Guide	1	(XH79L)

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

The above items are available as a kit, which offers a saving over buying the parts separately.
Order As LT87U (418MHz Encoded Transmitter) Price £26.99

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 items, which are included in the kit, are also available separately.
MPT1340 Label **Order As (KP72P) Price 59p**
418MHz Transmitter PCB **Order As (GH94B) Price £2.49**
418MHz Transmitter Module TMX-418-A
Order As (AM27E) Price £17.99

Designing Linear Circuits with Operational Amplifiers

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

The operational amplifier (op amp) is one of the most useful devices ever, and has largely displaced the discrete transistor as the basic active device for many low frequency circuits. We shall mostly be considering op amps handling audio signals, but the conclusions will be fairly general.

Types of Op Amp

There are now several different functional types of op amp available: 'normal', which have a high input impedance and a low output impedance, and are, therefore, voltage amplifiers; Norton or current-mirror op amps, such as the LM3900; and operational transconductance amplifiers, such as the LM13700. These types have various input and output impedances, and the circuits for them are quite different from those for normal op amps. We shall be concentrating on the first type, because they are the most widely used.

There are also different construction techniques for op amps: bipolar; CMOS; and bipolar with JFET inputs. While the input impedance of bipolar types is quite high, the latter types have such an enormous input impedance (of the order of one million megohms – one terohm, symbol TΩ) that its effect on the circuit currents is normally completely negligible.

A third way in which op amps differ is in terms of the type of supply voltage required. In principle, most op amps require both positive and negative supplies, but there are two sorts of exception: a real one and a false one. The false exception is where the device actually still requires the inputs to sit at a DC voltage above the negative supply rail, although not necessarily as high as half the supply voltage. Examples are the LM358 and LM324. The true exception is where the inputs are, or can be, referenced to the negative supply, while the quiescent output sits at half the supply voltage. The LM381 and LM387 are of this type, and may be regarded as op amps, although they are listed in the catalogue as audio preamplifiers.

Infinite Gain

The word 'operational' does not mean 'working' but is similar to 'theoretical' or 'ideal'. The ideal voltage amplifier has infinite input impedance and zero output impedance. Almost all devices approach this quite closely in practical circuits, through the application of large amounts of negative feedback. In order to achieve this, and still preserve a useful amount of *closed-loop gain*, the *open-loop gain* (i.e. with no feedback) is made very large indeed. One of the lowest open loop gains, that of the TL064, is still 75dB, which is ×5623. Op amps are never used in linear circuits without substantial negative feedback. In general, we can assume that an op amp has *infinite* open-loop gain, and consequently, *there is no measurable signal voltage between its two inputs.*

Why Two Inputs?

All op amps have two inputs, called *inverting* and *non-inverting* (see Figure 1). If we apply a positive voltage to the inverting input, the output goes negative, and *vice versa*, whereas the output follows the polarity of the non-inverting input. We need the inverting input so that we can apply the necessary negative feedback, but if we only had this one input, we could not preserve signal polarity over an odd number of stages. So, the non-inverting input is necessary as well, and it also gives scope for many more circuit configurations, including *balanced input*, which is very useful for rejecting spurious signals and interference. Also, the internal circuit of all 'normal' op amps includes a 'long-tailed pair' of input transistors, inherently giving both inverting and non-inverting inputs (Figure 2).

Feedback and Compensation

If we have a very high gain amplifier, and apply large amounts of negative feedback, the amplifier bursts into oscillation. This is because, while the feedback is negative at low frequencies, phase lags occur in the circuits, due to stray capacitances, and in the transistors, due to capacitances and conduction time effects. At a sufficiently high frequency, these lags add up to 180°, which makes the feedback positive, and oscillation results. To prevent this in a predictable way, it is usual to insert a shunt capacitor at a specific point in the internal circuit (see Figure 2). This reduces the gain of the amplifier at high frequencies, and well as introducing more phase-lag. The value is chosen so that it reduces the gain to less than 1 at the frequency where the total phase lag reaches 180°. If the gain is less than 1, no oscillation can occur, and this technique is called *dominant lag compensation*. The open-loop gain reduction begins at quite low frequencies, typically as low as 10Hz, but the negative feedback extends the bandwidth a great deal. For example, a 40dB gain (100 times) amplifier, using a 741, has a bandwidth of 10kHz.

We get the largest possible amount of negative feedback by connecting the inverting input to the output, and this is known as the *follower configuration* (Figure 3). The input signal is applied to the non-inverting input, of course. In this case, the gain is 1, and this makes the most severe demands on the compensation. Not all op amps have sufficient

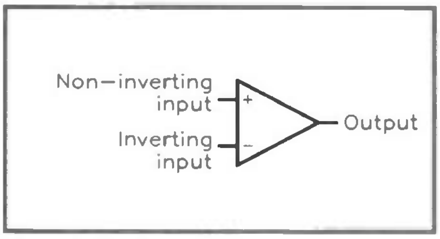


Figure 1. Circuit symbol for an op amp, showing inputs and output.

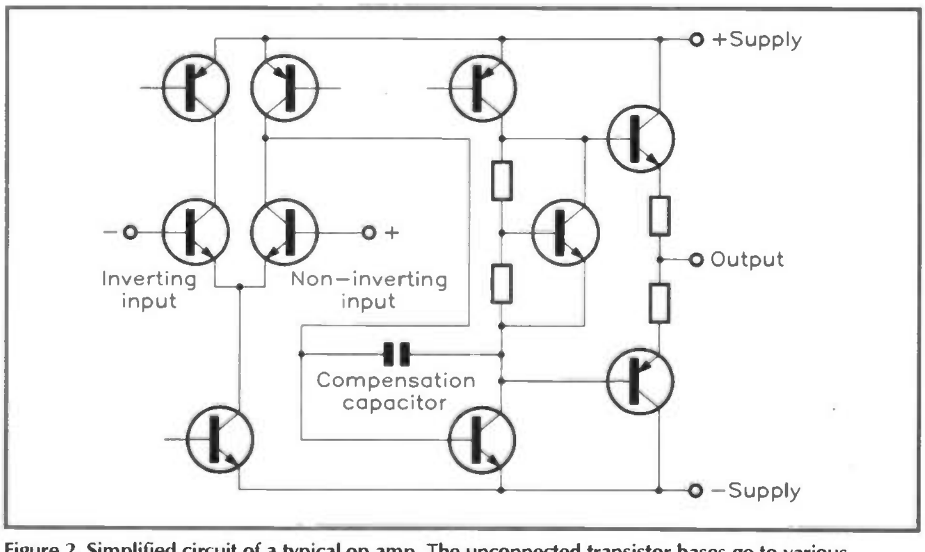


Figure 2. Simplified circuit of a typical op amp. The unconnected transistor bases go to various biasing circuits.

internal compensation to work as followers; the NE5534, for example. Unlike the NE5532, this is compensated only for loop gains of 3 or more, and it requires an external 22pF capacitor between pins 5 and 8 for follower operation.

Devices differ considerably in the value of external compensation capacitor needed, and to which pins it must be connected. It is therefore necessary to look at the manufacturer's data sheet in such cases.

Supply Current, Load Resistance and Maximum Output Voltage

Although the trusty catalogue gives a good deal of data about each type of op amp, there are often important points which the manufacturers either do not specify, or give as graphs, which would take up too much space if reproduced therein. Since the absence of this information can cause a lot of confusion, and it directly affects the choice of device for a given circuit position, it seems worthwhile to devote space to it here. The test circuit is shown in Figure 4, and all the measurements were done at 1kHz. The circuit is a non-inverting amplifier with a gain of 11 (21dB), and the supply voltage was set at ±12·5V. The measurement results are very dependent on the supply voltage, but to introduce yet another parameter would convert the article into a complete mass of figures, so I would suggest that you build the test circuit and do your own measurements at other supply voltages. Since the currents are quite low, battery supplies are practicable. Note that there is virtually no current in the 0V lead to the power supply: what goes in at the positive lead comes out at the negative lead.

Only one sample of each device type was measured, so the values in Table 1 have to be taken as 'typical', and there will be some variation between devices made at different times, and by different makers. The Table shows the following characteristics: No-signal supply current; maximum unclipped output voltage with 1kΩ load; and supply current under those conditions.

Figure 5 shows the maximum unclipped output voltage as a function of load resistance. Operation with loads as low as 100Ω is not normal, but devices such as NE5532 and NE5534 can cope quite well. Figure 6 shows the variation of supply current with output voltage with a 470Ω load resistance, and Figure 7 shows the same characteristic for a 4·7kΩ load. It can be seen that all the devices operate in Class B (supply current varies with signal level) with the 470Ω load, except for the NE5534 and LM833 at very low output levels; those devices are practically in Class A conditions with the 4·7kΩ load.

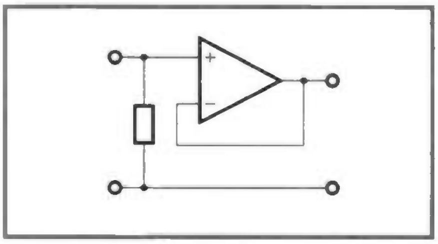


Figure 3. A follower circuit, giving a non-inverting gain of 1, and a very low output impedance.

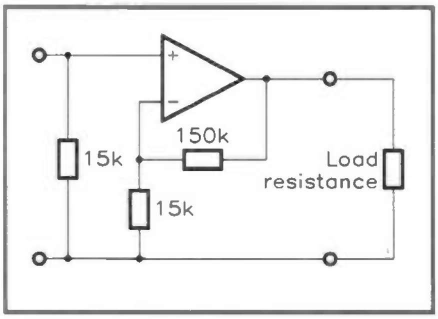


Figure 4. The test circuit, giving a non-inverting gain of 11.

Package Dissipation

8-pin DIL devices have a total package dissipation limit of about 500mW at 25°C, while 14-pin devices are typically allowed 1W. Table 1 and Figures 5 and 6 show that these values are not reached in normal operation; only if the device is severely over-driven into a very low load impedance or a short-circuit is there likely to be a problem. Short-circuit of the output pin to the positive supply is usually the most likely to cause damage.

Care must be taken that h.f. oscillation does not occur. Both supply rails must be decoupled close to the device by low-inductance 100nF capacitors. If a capacitive load greater than 50pF is to be driven, some devices need a stand-off resistor (usually 56Ω is enough) between the output pin and the load, *outside the feedback loop!*

Output stages

All of the devices tested have output stages that operate in Class AB, which means that, for high load resistances, the current in each output transistor does not drop to zero at any time during the signal cycle. However, with low load resistances, each transistor conducts for about half the cycle. Naturally, there is no abrupt transition from one mode to the other at a specific value of load resistance.

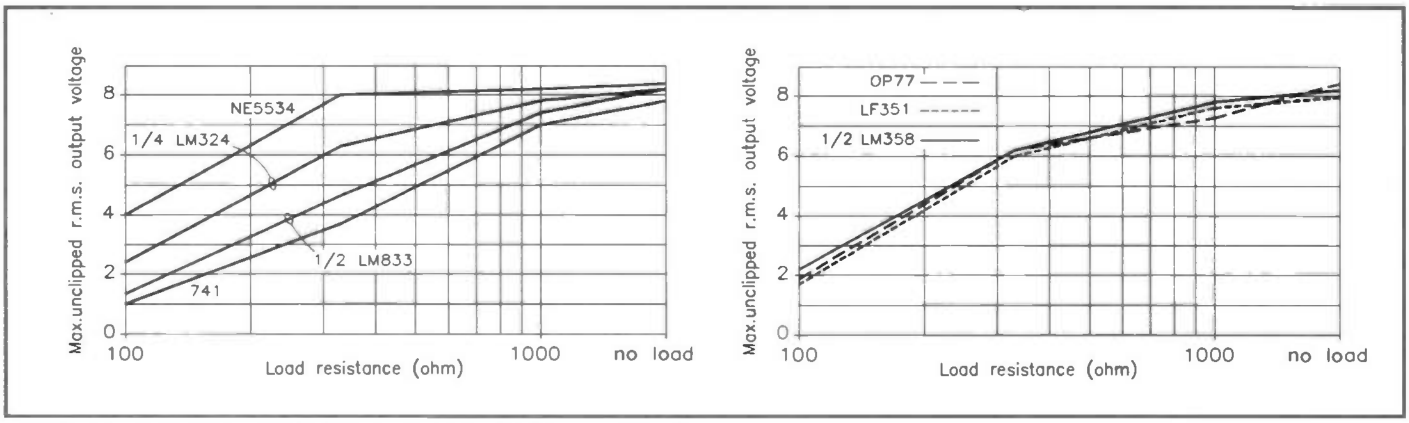


Figure 5. Output voltage/load resistance characteristics with ±12·5V supplies.

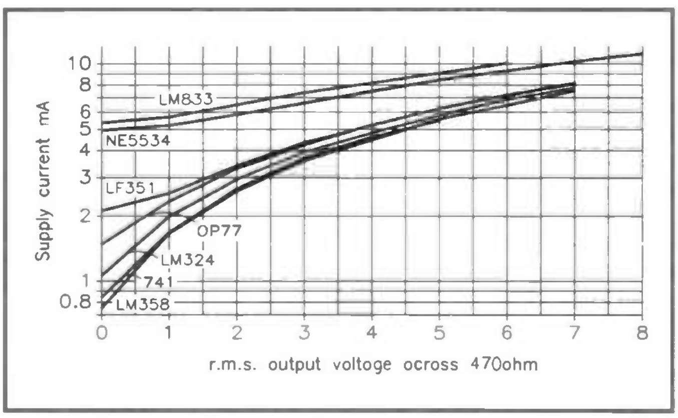


Figure 6. Supply current variation with rms output voltage (across 470Ω). For dual and quad packages, only one op amp is working; the others are drawing no current.

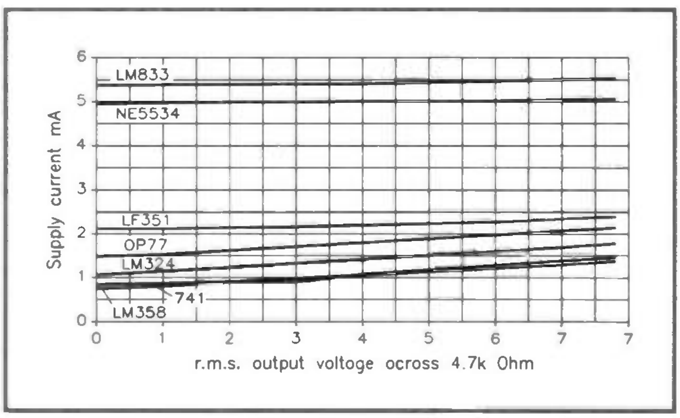


Figure 7. Supply current variation with rms output voltage (across 4·7kΩ). For dual and quad packages, only one op amp is working; the others are drawing no current.

Type/Characteristic	741	NE5534	LF351	OP77	*LM358	*LM324	*LM833
Supply current (mA), no signal	0·84	4·95	2·12	1·48	0·75	1·06	5·37
R.M.S. output voltage at clipping 1kΩ load	7·0	8·2	7·61	7·27	7·80	7·80	7·40
Supply current (mA) at clipping with 1kΩ load	3·7	7·3	5·3	5·02	4·24	4·55	7·72
* These are dual or quad devices with common supply pins. Only one op amp was tested, the others being connected as followers with inputs earthed.							

Table 1. Typical measured characteristics of several commonly used types of op amp.

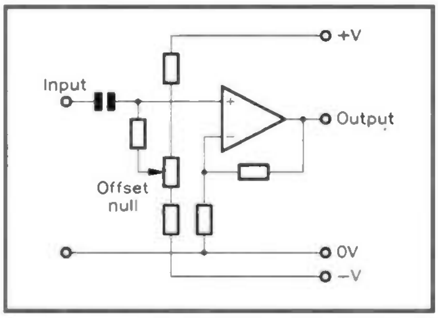


Figure 8. Basic circuit for offset voltage compensation of an op amp with no special provision, e.g., NE5532. Adjust the preset for zero DC output voltage.

The possibility of Class B operation brings up the question of crossover distortion – distortion at or near the zero-voltage crossing point of the signal waveform. This is caused by the current in one output transistor cutting off at an earlier point in the cycle than that at which the other transistor begins to conduct. It is normally prevented by the standing (or quiescent) current in the output stage, which also allows Class A operation with high load resistances. During the tests, no special search was made for low levels of crossover distortion, but the LM324 and LM358 samples tested did, in fact, show rather high levels of this effect, in the order of 0·5%, which would be unacceptable for many audio applications. They were, therefore, retested in one of the manufacturer's application circuits (also a 21dB gain non-inverting amplifier), with the same results. It is possible that my samples are atypical, but I suggest that you check for crossover distortion (an oscilloscope will show it easily) if you use either of these devices for audio work.

DC Conditions

To get the maximum possible output voltage swing, the output pin must sit very nearly at half the total supply voltage, i.e. at 0V in split-rail operation. This also allows direct coupling between cascaded devices. We can control the DC voltage at the output pin from the DC voltages at the input pins. Figure 2 shows that these are directly connected to the bases of the input long-tailed pair of transistors, so we have to supply DC base bias currents from the external circuit. (For op amps with PNP inputs, such as LM358, the base current flows *out* of, instead of into, the chip. This makes little difference!) Luckily, the currents required are very low, so that we can normally forget them unless it is essential to include really high value resistors (over 100kΩ) in the input circuit. In that case, the use of a JFET input op amp still allows the bias currents to be assumed to be zero.

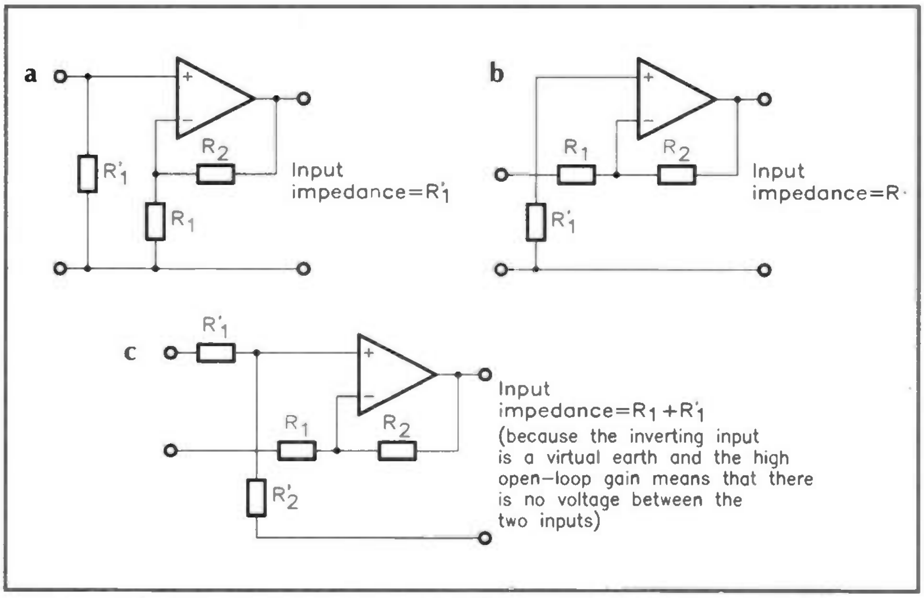


Figure 9. Standard amplifier configurations: (a) Non-inverting amplifier; (b) inverting amplifier; (c) balanced-input amplifier.

The need to supply offset compensation increases both cost and complexity of board layout, so is best avoided if possible. In fact, it is normally unavoidable only in high-gain DC amplifiers. For AC amplifiers, the simplest way to avoid the need for compensation is to follow these rules:

- no more than 20dB of gain between AC (capacitor) couplings

- equal, or nearly equal, DC resistances to common rail (0V) from both input pins.

The first rule minimises the offset voltage transferred to later stages, while the second minimises the effects of offset current.

Unfortunately, while offset compensation is fairly straightforward in principle, there are some complications. Firstly, the bias currents are inherently temperature-dependent, so that some thermal drift occurs in high-gain DC amplifiers unless op amps with temperature-compensated bias currents are used. Secondly, we have to deal with input current offset and input voltage offset. These are due to mismatches between the two input devices. IC fabrication produces very close matching, but the following high-gain amplifier causes even small mismatches to be significant.

Input voltage offset is due to differences in V_{be} of the input transistors for equal collector currents. Some op amps have pins for the connection of offset-trim circuits. The op amp can often be very easily damaged by wrong connections to these pins, and the offset trim circuits differ considerably between type numbers, so again, it is necessary to look at the data sheet.

Input current offset is due to differences in current gain of the input transistors. Normally, a single offset-trim adjustment takes care of both current and voltage offset, but there are cases where even this is unsatisfactory. Low-offset op amps are available for such critical applications.

8-pin dual and 14-pin quad devices do not have offset-trim pins, and for these devices any necessary trim voltage has to be provided at the signal input. Figure 8 shows a way of doing this. Note that the range of the trim pot should be very restricted, otherwise it will be very difficult to adjust, and its own stability may be insufficient to prevent serious drift of the DC conditions. Multi-turn cermet trimmers are recommended.

Amplifier Configurations and Gain Calculations

There are three common amplifier configurations: non-inverting; inverting; and balanced (Figure 9). Because of the very high open-loop gain, the closed-loop gains are very close to the values given by simple feedback theory:

Non-inverting: gain $= (R_1 + R_2)/R_1$, input impedance $= R_1'$

Inverting: gain $= -R_2/R_1$, input impedance $= R_1$

Balanced: gain $= R_2/R_1$, input impedance $= R_1 + R_1'$

In the first two cases, the resistor $R1'$ is equal to $R1$ and is purely to reduce offset, but in the balanced configuration, $R_1' = R_1$ and $R_2' = R_2$ are essential for correct operation.

