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No. 87

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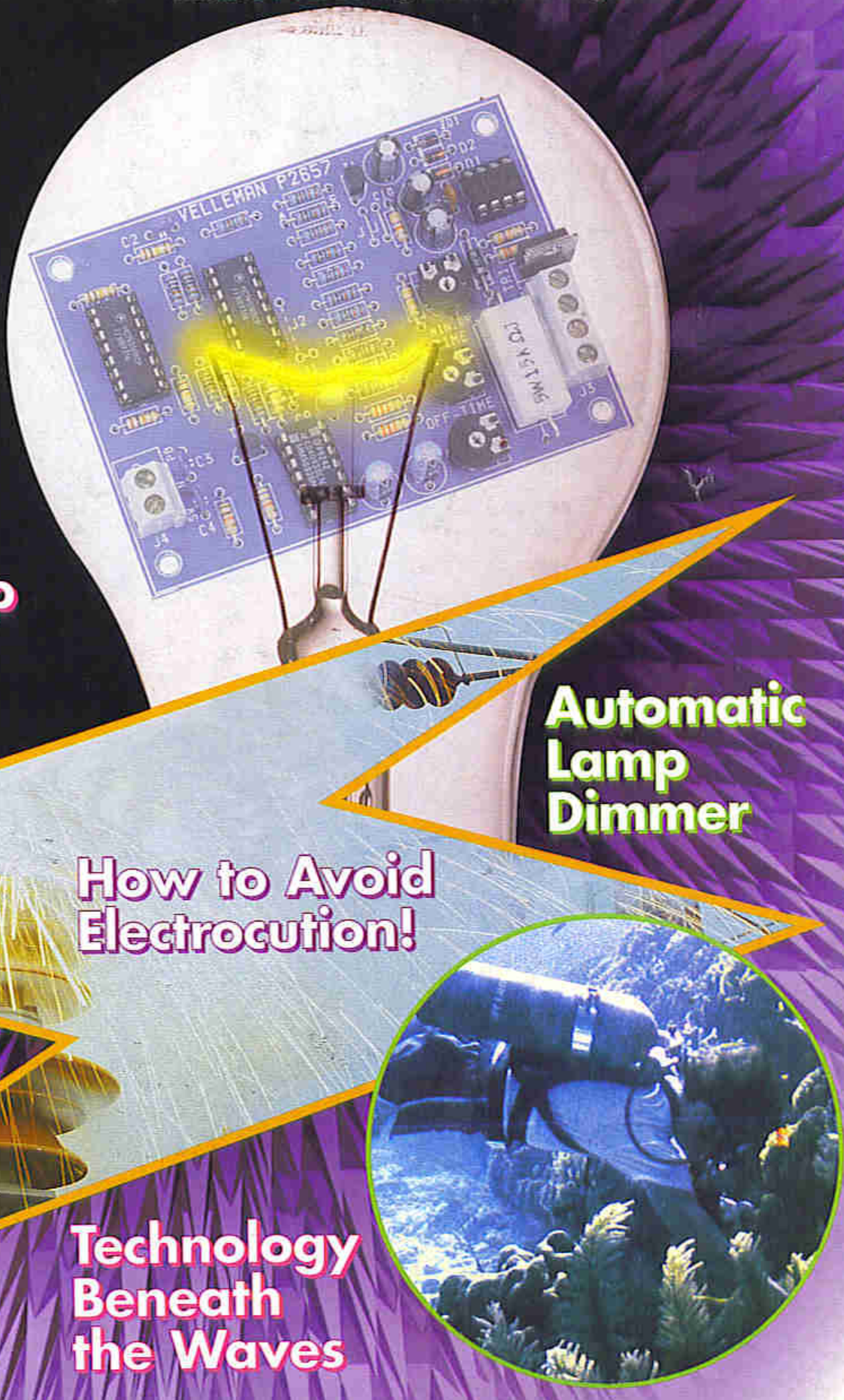
MARCH 1995 • £2.10

Printed in the United Kingdom

ELECTRONICS

The Maplin Magazine

Britain's Best Selling Electronics Magazine



How to Build an Ingenious Continuity & Leakage Tester

Electronic Memo Pad Project

Update on the Millennium 4-20 Valve Power Amp

All About Field Programmable Gate Arrays

Automatic Lamp Dimmer

How to Avoid Electrocution!

Technology Beneath the Waves

ISSN 0957-5456

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MARCH 1995
VOL 14. No. 87

IN THIS ISSUE...

PROJECTS *FOR YOU TO BUILD!*

FEATURES *ESSENTIAL READING!*

REGULARS *NOT TO BE MISSED!*

ABOUT THIS ISSUE . . .

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

Little did we know in 1993 that the 'Valve Technology' series published in *Electronics* would cause such a revival of interest in valves! The end of the series was marked by the publication of the Millennium 4-20 valve power amplifier project and more recently the publication of the Newton valve preamplifier project. Since publication of the Millennium, we've had a great deal of feedback from people who have built it, a rave review in *Hi-Fi World* and a lot of interest from the USA. In response to this, a number of refinements have been introduced to improve the performance of the Millennium still further and provide dual 115/230V 50/60Hz AC mains operation. For the benefit of the many readers who have already built the Millennium, details of these refinements appear in this issue, happy listening! North American readers interested in building the Millennium should contact Old Colony Sound Laboratory, P.O. Box 243, 305 Union Street, Peterborough, NH 03458-0243, USA. Tel: (603) 924 6371 or (603) 924 6526. Fax: (603) 924 9467. Readers in other countries should contact their nearest Maplin Distributor, see page 38 for details.

Surface mount technology is fast becoming the norm in consumer products such as TVs and VCRs, and has made previously bulky items more manageable. Testimony to this is the transformation over the last decade of the 'lugable' separate video camera/recorder, through 'camcorder', into the shrunken 'palmcorder'. Recently we have published a wide-band RF preamp using surface mount components. The reduction in stray inductance by using surface mount technology (otherwise introduced by conventional component leadouts) was necessary for the design to operate across the VHF and UHF bands.

For certain projects, miniaturisation is highly desirable, an example is the pocket-sized electronic Memo Pad project in this issue. This unit *would* work if built using conventional full-size components, but the result would be a much bulkier unit – certainly not pocket-sized!

Please write in and let us know what you think of projects using surface mount technology (go on, give them a try before casting judgement and dismissing them as impossible to build!). We've put a lot of thought into making construction as easy as possible, so it would be interesting to learn what you find easy, and what you find difficult.

Test equipment projects are frequently requested and always prove popular, however, it is quite a challenge to develop innovative test equipment designs. For example, how many run of the mill continuity testers have you seen published before – quite a few is the probable answer! However, the design presented in this issue is genuinely very different. The unit combines the functions of continuity and leakage testing, covering the range from short circuit to 10MΩ. Indication is by means of a variety of easily interpreted audio tones. Thus the unit is ideal for checking wiring, switches and connectors. It can also be used to check a wide range of discrete active and passive components such as diodes, transistors, capacitors and inductors. Long battery life can be expected since in the quiescent condition current drain is under 1mA and 13mA when operating. In case that all this is not enough, the unit includes an audible 'left switched on' reminder and is capable of surviving accidental connection to energised circuits, even AC mains!

Plus of course there are other great projects to build and features to read!

So until next month, from everyone here at *Electronics* enjoy this issue!

Exclusive Subscribers' Club Special Offer

Featured on page 71 is the 'Terminator 10', an exciting new electronic mult-test screwdriver. This new product is normally £6.99, but as a special introductory offer, to subscribers for this month only, it is available for just £5.49. If you are a subscriber, full details of how to order this item are included in the special offer leaflet in this issue – if the leaflet is missing, contact Customer Services, Tel: (01702) 552911. If you are not a subscriber and would like to take advantage of future special offers and other benefits of subscribing, turn to page 19 of this issue to find out more or Tel: (01702) 554161.

Front Cover Pictures: *Grid-station Equipment*

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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.

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UK NEWSTRADE DISTRIBUTION

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

Project Ratings

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

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

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

Visit your local Maplin store, where you will find a wide range of electronic products.

If you do not know where your nearest store is, Tel: (01702) 552911. To avoid disappointment when intending to purchase products from a Maplin store, customers are advised to check availability before travelling any distance.

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If you have a personal computer equipped with a MODEM, dial up Maplin's 24-hour on-line database and ordering service, CashTel. CashTel supports 300-, 1200- and 2400-baud MODEMs using CCITT tones. The format is 8 data bits, 1 stop bit, no parity, full duplex with Xon/Xoff handshaking. All existing customers with a Maplin customer number can access the system by simply dialling (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.

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Prices of products and services available from Maplin, shown in this issue, include VAT at 17·5% (except items marked NV which are rated at 0%) and are valid between 3rd February 1995 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.

'Get You Working' Service

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

Kit Retail Price	Standard Servicing Cost
up to £24.99	£17.00
£25.00 to £39.99	£24.00
£40.00 to £59.99	£30.00
£60.00 to £79.99	£40.00
£80.00 to £99.99	£50.00
£100.00 to £149.99	£60.00
Over £150.00	£60.00 minimum

Readers Letters

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

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

TECHNOLOGY WATCH!

with Keith Brindley

Keep Passing the Open Windows

The next-generation operating system for millions upon literally millions of computer users' worldwide is moving into its final beta stage. Microsoft's *Windows 95*, previously code-named *Chicago*, has until recently only been available in fairly early beta stages, but is due to ship as an almost-finished product as you read this.

Windows 95 is, as many readers will already know, the latest version of Windows (the last version was 3.11) and promises significant improvements over its earlier incarnates. It has taken a little while for it to come to fruition, and has been a mammoth task for Microsoft, which must be applauded for what it has achieved. The new operating system is (for the first time) a true operating system. It's not piggybacked on top of a command-line operating system (MS-DOS, standing for *Microsoft disk operating system*) anymore, but an operating system in its own right. You can still run MS-DOS programs through MS-DOS if you want, or opt to run them through MS-DOS running itself through Windows if you want. But, its *real* power lies in the fact that it does not depend on MS-DOS anymore, releasing it from MS-DOS constraints.

Coupled with this step to full-blown operating system status is a consequent increase in capabilities. Pre-emptive multi-tasking (the ability for programs to run effectively in parallel) is a new feature, along with 32-bit operation and a host of others.

With a final beta version out and available to some 400,000 test users worldwide, it should not be too long before *Windows 95* is shipping in its millions. It will be (and nobody can or will dispute this prediction) the best-selling computer software package of all time. But, that is no reason to give it a silly name. After all, software versions usually go up in a strict order of availablity – *Windows 1, Windows 2, Windows 3, Windows 3·1, then 3·11* – but *95*?

Ah well, with the proverbial Brindley-tongue-in-cheek, here's a few reasons that have been suggested to me how the name *Windows 95* came about (not my ideas honest!):

- 95 is the number of disks the software comes on
- 95 is length of time in hours it takes to install
- 95 is the number of days of adjusting its facilities to get it running acceptably
- 95 is the amount of disk space in megabytes you need on your hard disk to install it
- 95 is the amount of RAM in megabytes you need to run it
- 95 is the planned year of arrival
- 95 is the expected amount of money in $billions that Bill Gates (the Microsoft boss) is expected to make from it

Actually, before Microsoft's attorneys start the lawsuits, I will put matters to rights and say that the list is somewhat from the truth. A joke, in fact. I am actually beta testing *Windows 95* myself and have to report that it is a nifty piece of work – far better than the above list might suggest. It comes on *only* 20 disks!

Blast Off

Astra 1D, the new satellite launched by the satellite television operator SES from the European Space Centre in Kourou, French Guiana on 31 October is in position and starting to become operational. A test transmission on channel 60 is broadcasting at the time of writing (a smidgin afore Christmas). Real broadcasts are scheduled to start by the time you are reading this and so the service will soon be boasting up to 64 channels broadcast from the Satellites' slot at 19·2° East.

The new satellite is the first in the Astra group that is capable of digital transmissions. It can be operated in the *broadcast satellite services* (BSS) frequency band, although it is more likely that it will operate for the main in the D-band of Astra's standard frequency slot. This might have an impact for those who already have satellite receivers (see later). Its digital capability, however, means that certain of its channels will be used for digital transmission test purposes, giving hardware manufacturers and programme providers alike, the potential to test output long before digital transmissions become the norm.

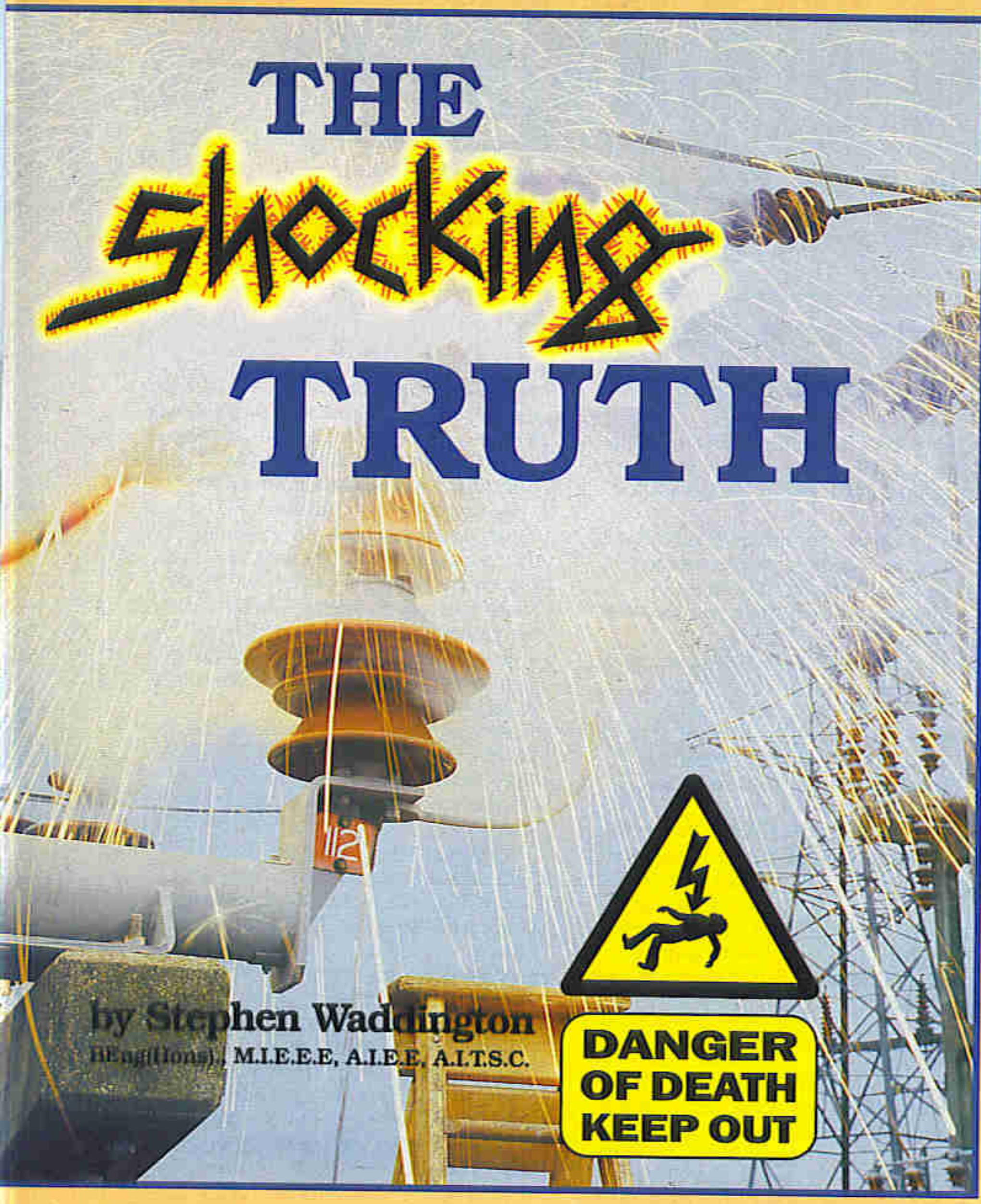
Alongside the new *bird's* arrival, broadcasters now have the chance to expand and increase their services. Many programme providers had been forced to share channels on the three earlier satellites' jam-packed transponders, and the new 16 transponders mean that older channels as well as new channels now have the chance to transmit for longer periods.

So availability of transponders on the new satellite mean two things for existing viewers. First, some of the channels you might have been watching have changed transponder and hence channel number. CMT (Country Music Television) and CNE (Chinese News and Entertainment) are examples. Second, the new satellite's D-band transmissions may be beyond the range that your existing satellite receiver can pull in. This should not be a problem if your receiver is a relatively recent purchase, as manufacturers have been building in the capability to extend their range down to the D-band frequencies. But if your receiver cannot do this automatically, you may need a new LNB (*a low-noise block down-converter* the bit on the front arm of your dish which picks up all the microwaves), or a converter to switch received frequencies, or possibly even a new receiver or complete system, or a combination of these solutions. Which you need depends on your existing set up, and what you want from your system.

All this does not mean your existing set up won't work – you'll not have noticed much since Astra 1D's arrival (apart from a couple of channels moving), and all your existing channels will still be there as before. It is just that to receive the new channels as they come along changes in your set up may be required. Speak first to your dealer if you want to receive the new channels.

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

THE Shocking TRUTH



by Stephen Waddington
BEng(Hons), M.I.E.E.E, A.I.E.E, A.I.T.S.C.

WHILE arguments abound over the danger of AC as opposed to DC and the importance of current as opposed to voltage, in contributing to fatality, here *Stephen Waddington* demonstrates that whatever its form, electricity is potentially a killer.

In October, *Electronics* featured a series called 'A Guide to Mains Safety' in which Andrew Chadwick explained how to design safely at mains voltages. In coming months, electrical safety devices such as fuses, residual current devices (RCDs) and miniature circuit breakers will be covered in detail. In many ways this feature is complementary to a number of articles that are due to appear or have recently appeared in *Electronics*.

Prevention is always better than cure, and measures should always be taken to avoid the possibility of electrocution at all costs. But with the best will in the world, electrical accidents will never be banished completely, as recent figures from the Royal Society for the Prevention of Accidents illustrate. Last year there were 28 deaths due to electrocution in the UK alone. Add to this figure the 2,000 electrical injuries requiring hospital attention and you quickly realise that electrocution is a major problem.

That's without considering the 8,000 domestic and 6,000 other fires caused by electrical faults in 1993 (as illustrated in Figure 1), and the bad news is, it is not getting any better. Incidents are, unfortunately, up on previous years.

First Aid

Knowledge of how the human body reacts to electrical impulses and basic First Aid principles can only serve to aid any person confronted with a victim of an electric shock. No matter how large or small the current, voltage or duration, it is the first few minutes after a shock that can mean the difference between life and death. To this end, I have advocated for a long time that First Aid should be taught in schools. The principles are so straightforward and the results can be startling, literally meaning the difference between life and death.

Equally, First Aid applied incorrectly can be dangerous. While basic principles are discussed here, readers are recommended to seek further instruction from one of the First Aid organisations detailed at the end of the feature. Contact numbers can be obtained from your local telephone directory or directory enquiries.

It is worth noting that the same principles can be applied to drowning, heart attack and suffocation.

Electric Shock

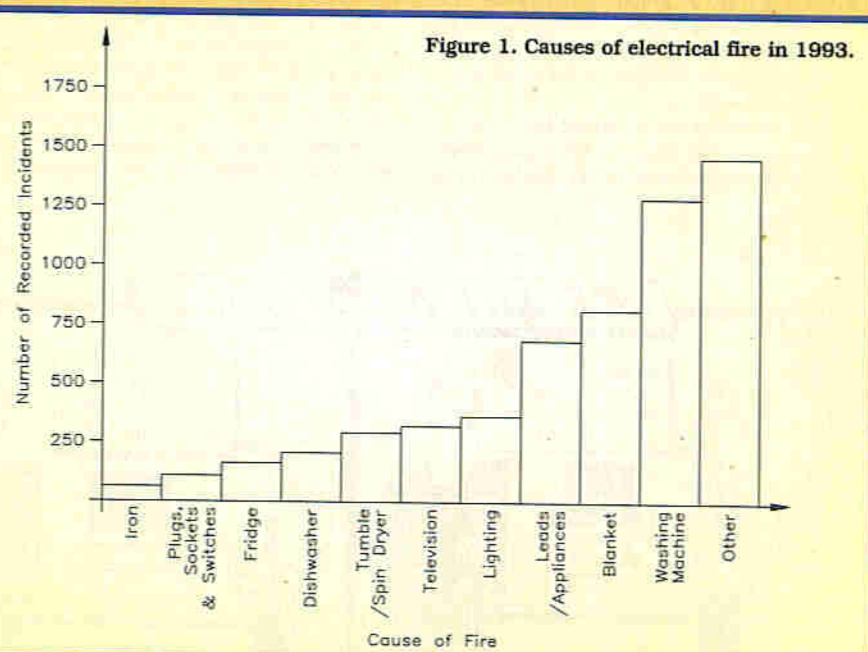
An electric shock is the body's reaction to the passage of current. It may vary from a slight tingling to sudden unconsciousness, and the affected patient may appear dead. Here lies the first rule of First Aid, never assume death after an electric shock. While the pulse may vanish and breathing cease, life can very often be restored if action is taken promptly.