With the feedback applied, the inverting input pin is a *virtual earth*, which means that the impedance there is very low indeed. At the same time, the gain from there to the output is the *open-loop gain* of the op amp. Therefore, it is very easy to pick up unwanted signals at that point, so all leads to it must be kept very short. In fact, if any lead has to be more than about 10mm long, the layout should be revised!

There may seem to be a paradox, in that the data sheet says that the input impedance is 1TΩ, but I have just said it is very low. The difference is that the 1TΩ applies *without feedback*, whereas it is the feedback which creates the low impedance. No current flows into the inverting input itself; all the input current through R_1 flows into the feedback resistor R_2. The very high open-loop gain ensures that there is virtually no signal voltage between the two inputs, so any current at the inverting input produces virtually no voltage, which is just another way of saying that the impedance is very low indeed.

In Figure 9a, the input impedance is R_1', which is normally rather low, but if offset is not a problem (i.e. the closed-loop gain is low and/or the output voltage swing need not be very large, and the output is capacitively coupled to the next stage), then R_1' can be made very large, so that its loading on the preceding stage is minimal.

The open-loop output impedance is high, largely due to the fact that the output transistors are driven from a very high impedance source (see Figure 4). The feedback ensures that this is brought down to a very low value, but can do nothing about the limitation of output voltage swing due to the voltage drops across the output stage emitter resistors. In audio power amplifiers, these are typically less than 1Ω, but in the lower powered op amps they are much larger. For example, in the 741 they are about 35Ω.

Noise

You may wonder why I have not mentioned noise, and designing for the highest signal-to-noise ratio, especially as many of the op amps in the Catalogue claim very low noise levels in the curious units of nanovolts per root-Hertz (nV/√Hz). The reason is that noise would make a long article, or even a mini-series, in itself, and I have to save up something for the long winter evenings. Watch this space!

NEXT issue

There are more terrific projects and features heading your way in next month's super issue of *Electronics – The Maplin Magazine*, including:

PROJECTS

CAR AMPLIFIER PSU

An SMPS module especially designed to complement the 400W amplifier featured in this issue, and the AMP200, but it can be used for almost any in-car amplifier requiring a ± 35V DC supply. The PSU makes extensive use of decoupling to provide a very 'clean' output, which guarantees that your amplifier will 'pump out' stunning high-quality sound.

DAY/NIGHT THERMOSTAT

An ingenious and compact thermostat module which will make a useful addition to your domestic heating requirements, to control your central heating system, for example. There are separate temperature references for daytime and night-time, and the 'program' can have up to 19 possible steps.

CHRISTMAS TREE LIGHT SEQUENCER

Long chains of tiny, highly coloured light-bulbs are commonly used to decorate the branches of the Christmas tree. Following electromechanical devices employed to flash the lights on and off, it is now possible, with modern electronic circuitry, to have a more precise control over the intensity of the light. Interesting combinations and patterns can be formed, and the unit is capable of driving three separate channels of lights at up to100W per channel.

MODEL TRAIN PROJECTS

Three circuits that may be added to a model railway layout which uses the Maplin digital control system as described in Issue 71. They comprise a Train Head- and Tail-Lamp Control, Automatic Loop Control, and Track Circuiting methods.

QUIZ SCORER

Following last year's Priority Quiz Buzzer, similar to those found on many quiz shows, this year's festive project is a 3-digit LCD (or optional LED display) Up/Down Counter that will display the score of the contestant (one required for each contestant). The score can be incremented or decremented in Units, Tens or Hundreds and can be cleared to zero with the simple push of a button. It is also possible to cascade modules to make higher digit counters if the optional LED displays are used.

FEATURES

Special features include a fascinating look at the planet Jupiter, and an introduction to the new Maplin key call system that now enables you to place your mail orders directly onto the Maplin mainframe computer, 24 hours a day, seven days a week! Also the MPEG Video Compression system, valve voltage regulators, and lots, lots more.

All this, plus all your favourite serials and regulars as well!

ELECTRONICS – THE MAPLIN MAGAZINE

BRITAIN'S BEST SELLING ELECTRONICS MAGAZINE

418MHz ENCODED

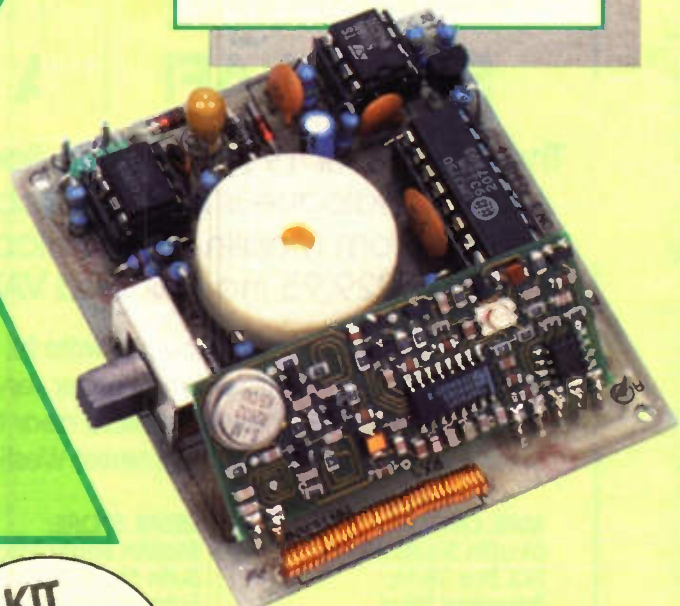
The 418MHz Encoded Receiver project presented in this article and its companion, the 418MHz Encoded Transmitter project (also presented in this magazine) are a boon for security and other applications. Using these projects means that standalone or wire-interconnected equipment can now be linked to good effect by totally wireless means. The Telephone Bell Repeater project (also presented in this issue) is an ideal candidate for wireless operation, but many more applications are possible.

FEATURES

* EASY TO BUILD AND USE
* WIDE SUPPLY RANGE
* LOW CURRENT CONSUMPTION
* READY-MADE AND ALIGNED RF MODULE
* 4,096 CODES
* FM OPERATION
* DTI APPROVED TO MPT 1340

IDEAL FOR:

* DOMESTIC/ COMMERCIAL SECURITY
* PAGING CAR ALARMS
* SITE PAGING RECEIVERS
* GUARD PATROL AND LONE WORKER PROTECTION
* NURSE CALL SYSTEMS
* REMOTE CONTROL SYSTEMS
* MEDICAL ACTION CALL
* FIRE ALARMS
* DOORBELL



Close-up of the assembled 418MHz encoded receiver PCB.

Designed by Chris Barlow and Alan Williamson

Text by Chris Barlow, Alan Williamson and Robin Hall

KIT AVAILABLE (LT88V) PRICE £39.99

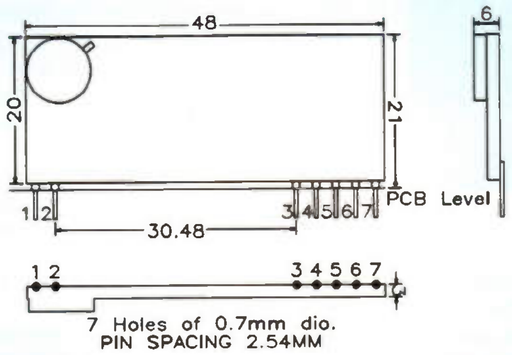
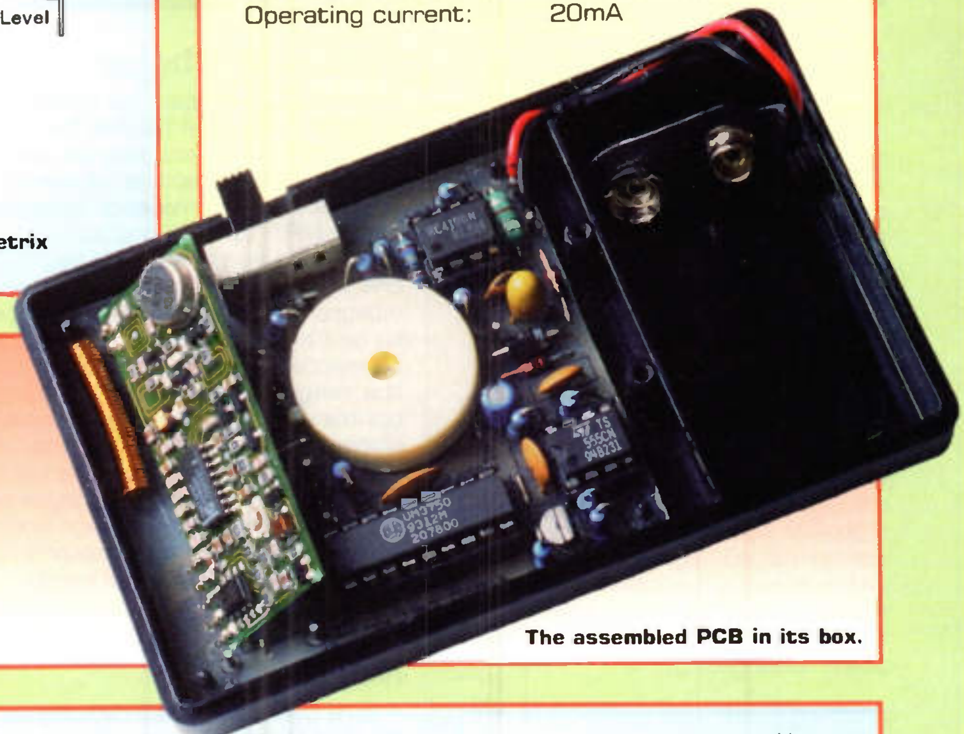


Figure 1. Physical dimensions of the Radiometrix SILRX-418-A 418MHz receiver module.

Specification

Power supply voltage:	3·5 to 9V (PP3 battery)
Current consumption	
Supply current average:	1·2mA
Supply current peak:	160mA @ 800µs
	20mA @ 4ms
Quiescent current:	0mA @ 49ms
Operating current:	20mA



The assembled PCB in its box.

PREVIOUSLY, it has been difficult for the electronics enthusiast to build, and legally use, UHF radio transmitters and receivers. However, this project uses a ready-built and aligned radio receiver module SILRX-418-A (AM28F), similarly, the Encoded Transmitter project uses a ready-built and aligned radio transmitter module TMX-418-A (AM27E). With ideal antennae, these modules are capable of transferring data reliably up to a distance 50m in buildings and over 200m under open field conditions. The modules have been optimised for battery powered operation and both are designed for reliability and performance in the field. They perform well with very small antennas and require no alignment whatsoever.

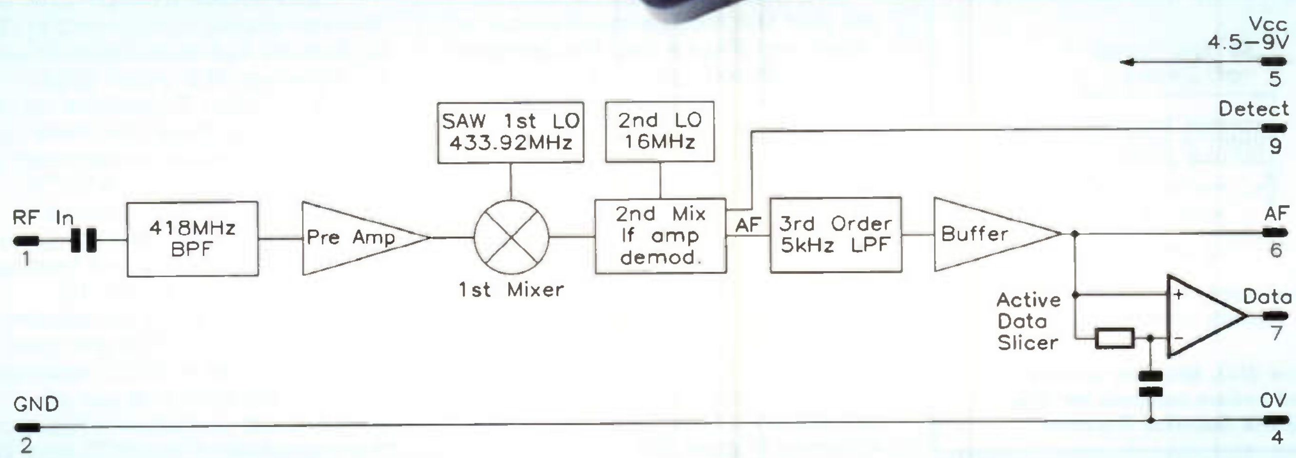


Figure 2. SILRX-418-A 418MHz receiver module block diagram.

The Receiver Module

The receiver module is a double conversion FM superhet with a data level converter driven by the audio output buffer. The 418MHz receiver module's specification (typical) is given in Table 1.

All the stages of the receiver are powered from a single +4·5 to +9V DC supply which is applied to pin 5 of the module. The 0V power connection is on pin 4 with the antenna ground on pin 2. For the physical dimensions of the SILRX-418-A 418MHz receiver module see Figure 1; Table 2 shows the 418MHz receiver module pinout.

As can be seen in the block diagram, Figure 2, the incoming 418MHz signal, picked up by the antenna, is connected to pin 1 of the module where it then passes through a capacitor into the 418MHz bandpass filter (BPF).

Operating supply range (V_{CC}):	4·5 to 9V DC
Supply current:	13mA
Overall frequency accuracy:	±100kHz
Sensitivity:	0·5µV for 20dB S/N
Carrier detector threshold:	1µV
RF input impedance:	50Ω
AF output level:	500mV Pk-to-Pk
Data bit duration:	0·2 to 30ms
Data mark/space duration:	5% to 66%
Data settling time:	10ms
Enable time:	1·5ms
Signal detect time:	1ms

Table 1. SILRX-418-A 418MHz Receiver module specification.

Pin 1: RF input – connection for antenna (50Ω).	Pin 4: 0V ground – connection for power and outputs.
Pin 2: RF ground – internally connected to pin 4.	Pin 5: Positive supply input.
Pin 3: Carrier detect – used to enable external circuits.	Pin 6: Audio out – FM demodulated output.
	Pin 7: Data out – digital output.

Table 2. Pinout of the SILRX-418-A 418MHz receiver module.

An RF preamplifier boosts the signal before it enters the first mixer stage.

The first local oscillator runs at a frequency of 433·92MHz which is accurately set by an SAW resonator. Its output is fed to the first mixer stage where it mixes with the amplified 418MHz received signal to produce the first IF signal at 15·92MHz. This is then fed to the second mixer where a second local oscillator running at 16MHz produces the final IF signal at a frequency of 80kHz. It is then amplified and the wide-band frequency modulated signal demodulated to produce an audio signal. In addition, a fast acting carrier detect signal is produced which is made available on pin 3 of the module and in this application is used to control a duty cycle power saving circuit.

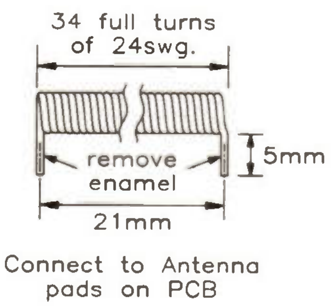


Figure 3(a). Winding details of the helical antenna for the 418MHz Encoded Receiver.

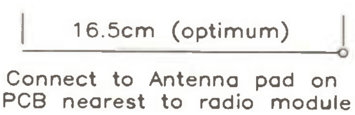


Figure 3(b). Fitting a length of wire as an antenna.

To improve the signal to noise performance and reject any unwanted signals the audio is processed by a third order low pass filter (LPF) with a 5kHz cutoff. This signal is fed to an audio buffer and its output is centred around the half supply reference and appears on pin 6 of the module. It is also tapped off to the active data slicer where the analogue audio signal is converted into a digital signal which appears on pin 7. This is output is fed to the decoder IC.

Antenna Choice

Any of the antennas, as similarly described in the 418MHz Encoded Transmitter project, may be used on the receiver module. However, the criteria for a receiver antenna under MPT 1340 is not as restrictive as those used by the transmitter. In addition to an integral antenna you are permitted to use an external antenna connected by a coax feeder. If the range of the system is to be optimised, consider a quarter wave dipole or ground plane antenna. As with the transmitter the positioning of the receiver antenna is of the utmost importance and will prove an important factor in determining the ultimate range of the system.

Helical

A wire coil, connected directly to pin 2 of the module, open circuit at other end (Figure 3a). This antenna is very efficient given its small size (20 x 4mm diameter). The helical is a high-Q antenna, trim the wire length or expand the coil for optimum results.

Whip

This is a wire connected directly to pin 2 of the module. Optimum total length is 165mm (¼ wave at 418MHz). Keep the open circuit (hot) end well away from metal components to prevent serious detuning (Figure 3b).

The choice of antenna and its position directly controls the effective range of the receiver. The best position, by far, is for the antenna to stick out the top of the finished boxed unit. This is often not desirable for practical or ergonomic reasons so a compromise may need to be reached. If an internal antenna must be used, keep it away from other metal components, batteries, PCB tracks/earth plane, etc.

IMPORTANT! The trimmer control on the receiver module is factory set and must never be adjusted.

418MHz Encoded Receiver

Circuit Description

Figure 4 shows the block diagram of the receiver circuit, while Figure 5 shows the circuit diagram.

The connections to the 418MHz receiver module are as previously described with pin 3 driving the base of TR4 to produce a carrier detect output signal. This output remains high until a 418MHz signal is received at which time it goes low until the signal is removed. The audio output from pin 6 of the receiver module is not used in this application (but is available on pin 'A'). However, the digital data output from pin 7 (available on pin 'D') is used to drive the same type of chip used in the transmitter circuit. This time the UM3750, IC1, is placed into its decode (receive) mode by connecting pin 15 to the 0V ground and feeding the received data to pin 16. The same R/C timing component values for R17 and C8 are used, to match those in the transmitter. The code pattern (one out of 4096) is set by solder bridges on the track side of the PCB next to

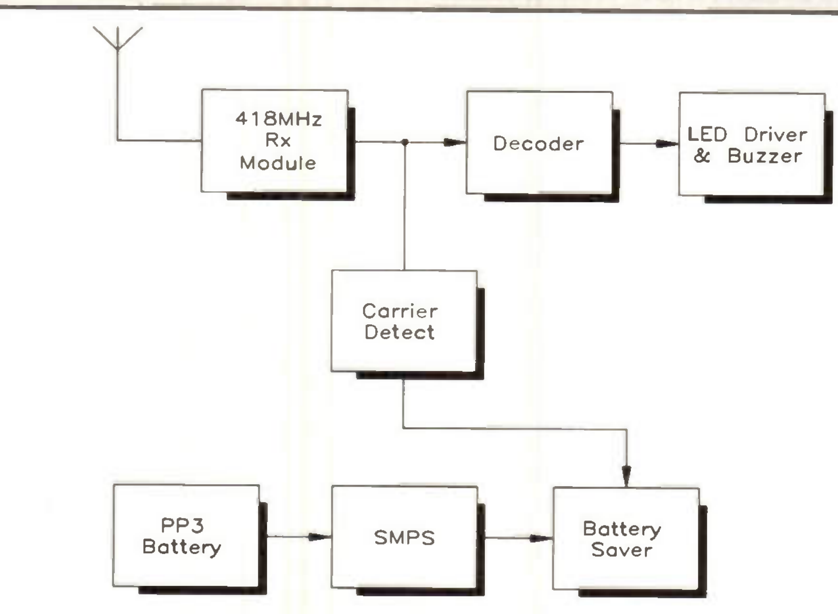


Figure 4. Block diagram of the 418MHz receiver.

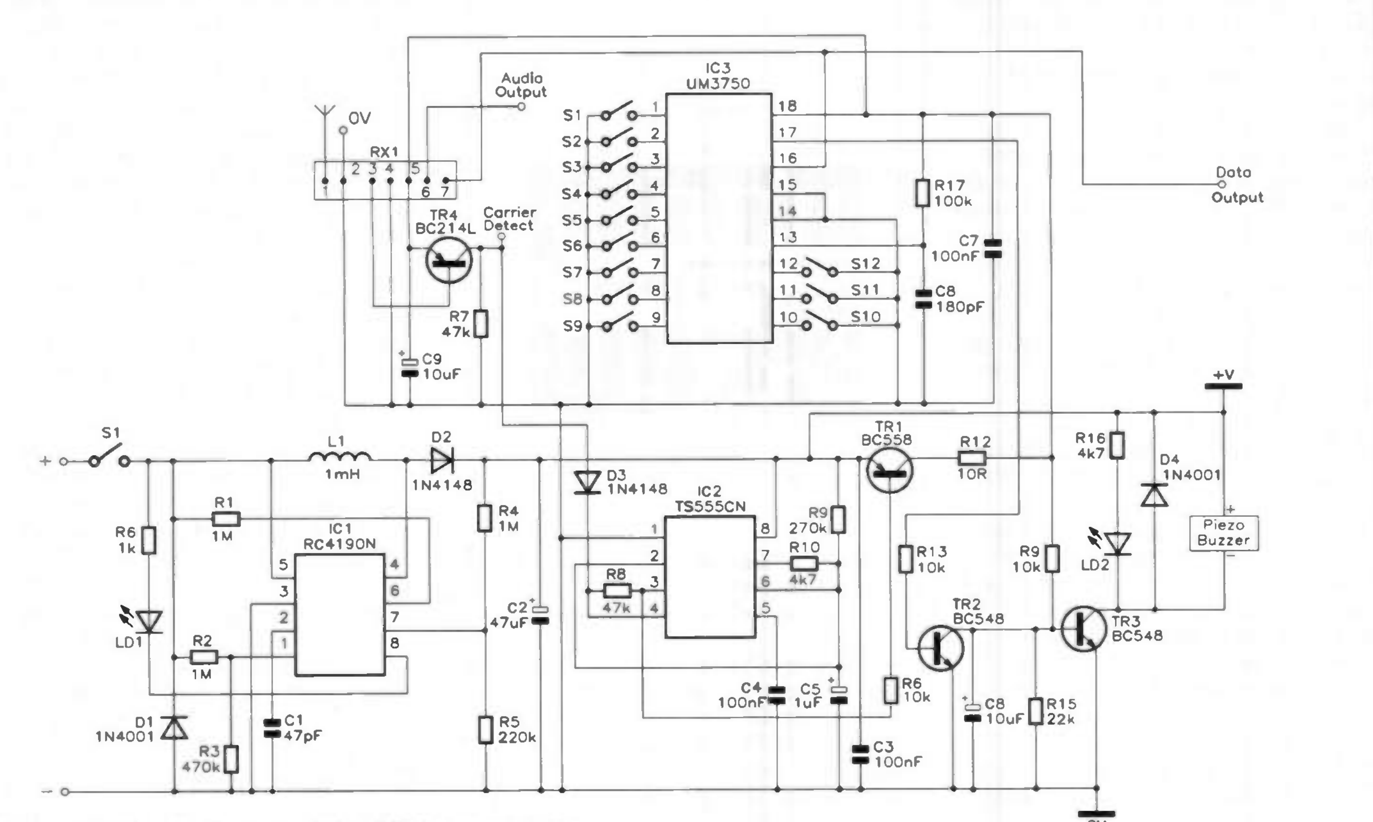


Figure 5. Circuit diagram of the 418MHz receiver.