The medical profession argues over which is more dangerous, direct current (DC) or alternating current (AC). In my mind this is a futile argument. They are both capable of killing. Besides, there is not a great deal of medical evidence to support either argument – there are not that many people queuing up, willing to take part in an experiment to see which is more painful, electrocution by AC or DC.

AC or DC

If we are to analyse degrees of danger, then DC is possibly the less threatening. A DC current will have little effect on

Figure 1. Causes of electrical fire in 1993.



muscle action as its constant value does not interfere with the body's own pulsed electrical signals.

AC is not quite so forgiving. At around 15mA AC – the so called let-go current – it becomes increasingly difficult to release a conductor held in the hand because the hand muscles lock. As the hand contracts, better contact is made, and so the current increases. By contrast, briefly touching a live conductor with the back of the hand, as opposed to the palm, will cause the muscles to contract and the hand to pull away.

But even a low voltage DC source can kill. While researching this article, I came across a case of a person who was electrocuted after being trapped under a 24V milk wagon for a couple of hours. DC currents applied for any period of time can cause severe tissue damage because of an electrolysis action.

Degrees of Shock

If skin, clothes or shoes are moist, the effect of any electric shock will be magnified because of improved current conducting capability. But often less obvious variables can have a large effect on the degree of an electric shock. For instance, a person who is tired will be better able to cope with a shock than one who is fresh. In this case, this is due to the level of fluid in the body, which falls dramatically when fatigued.

Ordinary domestic current at 240V, 50Hz can be detected at currents as low as 500μA. By contrast the same DC voltage must rise to 5mA before it is detectable. A 100mA shock at mains voltage will usually result in fatality, but equally a value of 20mA can be equally severe depending upon the individual. The length of exposure is another critical variable – with exposures of over five seconds at any current level, the danger of serious injury is great.

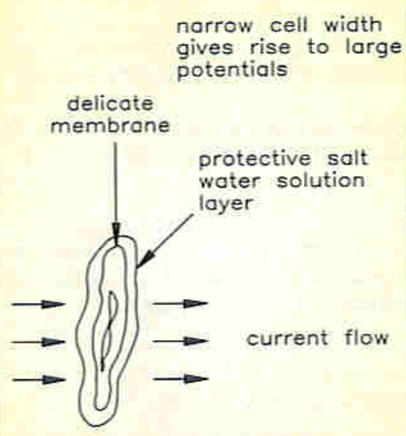


Figure 2. Nerve or muscle cell – large potentials can be formed across cell membrane.

At this point, I'm going to borrow a table from the first part of Andrew Chadwick's feature, 'A Guide to Mains Safety'. In Table 1, Andrew matches current levels with typical effects on the human body for a shock lasting for one second. Again, I must stress that these figures are only guidelines and will vary widely from person to person.

Current (mA)	Effect on human body
0·5 to 2·0	Threshold of perception.
2·0 to 10	Painful sensation.
10 to 25	Cramp and tightening of muscles and involuntary retention, preventing casualty from releasing hand. Strong danger of asphyxiation from muscle contraction.
25 to 80	Severe muscular contraction, possibly leading to bone damage. Loss of consciousness. Heart or respiratory failure. >80% burns at point of contact. Death from ventricular fibrillation.
Currents passed by hand for one second at 240V AC.	

Table 1. Approximate effect of current on human body at mains voltage.

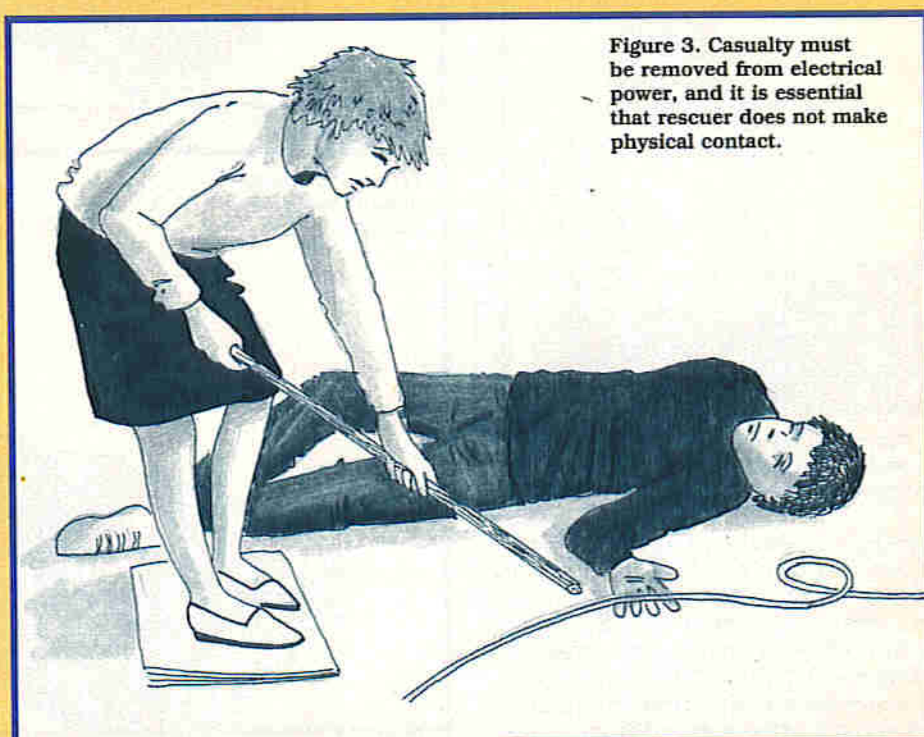


Figure 3. Casualty must be removed from electrical power, and it is essential that rescuer does not make physical contact.

Mouth-to-Mouth Resuscitation

The First Aid technique detailed below is intended solely as a guideline. Expert tuition is essential. If the mouth cannot be used, resuscitation can be achieved through the nose – mouth-to-nose – or through the mouth and nose in small children and infants – mouth-to-mouth-and-nose.

- Remove any obvious obstructions over the face or constrictions around the neck. Remove any debris from the mouth and throat as shown in Figure 4. Extend casualty's head and neck: Support nape of casualty's neck. Press forehead so that it is tilted backwards. Push chin upwards using hand from nape of neck. These moves lift the tongue forward clear of the airway.
- Open your mouth wide, take a deep breath, pinch the casualty's nostrils together with your fingers and seal your lips around the casualty's mouth as shown in Figure 5.
- Blow into the casualty's lungs, looking along his/her chest, until you can see his/her chest rise to maximum expansion as shown in Figure 6.
- Remove your mouth well away from the casualty's and breathe out any excess air while watching his/her chest fall as shown in Figure 7. Take a deep breath. Repeat inflation.

Bodily Conduction

Unfortunately, most of the body's interior acts as a salt solution and conducts electricity very well. Typically, the internal resistance between two limbs is a few hundred ohms. Conversely, skin has a reasonably high electrical resistance, about 2,000 to 3,000Ω when dry. But by applying Ohm's Law, we can quickly see how mains voltages can be fatal for direct contact with a live conductor:

$I = V/R$
$I = 240V/3,000\Omega$
$I = 80mA$

At 3,000Ω, the current level will reach the critical 80mA, rising to 120mA at

Figure 4. Remove debris from mouth and throat.

Figure 5. Preparing casualty's airway ready for mouth-to-mouth.

Figure 6. Blow into casualty's mouth, and observe chest rise to maximum expansion.

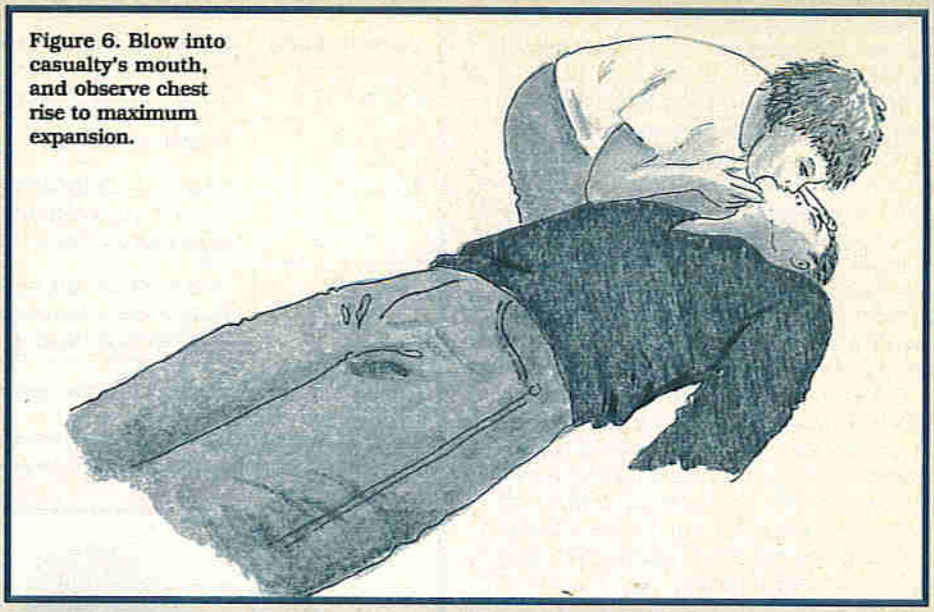
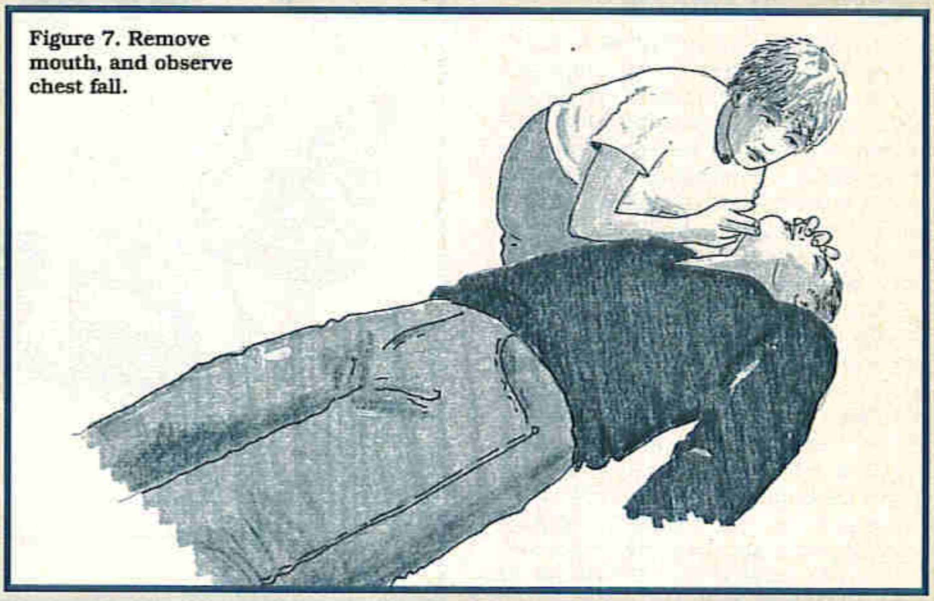


Figure 7. Remove mouth, and observe chest fall.



2,000Ω. The skin also has a capacitance of approximately $0{\cdot}04\mu Fcm^{-2}$, which means its impedance can drop to as little as 750Ω at high frequencies.

Once inside the body, current conduction is affected by the density, shape, orientation and size of tissue cells. A typical cell is constructed from a delicate membrane surrounded by a wall of salt water. Because cell membranes are good insulators, electricity passes around the outside of cells and not through them. In effect they act as high-pass filters, only conducting electricity at high frequencies.

Generally, resistance to current flow increases with cell density as one might expect. Current flowing through a cell will create a potential across the internal membrane as shown in Figure 2. This effect is magnified in long, narrow cells such as nerve or muscle cells, where current flows along the length. Considering the average nerve cell has a thickness of 10nm, it only takes 100V to develop a potential field of $\pm 100MVm^{-1}$.

Cell Deterioration

The major functions of the body are controlled by electrochemical impulses. For muscle cells, typical values are in the order of 90mV. External currents of between 1 and 10mA, at a potential field of $\pm 100MVm^{-1}$ will alter the membrane potential and excite nerves, producing sensory and muscular reactions. At higher levels, about 100mA, the electric field that develops across the membrane creates pores that interfere with the cell's normal operation.

The electric field is thought to draw

External Chest Compression

If the casualty's heart has stopped beating, external chest compression must be performed. This is because without the heart to circulate the blood, oxygen is unable to reach the casualty's brain.

Performed incorrectly, external chest compression can kill. It is essential that rescuers are trained. The First Aid technique detailed below is intended solely as a guideline. Expert tuition is essential.

- Lay the casualty on his/her back on a firm surface. Kneel alongside the casualty facing his/her chest. Find the junction of his/her rib margins at the bottom of his/her breastbone as shown in Figure 8. Place the heel of one hand along the line of the breastbone, two finger breadths above this point, keeping you fingers off the ribs.
- Cover your hand with the heel of your other hand and interlock your fingers. Your shoulders should be over the casualty's breastbone and your arms straight.
- Keeping your arms straight, press down vertically on the lower half of the breastbone, to move it 4 to 5cm as shown in Figure 9. Release pressure. Complete 15 compressions at a rate of 80 compressions per minute.
- Move back to the casualty's head, reopen the airway and give two breaths of mouth-to-mouth resuscitation.
- Continue with 15 compressions followed by two further breaths of mouth-to-mouth resuscitation. Repeat this format, checking the pulse after the first minute, thereafter checking the pulse after every three minutes.
- As soon the pulse returns, stop compressions immediately. Continue mouth-to-mouth resuscitation until natural breathing is restored, assisting where necessary. Observe the colour of the casualty's face and lips. The colour should improve

external water molecules into the cell which forms pores in an electrolysis action, similar to that which saw off the milkman mentioned earlier. If the pores become large enough, they will rupture the membrane. Scientists have observed that this effect, called electroporation, is reversible for currents up to about 200mA applied for approximately five seconds. Greater than this and massive internal damage is rendered to the structure of individual cells.

Electrical Burns

Electrical burns are caused by the passage of current through the body or electrical arcs. True electrical burns more closely resemble crush injuries than thermal burns. The damage below the skin can be far greater than the skin's superficial appearance. The injury to tissue along the path of electrocution is caused partly by heat, and for higher currents, electroporation.

The heat generated by contact with a high voltage source can generate temperatures in excess of 1,500°C and even if the period of contact is brief, massive tissue damage is inevitable. While at lower voltages, the path of current depends on the different resistances of muscles, bones and tissues, at high voltage, current passes indiscriminately throughout tissue. In this instance, current will evaporate water in the flesh leaving a charred wound, akin to an overcooked piece of meat. The flesh at a current exit usually looks like it has blown outwards, as if the current has exploded from the skin. Loss of limbs is common.

Heart Failure

Current paths between the arms or an arm and a leg are most hazardous because the current will pass through the heart. A current of about 100mA can produce an extra heartbeat, and at 250mA will induce ventricular fibrillation or uncoordinated contractions of the heart muscle.

The human heart is unable to recover from this level of abuse on its own, even when current is removed. Death is inevitable, unless defibrillation or external chest compression is used. A defibrillation machine delivers a jolt of energy at high voltage and current – typically 400

Figure 8. External chest compression – finding the junction of the casualty's rib margins at the base of the breastbone.

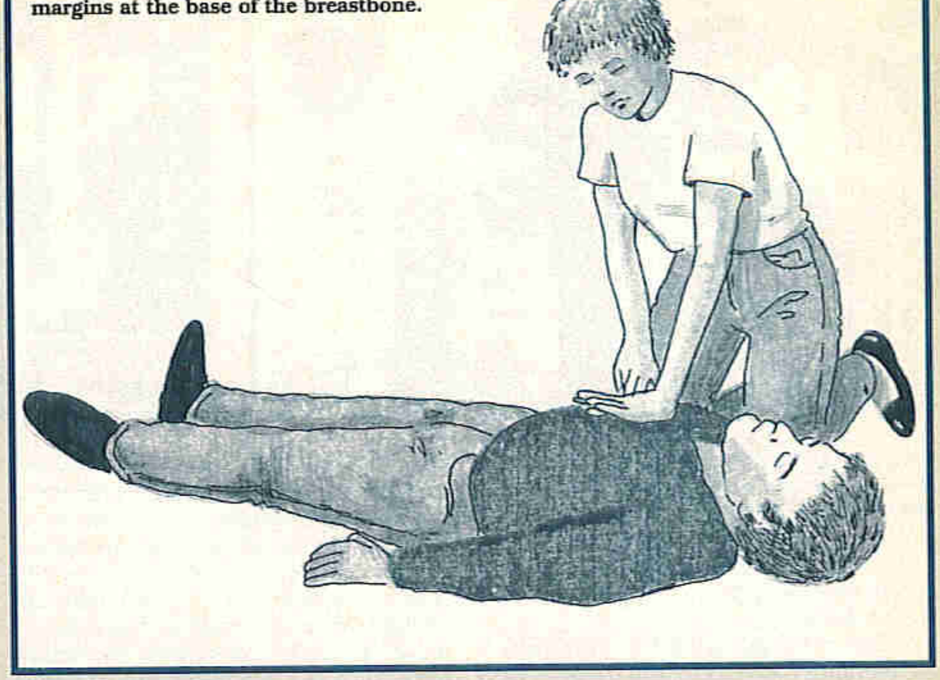
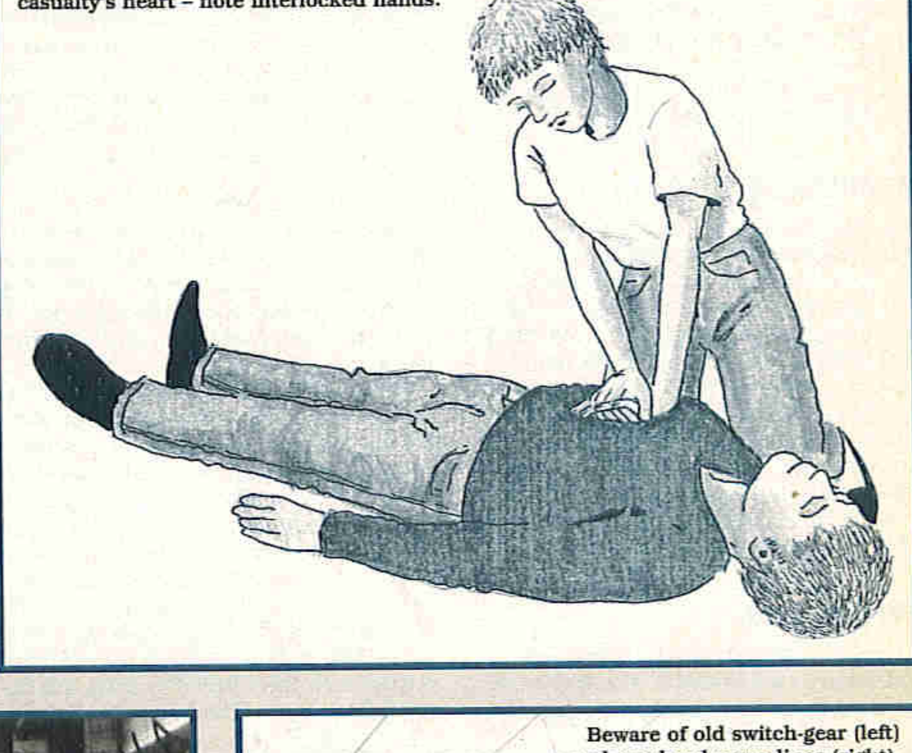
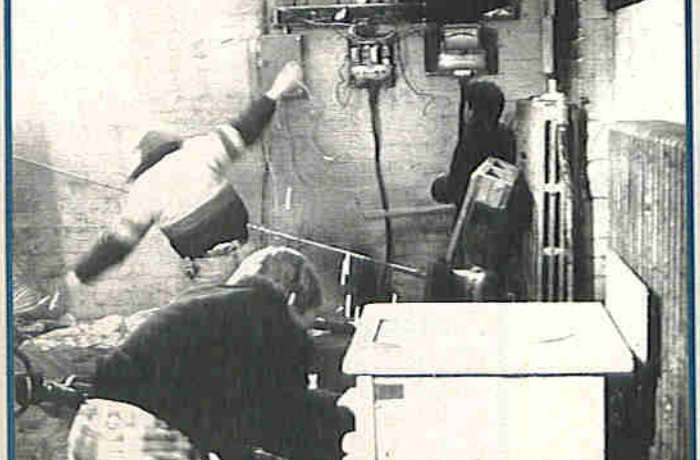
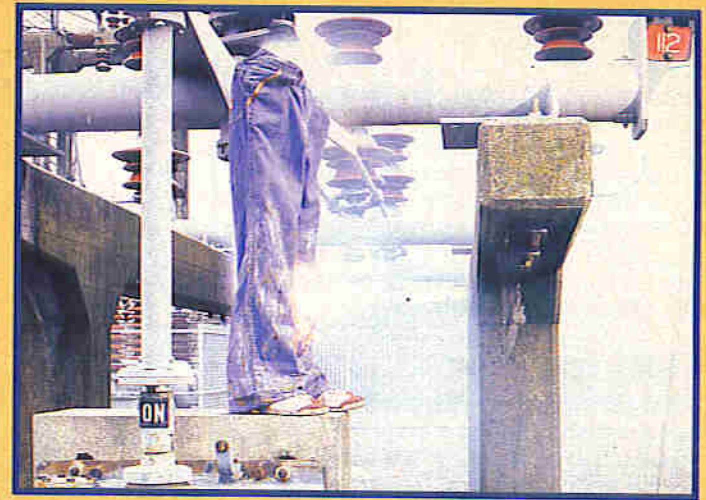