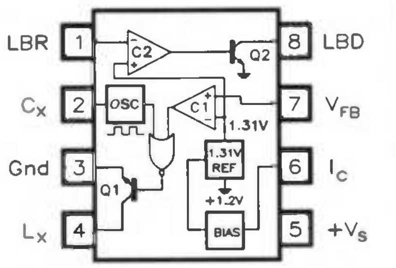


Figure 6. Functional block diagram of the RC4190 (SMPS).

IC1, and if a matching code is received, pin 17 will become active low for 128ms. If a further match is detected within that time the output will stay low for a further 128ms and so on. The additional transistor switching stage (TR2 & TR3) enables higher current devices (LD2 & BZ1) to be controlled.

The additional circuits for the receiver are a switch mode power supply (SMPS) battery life extender (IC1) and a power saving (IC2) circuit.

Diode D1 is connected in reverse bias across the supply input; in the event of the switch S13 being closed and the battery being inadvertently connected with the wrong polarity, the diode will clamp the negative voltage across the circuit to −1V (the maximum current flow is limited by the internal resistance of the PP3 battery), thus preventing expensive damage to the circuit.

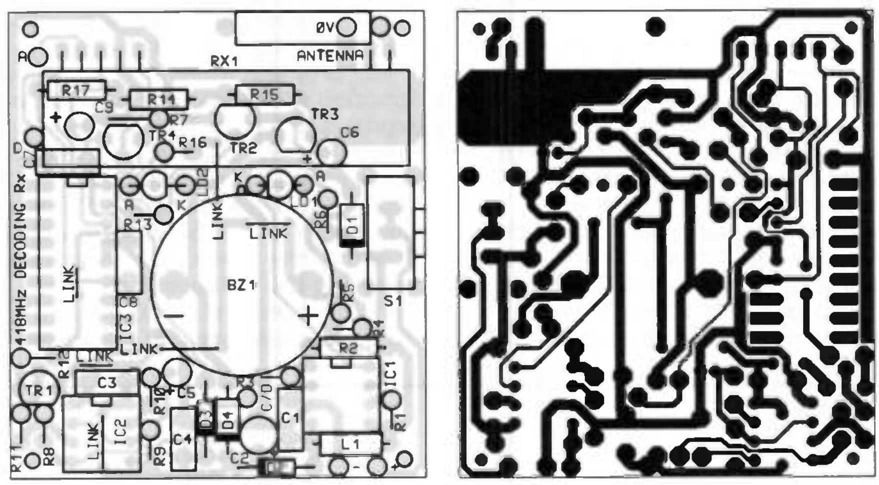


Figure 7. PCB legend and track.

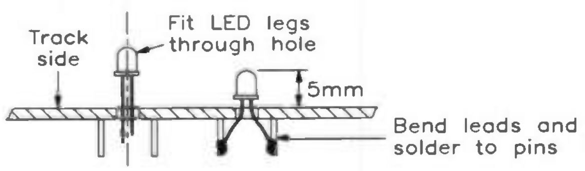


Figure 8. Fitting the LEDs.

Pin 1: Low battery (set) resistor (LBR).	Pin 5: + Supply voltage (+V_S).
Pin 2: Timing capacitor (C_X).	Pin 6: Reference set current (I_C).
Pin 3: Ground (Gnd).	Pin 7: Feedback voltage (V_{FB}).
Pin 4: External inductor (L_X).	Pin 8: Low battery detector output (L_{BD}).

Table 3. Pinout of the RC4190N.

IC1 is a low-power, high-efficiency DC-to-DC converter, specifically designed for battery operated equipment, and here configured as a battery life extender.

The pin function of the device is shown in Table 3 and a functional block diagram is shown in Figure 6. A fresh PP3 battery has a terminal voltage of +9V DC, which falls as the battery expends energy. When the battery voltage falls to +7V, the battery extender will 'kick in' and maintain the output voltage at +7V until the battery finally expires at +2·2V.

The device operates in the following manner: resistors R4 & R5 form a potential divider for Pin 7 to monitor the supply output voltage. If the voltage at Pin 7 is above 1·31V, the internal switch transistor is inhibited; below, the transistor is allowed to switch at the same frequency as the oscillator, which is determined by the capacitor C1. While the internal switch transistor is turned on, Pin 4 is effectively connected to 0V ground diode and D2 is reverse biased. The battery voltage is applied across the inductor L1; this causes a magnetising current to flow through L1, building up an increasing magnetic field. Turning off the switching transistor causes a current pulse to be generated from the energy stored in the magnetic field, through L1 in the same direction as the supply current. Diode D2 then conducts and charges the main reservoir capacitor C2. Because the oscillator frequency is much higher than the load impedance × C2 time constant, a constant DC voltage is produced. Variations in load demand do not affect output voltage as the switching transistor is automatically pulse width modulated (PWM) due to Pin 7 monitoring the supply. Resistors R2 & R3 form the potential divider to monitor the battery voltage, when the terminal voltage of the battery falls to approximately 3·5V, and LD1 illuminates indicating that a new battery is required. Resistor R1 supplies bias current to the internal reference voltage source connected to the comparators.

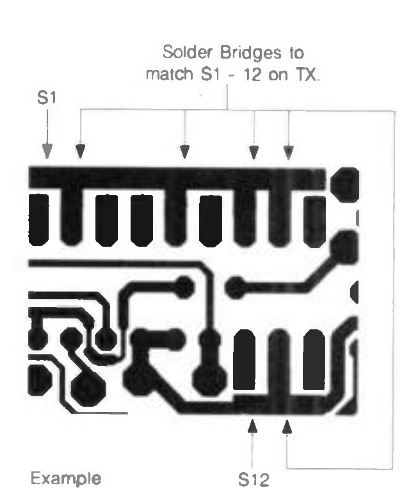


Figure 9. Decode selection by solder pads.

IC2 provides a duty cycle control function which latches on when a signal is present. The component values of R9, R10 and C5 have been selected to produce a 3·257ms on time and a 187ms off duration, i.e. a 1:57·4 duty cycle. This has the effect of significantly reducing the quiescent current consumption of the receiver, so increasing the battery life of the unit. Only when a 418MHz signal is received will the power to the receiver module, RX1, and the data decoder, IC3, be continuously applied until the signal is removed. This is achieved by connecting the carrier detect signal from TR4 via diode D3 to pin 4 of IC2. While pin 4 is high (no signal received) the 555 timer will produce its pulse output to the receiver circuit. However, if a signal is received then IC2 will produce a continuous output condition. This output is used to control the PNP power switching transistor, TR1.

The valid code output on pin 17 of IC3 is fed via R13 to the base of TR2, which is used to control the on/off switch action of TR3. When pin 17 becomes active low (received code is matched) TR3 turns on and current flows in the collector circuit. This causes the LED, LD1, to illuminate and the piezo buzzer to sound for the duration of the received valid code.

Construction

The PCB has a printed legend that will assist you when positioning each item, see Figure 7. Do not fit the 418MHz receiver module at this stage. If the optional box is to be used, before fitting the components to the PCB, use it as a template to mark out the holes for the two LEDs.

Construction is fairly straightforward: begin with the smallest components first, working up in size to the largest and inserting the PCB pins from the track side; do not insert pins for the antenna unless an external feeder is used. Be careful to correctly orientate the polarised devices, i.e. electrolytics, diodes, LEDs and ICs.

Refer to Figure 8 for fitting the two LEDs on the track side of the PCB. The shortest lead is the cathode (K) on the flat side on the legend. Next correctly orientate and insert the ICs into their sockets.

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.

Antenna Types

Decide upon the antenna type as previously discussed and then follow the relevant instructions to construct and then fit onto the PCB.

Helical

Use the shank of a 2·5mm drill as the former of the antenna; tightly and closely wind 34 full turns of the 24SWG enamelled copper wire onto the drill bit shank; remove the antenna from the drill bit. Then

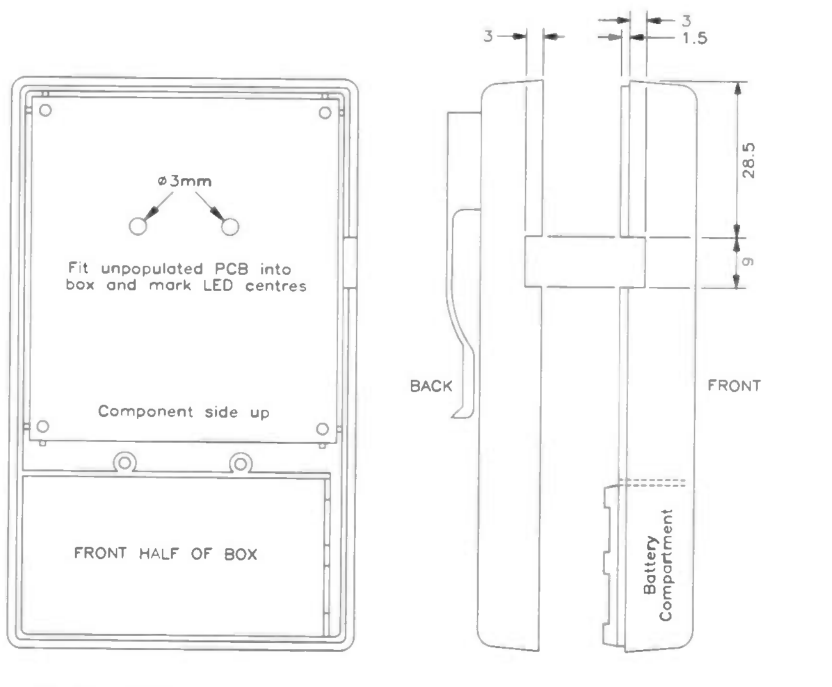


Figure 10. Box drilling.

preform as shown in Figure 3a, crop to 5mm and remove the enamel from the antenna lead ends; fit and solder to the PCB.

Whip

Straighten out the enamelled copper wire, then cut off a 170mm length. Scrape the enamel off one end of the antenna and solder to the PCB (refer to Figure 3b). A length of insulated multi-strand wire would be more practical than enamelled copper wire if a portable application is in mind.

Code Setting

The code pattern (one out of 4096) is set by solder bridges on the track side of the PCB of IC1 (refer to Figure 9). Obviously, set the same code for the receiver as the transmitter.

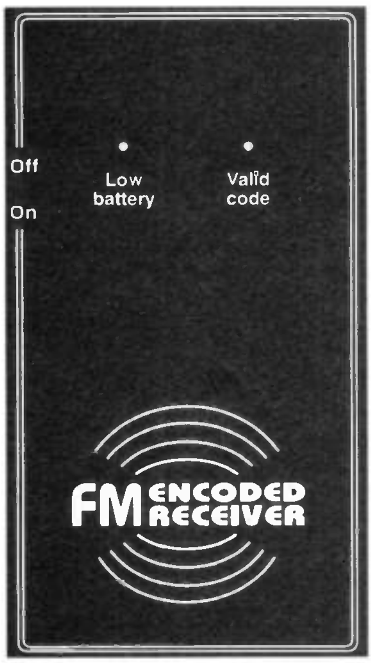


Figure 11. Front panel label.

Testing

Set a variable voltage PSU to +3V DC then connect to the module. Switch on the PSU and module; the red LED should illuminate.

Using a multimeter, set to read +10V DC minimum, then check the supply voltage across Pins 1 (–) & 8 (+) of IC2 (be aware of polarity when using an analogue meter); a reading of +7V should be obtained.

Connect the plus (+) meter lead to the junction of R12 and the collector of TR1; an unstable reading or meter flicker should be noted.

Disconnect the PSU. Fit the PP3 battery clip and preform the pins on the 418MHz receiver module, fit onto the PCB and solder in position. Connect a 9V PP3 battery to the battery clip and switch on the receiver.

On the transmitter connect the trigger(⊓L)pin to 0V and power up, so that it continuously transmits a valid code; the receiver module green LED should illuminate and the buzzer should sound.

The antenna on the receiver module can now be optimised by range testing. Walk away from the transmitter until the receiver stops working; 'tweak' the antenna using the appropriate technique until maximum range is obtained.

Box Drilling

To complete the project: The drilling details of a suitable optional box are given in Figure 10. A front panel label has been provided and is shown in Figure 11. When the box is prepared, install the project as shown in Figure 12, the exploded assembly drawing.

Use of the Receiver

One use of the 418MHz Encoded Receiver is with the 418MHz Encoded Transmitter and the Telephone Bell Repeater projects. With the 418MHz transmitter interfaced to the Telephone Bell Repeater, when the telephone rings, the Telephone Bell Repeater activates and keys the transmitter. This then transmits an encoded signal on 418MHz, and is received by the 418MHz receiver. The signal is decoded, and a piezo buzzer and LED then activate on the 418MHz receiver, informing the person with the receiver that the telephone is ringing. The receiver, when housed in the optional case, is a compact unit, and can be clipped onto a pocket or belt and carried around.

Other Applications

There are many other applications for the 418MHz receiver; such as part of a security system, 'nurse/relative call' for the elderly, wireless doorbell, etc.

The transmitter/receiver projects could be used as a means of connecting a remote sensor to an alarm system without having to run wires. A remote sensor can be connected to the transmitter by means of normally open contacts, such that when the sensor is triggered, the transmitter is activated. Interfacing the receiver to an alarm system can be achieved by connecting a low current low voltage relay in place of the piezo buzzer. The relay contacts would be connected to either a normally open or normally closed loop on the alarm system so that when a valid code is received, the relay is operated and the alarm system triggered.

This principle could be applied to provide a 'nurse/relative call' system for an elderly relative, the transmitter, fitted with a latching button could be carried in the relative's pocket, so it could be

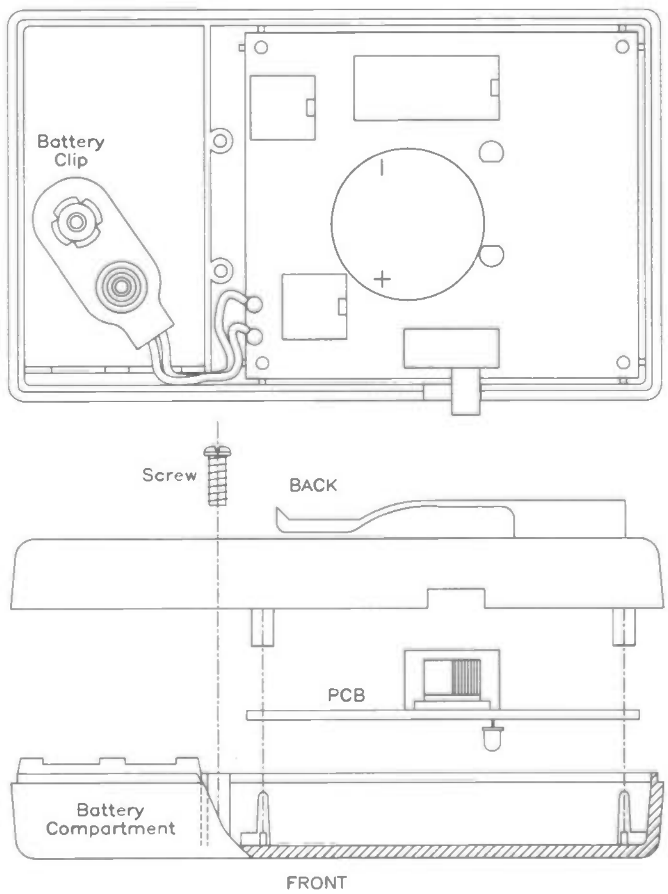


Figure 12. Exploded assembly drawing.

operated in case of emergency. The receiver could be connected to a telephone communicator, such as the GL03D unit stocked by Maplin, by means of a low current low voltage relay connected in place of the piezo buzzer. Activating the transmitter would cause the receiver to operate the relay, which in turn would cause the telephone communicator to dial the preprogrammed number and relay the prerecorded emergency message. The GL03D unit mentioned stores the emergency message in battery-backed up RAM and can be programmed with up to four telephone numbers.

By connecting the transmitter to a car or house alarm system, a paging system would be created such that when the alarm is triggered, the transmitter is activated. When a valid code is received, the piezo buzzer on the receiver would sound, alerting the owner to a theft attempt.

The transmitter and receiver could also form the basis of a wireless doorbell.

With a total of 4096 codes to choose from there is a plenty of scope for using multiple units in many different applications. In all cases it is wise to perform range tests to ensure adequate coverage is obtained. With security applications or emergency call systems, correct operation should be checked regularly and batteries replaced as a matter of course.

The 418MHz low-power receiver module used in this project was covered in a DATA FILE in Issue 73 of *Electronics*.

418MHz RECEIVER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1,2,4	1M	3	(M1M)
R3	470k	1	(M470K)
R5	220k	1	(M220K)
R6	1k	1	(M1K)
R7,8	47k	2	(M47K)
R9	270k	1	(M270K)
R10,16	4k7	2	(M4K7)
R11,13,14	10k	3	(M10K)
R12	10Ω	1	(M10R)
R15	22k	1	(M22K)
R17	100k	1	(M100K)
CAPACITORS			
C1	47pF Metallised Ceramic	1	(WX52G)
C3,4,7	100nF 16V Miniature Disc Ceramic	3	(YR75S)
C2	47µF 10V Tantalum Bead	1	(WW75S)
C5	1µF 63V Sub-min Radial Electrolytic	1	(YY31J)
C6,9	10µF 16V Sub-min Radial Electrolytic	2	(YY34M)
C8	180pF Metallised Ceramic	1	(WX59P)
SEMICONDUCTORS			
D1,4	1N4001	2	(QL73Q)
D2,3	1N4148	2	(QL80B)
LD1	3mm 2mA Red LED	1	(CZ28F)
LD2	3mm 2mA Green LED	1	(CZ30H)
TR1,4	BC558	2	(QQ17T)
TR2,3	BC548	2	(QB73Q)
IC1	RC4190N	1	(UR15R)
IC2	TS555CN	1	(RA76H)
IC3	UM3750	1	(UK77J)
WOUND COMPONENTS			
L1	1mH Choke	1	(WH47B)
MISCELLANEOUS			
RX1	418MHz Receiver	1	(AM28F)
BZ1	PCB Buzzer	1	(KU58N)
S1	PCB Slide Switch SPDT	1	(FV01B)
	Enamelled Covered Wire 0·56mm 24SWG	1 Reel	(BL28F)
	8-Pin DIL IC Socket	2	(BL17T)
	18-pin DIL IC Socket	1	(HQ76H)
	Single-ended PCB Pin 1mm (0·04in.)	1 Pkt	(FL24B)
	Front Panel Label	1	(KP73Q)
	PCB	1	(GH95D)
	Instruction Leaflet	1	(XU97F)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	Pocket Clip Case	1	(KC95D)
	9V PP3 Alkaline Battery	1	(FK67X)
	PP3 Battery Clip	1	(HF28F)

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 LT88V (418MHz Encoded Receiver) Price £39.99

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

418MHz Encoded Receiver PCB
Order As GH95D Price £2.69

418MHz Encoded Receiver Label
Order As KP73Q Price £1.49

418MHz Receiver Module SILRX-418-A
Order As AM28F Price £29.95

CLASSIFIED

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

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

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

COMPUTERS

OLD NCR TERMINAL, Monitor Keyboard. I.O. Unit, Processor Unit plus 8" double floppy drive. £75 o.n.o. Buyer collects. Tel: 01452 423671. Charlie Markwick, 46 Tuffley Crescent, Gloucester.

BBC B COMPUTER, Cub high resolution monitor, Epson printer, Mega 3 ROM (Interword/Sheet/Chart), Screen dump, Joystick. All manuals plus many software applications. £200. Tel: (0734) 699460.

AMSTRAD PC15125D IBM PC compatible: 640K RAM, 32Mb H/D (Auto parking), Colour CGA monitor, 8087 Co-Pro, Keyboard, Mouse, 5¼" F/D, Original disks and manuals. £120 o.n.o. Tel: Paul (0243) 786585 or (0703) 592771.

FOR SALE. ADVANCED GRAVIS ULTRASOUND PC Sound Card. Used once, excellent condition, complete with bundled software. £85. Tel: 0223 440492.

MUSICAL

COMMODORE 64 MIDI UTILITIES: Filter, real time/storage analyser, channeliser, data filer. £17. For detailed info send SAE to: D. Williams, 12 Old Forge Way, Skirlaugh, N. Humberside HU11 5DX.