Figure 9. Applying compressions to the casualty's heart – note interlocked hands.





Beware of old switch-gear (left) and overhead powerlines (right).



Keep out of electrical substations. Even if direct contact is not made, high voltages can arc (jump) many feet.

joules – to the victim. After the initial shock, the heart relaxes and picks up its normal beat.

Higher currents (several amps or so) do not cause the heart to beat irregularly, but place it in a state of excitation from which it can usually recover unaided. Consequently there is a narrow current band which can cause death by heart failure. This explains in part why heart fatalities occur at relatively low voltages while high-voltage fatalities are mainly due to breathing irregularities or burns.

Breathing Problems

Not surprisingly the head is the most common point of entry for high-tension electric current. As well as inflicting thermal damage, currents travelling through the head progress down the brain stem and paralyse the parts of the brain that control breathing. While an AC current of several hundred milliamps passing transversely through the brain rarely causes breathing problems, a current flowing vertically will pass through muscles that control breathing. Almost certainly causing breathing to cease.

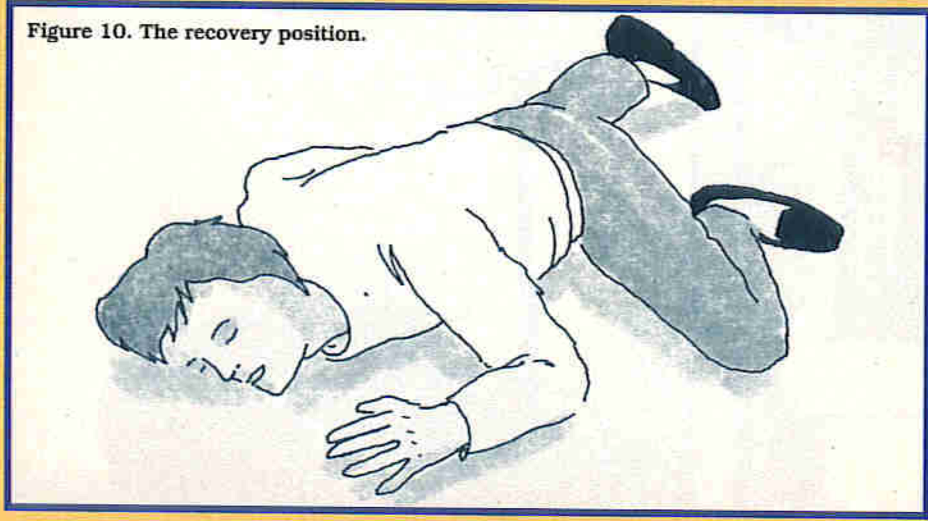
Treatment

Having identified an electric shock, speed and coolness are essential. The first move must be to remove the patient from the source of electricity. This is best achieved by removing the source of the current at the main distribution point or isolating switch. If this is not possible, the patient must be physically moved from the source. However, this is fraught with difficulty – great care must be taken not to make electrical contact with the victim. Stand on a dry non-conducting material such as a rubber mat, a coat or piece of cardboard. Push the victim with something equally non-conducting such as a chair, wooden broom or walking-stick as shown in Figure 3. Alternatively wear rubber gloves or wrap your hands in dry thick material such as a rug or carpet. Do not under any circumstances touch the casualty with bare hands or use wet, greasy objects.

Once the casualty has been removed from the electrical source, check whether the heart has stopped. If it has, there will be no neck pulse and the face will be blue or very pale and the pupils enlarged. If you have been trained to, start external chest compression.

Next check breathing. If the casualty is not breathing, start artificial respiration alternating with external chest compression. Keep this up. In about half of all electrocution cases where the patient ceases breathing, there is recovery with artificial respiration. Ninety per cent of all patients who start breathing do so within half an hour. Delay in starting artificial respiration can be fatal. If it is started at once, 70% of all patients recover. If there is more than three minutes' delay, this figure falls to 20%. The lesson is obvious.

Figure 10. The recovery position.



Once the casualty has recovered breathing, place in the recovery position as shown in Figure 10 – again expert tuition is essential in order to be able to perform this procedure correctly.

Next call the emergency services. If you are not alone when discovering the casualty, then a second person should summon assistance *immediately*. After *any* electric shock, it is essential that expert medical treatment is sought. The physical and psychological effects of shock can last for days and electrical burns require expert attention.

High Voltage

With high voltages from sources such as substations or overhead cables, the patient will usually have been thrown clear of the source. If not, the danger to the rescuer is very great while the current remains on. High voltage can arc considerable distances, especially in damp conditions, so you should keep well clear of the casualty and the electrical equipment. In this situation your chances of doing anything are minimal. The emergency services should be called, who will contact the appropriate electricity company to request that power be removed.

References and Further Reading

Electricity, Magnetism and the Body – Some Uses and Abuses by A. T. Barker.
Electrical Stimulation and Electropathology by J. Patrick Reilly.
Electrical Trauma – the Pathophysiology, Manifestations and Clinical Management by R. C. Lee, E. G. Cravalho and J. F. Burke.
First Aid in the Workplace by Lord Stephen Taylor and Dr Patricia Elliot.
Health and Safety Law by B. Barrett and R. Howells.
First Aid Manual – The Authorised Manual of St. John Ambulance, St. Andrew Ambulance Association and The British Red Cross Society.

About the Author

When he was aged 8, Stephen Waddington suffered a shock from an electric cattle fence, while walking around the perimeter of a farm. He has had a healthy distrust of electricity ever since.

Design by Nigel Skeels
Text by Nigel Skeels and
Robin Hall

Electronic Memo Pad

Ideal as a personal memo pad, a phone message pad or as an audible reminder!

3 PROJECT RATING

KIT AVAILABLE (LT79L) PRICE £29.99

An extremely useful device for the home or office for recording short voice messages with instant playback. It can be used to record tones, but only within the passband of the device.

FEATURES

* Uses new analogue recording technique * 16 seconds record time * Surface mount miniaturisation * On board loudspeaker * Single voltage supply * Ten year voice retention * Excellent record quality * Message waiting indication * Message overwrite protection

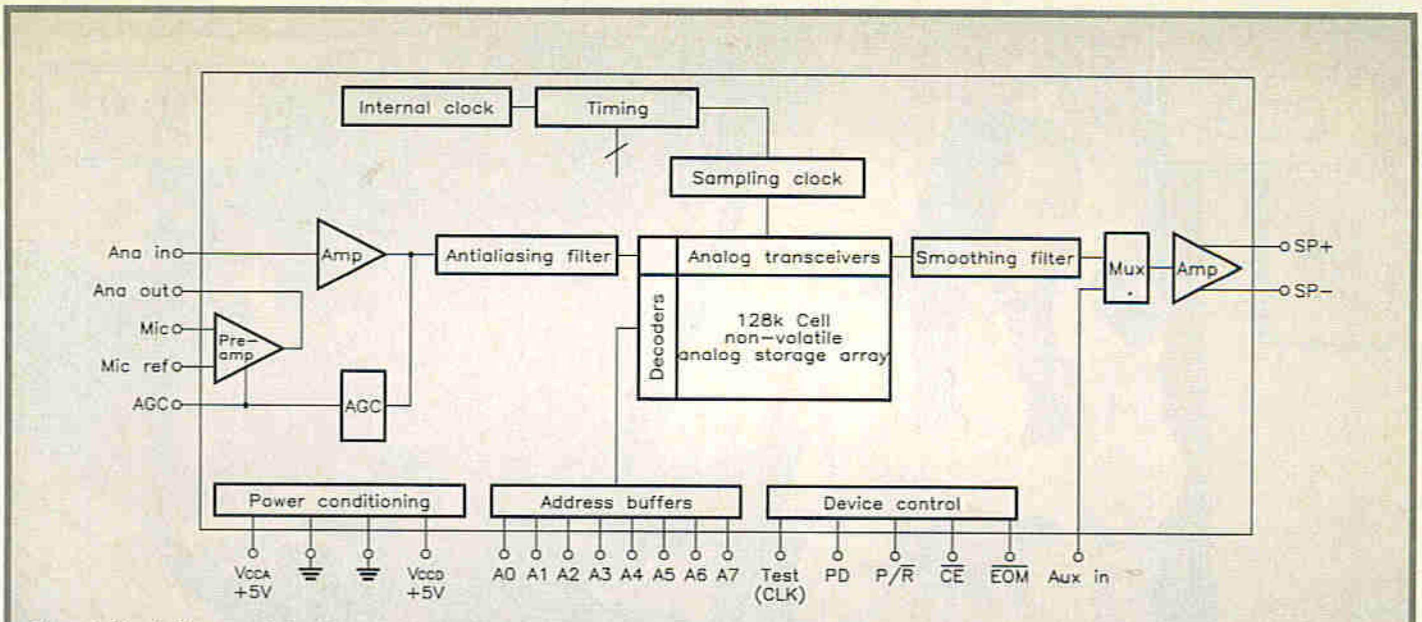
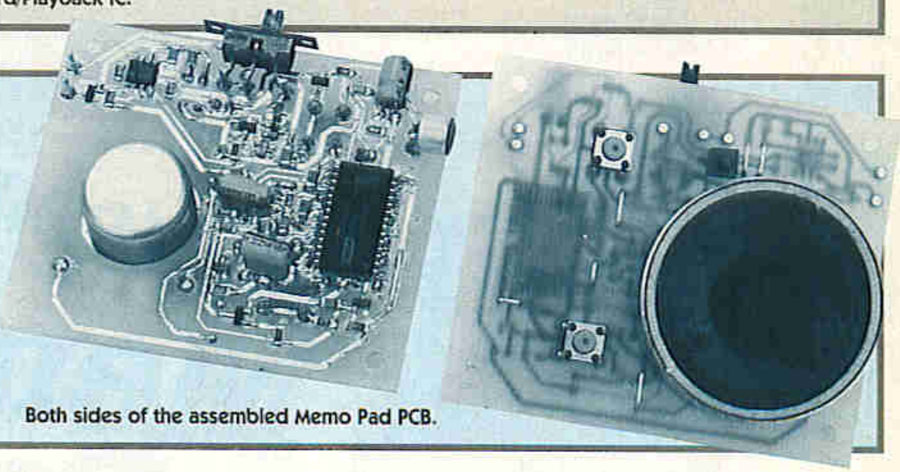


Figure 1. Block diagram of the ISD1016AG Voice Record/Playback IC.

Specification

Supply voltage	
Minimum:	6·3V
Maximum:	9·5V
Supply current	
Standby:	194μA
Average playback:	65mA
PCB size:	65 × 55mm
Box size:	107 × 60 × 25mm
Weight:	129g (with battery)



Both sides of the assembled Memo Pad PCB.

Making a grab for the pen (which seemed to have a life of its own) as it disappeared into the mysterious void between the cupboard and the floor, never to be seen again. What could she do? If she did not make a note of that phone number it would be lost for ever, just like the pen! Then she remembered her new-fangled memo pad. Forgetting which pocket she had put it in, she frantically checked each one, on finding it, she clasped it in her clammy hand; holding it up to her mouth to record the message, she noticed the red LED flashing. "What's this?", she thought to herself, she had to replay the last recorded message, her finger pushed the button and from the compact speaker she could clearly hear her own voice. A look of pure astonishment passed across her face, as playing back from the speaker was the same phone number that she was going to make a note of. The scatter-brained idiot had forgotten the message she had recorded earlier. It was the number of the doctor she was seeing about her amnesia!

Circuit Description

The circuit is relatively simple, and owes much to the ISD1016AG single chip voice record/playback device (the block diagram of the ISD1016AG is shown in Figure 1). Its revolutionary method of recording and storing does away with the need for digital memory, as the IC uses *non-volatile* EEPROM technology, and allows analogue data to be written directly into the cells without A-to-D or D-to-A conversion, modulators and battery back-up circuits. It means lower chip count, and the storage density is eight times greater than conventional digital memory. Another point is that if just a single cell fails in conventional digital EEPROM memory, this renders the whole memory IC unusable. In the ISD1016AG, a single cell failure during programming will only result in an imperceptible change in distortion, and in fact, many hundreds of random failures would have to occur before recording quality noticeably degrades.

The block diagram for the Memo Pad is given in Figure 2. As can be seen, IC1 (ISD1016AG) is the heart of the system, and provides the audio preamp, power amp, automatic gain control and filtering, and of course the memory. In fact everything that is needed for a complete message system. The external components are the play and record buttons, electret microphone, loudspeaker and the power supply unit.

The circuit diagram is shown in Figure 3. The supply is from a 9V PP3 battery and is switched by S3. Diode D5 polarity protects the circuit. IC1 must not have more than +7V applied to it; a new PP3 will have a terminal voltage +9·5V. Since the requirement is for low power consumption, rather than having a Zener or a conventional voltage regulator the configuration of D3, D4, TR4 and R16, take the place of a dropper resistor and ensures the

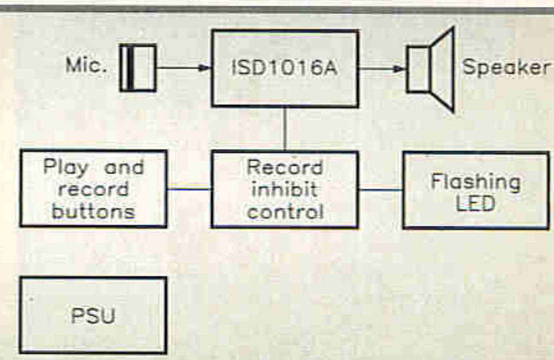


Figure 2. Block diagram of the Memo Pad.

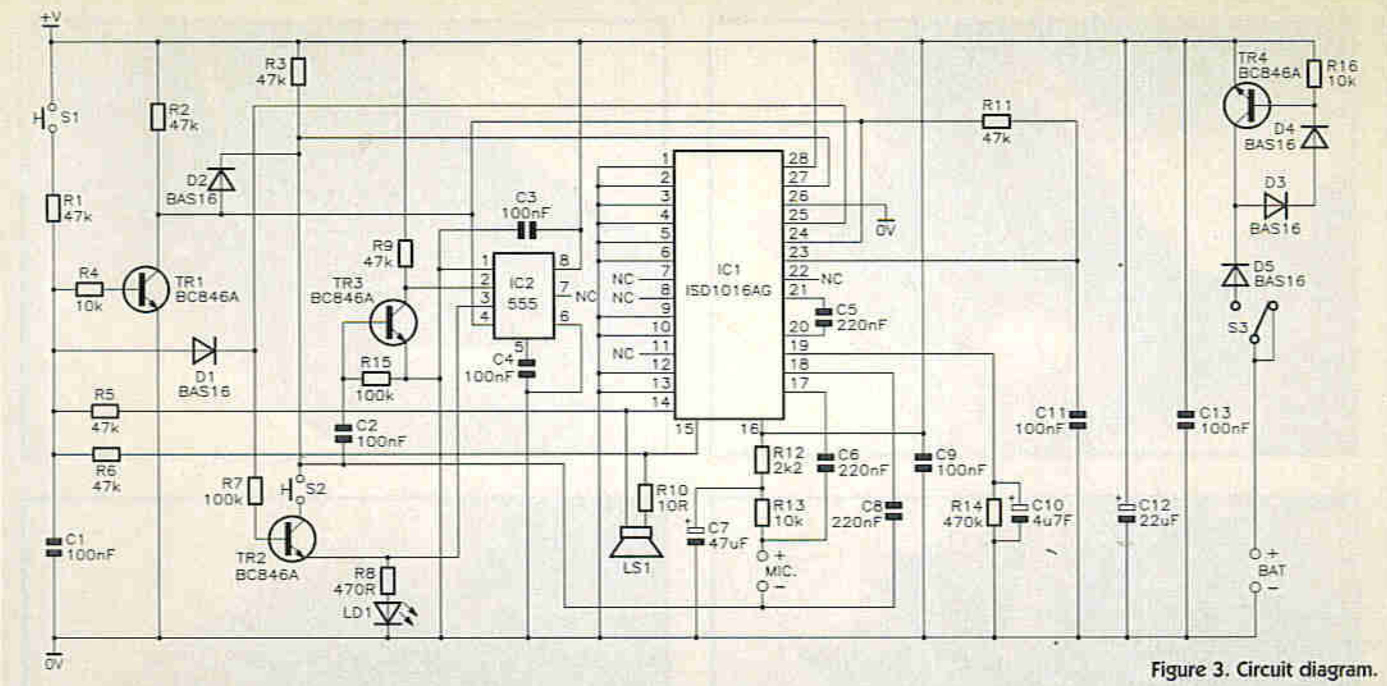


Figure 3. Circuit diagram.

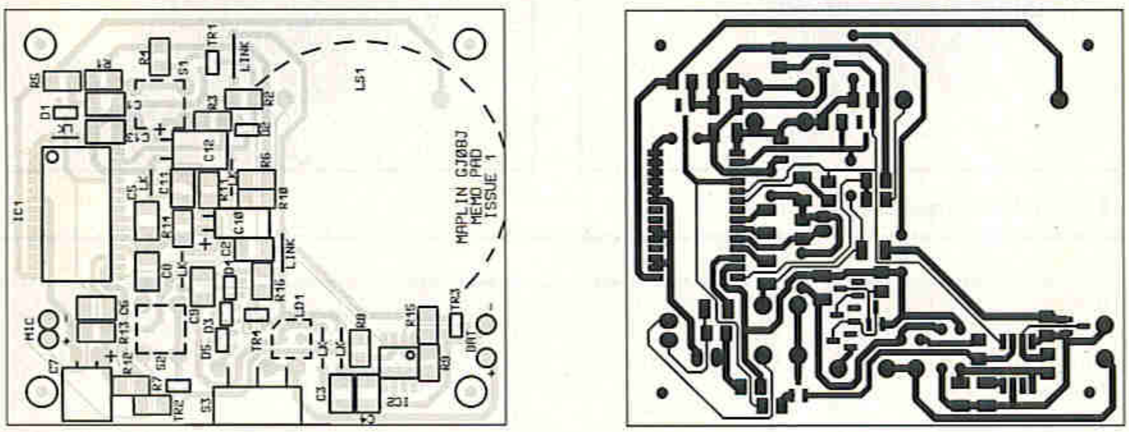


Figure 4. PCB Legend and track.