VARIOUS

NEW COMPONENTS, plus free PCB mounting Nicad. Assorted mixture list price £50 plus, £12 per bag inclusive of postage and packing. Mr D. J. Brown, 2 Glentworth Avenue, Whitmore Park, Coventry, West Midlands CV6 2HW.

MAPLIN HOME SECURITY SYSTEM, assembled and tested. Includes burglar alarm kit, break contact kit, external horn timer, ultrasonic module, siren etc. All for £99. For details tel: 0243 574004.

HEATSINKS, 0·5°/C watt 'H' shape £7 each as new undrilled. 500VA 30-0-30 Toroidal Transformer (new) £18. Hand held top quality Digital Optical Tachometer (RS type) £50. Tel: 0254 57980.

WANTED

SSP6N60A information and/or source of supply for this Power Mosfet used as chopper in the switchmode PSU of a PC monitor. Tel: Norman (0782) 550684.

NOTE 3300A utility disk or supplier information for NOTEBOOK PC. Tel: Steve (0872) 325571 Daytime.

CLUB CORNER

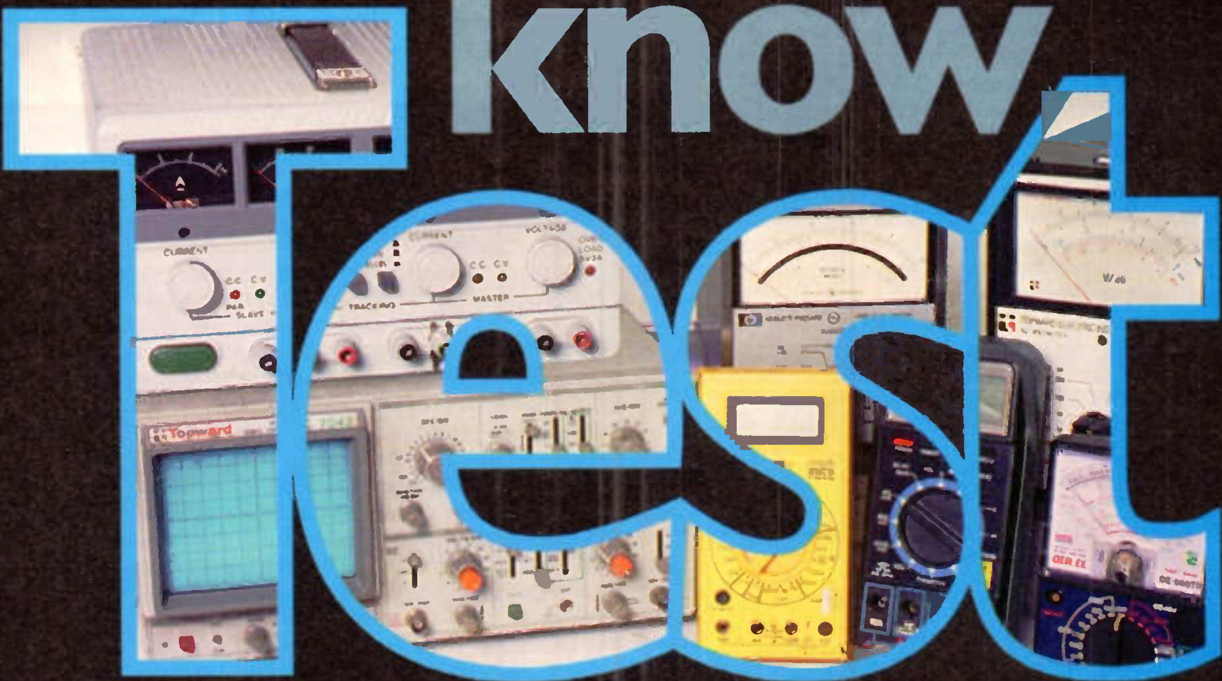
WIRRAL AND DISTRICT AMATEUR RADIO SOCIETY meets at the Irby Cricket Club, Irby, Wirral. Organises visits, DF hunts, demonstrations and junk sales. For further details, please contact: Paul Robinson (G0JZP) on (051) 648 5892.

SOUTHEND & DISTRICT RADIO SOCIETY. Meets at the Rocheway Centre, Rochford, Essex every Friday at 8pm. Details F. Jensen (G1HQQ) P.O. Box 88, Rayleigh, Essex SS6 8NZ.

THE LINCOLN SHORT WAVE CLUB meets every Wednesday night at the City Engineers' Club, Waterside South, Lincoln at 8pm. All welcome. Further details from Pam, G4STO (Secretary) Tel: (0427) 788356.

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

Getting to know Test EQUIPMENT



by Keith Brindley

PART 4
Digital Meters

In electronics, more and more functions which previously were regarded as exclusively analogue by nature are now being accomplished using digital techniques. An obvious example is the digital compact cassette (DCC) sound recording medium, using digitally recorded cassette tapes to hold music, which on replay presents the listener with high quality sound, free from the inherent weaknesses of the existing analogue recording medium of analogue compact cassette.

Digital techniques, although generally more complex and more expensive (initially, at least) than their analogue counterparts, have a number of operational advantages: they are more accurate, more reliable and, may offer increased performance. Digital meters are the epitome of this. Their internal circuits are necessarily much more complex than those of analogue meters, because the nature of the measurement is such that inherently analogue measurand values are converted to digital ones before display.

Accuracy of measurements taken using digital meters, on the other hand, is not limited to the accuracy of a mechanical meter movement or to the resolution with which an observer reads the display. Instead, accuracy is purely dependent on the meter's circuits, so much higher accuracy is possible.

Like analogue meters, digital meters are most commonly encountered as general-purpose multimeters, although digital power meters, distortion meters and so on, are all available using the digital meter as a display. The typical digital multimeter (DMM) performs all the usual functions of the analogue meter, but generally at a higher performance.

The block diagram of Figure 18 shows the action of a basic digital multimeter, albeit in a simplified form. The signal converter block converts the measurand functions of voltage, current, resistance, or whatever you are measuring, into a form which the analogue-to-digital (A-to-D) converter block can deal with; typically 200mV DC or 2V DC. A-to-D conversion then takes place and the result is displayed digitally.

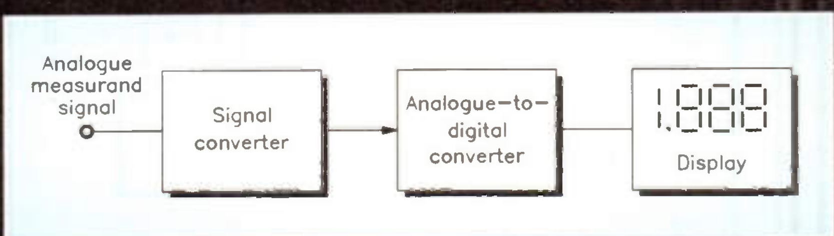


Figure 18. The basic block diagram of a digital multimeter.

Signals and Functions

Signal conversion is essentially similar to the analogue multimeter's (see Issue 81 of *Electronics – The Maplin Magazine*). In most digital multimeters a resistive divider chain attenuates the measurand voltage value in switched steps, so that the output voltage is within the input range of the A-to-D converter. AC voltage measurement is usually done with the use of a circuit called a true RMS converter, which measures the RMS value of applied measurand AC voltages, whether they are sinewaves or otherwise, and presents this as a DC voltage to the A-to-D converter. Multimeters (digital or analogue) which use a true RMS converter are given a crest factor specification, which indicates the ability of the converter to correctly measure and display different AC waveforms. The crest factor of an AC waveform is the ratio of peak voltage to RMS voltage, so if a waveform's crest factor lies within the crest factor specification of a multimeter it will be accurately measured. Examples of waveform crest factors are: square wave – 1; sinewave – 1·414; triangular wave – 1·732. Digital multimeter crest factor specifications of around 7:1 and above are available.

Current may be displayed by measuring the voltage which the current creates across a known internal resistance. When measuring alternating currents, the AC voltage across the resistor is applied to the RMS converter before measurement.

Resistance may be displayed by measuring the voltage developed across a known internal resistance in series with the unknown resistance, caused by a reference voltage source within the meter. By suitable scaling within the meter the resistor value may thus be displayed.

Switching between ranges when taking a measurement is usually a manually undertaken role, but many modern digital multimeters have an auto-ranging facility, which electronically senses the level of the measurand signal and selects the appropriate range for display. Digital

Left: A quality, handy digital multimeter with a 3½-digit LCD screen display, providing measurements over a number of different ranges.

multimeters of the cheaper kind, which do not have auto-ranging functions, generally have an over-range indication where the most significant digit of the digital display becomes a '1' with no other digits displayed. Over-range protection is normally built-in to all digital multimeter signal conversion circuits, so that connection to large, potentially harmful voltages or currents cannot damage the instrument.

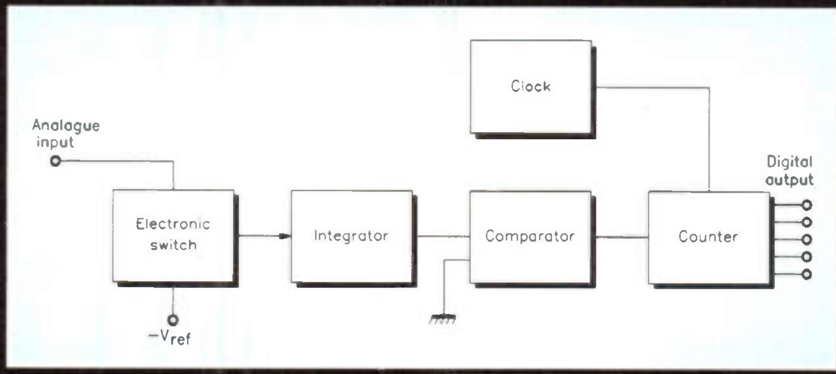
Analogue-to-Digital Conversion

The process of converting an analogue signal to one of a digital nature is fairly easy in principle. The analogue signal is merely sampled, that is, a measurement of the signal value is taken at regular intervals, and each sample is presented in a binary digital way; so that, for instance, an analogue voltage of 1·5V may be presented in a digital way as, say, 1010 – a binary digital number. In the case of the common digital multimeter, this binary number is then decoded to drive the digital display, where the decimal digits '1·5' are displayed.

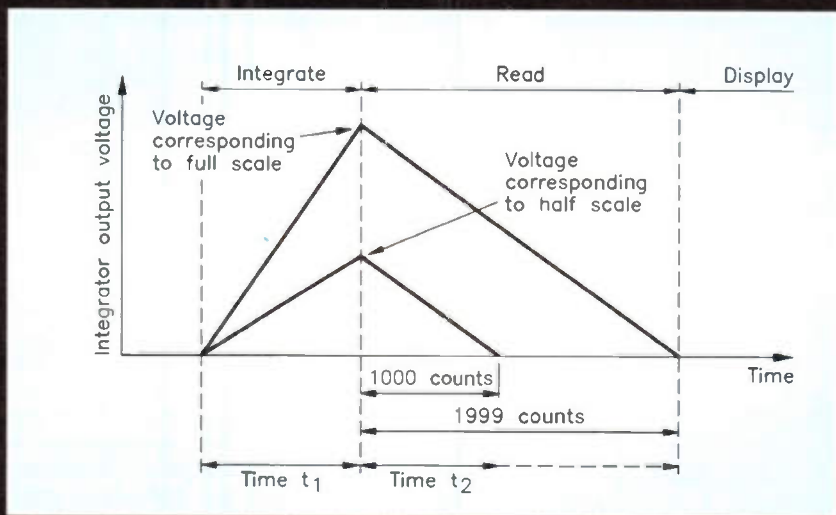
Under certain conditions the string of sampled values is perfectly representative of the measurand signal. The main condition which governs the conversion is that the samples should be taken at close enough intervals so that all variations, however fast, within the measurand signal are converted also. Put another way, if the analogue measurand signal consists of frequency components in the range from DC to f_{max}Hz, then it must be sampled at a rate of $2f_{max}$ samples per second.

In the case of a general-purpose digital multimeter, which is used to measure a fixed, or very slowly changing, voltage or current, this is no problem and samples can be taken at very low rates. If the signal varies at a maximum frequency of, say, 1Hz, then a sampling rate of twice per second is perfectly adequate to represent the measurand digitally. A digital multimeter whose display changed much more often than this would prove, at best, irritating and, at worst, unreadable anyway. Most general-purpose digital multimeters do, in fact, have a sampling rate of around 2 to 2·5 samples per second.

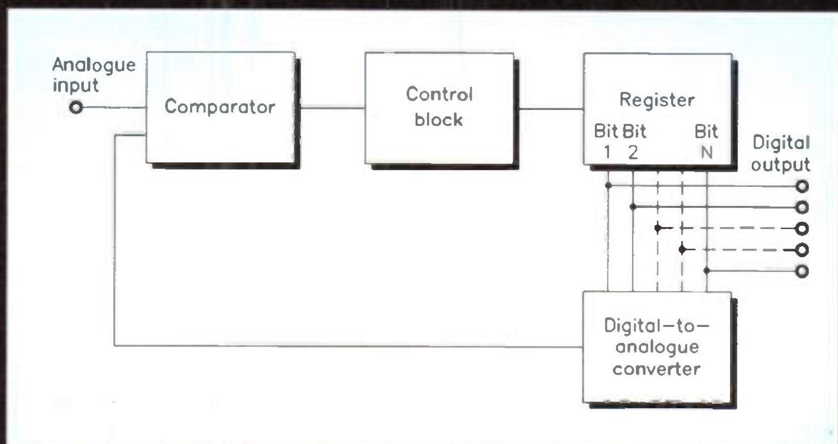
The A-to-D converter circuit used in such digital multimeters is usually a dual-slope converter. It is shown



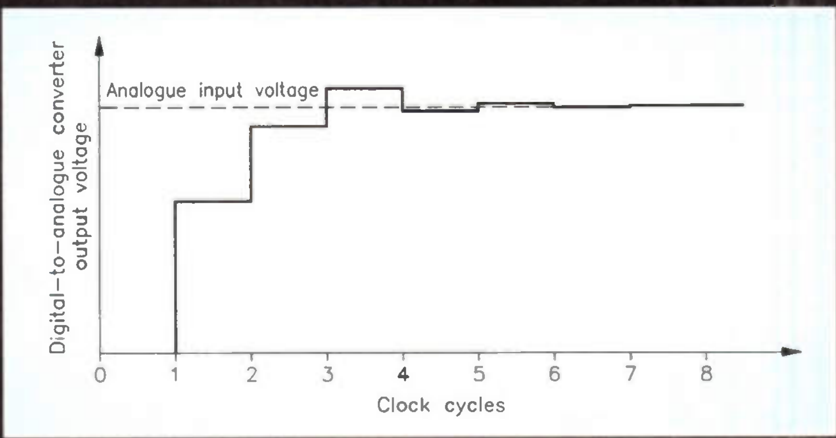
Above: Figure 19. A dual-slope A-to-D converter.



Below: Figure 20. Output voltage of intergrator in a dual-slope A-to-D converter, for two values of input voltage.



Bottom: Figure 21a. Block Diagram of a successive approximation A-to-D converter.



Top: Close-up of an LCD.

Above: Figure 21b. Output voltage from D-to-A converter used in a successive approximation A-to-D converter.

in block diagram form in Figure 19. The input of the integrator is electronically switched between a reference voltage $-V_{ref}$, and the voltage to be converted, V_{in}. By integrating the analogue voltage for a fixed period of time t_1 as the integrator output voltage ramps up from zero, then counting the clock pulses for the variable time t_2 which the integrator takes for its output voltage to ramp back down to zero, a very accurate analogue-to-digital conversion can be made, because the time t_2 is proportional to the analogue voltage.

A couple of examples should clarify converter operation. If a voltage of, say, 1·999V, is measured, the integrator output voltage (Figure 20) increases in time t_1 to the full scale voltage shown. As the integrator ramps back down to zero 1,999 clock pulses are counted during time t_2, and the display reads '1·999'. When the input voltage is 1V, the integrator output voltage only reaches the half scale voltage in time t_1, so only 1,000 clock pulses are counted in time t_2 before the integrator output ramps back down to zero. The display now reads '1·000V'.

Converter circuits like the dual-slope converter are ideally suited for general-purpose digital multimeter applications: they are cheap and highly accurate. However, their slow-speed operation precludes them for use as A-to-D converters in high-speed applications.

Digital multimeters used in systems measurement applications in say process control situations, where measurements may be required hundreds of times a second, must use faster (and usually more expensive) converters. One converter typically used in such applications is the successive approximation converter, a block diagram of which is shown in Figure 21a. The successive approximation converter is an example of an A-to-D converter which uses a digital-to-analogue (D-to-A) converter within itself (D-to-A converters are inherently much simpler, not relying on timed samples to function) as part of normal circuit operation. In essence, the digital output of the converter is reconverted back to analogue by the D-to-A converter, then compared with the analogue input voltage by a comparator. The comparator output is logic 1 if the analogue input signal is greater than the D-to-A converted signal, but logic 0 if the converted signal is larger than the analogue signal. At commencement of operation, the digital output is assumed to be zero, therefore the output of the D-to-A converter is also zero. Thus, any applied analogue input signal causes the comparator output to be logic 1. The first clock pulse causes the control block to set the most significant bit (that is, bit 1) of the register to 1, and so the D-to-A converter output increases. If the applied input voltage is still higher than this, the output of the comparator remains at 1 and the next clock pulse causes the control block to set the next most significant bit (that is, bit 2) to 1, and so on.

When the D-to-A converter output voltage finally becomes higher than the applied voltage, the comparator output changes to logic 0 and the next clock pulse causes the control block to reset the last bit to 0 *before* setting the next bit to 1. Thus the process can be seen to be a number of successive approximations of the applied voltage (hence the name). Figure 21b shows a timing diagram of the analogue output voltage of the D-to-A converter within an 8-bit successive approximation A-to-D converter. After the final approximation has taken place, the converter's digital output represents an accurate conversion of the applied analogue input, which may be directly displayed.

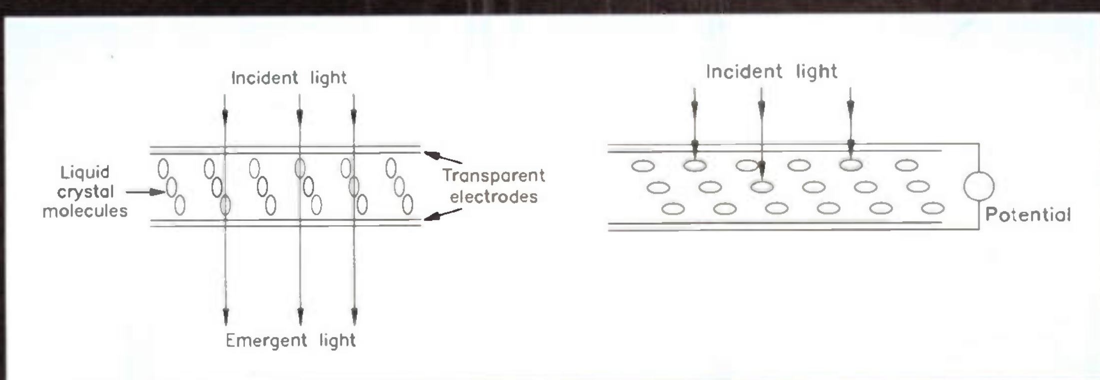
Successive approximation is a beautiful concept which pops up in other digital applications, as well as many more mundane ones. A simple example of its use is in a manual search for a taped television programme on an ordinary videocassette tape. You know the part of the programme you want is somewhere on the videocassette, but you are not sure where. You have two options:

One, you can fast forward through the videocassette a few seconds at a time. If you are lucky you might find the part you want somewhere towards the beginning of the recording, say after two or three stops. If you are unlucky, on the other hand, it might be towards the end, and you might have to stop twenty or so times.

Two, using successive approximation, you can cut down the time considerably – simply stopping halfway through the tape and noting if the part you want is before the mid-point or after where you stop.

If it is before, rewind to the mid-point of the first half of the tape. If it is after, fast forward to the mid-point of the second half. At either of these mid-points, again stop and view the tape, again deciding if the point you want is before or after, and again, rewinding or fast forwarding to suit. Within say five or six cycles you will probably find the point you are after.

In digital logic terms the total conversion time of a successive approximation converter is equal to N clock cycles, where N is the number of bits. The conversion



Right: Figure 22. Liquid crystal displays.
(a) Under no electric influence light passes through the molecules of the structure.
(b) When a voltage is applied molecules turn, preventing light flow through the structure.

time is thus independent of the input voltage (unlike the dual-slope converter's conversion time) and, in fact, is only limited by circuit delays. Many more samples per second can thus be taken using this technique, and typically, digital multimeters which take 200 to 1,000 samples per second are available, depending on the number of bits converted.

Displays

Most general-purpose digital multimeters use seven-segment liquid crystal displays (LCD). Low power consumption of LCDs means that, with low current consumption signal conversion and A-to-D conversion circuits (say, of CMOS origin), the complete multimeter may have an overall current consumption of only a few μA. This is an obvious advantage in portable, battery-powered equipment. Bench test equipment, however, being mains powered, does not have this power consumption limitation and light-emitting diode (LED) displays or, sometimes, vacuum fluorescent displays are common in larger digital multimeters used in systems applications.

Generally between four and eight digits are displayed by a digital multimeter. A decimal point is usual, which moves along the display corresponding to the range being displayed. Usually the most significant digit in the display is not of seven-segments, but merely displays the number 1 or nothing at all. For this reason, a meter with three full seven-segment digits plus a most significant digit of this type is said to have a three-and-a-half digit display, and most hand-held, portable digital multimeters of a general-purpose nature have displays of this size. Maximum indication possible using a 3½ digit display can only be '1·999', but more expensive digital multimeters are available with up to 8½ digit displays, where greater resolution is required.

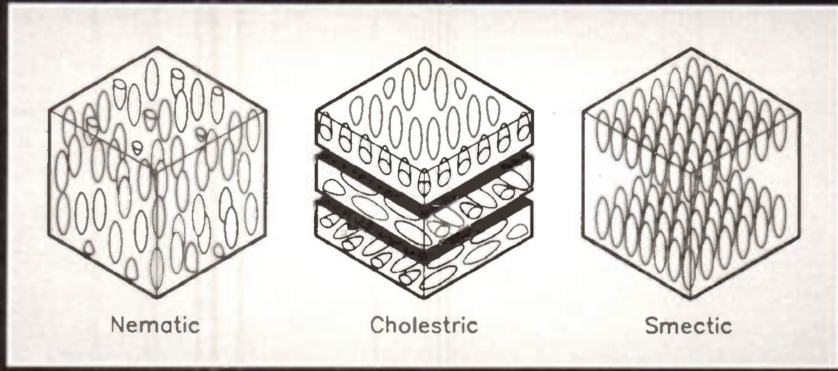
Advantages of Digital Meters

Accuracy of analogue meters is determined primarily by the moving-coil meter movement used in them, together with the position of the pointer on the scale. Thus the highest accuracy a moving-coil meter can have is given by its percentage accuracy at full-scale deflection. Other sources of error are loading of the measurand circuit by the input resistance of the meter when measuring voltage, and the resolution with which the reading is taken by an observer.

In a digital meter these three error sources are eliminated. The display is totally electronic, without any moving parts, so cannot possibly be inaccurate – whatever the preceding circuit supplies it with, the display presents as a numerical read-out. This numerical read-out is not subject to resolution problems such as parallax or pointer position errors. Finally, the electronic circuits used in a digital meter present an extremely high input resistance (typically 10MΩ) to the measurand circuit, thus preventing the possibility of loading errors in all but the highest resistance measurand circuits. Instead accuracy and resolution of a digital meter are dependent on the accuracy and resolution of the internal electronic circuits, so that errors in indicated measurements are due mainly to component inaccuracies and poor calibration, although sometimes poor design may be a culprit.

Typical accuracy of a low-cost, general-purpose digital multimeter is less than ±1% of the reading (whatever the reading, not the full-scale deflection limitation of analogue meters), and resolution is about one in 2,000 parts. Accuracy of high-quality digital multimeters is generally less than ±0·005% of reading with a resolution of about one part in 100,000.

Overall, the digital multimeter, and digital meters in general, have many advantages over analogue multimeters and meters. The need for greater accuracy in manufacturing and servicing has meant they have become increasingly popular as test equipment instruments. Although general-purpose digital multimeters tend to be slightly more expensive than analogue counterparts, analogue meters of the accuracy and resolution afforded by high-quality digital meters could never be made, whatever the price. The digital meter has created its own marketplace, which the analogue meter can never over-



Above: Figure 23. The three molecular structures in common LCDs.
(a) nematic.
(b) cholestric.
(c) smectic.

Below: A range of digital multimeters (DMM), including pocket and probe types.

Top right: Analogue/Digital Multimeter with an analogue scale and range hold.

turn. On the other hand, of course, some measurements you would never dream of taking with a digital meter. It is impossible, for example, to make sense of any readings taken using a digital meter of a slowly varying analogue voltage. Many professional audio engineers might also prefer to use an analogue meter because it is a more 'down-to-earth' instrument, and, after all, accuracy is not everything in such applications.

Digital Displays

There are a number of types of digital displays. The most common on recent test equipment are LCDs, LED displays, and vacuum fluorescent displays (VFD). Of these, it is the LCD which is used more often than not.

The main principle which all LCDs follow is illustrated in Figure 22a, where a layer of liquid crystals is shown sandwiched between two transparent electrodes. The molecules of the liquid crystals are generally aligned in the vertical direction and so light from behind the device can pass through. When an energizing potential is applied across the electrodes, as in Figure 22b, however, the liquid crystal molecules are polarized into horizontal alignment, which prevents light from passing through. Generally, a layer of reflecting material is placed directly behind the rear electrode, so that incident light passes through and is reflected back in the unenergised state (giving the appearance of a white object), or does not pass through so cannot be reflected back in the energized state (giving the appearance of a dark object). Such a display is non-emissive, and depends for its visibility on an adequate amount of ambient lighting. Sometimes, however, LCD displays are used which have some form of back-lighting (that is, a light source positioned to the rear of the display), creating an emissive display.

Three main varieties of liquid crystal; nematic, cholestric and smectic, differing mainly in molecular alignment as shown in Figure 23, are used to make LCDs.

Nematic liquid crystals are more commonly called 'twisted nematic' crystals, because the crystals are twisted through 90° between one electrode and the other when unenergized. Polarizing sheets (at 90° to each other) are applied at the front and back of the device, so that incident light entering the display is polarized into one plane by the first polarizing sheet, passes through the liquid crystal where it is twisted through 90° by the structure, then leaves the device through the second polarizing sheet. When an energizing potential is applied, the molecules are all aligned in the same direction as the light, which now passes through the liquid crystal without being twisted, so cannot pass through the rear polarizing sheet.

A cholestric LCD has no polarizing sheets but a dichroic dye is added to the liquid crystal. Dye cells align themselves with the liquid crystal molecules, in effect producing an electronically controlled colour filter which changes colour with the applied voltage. This dye addition is the reason why displays using this principle are sometimes known as 'guest-host' devices; the dye cells are the 'guests' in the crystal 'host'.

Smectic LCD rely on the different properties (that is, phases) of liquid crystals at different temperatures. In the smectic temperature phase, molecular arrangement of the liquid crystal cannot be changed by application of an energizing potential. However, when heated to the nematic phase, then cooled to the smectic phase, orientation of the molecules will be as it was in the nematic phase. To use these phenomena, smectic displays use a combination of matrices of electrical lines, so that each individual display element can be addressed and heated, from their normal smectic state to the nematic phase. Operation of a smectic display is therefore something like that of a twisted nematic display, but it has a memory facility which retains and displays the last information input during the nematic phase.

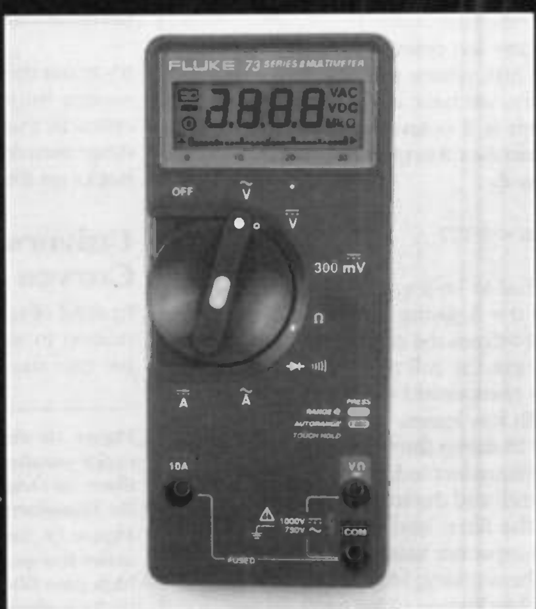
The shape of the LCD depends purely on the display requirements, as the electrodes can be manufactured in almost any shape and size the user may require. For basic numerical applications (say, a simple digital multimeter, which is to display a number of digits) a seven-segment arrangement is sufficient, but more complex alphanumeric or graphic information (to be displayed on a computer or an oscilloscope) requires a correspondingly more complex LCD, typically of dot-matrix form.

The advantages of LCDs, and indeed of all types of digital displays, in test equipment instruments are manifold. Most important, in a display of seven-segment or alphanumeric nature, accuracy and resolution depends not on the device, but on the measuring circuit which feeds the digital information to the display. Users' reading errors, inherent in the use of moving-coil or cathode ray tube analogue displays, are eliminated for the same reason. Test instruments using digital displays are therefore typically much more accurate than analogue equipment of the same price.

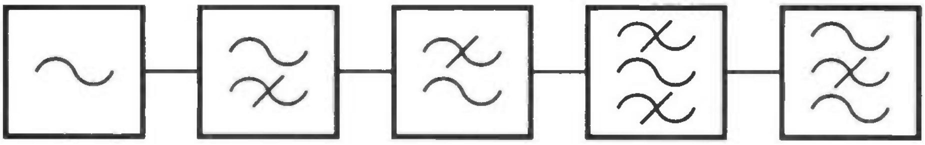
On the other hand, numerical digital displays are updated at rates of between about two or three times a second, allowing sufficient time for the user to read one measurement before the next is displayed. So, measurement of, say, a slowly varying measurand is not possible, and can only effectively be done with an analogue display.

LCDs, unlike most other forms of digital displays, have a very low power consumption, so they can be built into portable battery-powered test equipment. In most applications, therefore, LCDs are eminently suitable.

Some applications, on the other hand, are not suited to LCDs. Being non-emissive they rely on a suitable level of background light, something which is of no consequence in the laboratory, but may be of significance elsewhere. Back-lit displays are available however, but this defeats the low power consumption argument. The other types of digital displays such as the LED or VFD will probably be more useful here, as they are emissive and can be easily viewed in the darkest of environments – but consequently they have a greater power consumption. E



Right: Digital Multimeter with LCD display incorporating a 31 segment analogue scale.



FILTERS

Part 2: High-pass and More Theory

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

In Part 1, we saw the basic network theory of filters and the ideas of poles and zeroes. This led to low-pass filters of various orders, with, in particular, Butterworth (maximally-flat) responses. We looked at both passive and active filters, and discussed how to choose between them. Now, we go on to high-pass filters, with some more general theory on the way.

Filter Transformation

We don't have to start again from basic theory for high-pass filters. Instead, we can derive a high-pass filter from the corresponding *normalized* low-pass filter, of the same order. Figure 16 shows a second-order normalized (to $\omega = 1$) passive low-pass filter and the high-pass filter that results from the transformation. In this process, capacitors in passive filters are replaced by inductors, and *vice versa*. In active filters, it is capacitors and resistors which change round, but only those resistors which are part of the filtering process itself: other resistors in the circuit do not change. This process is shown in Figure 17. As well as changing places, the values in the *normalized circuit* change. The new value is the reciprocal of the old value (1 divided by the old value), as shown in Figures 16 and 17, and the units (farads, henrys and ohms) change appropriately.

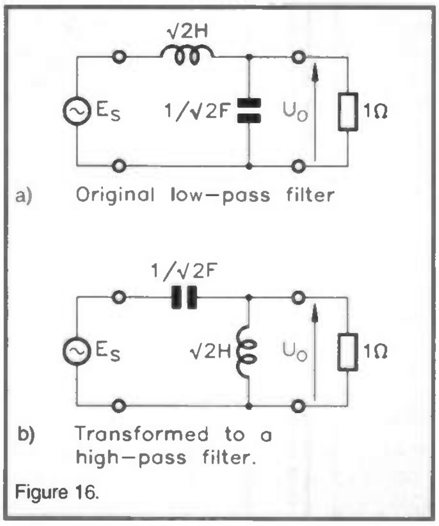


Figure 16.

Figure 16. Transformation of a second-order passive low-pass filter to a high-pass filter: (a) Original low-pass filter; (b) Transformed to a high-pass filter.

Designing a Passive High-Pass Filter

Suppose we want a high-pass filter with a corner frequency (–3dB) at 400Hz and at least 50dB attenuation at 50Hz. The filter is to be driven from a low impedance and has a high impedance load. This would be a typical requirement for a filter to cut out mains hum components from the signal in a distortion meter. The response of the high-pass filter is to be at least 50dB down at the corner frequency *divided by 8*. Now, we think of a LOW-pass filter whose response is at least 50dB down at *8 times* its corner frequency. According to the semi-infinite (straight-line) approximation that we met in Part 1, the attenuation of the low-pass filter grows uniformly at 6ndB/octave (an octave being a frequency range of 2:1), where n is the order of the filter. Here, we have a frequency range of 8:1, which is 3 octaves, so we get 18ndB attenuation over 3 octaves. We can thus find n fairly easily:

$$n = 50/18 = 2{\cdot}777\ldots$$

But n has to be a whole number, so we settle for $n = 3$, giving 54dB attenuation, in theory, at 8 times the corner frequency. We may not get the full 54dB unless we use accurate component values, and components with low losses.

Figure 18 shows the normalized low-pass filter, the transformed high-pass filter (still normalized) and the scaled (denormalized) form of the filter, and the way to achieve practical capacitor values. In order to keep track of the working, I find it useful to make sketches like Figure 18 for each design.

Source and Load Impedances

The source and load impedances are called the 'terminations' of the filter, and it is important to get them right. In this case, the source resistance was set to be zero (or negligibly low), and the terminating resistor of 1 kΩ at the load end was chosen so as to give convenient component values. We can do this because we are told that the following circuit presents a high impedance. If it presented a specified impedance, we would have to design the filter around that value or a lower value. It is also possible to design for a specified *source* impedance, instead of a very low (i.e. negligible) value. This is less often required in experimental designs for audio frequencies, because an op amp follower will always provide a negligible *source* impedance very conveniently. For high frequencies, it is more usual to require the filter to work between equal source and load impedances, such as 50Ω or 75Ω ('matched' conditions, properly 'iteratively matched' or 'matched for maximum power transfer'). Both non-negligible source impedance and matched conditions change the values in the normalized circuit quite dramatically, so don't try to use the values given in Part 1 for 'zero' source impedance and finite load resistance in these cases. Tables of values for other termination conditions are given in books on filter design.

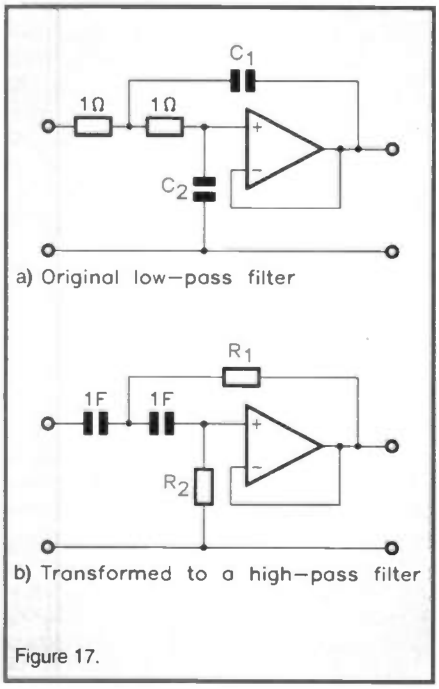


Figure 17.

Figure 17. Second-order Sallen and Key active low-pass filter transformed to a high-pass filter: (a) Original low-pass filter; (b) Transformed to a high-pass filter.

Universal Response Curves

Instead of using the semi-infinite approximation to calculate the order of the filter, we can use graphs of the responses of normalized filters of different orders. These also give the actual responses at any frequency, which is especially close to the corner-frequency, where the semi-infinite approximation is at its most approximate (maximum error 3dB). Figure 19 shows a set of these curves for Butterworth-response filters of orders from 1 to 6. Because the design of a high-pass filter starts with a low-pass filter, we only need a set of curves for the low-pass filter. These curves are valid for all cases of correct termination of the filter.

Poles and Zeroes Again

The transformation of the low-pass filter to a high-pass filter has an important effect on the poles. The basis of pole-zero analysis was explained in Part 1, but here is a short summary.

We work with the normalized circuit, and determine the transfer function $T(s) = U_0/E_s$ in Figure 16. We can do this by using the impedances of the components in term of $j\omega$ to find U_0/E_s, and then changing the variable from $j\omega$ to $s = \sigma + j\omega$, the *complex frequency variable*. In general, this gives $T(s)$ as a ratio or fraction $N(s)/D(s)$. The *poles* and *zeroes* (if any) of $T(s)$ are given by the equations $D(s) = 0$ and $N(s) = 0$, respectively. (It is also possible to get one or more zeroes if $D(s)$ becomes infinite, as we shall see later, but it appears impossible for this to happen at a finite frequency.) I suggest that you don't worry too much about physical explanations of these mathematical gymnastics: there is an explanation in Part 1 and some more to follow. Meanwhile, please be assured that, if done correctly, they give the right answers.

We saw in Part 1 that $T(s)$ for a second-order Butterworth low-pass filter was:

$$T(s)_{lp} = \frac{1}{s^2 + \sqrt{2}s + 1}$$

In changing round the capacitor and inductor in Figure 16, we have changed the inductive reactance, which was proportional to s (i.e. sL), into a capacitive reactance, proportional to $1/s$ (i.e. $1/sC$), and *vice versa*. We have just consistently and uniformly replaced s by $1/s$ everywhere, so we can simply do the same in $T(s)$, giving:

$$T(s)_{hp} = \frac{1}{\frac{1}{s^2} + \frac{\sqrt{2}}{s} + 1}$$

which can be simplified to:

$$T(s)_{hp} = \frac{s^2}{s^2 + \sqrt{2}s + 1}$$

We now have $N(s) = s^2$, which is zero (twice, for good measure) at $s = 0$, while $D(s)$ is the same as for the low-pass filter, giving poles where $D(s) = 0$, i.e. at $s = -1/\sqrt{2} \pm j/\sqrt{2}$.

What does the (double) zero at $s = 0$ mean? Simply that the high-pass filter has infinite attenuation at zero frequency, i.e. for d.c. Since Figures 16 to 18 show that second-order high-pass filters invariably have one capacitor in series in the signal path, not shunted by a resistor, or anything else, it is hardly surprising that they do not pass d.c. too well! The second zero arises from the fact that the inductor (theoretically with zero resistance) in the passive filter is a perfect short-circuit across the signal path at d.c., giving a second reason why U_0 should be zero. In the active filter we have two capacitors in series with the signal path.

Let us look back at $T(s)_{lp}$ for a moment. We can see that it continually decreases as s increases, and is zero if s is infinite. In fact, since $D(s)_{lp}$ contains a term in s^2, $T(s)_{lp}$ is 'zero twice at infinity' in mathematical jargon. So we see that both low-pass and high-pass filters have two zeroes, but we can 'get at' the zeroes of the high-pass filter at d.c., whereas we cannot get at those of the low-pass filter at infinite frequency.

Further Exploration of Complex Frequency

The concept of complex frequency was originally introduced to simplify (!) the allowance for unavoidable losses in the filter components, especially the copper and iron losses of inductors. There was an earlier way of doing this, but it was immensely complicated. There is a parallel in the simplification of the study of planetary orbits in the solar system afforded by the Sun-centred (Copernican) theory as opposed to the Earth-centred (Ptolemaic) theory. Copernicus showed that the planets appeared to orbit the Sun in (nearly) circles, as opposed to the complex epicyclic orbits required to explain their movements if they moved round the Earth. This was all very well, but it needed Newton's theory of gravitation (in turn depending on the branch of mathematics known as differential calculus) to explain the (near) circles. In the same way, we need complex number theory to explain why this method of accounting for losses actually works.

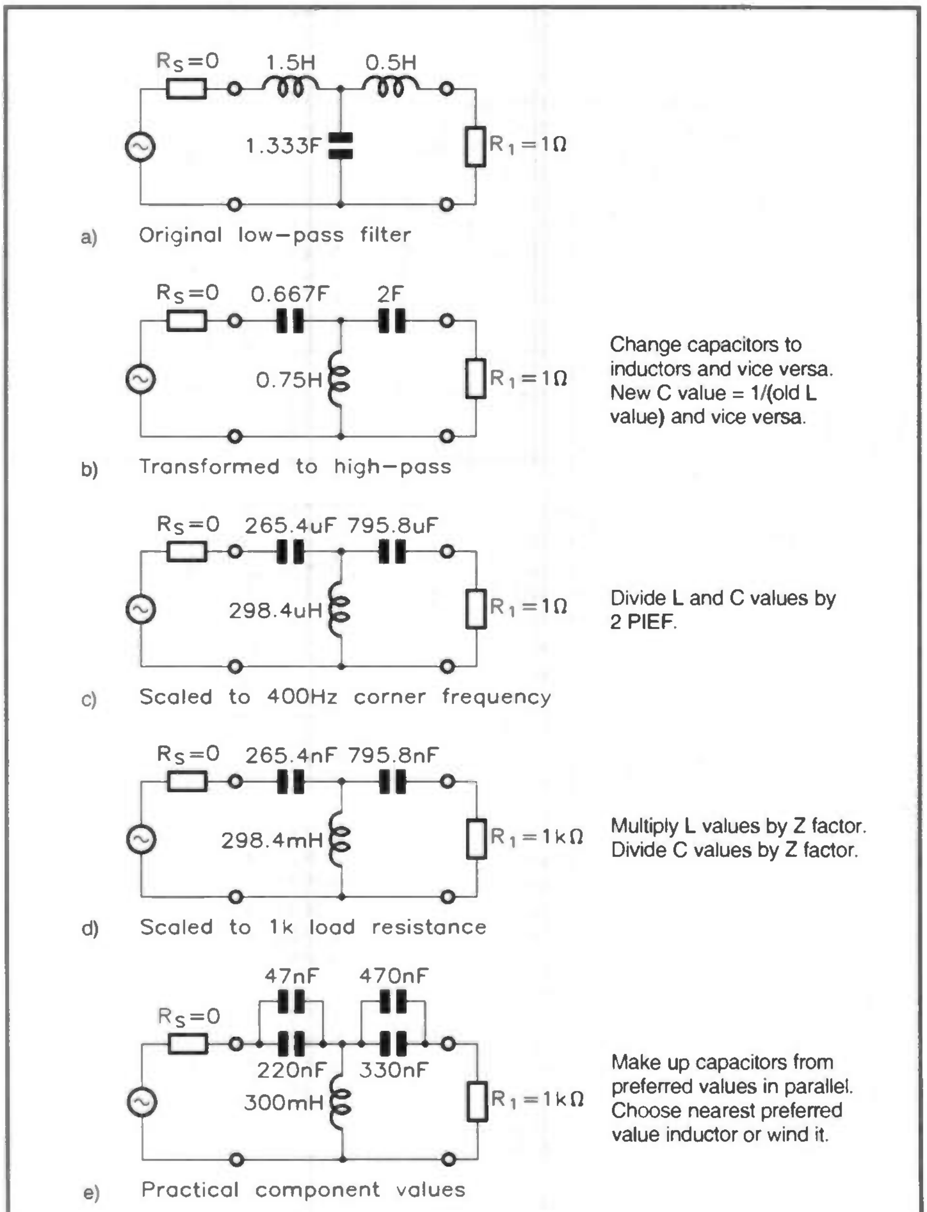


Figure 18.