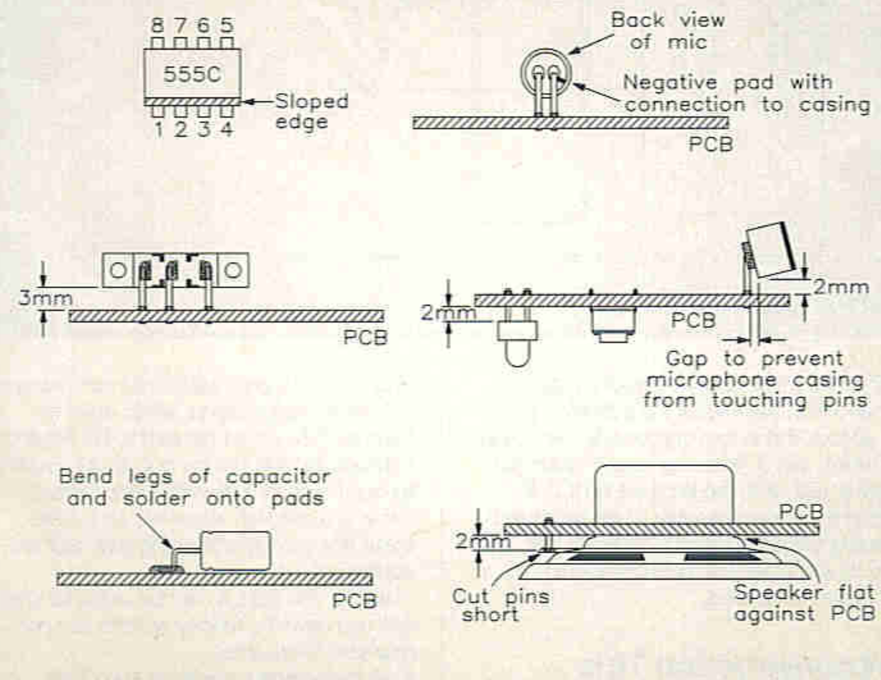


Figure 5. Special component fitting requirements.

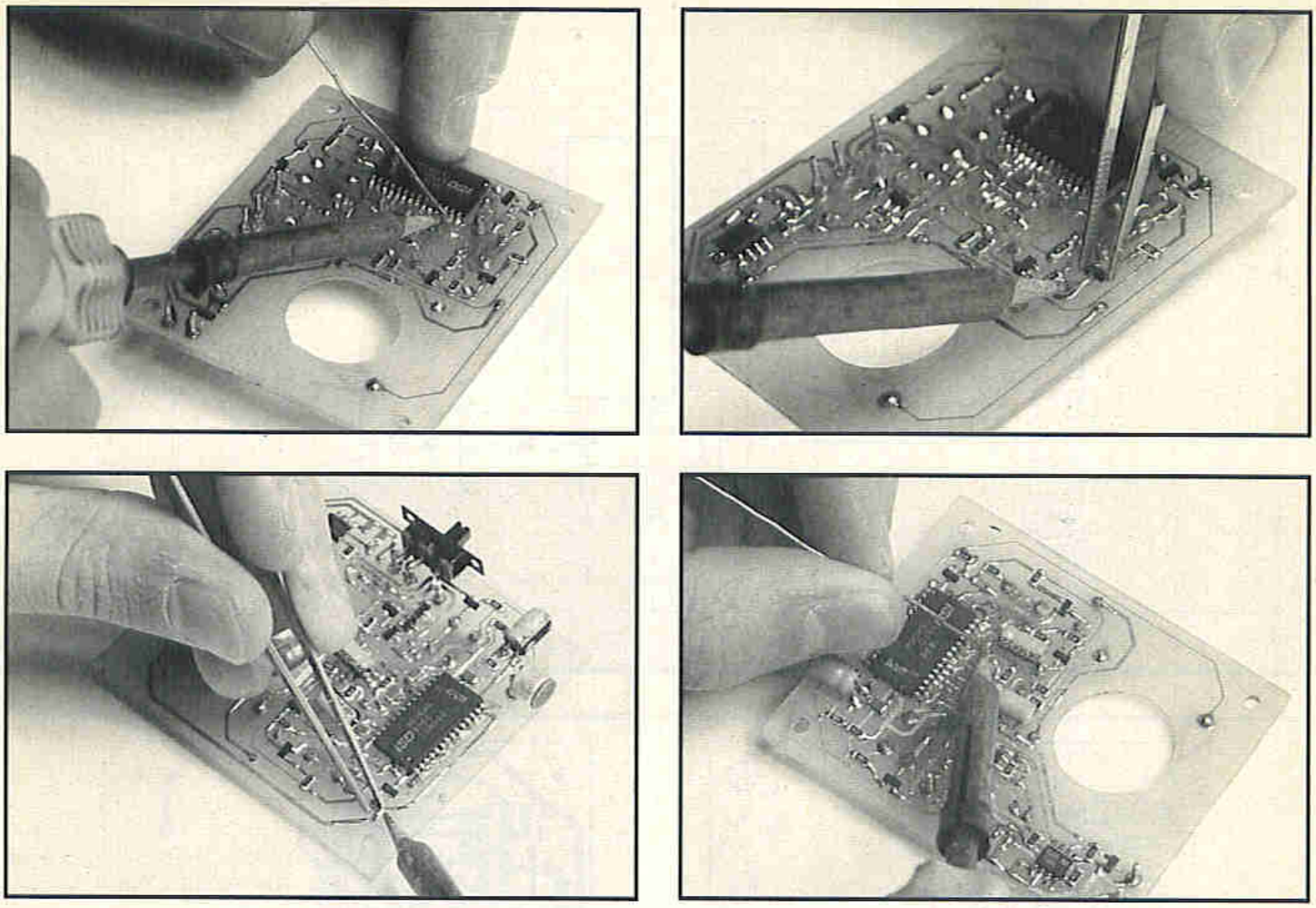
correct voltage to the rest of the circuit. Capacitor C12 smoothes the supply and C13 provides high-frequency delooping. The electret microphone is connected between +&–MIC. The network of resistors R12 and R13 biases the microphone, and C6 feeds the audio to the input stage of IC1. Capacitor C7 smoothes the supply to the microphone. Capacitor C10 and resistor R14 set the AGC operating characteristics on IC1. Capacitor C5 provides low-frequency cut off.

The minimum audio output impedance of the ISD1016AG is 16Ω, but as the Memo Pad uses an 8Ω loud speaker, an additional 10Ω resistor, R10 has been included in series with the loudspeaker.

IC2 is a SMD 555 timer IC. This is used in its set/reset mode, and the purpose of this is to form a latch to prevent new messages from being erased (a message cannot be erased until it has been played back at least once.

Playback Mode

At switch on, transistor TR1 is biased off with the collector at V_{CC}. Pressing the play button (S1) biases transistor TR1 on and its collector potential drops, presenting a negative going edge to pin 24 on IC1 for playback mode, and via R11 to pin 23, the chip enable ($\overline{CE}$). This starts the playback of the message.



Fitting surface mount devices requires a steady hand!

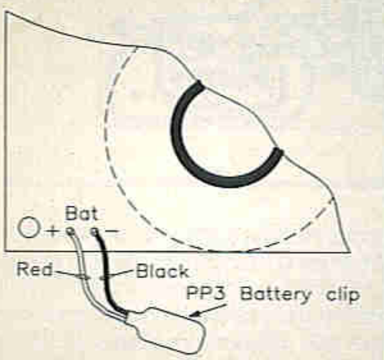


Figure 6. Battery clip wiring.

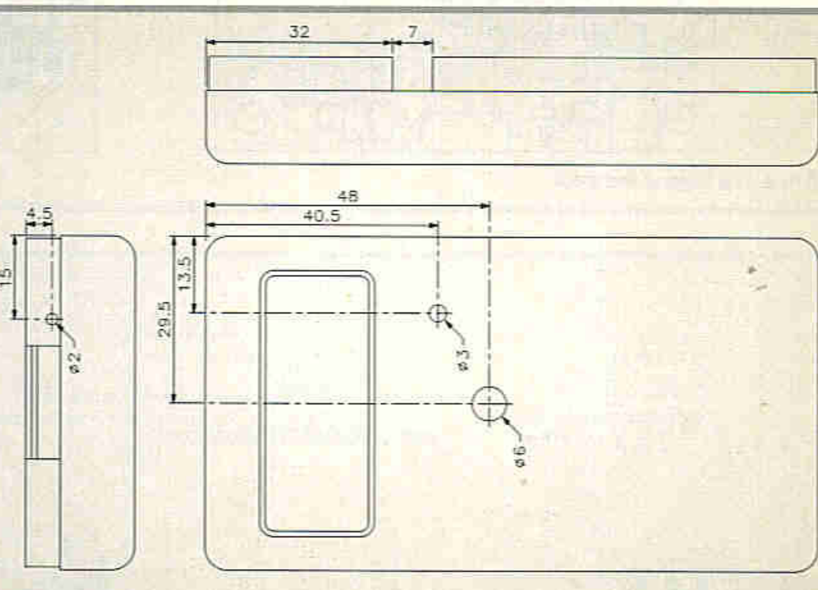


Figure 7. Box preparation.

When the play button is released, due to a positive voltage from IC1 via R5 and R6, the positive bias is maintained on the base of TR1. When IC1 finishes its 16 seconds playback, a negative going edge from the 'end of message' ($\overline{EOM}$) on pin 25, is sent via D1 to the base of TR1 and thus switches it off. The potential on the collector of TR1 rises again and IC1 is then put back in its standby mode.

Record Mode

Pressing the record button (S2) pulls pin 27 (P/R) on IC1 low, and a negative going edge is passed through D2 which resets IC2 on pin 4 and pulls pin 23 on IC1 low via R11, this is the chip enable ($\overline{CE}$), and pin 24 (PD), IC1 now goes into its record mode. With the line held low by S2 when TR2 is biased on, the output of 555 is low. When S2 is released or pin 25 on IC1 ($\overline{EOM}$) goes low, TR2 is biased off and generates a pulse via C2 and R15, this causes the collector of TR3 to go low, this in turn triggers IC2, the output of which, pin 3, goes high and enables the flashing LED. With the latch set on IC2, it prevents another message to be recorded. Pressing the play button (S1) resets IC2 and thus enables another message to be recorded if required.