Figure 18. Steps in the design of a passive high-pass filter: (a) Original low-pass filter; (b) Transformed to a high-pass filter; (c) Scaled to 400Hz corner frequency; (d) scaled to 1k load resistance; (e) Practical component values.

General Response of a Lossy Low-Pass Filter

Figure 20 shows a second order low-pass filter, with the resistance of the inductor represented by the resistor R. To a first approximation, we can increase the value of R slightly to allow for any core losses,

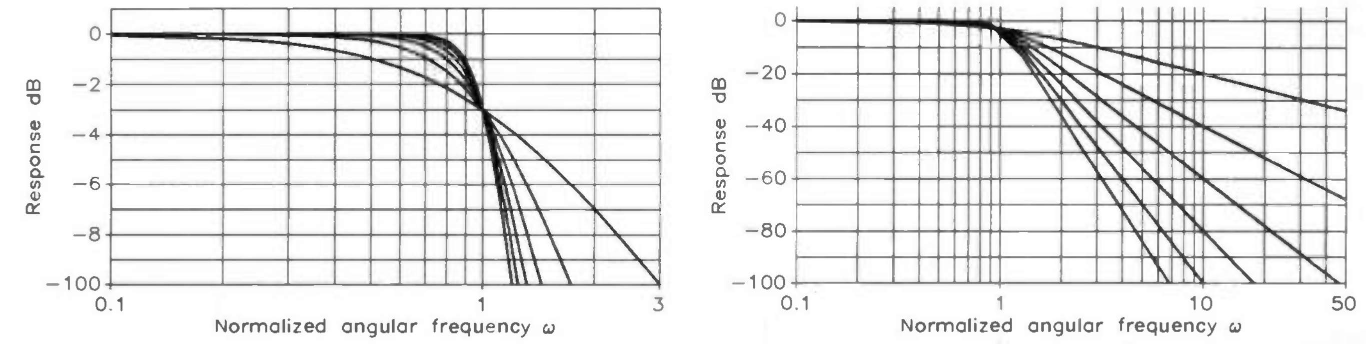


Figure 19.

which should strictly be represented as a resistor, perhaps frequency-dependent, in parallel with L. The capacitor C is assumed to be loss-free. We are not using this circuit as a filter, however, but in a basic experiment, for which we have added the d.c. generator, the switch S and the resistor R', which is simply to protect the generator from short-circuiting when we put S to position 2. We should not allow our theoretical circuits to set fire to the paper they are printed on!

If you do the experiment, I suggest that you use values similar to those in Figure 20, because it is possible to get considerably different results with different component values. The specified values give a nice, spectacular result, which actually is not typical of a normal, well-designed filter! We shall see why, later.

With the switch in position 1, we allow the circuit to settle down until the current I is steady. This current stores energy in the magnetic field of the inductor, and when the current is steady, the store is full. We then move the switch to position 2. This removes the generator as a source of energy, while leaving a current path through R, L and C – in fact we have made a series-tuned circuit. To find out what happens now, we have to remember (or take on trust) two facts:

Rate of change of voltage U across C (written dU/dt) = I/C (Coulomb's Law).

Rate of change of current I through L (and through R and C, since it is a pure series circuit) $dI/dt = (-RI - U)/L$. (Faraday's and Ohm's Laws.)

From the latter, we get:

$$U = -L\frac{dI}{dt} - RF$$

so that:

$$\frac{dU}{dt} = L\frac{d^2I}{dt^2} - R\frac{dI}{dt} = \frac{I}{C}$$

Hence:

$$\frac{d^2I}{dt^2} + \frac{R}{L}\frac{dI}{dt} + \frac{I}{LC} = 0$$

Since this is not an article on solving differential equations, we just take as an inspired guess (which is not too far from what it really is) that this equation has solutions in the form:

$$I = e^{mt}$$

where e (sometimes written ϵ, the Greek 'epsilon' or short 'e') = 2·718… is the base

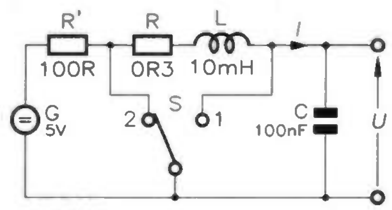


Figure 20.

of natural logarithms, now written 'ln' instead of '$\log_e$' and found on most scientific calculators. It is usual now to write '$\exp(mt)$' instead of 'e^{mt}', because it is easier to print and read, and the 'exp' function is also provided on most scientific calculators.

We find m by writing it in place of dI/dt in the differential equation (with the convention that $m^n = d^n/dt^n$ and not $(d/dt)^n$, an entirely different animal!):

$$m^2 + \frac{R}{L}m + \frac{1}{LC} = 0$$

This is a quadratic equation in m, and therefore has solutions:

$$m = \frac{1}{2}\left(\frac{-R}{L} \pm \sqrt{\frac{R^2}{L^2} - \frac{4}{LC}}\right)$$

For a circuit (normally) usable as a filter, R^2/L^2 must not be greater than $4/(LC)$, which means that, except for the limiting case when they are equal, $L/C > R^2/4$. This makes the expression under the square root sign negative, which means that we have to introduce j, the mysterious 'square root of minus 1'. The secret of this is that it doesn't bite if you are not afraid of it. In Part 1, we saw that it simply represents a sharp left turn!

Figure 19. Response curves of normalized low-pass filters of orders 1 to 6.
Figure 20. Low-pass filter with lossy inductor in experimental circuit.
Figure 21. Damped cosine wave produced by the experimental circuit of Figure 20.

We therefore rewrite the equation for m as:

$$m = \frac{-R}{2L} \pm j\left(\frac{1}{LC} - \left(\frac{R}{2L}\right)^2\right)$$

which we can write as:

$$m = -\sigma_1 \pm j\omega_1$$

So solutions of our differential equation for I are:

$$I = \exp(-\sigma_1 t + j\omega_1 t) \text{ and } I = \exp(-\sigma_1 t - j\omega_1 t)$$

But if either of these satisfies the differential equation, so does their sum, which gets us very conveniently out of the complex plane back into (fairly) familiar ground. The rules for adding indices tell us that if:

$$I = \exp(-\sigma_1 t + j\omega_1 t) + \exp(-\sigma_1 t - j\omega_1 t)$$

then:

$$I = \exp(-\sigma_1 t)\ \{\exp(j\omega_1 t) + \exp(-j\omega_1 t)\}$$

The first term in this equation represents an *exponential decay*, the way the voltage across a capacitor decays as the capacitor discharges. The second term, believe it or not, represents a cosine wave, the same as a sine wave except that it starts at a peak instead of at a zero-crossing. This is logical, since we know we started with a steady current, not zero. The product of these factors is a decaying sine wave, as shown in

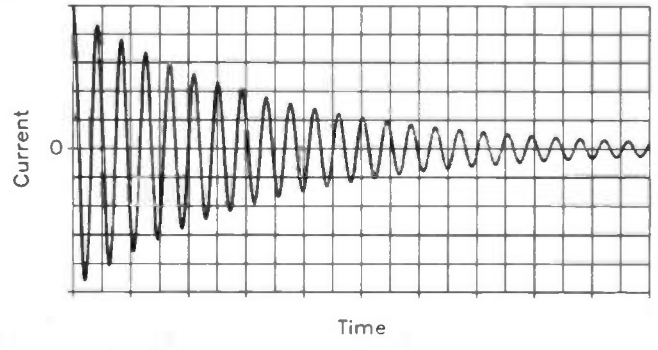


Figure 21.

Figure 21. If you build the Figure 20 circuit and look at the current waveform on an oscilloscope, by connecting it across a low-value resistor inserted in series with C, that is exactly what you see when you operate the switch. This decaying sine wave is called a 'ring', and the phenomenon is 'ringing', because it is the electrical equivalent of what a bell does in the mechanical world. In performing this experiment, we have actually been investigating the *transient response* of the filter, which is usually regarded as quite a difficult subject. I hope that the experiment, at least, helps to make it simpler. In any case, it raises the point that ringing is a distortion of the signal in the time domain, and leads to the question whether filters can be made that do not ring, or only a little bit. This is, in fact, possible, but the discussion needs some more groundwork.

You may have noticed that what we called m in the above represents two specific values m_1 and m_2, called roots, of what we have been calling s previously, the complex frequency variable. You can also see how σ_1 (= $R/2L$) represents the losses in the circuit, while ω_1 represents the effect of the frequency-selective components L and C. ω_1 is sometimes called the 'diminished frequency', since it is always less than the conventional resonance frequency $\omega_0 = 1/\sqrt{LC}$.

Roots and Poles

If we take our lossy filter from Figure 21 and supply it with a sinusoidal signal, as in Figure 22, we can proceed as follows, writing s directly in place of $j\omega$:

$$U = \frac{I}{sC}$$

$$E = I\left(\frac{1}{sC} + R + sL\right)$$

$$= \left(\frac{I}{sC}\right)(1 + sCR + s^2LC)$$

So:

$$\frac{U}{E} = T(s) = \frac{1}{1 + sCR + s^2LC}$$

The equation for the poles, $D(s) = 0$ is of exactly the same form as the quadratic equation in m! This means that the roots derived from the differential equation for the current I are also the poles of the transfer function.

Root movement

Since the roots m_1 and m_2 are complex, we can plot them on the Argand diagram (just a graph with axes σ and $j\omega$, and what I called the 'complex plane' above), as shown in Figure 23. Consider the root m_1. If we move it sideways, we are varying σ, the 'loss' term, but not ω, the 'frequency' term.

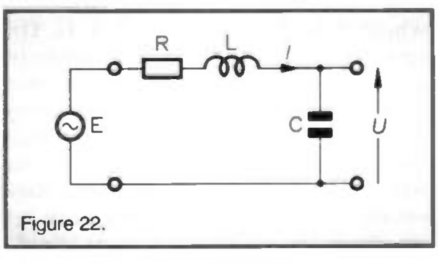


Figure 22.

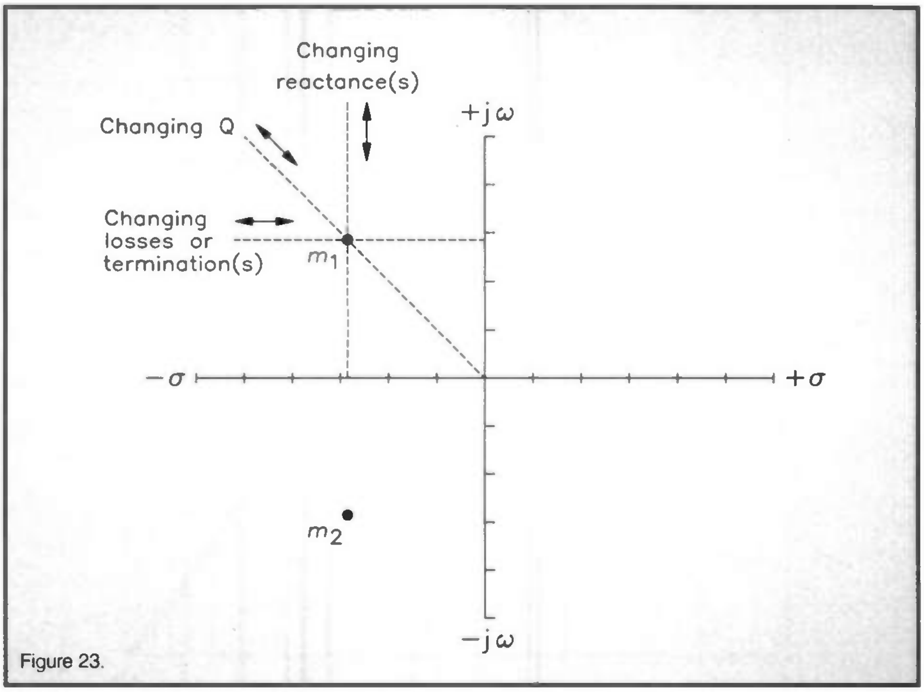


Figure 23.

The nearer σ comes to zero (the $j\omega$ axis), the lower the losses and the longer the ringing lasts. Moving the root vertically means changing only ω, or 'tuning' the filter to a different corner frequency. Suppose, however, we move the root *radially*, along the line Om. This varies both σ and ω, but keeps the ratio ω/σ constant. Both σ and ω are measured in units of inverse seconds ('per second'), so the ratio is a dimensionless quantity. It is in fact twice the ratio of reactance to resistance in the circuit, which is given the symbol Q. This concept of filter Q is quite important, because it is a convenient parameter for exploring the different frequency responses and transient responses which are obtained as the losses in the circuit, and the ratios of load and/or source resistance to the reactances, are varied.

Q and the Transfer Function

If we slightly rearrange the equation for $T(s)$ above, to:

$$T(s) = \frac{1}{LC\left(\frac{1}{LC} + \frac{sR}{L} + s^2\right)}$$

and apply it to a filter with corner frequency 1 rad/s, for which $LC = 1$, then:

$$T(s) = \frac{1}{s^2 + \frac{s}{Q} + 1}$$

so that:

$$T(j\omega) = \frac{1}{(1 - \omega^2) + \frac{j\omega}{Q}}$$

By fixing the corner frequency at 1 rad/s, we are just doing a scaling operation to get rid of the term LC in $D(s)$, which we don't need for the present purpose. We now get rid of the j-term by forming the *modulus* $|T(j\omega)|$ (see Part 1):

$$|T(j\omega)|^2 = \frac{1}{(1 - \omega^2)^2 + \left(\frac{\omega}{Q}\right)^2}$$

Figure 22. Low-pass filter with lossy inductor, with sine wave signal applied.
Figure 23. Argand diagram showing root movements.

$$= \frac{1}{1 + \left(\frac{1}{Q^2} - 2\right)\omega^2 + \omega^4}$$

So if $Q = 1/\sqrt{2}$, the term in ω^2 is zero, and:

$$|T(j\omega)| = \frac{1}{\sqrt{1 + \omega^4}}$$

We met this in Part 1: it is the transfer function for a second-order Butterworth response! We can now see that this response is not an accident: it was hidden there in the equations for us to discover, and we now know why the filter Q has to be $1/\sqrt{2}$ in this case. Note that this is the *filter Q*, not the Q of the inductor alone. This may appear to contradict what we said about the circuit of Figure 20, where R was called the resistance of the inductor. This is true for the experiment, but when this circuit is in use as a filter, R includes the source resistance. It is a bit unfortunate that the circuit which is easiest to analyse in the way shown above is the case with finite source resistance and infinite load resistance, not the case with near-zero source resistance and finite load resistance. It is possible to analyse the latter in a similar way, but you would not enjoy it. However, the same results for the effect of filter Q on the frequency response etc. apply.

Q and Frequency Response

With the aid of the computer, we can plot curves of $|T(j\omega)|$ for different values of Q, as shown in Figure 24. As we found in Part 1, the use of decibels not only gives a simpler equation to plot but also curve shapes that are much easier to understand and use. We can see that very low values of Q give 'soggy' responses which are not very useful. The curve labelled '0·7' actually should be labelled '$1/\sqrt{2}$', if there were

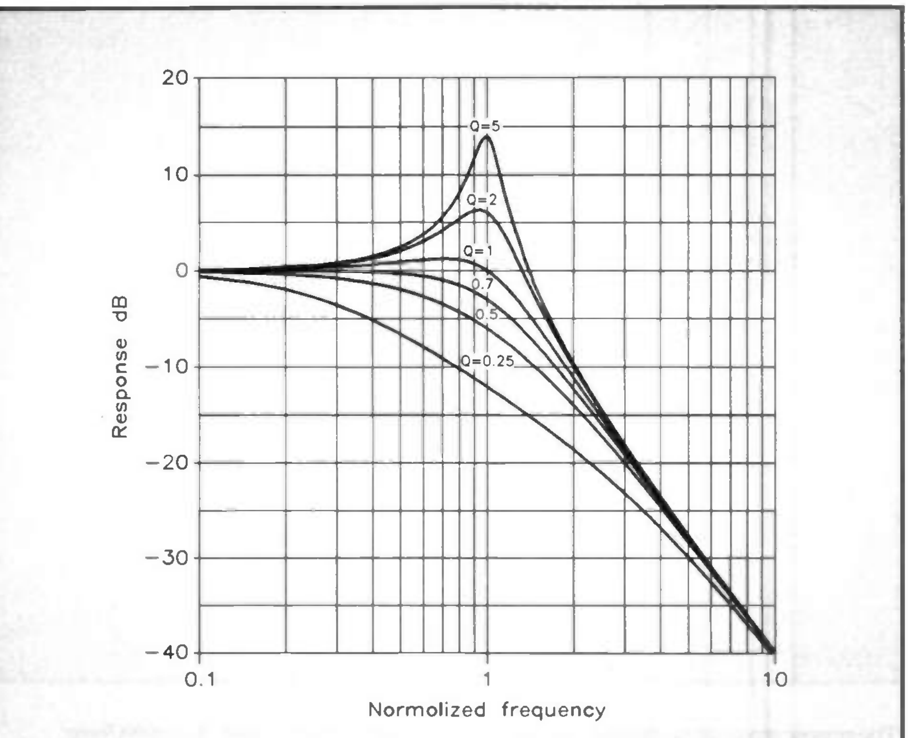


Figure 24.

Figure 24. Effect of varying Q on the low-pass filter response.

room, and is the Butterworth response. High values of Q show peaks at the corner frequency, and for Q greater than about 10, the circuit is better regarded as a tuned circuit, resonant at the corner frequency. Even the $Q = 5$ curve shows a fairly symmetrical peak from $\omega = 0{\cdot}8$ to $\omega = 1{\cdot}25$.

The case of $Q = 0{\cdot}5$ is interesting. Let us go back to the equation for m:

$$m = \frac{-R}{2L} \pm j\sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2}$$

The two terms on the right-hand side are the co-ordinates of m_1 and m_2 on the Argand diagram or complex plane. If $Q = 0{\cdot}5$, the second term is zero, and the two roots coincide at the point $(-R/2L,0)$, or $(-1/2,0)$ for the normalized filter, on the negative σ axis. The absence of the j-term means that the transient response does not oscillate, simply declining uniformly to zero (theoretically it takes infinite time to do so, but we do not need to wait that long in practice!). This type of filter is not often used, because its attenuation characteristic is not very attractive and its transient response is rather slow, but its transient response is called 'dead beat' in mechanical engineering.

Phase and Delay Responses

Since the dead-beat response is notably more soggy than the Butterworth (see Figure 24), why bother with it? Simply because it brings up the matter of waveform distortion of non-sinusoidal signals. The dead-beat filter does not add any ringing to a transient, which is certainly a good thing. However, this is not the whole story, and to go further we have to bring in the phase-shift introduced by the filter, and the phase response, which is the phase-shift as a function of frequency. If we only ever applied individual sine waves, the phase response would hardly matter, but we are quite likely to want to put in, for example, a digital signal, which is a succession of rectangular pulses, and we do not want the pulse shape to be distorted too much. (Naturally, the fundamental frequency of the signal must be well below the corner frequency of the filter, otherwise the pulse shape will be distorted anyway by the attenuation of the higher harmonic frequencies.)

The phase-shift introduced by the filter at any frequency can also be regarded as a time delay. For example, if a 1 kHz signal is subject to 90° phase-shift, this is a quarter of a cycle, and a cycle lasts 1ms. So the phase-shift is equivalent to a time delay of 250μs. If we think of the complex signal to be made up of separate sine-wave signals (as the theory of Fourier analysis says we can), we want them to remain in step. In other words, they must all be delayed equally. A constant delay is equivalent to a phase-shift that is proportional to frequency, because the delay time is constant but the time for one cycle is inversely proportional to the frequency. This delay is usually called 'group delay', τ_g (that's the Greek letter 'tau'), for reasons we need not go into, and is related in general to the phase-shift ϕ by:

$$\tau_g = \frac{d\phi}{d\omega}$$

i.e. it is equal to the rate of change of phase-shift with angular frequency.

Consider again one of the above equations:

$$T(j\omega) = \frac{1}{(1-\omega^2) + \dfrac{j\omega}{Q}}$$

If we rationalise this (see Part 1) to get the j-term into the numerator, where it is more tame, we get:

$$T(j\omega) = \frac{(1-\omega^2) - \left(\dfrac{j\omega}{Q}\right)}{(1-\omega^2)^2 + \left(\dfrac{\omega}{Q}\right)^2}$$

The numerator has two terms, one with j and one without. The denominator has no j-term, of course, so has no effect on what follows. In fact, the two terms of the numerator are phasors (formerly vectors) which represent the in-phase and quadrature (90° phase) components of the signal after it has been 'processed' by $T(s)$. So the phase angle ϕ of the output signal is given by:

$$\phi = \arctan\left(-\frac{\left(\dfrac{\omega}{Q}\right)}{(1-\omega^2)}\right)$$

It isn't possible to choose Q so that ϕ is proportional to ω (i.e. $\phi = k\omega$, where k is a constant) over a wide frequency range, but the dead-beat response gives a reasonable approximation up to $\omega = 0{\cdot}6$ or so.

A family of better approximations can be discovered by working backwards from $\phi = k\omega$. This can give the well-known Bessel family of responses, whose transient responses are nearly free of ringing, and which maintain ϕ proportional to ω, i.e. constant group delay, up to $\omega = 2$ for high-order filters. Bessel filters have soggy attenuation characteristics, so they are not often used. Some loudspeaker crossover networks claim Bessel responses: it is far from clear what advantage this gives to counteract the problems which almost inevitably arise from the slow rates of increase of attenuation. We shall look at filters for crossovers in a later part of the series.

Working Backwards

The simplest way for ϕ to depend on ω is simply $\phi = \omega$. Then $\tan\phi = \tan\omega = \sin\omega/\cos\omega$. Thus:

$$T(j\omega) = \frac{1}{\cos\omega + j\sin\omega}$$

$$= \frac{1}{\exp(j\omega)}$$

because $\cos\omega$ and $\sin\omega$ are components of the vector (there is no t – this one isn't rotating so it isn't a phasor) $\exp(j\omega)$. You will see soon why I have not gone so far as to write $T(j\omega) = \exp(-j\omega)$.

So $T(s) = 1/\exp(s)$. Unfortunately, this transfer function requires an infinite number of components in the filter, which is rather expensive. We can obtain approximations to $\exp(s)$ by using its Taylor Series expansion (but I don't have space to explain Taylor Series here). The first three terms give a second-order Butterworth filter again:

$$T(s) = \frac{1}{1 + s + \dfrac{s^2}{2!}}$$

where 2! is 'factorial 2' (= 2 × 1). This requires a snag to be overcome. When we are using these 'scaled' or 'normalized' forms of the equations, which make everything much simpler, we must make sure that we have no scale factor hidden away where it can make the results wrong. Here, we do have a scale factor, because our equations are not properly normalized if either the coefficient of s^2 or the constant term is not 1. To make this so, we rescale by writing $s' = s/\sqrt{2}$, giving:

$$T(s') = \frac{1}{1 + \sqrt{2}s' + s'^2}$$

which we can recognise at once as Butterworth.

If we use a different type of approximation to exp(s) (still three terms), we can get:

$$T(s) = \frac{3}{3 + 3s + s^2}$$

This has scale factor problems, and reduces to:

$$T(z) = \frac{1}{1 + \sqrt{3}z + z^2}$$

This is the second-order Bessel response, and we can see that $Q = 1/\sqrt{3}$ for this filter, as opposed to $1/\sqrt{2}$ for the Butterworth. The amplitude response is:

$$|T(j\omega)|^2 = \frac{1}{\sqrt{1 + z^2 + z^4}}$$

and it is the z^2 term which causes the response roll-off to be gradual. When z is much larger than 1, z^4 takes charge and the attenuation increases at 12dB/octave, as for the Butterworth response.

Q and Pole Positions

A very low-Q filter (low-pass or high-pass) has poles on the $-\sigma$ axis, one near the origin and one quite distant. As Q increases, the poles move together to the point (–1/2, 0) when $Q = 0{\cdot}5$, as we saw above. The two poles then split apart again, because they have j-terms of opposite sign. If we go right back to the equation for m:

$$m = -\frac{R}{2L} \pm j\sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2}$$

and recall that the real and j-terms represent the coordinates $(-\sigma_1, \pm\omega_1)$ of the poles on the complex plane, we find something very interesting. The sum of the squares of the two terms is a constant, $1/LC$ in the general case, and this is equal to 1 for the normalized filter. The poles thus lie on a circle, centred on the origin, and with a radius 1 in the case of the normalized filter. As Q increases, the poles move round the left half of the circle in opposite directions towards the $j\omega$ axis, as shown in Figure 25, and they would reach the axis if the Q became infinite. This is what we arrange in a sinusoidal oscillator, by cancelling the circuit power losses with an amplifier.

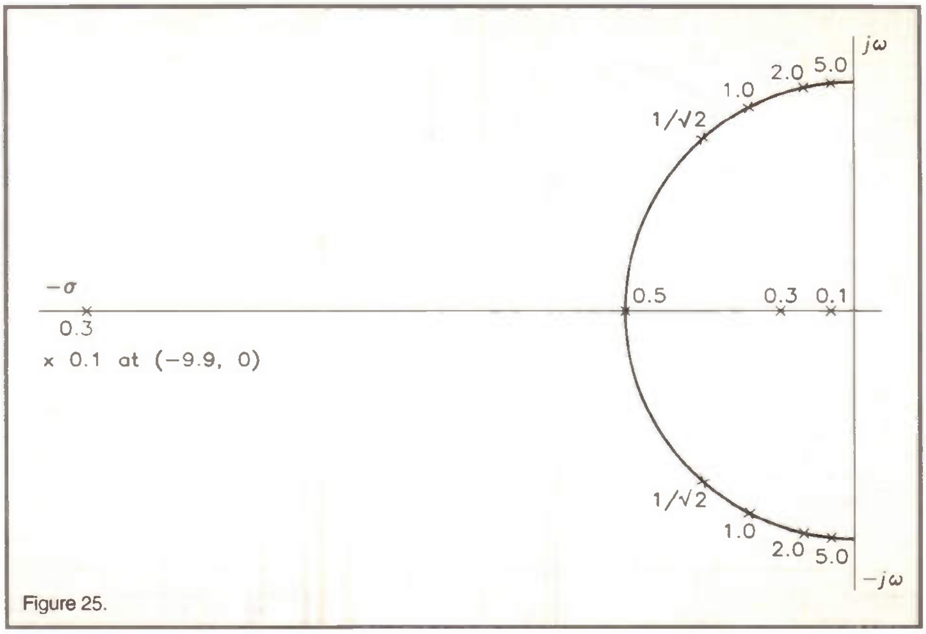


Figure 25. Movement of poles of a second-order low- or high-pass filter with variation of filter Q.

Things to Come

We have had a heavy dose of theory this time, but with quite a bit of practical design for high-pass filters. Next time, we will look at band-pass and band-stop filters.

Stray Signals

by Point Contact

Towards a Greener World?

Many local authorities have bottle-banks in strategic locations, such as car parks; some authorities have other 'banks' for paper, aluminium, and tin cans, etc. But, domestic waste disposal is still a huge problem, with landfill sites becoming scarce, and incinerators under fire (sorry about the pun) for the atmospheric pollution, including dioxins, that they produce. So more extensive use of recycling of worn-out or superseded products seems a good move – on the face of it.

Our industry – electronics – should, surely, set a good example, but things are never quite as straightforward as they seem. By the time you read this, a European Union task force is due to have submitted its report, which will probably, among other things, recommend European legislation on the recycling of electronic products, to match that already in place in Germany and Holland. As I write, the DTI is awaiting a report, due this summer, being prepared by an industry recycling group, but an existing report from ERA points out that recycling costs money. German companies estimate typical costs as around £15 for a PC and £30 for a TV. Clearly, 100% recycling of components will never be practical, but it would be nice to improve on the current average of 5%!

The bulk of the recycling is mainly in products such as PCs and TVs (which accounts for a not inconsiderable proportion of the materials). If cars were designed with everlasting bodies, and engines designed for economical reconditioning, then vehicles could be kept going almost for ever – as many vintage cars are! But, I guess that the resultant unemployment in the motor industry would be considered quite unacceptable.

Spirit of Times Past

Browsing around a second-hand bookshop in Barnstaple recently, PC found a dozen or so copies (dating from the late '50s) of a hobbyist magazine, still appearing regularly on newsagents' shelves. What I had not realised (until a recent conversation with a senior citizen who was once his secretary) was that the editor, F. J. Camm, not only edited the magazine, but actually wrote much of it himself, under a variety of pen names. Of course, the articles all seemed very dated, mostly still featuring valves, etc., but one novelty was a stereo amplifier for handling both channels of standard 45/45 degree stereo records. With no phase splitter stage, the amplifier was push/pull throughout, with the left channel connected to one input and the right channel to the other. One speaker was connected between one end of the centre-tapped secondary of the output transformer and ground, the other speaker likewise, to the other end. Since most stereo pick-ups give in-phase outputs for horizontal needle movement (left signal equals right signal), it was necessary to use a cartridge where both ends of each element were brought out, so that one input channel could be reversed, making the sum signal push/pull. The amplifier then operated as two single-ended amplifiers in parallel to the smaller difference signal. This was picked off by the primary of an auxiliary transformer, in series with the HT supply to the centre tap of the main push/pull output transformer primary. The secondary of the auxiliary transformer was connected between the centre tap of the secondary of the push/pull transformer and ground, this 'matrixing' arrangement providing push/pull amplification to the sum signal, whilst restoring separation of the channels at the loudspeakers. Simple really! Got it?

Another technological marvel from those pages was 'A Supersensitive Transistor Receiver'. This used a 'white spot' (RF) transistor, powered from a RM250 1.3V button cell, in a circuit which was, actually, a thinly disguised Hartley oscillator. A variable bias resistor enabled the transistor current to be adjusted to the point where it was barely (not) oscillating, providing, it was claimed, adequate listening on a pair of 4,000Ω headphones, using a short wire aerial: 2 feet according to the circuit, or two yards according to the text. This advanced design was published by a certain C. Sinclair, presumably the same one who went on, later, to market so many other wonderful high tech products.

One of the most fascinating aspects of browsing through the pages of these old magazines were the adverts, which included some odd offerings. The 'Gramdeck tape recorder adapter' was one such offering: it fitted over the turntable of a record player, which it used as the motor for both capstan and take-up reel drive. With a 78/45/33 rpm player, you actually got a choice of three tape speeds, but 'fast' forward was not very fast, and rewind involved swapping the reels over. I do not know who would have bought one because a dedicated tape deck was available from other manufacturers for the same price or less.

The prices quoted for the goods offered in the adverts were also an eye-opener. For instance, the Jason FM tuner kit cost £6.19s.6d or well over £100 in today's money, allowing for inflation. The AVO Minor, a 10kΩ/V multimeter, equivalent to multimeters in the current Maplin Catalogue costing £10 to £20, then cost £9.10s, or around £200 at today's prices. No wonder we used to buy, or better still scrounge, second-hand and ex-government components!

Gobbledygook

PC was keeping abreast, the other day, with some of the publications emanating from the headquarters of the ITU (International Telecommunications Union) in Geneva. One paper concerned spectrum management; a burning international issue with everybody wanting more frequency allocations. The paper included two Annexes, Annex 1 being 'Electronic Spectrum Management Information Exchange' and Annex 2 being 'Electronic Exchange of Spectrum Management Information'. If you think about it for long enough, they are different – *aren't they?*

Yours sincerely,

Point Contact

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

2
PROJECT RATING

Text by Dean Hodgkins BEng(Hons) and Alan Williamson

IN-CAR 400W MONO/ STEREO AMPLIFIER

KIT AVAILABLE (VF40T) PRICE £59.99 H10

FEATURES

* 2×100W rms output power (into 4Ω load)
* Three input sensitivities
* Overload, short circuit protection
* Speaker pop suppression
* Thermal protection possible
* Compact and robust design
* Ready-built unit available

APPLICATIONS

* IN-CAR AMPLIFIER MODULE
* DOMESTIC USE * PA SYSTEMS

Specification

RMS output power:	2×100W (4Ω load); 2×75W (8Ω load)
RMS mono-bridged power:	200W (8Ω load)
Total music output:	400W
Harmonic Distortion:	0·003% at 1kHz
Signal-to-noise ratio:	96dB
Stereo channel separation:	76dB
Damping factor (at 100Hz):	>2000
Input impedance:	22kΩ
Input sensitivity:	150mV; 500mV; or 950mV switchable
Supply voltage	
(for 8Ω load):	±40 to ±45V DC @ 2·5A
(for 4Ω load or mono):	±30 to ±35V DC @ 5A
Dimensions:	350 × 62 × 85mm

This superb amplifier is small and compact, and it certainly packs a punch! It is very versatile, being ideal for domestic use, car or caravan, and PA systems. The amplifier is housed in a robust stylish black case, which also doubles as its heatsink. Note that a ready-built Gold-line version of the amplifier is also available (Stock Code VF45Y).

If the amplifier is going to be used for portable applications (in the car/caravan, for example), then the K3508 In-Car PSU kit is required (Stock Code VF38R). A ready built Gold-line version, the SPS200, is also available (Stock Code VF47B).

For domestic use, the choice of mains powered supply will depend upon the load requirements; the Gold-line APS204 (Stock Code VF51F) is suitable for stereo mode (2 × 4Ω loads) and bridged mono mode with an 8Ω load. The APS208 (Stock Code VF52G) is appropriate for stereo use with 2 × 8Ω loads.

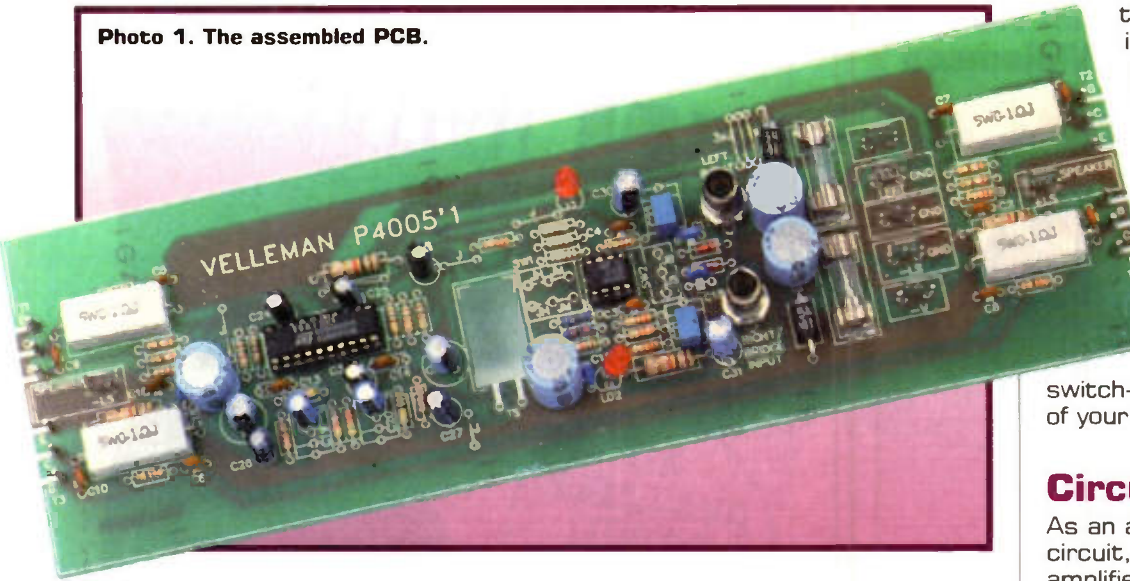


Photo 1. The assembled PCB.

The Gold-line APS200 (VF49D) is a PSU module (not encased, and without a transformer) which is, primarily, designed to be integrated with the power amplifier into an enclosure of your choice. There are two choices of transformer available for the PSU; the choice is, again, dependent upon the load requirements. The 2 × 30V 225VA (Stock Code DH72P) is suitable for use with 2 × 8Ω loads, and the 2 × 22V 300VA (Stock Code DH74R) must be used with 2 × 4Ω loads, or an 8Ω load (bridged mono). Construction is quite easy, even though the component count is fairly high, as no elaborate test equipment is required for setting up the completed module. The amplifier has overload (the main IC even has its own in-built overload current protection!) and short circuit protection (although we do not recommend that you deliberately abuse the module), and also speaker 'pop' suppression at switch-on/off, to extend the life of your speakers.

Circuit Description

As an aid to understanding the circuit, a block diagram of the amplifier is shown in Figure 1. Referring to the circuit diagram of Figure 2, it can be seen that the circuit comprises two stages: The input preamplifier stage, and the main amplifier stage.

The Preamplifier Stage

The input stage consists of a TL072 dual low-noise operational amplifier (op amp); the signal is applied to IC1 via AC coupling capacitors C21 and C22.

The capacitors C21 & C3 (right channel), and C22 & C4 (left channel), combined with the input resistors R1 and R2, provide band-pass filtering.

The right channel preamplifier is non-inverting, and the left channel is inverting; the reason for this will be explained later.

Both of the preamplifiers have selectable gain/sensitivity (by means of fitting links or an optional switch on the PCB); the gain of a

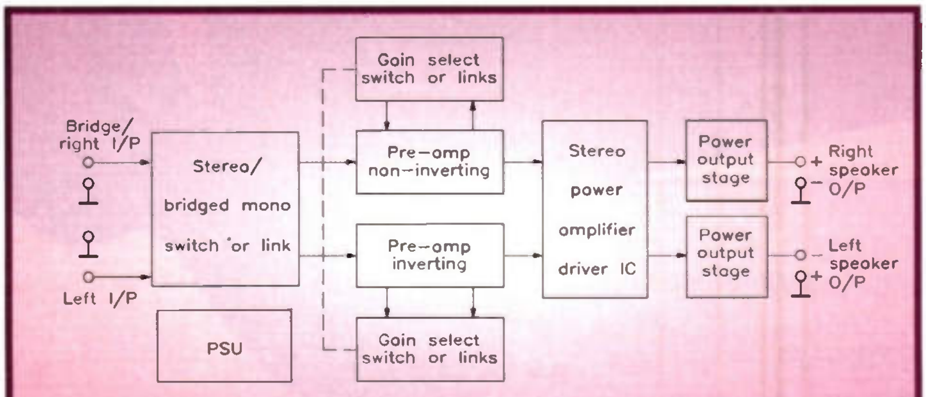


Figure 1. Block Diagram.

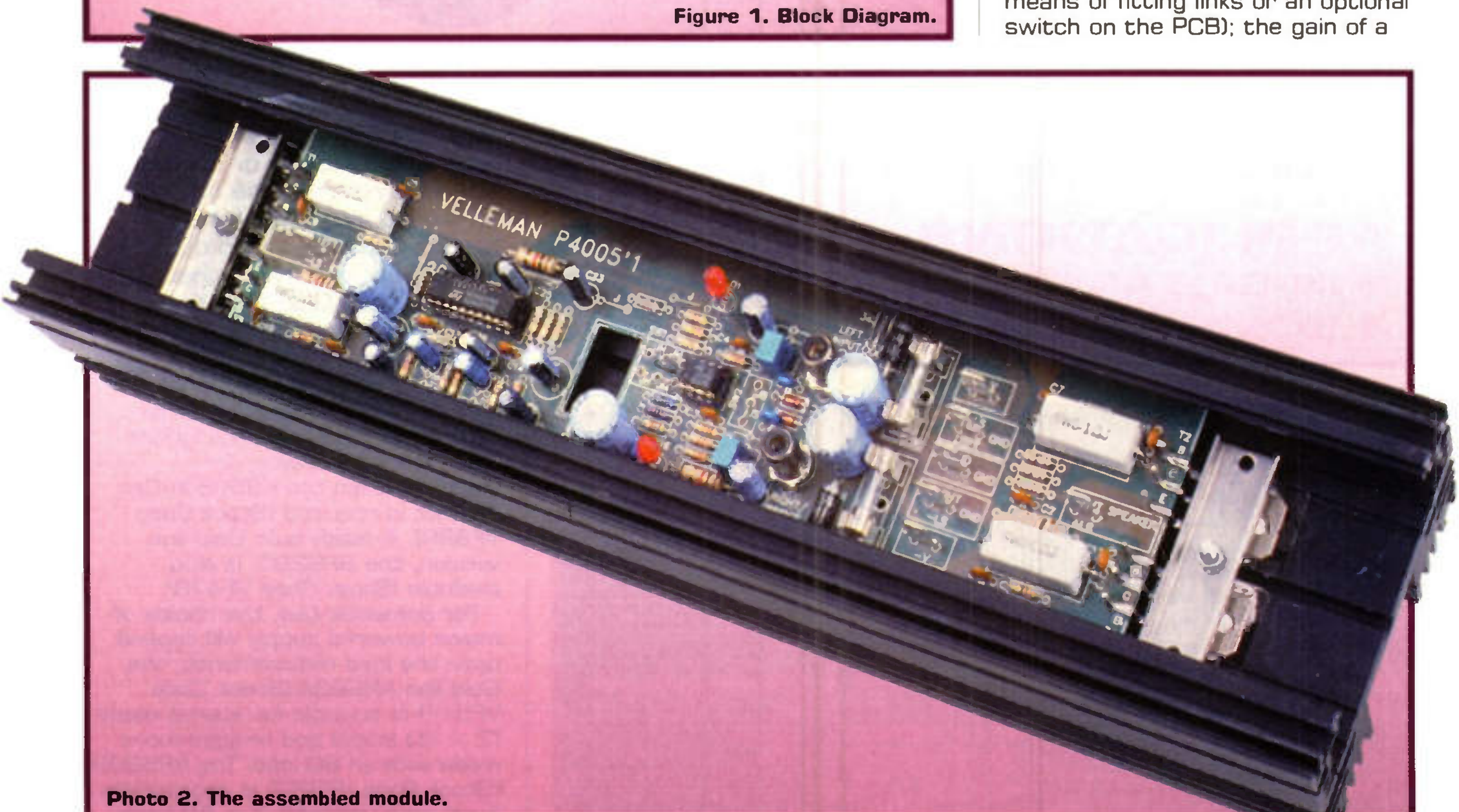


Photo 2. The assembled module.

non-inverting op amp is determined by dividing the total resistance of the feedback network (R9, R10, R11) by R8, then adding 1:

$$A_{V+} = \frac{R_F}{R8} + 1$$

where: R_F = R11 or R11 // R10 or R11 // R9 depending on position of SW1a. A_{V+} = non-inverting voltage gain.

The gain of an inverting amplifier is determined by dividing the total resistance of the feedback network (R15, R13, R12) by R2:

$$A_{V-} = -\frac{R_F}{R2}$$

where: R_F = R15 or R15 // R13 or R15 // R12 depending on position of SW1b.

If a link (or optional switch) is fitted in the SW2 'BRIDGE' position, and a signal is applied to the right channel input, then the outputs of the op amps will have a 180° phase difference. This is an ideal arrangement for converting a stereo amplifier into a bridged mono amplifier because it doubles the output voltage swing to the load (the load is connected between LEFT −LS and RIGHT +LS).

The Zener diodes ZD1 and ZD2 set the preamplifier voltage rails at ±15V. Resistors R35 and R36

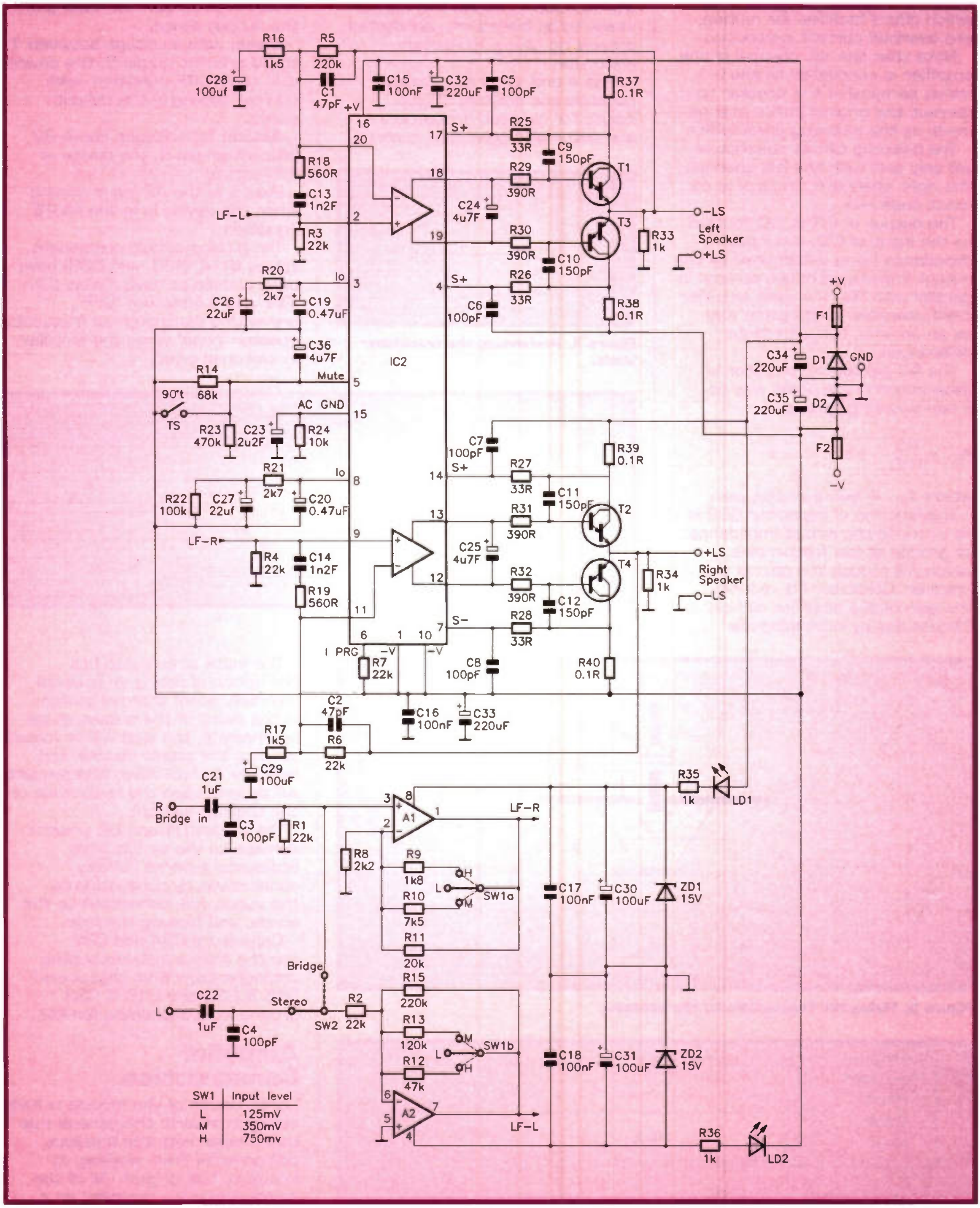


Figure 2. Circuit Diagram.

limit the current to the preamplifier circuit and, through the LEDs LD1 and LD2, which are included to enable 'visual conformation' that the supply rails are established. Capacitors C17 & C30 and C18 & C31 provide local decoupling for IC1.

The Main Amplifier Stage

The main amplifier stage is designed around the TDA7250 60W Hi-Fi dual audio driver chip, which offers facilities for muting, and overload current protection.

Note that the left channel of the amplifier is connected to the (–) minus terminal of the speaker to correct the original phase change made by the inverting preamplifier.

The following circuit description will only deal with the left channel; the right channel's circuitry is an exact duplicate.

The output of IC1 is DC coupled to the input of IC2, the input impedance being determined by the output impedance of the op amp in parallel with R3. The main amplifier itself operates in the same way as an op amp, but with slight differences.

The AC gain of the amplifier is determined in the same way as a non-inverting op amp:

$$A_{V+} = \frac{R5}{R16} + 1$$

where A_{V+} = non-inverting gain.

The function of capacitor C28 is to increase the circuit impedance to ground at low frequencies, which will reduce the gain of the amplifier. Capacitor C1 reduces the gain of the amplifier at high frequencies by increasing the amount of feedback. The resistor R18 and the capacitor C13 also provide high frequency filtering at the input of the amplifier, by increasing the common mode signal.

The main power output stage consists of a complementary pair of Darlington transistors in a push-pull emitter follower configuration.

Although the dual outputs from IC2 are in-phase, a DC voltage is required to be present between the outputs to enable the output stage to be biased into conduction, preventing gross crossover distortion.

Pins 4 and 17 of IC2 are the negative and positive SENSE inputs for overload protection, and automatic quiescent current control in the output stage. Pin 3 is the quiescent current control integrator capacitor input, which controls the current in the output stage in no-signal conditions.

Pins 5 and 15 are common to both channels; pin 5 is a voltage controlled three function input (standby/mute/active):

Standby: when the pin voltage is less than 1V (referenced to pin 10, the negative supply voltage pin), the device is in STANDBY mode, with no current flowing in the output stage.

Mute: with a voltage between 1 to 3V present on pin 5, the device is in the MUTE condition, with current flowing in the output stage.

Active: for voltages above 3V present on pin 5, the device is fully active.

Pin 15 is the AC input ground when the device is in the MUTE condition.

The muting circuit component values (R14, R23, and C36) have been chosen to have a slow turn 'ON' and a fast turn 'OFF', preventing damaging low frequency speaker 'pops' when the amplifier is switched on/off.

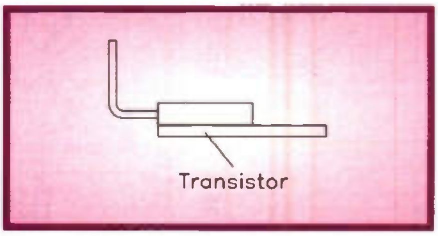


Figure 3. Preforming the transistor leads.

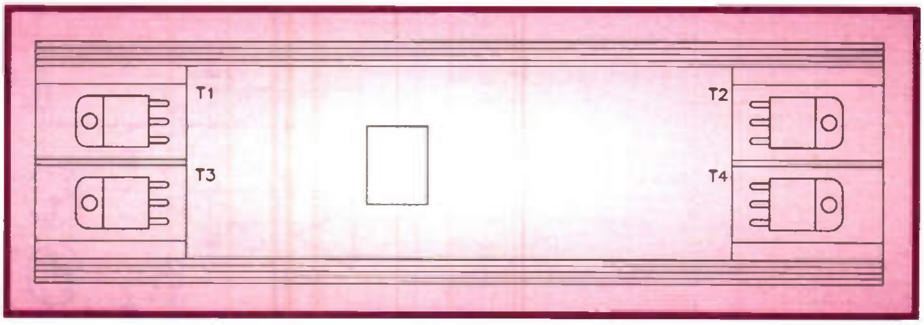


Figure 4. Locating the transistors.

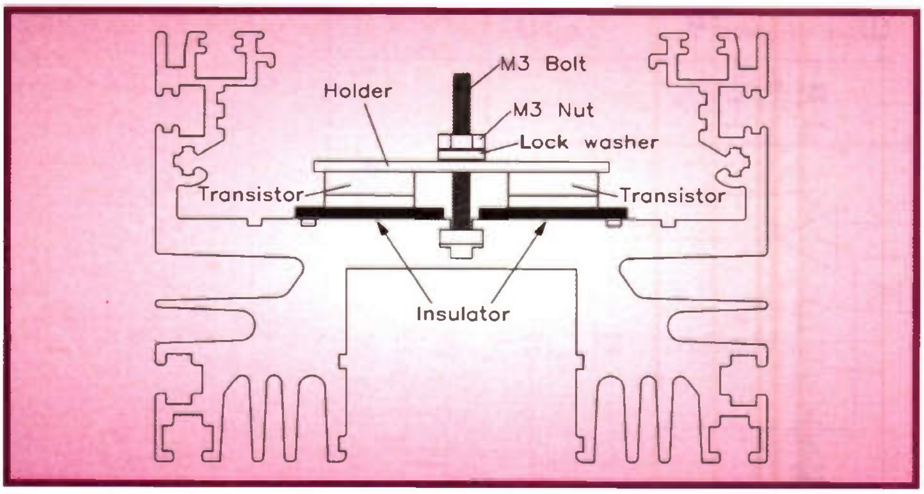


Figure 5. Fixing the transistors to the heatsink.

Figure 6. PSU wiring diagram.

The mute circuit also has the option of fitting an optional (normally open) thermal switch; in the event of the output stage overheating, the load will be muted, allowing the power devices and heatsink to cool down (the amount will depend upon the hysteresis of the thermal switch).

The diodes D1 and D2 prevent damage to the circuit from accidental reverse polarity connections by conducting to the supply rail, connected to the anode, and blowing the fuse.

Capacitors C34 and C35 are the main supply decoupling components, whilst capacitors C15 & C32 and C16 & C33 provide local decoupling for IC2.

Amplifier Construction

Construction of the module is fairly straightforward; the general rule being: begin with the smallest components first, working up in size to the largest. All of the components are mounted on a single-sided PCB, shown in Photo

1, and the assembled module is shown in Photo 2.

First, decide upon the level of input sensitivity required. Referring to the PCB legend, mount the jumper JH for a sensitivity of 950mV, or jumper JM for a sensitivity of 500mV. If you require a sensitivity of 150mV, then leave both jumper connections open.

The next decision to be made is whether or not the amplifier is going to be used for mono or stereo applications. For a stereo amplifier, fit the jumpers JS; for a mono bridged amplifier, fit jumpers JB.

If you intend to use the amplifier for several different applications, you may find it helpful to fit switches (not supplied) in place of the jumper connections. Replace the sensitivity selection jumper with a DPDT toggle switch (Stock Code FH05F), and use a SPDT toggle switch (Stock Code FH00A) to replace the stereo/bridged-mono mode jumper.

The recommended component assembly order is as follows: First, insert and solder the 0·25W resistors (R1 to R32), followed by the 1W resistors (R33 to R36). Next, insert and solder the diodes D1 and D2, followed by Zener diodes ZD1 and ZD2. Care must be taken to fit the diodes the right way around; the cathode is indicated by a band on the body of the diode, and this must face the thick white band on the PCB legend.

Mount and solder the 5W resistors (R37 to R40), followed by the IC sockets and PCB pins. Insert pins TS if the thermal protection switch (optional) is to be connected.

Mount the capacitors next, taking care to insert the polarised devices correctly – the negative lead is identified by a black band and (–) symbols on the capacitor's body.

Next, mount the male blade connectors, followed by the fuseholders; the fuseholders should be fitted as closely as possible to the PCB.

Fit the LEDs, taking care that the 'flat' on the LED's body corresponds to the straight line on the PCB legend. The tip of the LED should be approximately 20mm from the PCB.

Insert and solder the phono connectors; if the amplifier is only to be used in mono-bridged mode, then only the right input phono connector is required.

Thoroughly check your work for errors, such as misplaced components, solder bridges, and dry joints, etc. Clean any flux off the PCB using a suitable solvent.

Finally, fit a T5A fuse into each fuseholder, and insert the ICs into their sockets.

Module Assembly

Slide the PCB into the largest slot in the heatsink, positioning the PCB in the middle of the case. Use a pair of pliers to carefully bend the leads of the power transistors (T1 to T4) until they are at right angles to the transistor body (see Figure 3). Smear some thermally conductive paste (included) on to the surface of the transistor which will be in contact with the heatsink, and place an insulating mica washer over the paste. Apply a small amount of paste to the mica washer, and place the transistor in the correct position on the heatsink (refer to Figure 4). Fix the transistors in place by sliding a hexagonal bolt (supplied) into the slot in the heatsink (shown in Figure 5). Place a metal retainer plate over each pair of transistors (the bolt must pass through the hole in the centre of the plate), and secure the retainer by using a locking washer and nut. *It is important to ensure that the transistor connection leads do not come into contact with the metal plate.* Finally, carefully bend the transistor leads again, so that they make contact with the appropriate PCB pins, and solder.

Testing

Referring to the connection diagram of Figure 6, connect a symmetrical PSU, which is capable of providing ±30V to ±45V DC, between the –V, +V, and GND terminals. The PSU must not be turned on before the connections to the amplifier have been made!

Turn on the PSU; both LEDs on the PCB should illuminate to show that power is being supplied.

Using a multimeter, measure the voltage across each of the 5W resistors; a voltage of approximately 0·01V should be detected. Next, measure the voltage between each speaker output terminal and the GND

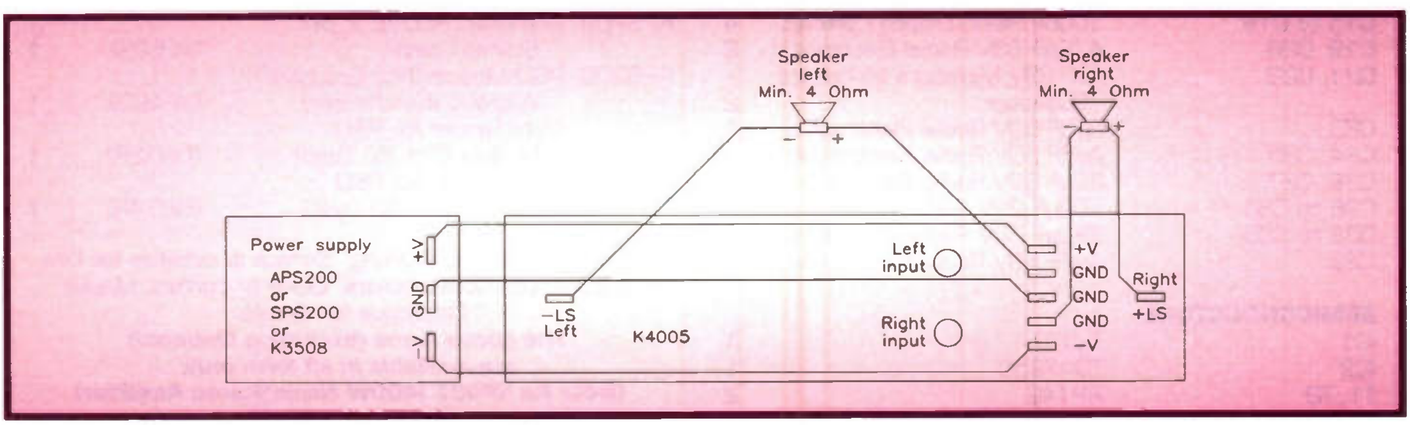


Figure 7a. Wiring the speakers for stereo mode.

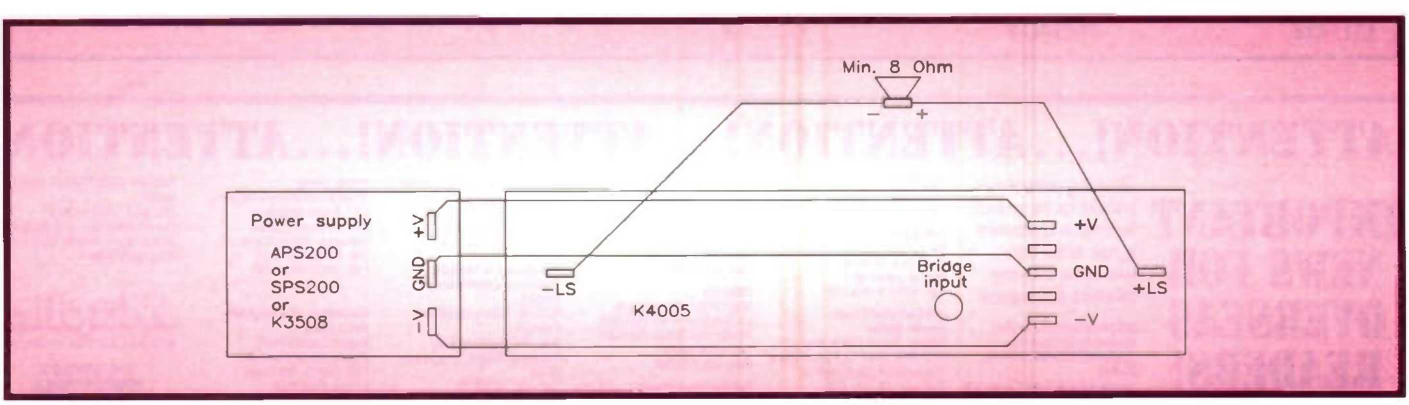


Figure 7b. Wiring the speakers for bridged-mono mode.

terminal; this should be close to 0V, but certainly no greater than 0·5V.

The amplifier is now ready for use.

Final Construction and Use

Attach the front panel sticker to the heatsink 'lid', and cut out the holes in the sticker using a craft knife. Slide the lid into position, and secure it in place using the screws supplied.

If the amplifier is to be operated in stereo mode, connect the left and right speakers (taking care to observe correct polarities) as shown in Figure 7a. The minimum impedance of each speaker must not be less than 4Ω.

For mono-bridged operation, use the Right/Bridge input terminal. Connect a speaker (minimum impedance: 8Ω) between the −LS Left Speaker and +LS Right Speaker outputs, as shown in Figure 7b.

Remember, always connect the speakers before turning on the PSU! E

400W Mono/Stereo Amplifier Parts List

RESISTORS: All 0·25W 5% Metal Film (Unless specified)

R1 to R7	22k	7
R8	2k2	1
R9	1k8	1
R10	7k5	1
R11	20k	1
R12	47k	1
R13	120k	1
R14	68k	1
R15	220k	1
R16, R17	1k5	2
R18, R19	560Ω	2
R20, R21	2k7	2
R22	100k	1
R23	470k	1
R24	10k	1
R25 to R28	33Ω	4
R29 to R32	390Ω	4
R33 to R36	1k 1W	4
R37 to R40	0·1Ω 5W	4

CAPACITORS

C1, C2	47pF Ceramic	1
C3 to C8	100pF Ceramic	6
C9 to C12	150pF Ceramic	4
C13, C14	1n2F Ceramic	2
C15 to C18	100nF Resin-Dipped Ceramic	4
C19, C20	470nF 63V Radial Electrolytic	2
C21, C22	1μF 63V Miniature Metallised Polyester	2
C23	2μ2F 50V Radial Electrolytic	1
C24, C25	4μ7F 50V Radial Electrolytic	2
C26, C27	22μF 50V Radial Electrolytic	2
C28 to C31	100μF 25V Radial Electrolytic	4
C32 to C35	220μF 50V Radial Electrolytic	4
C36	4μ7F 50V Radial Electrolytic	1

SEMICONDUCTORS

IC1	TL072	1
IC2	TDA7250	1
T1, T2	TIP142	2
T3, T4	TIP147	2
LD1, LD2	Red LED 5mm	2
ZD1, ZD2	15V 1·3W Zener Diode	2
D1, D2	1N5404	2

MISCELLANEOUS

	8-Pin DIL IC Socket	1
	20-Pin DIL IC Socket	1
	PCB	1
	PCB Pins	14
+LS, −LS, GND, +V, −V	Flat Blade Connectors	7
	Phono Sockets	2
F1, F2	5A T-Type 20mm Fuse	2
	20mm Fuse Clip	4
	Heatsink and Lid	1
	M5 Screw	6
	M3 Nut	2
	M3 × 20mm Hexagonal Bolt	2
	Lock Washer	2
	Metal Retainer Plate	2
	Thermal Paste	1
	Insulating Mica	4
	Cover Sticker	1
	Leaflet	1

OPTIONAL (Not in Kit)

THERMIC	Thermal Switch		1
K3508	In-Car PSU Kit	(VF38R)	1
SPS200	Ready-Built In-Car PSU	(VF47B)	1
APS204	Domestic PSU (Mono/ 2 × 4Ω Stereo Load)	(VF51F)	1
APS208	Domestic PSU (2 × 8Ω Stereo Load)	(VF52G)	1
APS200	PSU Module (Not Encased/ Without Transformer)	(VF49D)	1
	Transformer for PSU Module (2 × 8Ω Load)	(DH72P)	1
	Transformer for PSU Module (2 × 4Ω Load)	(DH74R)	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 in kit form only.

Order As VF40T (400W Mono/Stereo Amplifier) Price £59.99 H10

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