Preconstruction Tips

At first sight, the fact that this is a surface mount device (SMD) project may seem daunting, as circuits using SMD components will always require extra skill to build by hand as they were intended to be fitted by machine, but do not be put off, it is possible to build such circuits with a little patience. There is a relatively easy way to solder these tiny components using only 'ordinary' equipment.

Before you start, it may be useful to check that you have the following items laid out near your work area:

1. A low wattage soldering iron (15W or less) with a fine bit (0·5mm is recommended).

Figure 8. Exploded assembly of the Memo Pad.

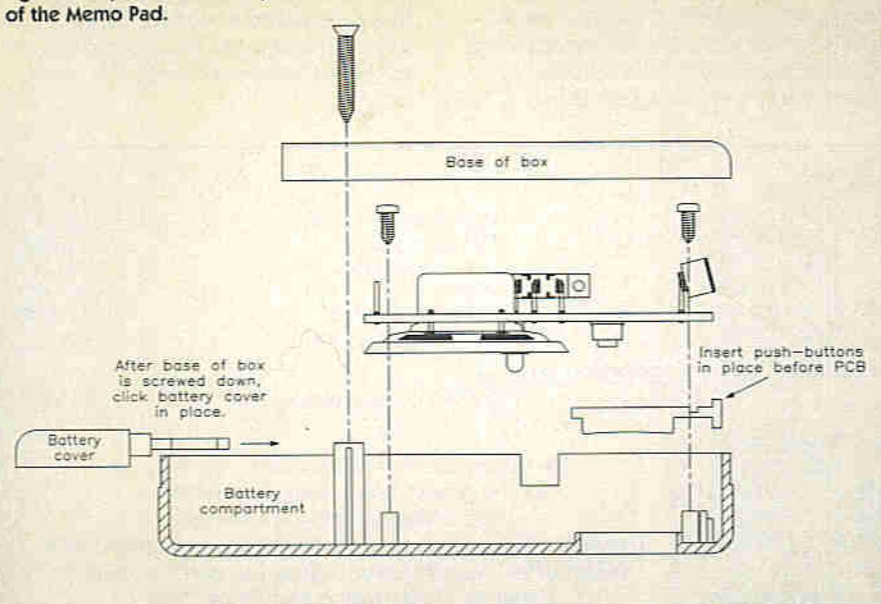


Figure 9. Memo Pad front label.

2. A pair of tweezers or snipe-nose pliers.
3. A magnifying glass.
4. A sheet of clean white paper (A4 is ideal) upon which to place each surface mount component, prior to positioning.
5. PCB cleaner and a small brush.

Construction

Before attempting any soldering, ensure that you double-check that the type, value, and positioning of the components are correct. The PCB legend (see Figure 4) will assist you when positioning each item.

Using the wire provided for the links, cut to the correct lengths, and fit and solder conventionally into the PCB. Next fit and solder the four PCB pins from the non-foil side of the PCB, soldering onto the tracks on the other side.

The next stage is to identify the SMDs, with the exception of the two SMD ICs, and fit to the PCB. First the SMD resistors, then the SMD capacitors, SMD diodes and SMD transistors, these will be contained in their own dispensers.

Remember try not to heat the SMD components for too long as damage may occur.

The correct procedure is as follows:

1. 'Wet' one of the component pads with solder.
2. Hold the component in position using tweezers or snipe-nosed pliers.
3. Reflow the solder to 'wet' the component (hold it in position until the joint cools).
4. Make the other joint.
5. Remake the 1st joint with fresh solder.

The correct orientation of the two SMD ICs is as follows: The ISD1016AG has a small round indentation on the top left side, denoting pin 1, and the 555C has a sloping edge on the left side denoting pin 1.

Special care must be taken when soldering the two SMD ICs to the PCB, as they will be almost impossible to desolder once in position.

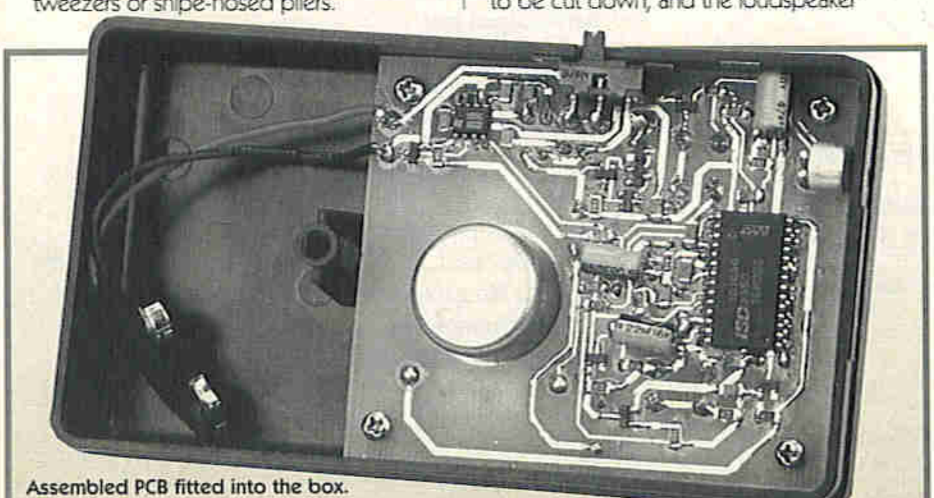
Refer to Figure 5 which shows how to mount the larger of the components.

When fitting the electrolytic capacitors make sure that they are correctly orientated, Figure 5 shows how the leads are bent at right angles, with the body of the capacitor resting against the PCB. The electret microphone must also be correctly orientated and fitted at a slight angle, see Figure 5.

Note that the negative pad on the microphone is connected to the microphone casing, and is soldered in position making sure that the microphone casing does not short out against the PCB pin.

The LED and the two push switches, are mounted conventionally on the reverse side of the PCB, and soldered in position.

Now position S3 (slide switch), this is soldered onto the PCB pins at the side of the PCB. The PCB pins for the loudspeaker need to be cut down, and the loudspeaker positioned as shown and soldered in place. Finally fit and solder the battery clip, making sure that the polarity is correct, as shown in Figure 6.



Assembled PCB fitted into the box.

Box Preparation

The box comes precut for two press switches, the only holes to be prepared are for the LED, speaker and for the On/Off switch. Referring to Figure 7 for box preparation, use a hacksaw blade to cut two vertical lines down the plastic for the On/Off switch, then use a sharp Stanley knife (be extremely careful) to score the plastic along the moulding line, snapping off the plastic. Using the label as a template, drill the hole for the LED, clean up any plastic swarf, and fit the label in position. Next fit the PCB, pressing in both of the buttons located in the case, to allow the edge of the speaker to pass under the edge, so as not to catch.

Note the post (bottom centre of box) may need a slice of plastic removed to allow the speaker to sit flat on the bottom of the box. Secure the PCB with the screws provided with the box.

Testing and Operation

Ease of use is one of the main features of this project, with only two press buttons as well as an On/Off switch, how can you go wrong?

Operation is similar to an ordinary tape recorder, with S2 (●) acting as the record button, and S1 (▶) as the playback button.

After fitting a new 9V PP3 battery into the compartment provided, switch on the unit. This operation will cause the red LED to flash. This normally reminds users at this point that a message has been previously recorded, but on this occasion, as it is the first time the unit has been powered up, there will probably be random digital noise. Press the playback button (▶) and listen to the loudspeaker anyway. When the Memo Pad has finished playing back whatever is in the memory, the LED will extinguish and a new message can be recorded.

To record your first message, press and hold in the record button (●), and speak into the microphone. Once you have finished talking release the record button. If you have talked for longer than 16 seconds you will notice that the LED is flashing; this means that the memory is completely full and the last part of the message will be lost.

In order to listen to the message recorded on the Memo Pad, press the playback (▶) button. Remember that playing back the message will clear the flashing LED (which could be a problem if you wanted someone else to find the message). For it to flash for the message that you have just played; switch the unit off; wait 2 seconds and then switch on again. This will make the LED flash, thus protecting the message.Remember when a message has been recorded it will not be lost when the device is powered down. E

MEMO PAD PARTS LIST

RESISTORS: (All Surface Mount)			
R1,2,3,5,6,9,11	47k	1 Pkt	(DJ20W)
R4,13,16	10k	1 Pkt	(DJ17T)
R7,15	100k	1 Pkt	(DJ22Y)
R8	470Ω	1 Pkt	(DJ10L)
R10	10Ω	1 Pkt	(DJ02C)
R12	2k2	1 Pkt	(DJ13P)
R14	470k	1 Pkt	(DJ25C)
CAPACITORS			
C1,2,3,4,9,11,13	100nF SMD Ceramic	1 Pkt	(DJ00A)
C5,6,8	220nF SMD Ceramic	1 Pkt	(DJ01B)
C7	47µF 16V Sub-min Radial Electrolytic	1	(YY37S)
C10	4µ7F 35V Sub-min Radial Electrolytic	1	(YY33L)
C12	22µF 16V Sub-min Radial Electrolytic	1	(YY36P)
SEMICONDUCTORS			
D1-5	BAS16 SMD	1 Pkt	(DB13P)
LD1	3mm High Brightness Flash Red	1	(UK33L)
TR1-4	BC846A SMD	1 Pkt	(DB17T)
IC1	ISD1016AG SMD	1	(KU64U)
IC2	TS555CD SMD	1	(DB97F)
MISCELLANEOUS			
S1,2	Small PCB Push-button Switch	2	(KR89W)
S3	Right-angle SPDT Switch	1	(FV01B)
	Electret Omni-directional Microphone	1	(QY62S)
	Loudspeaker Lo-Z 388	1	(WB04E)
	Enclosure with Buttons	1	(CW26D)
	PP3 Battery Clip	1	(HF28F)
	Front Panel Label	1	(KP79L)
	PCB	1	(GJ08J)
	Instruction Leaflet	1	(XV24B)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	9V PP3 Duracell Battery	1	(JY49D)

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 LT79L (Memo Pad) Price £29.99

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

Memo Pad PCB Order As GJ08J Price £1.99

Memo Pad Front Label Order As KP79L Price £1.99

@Internet

One of the most common ways of getting onto the Internet is by a dial-up telephone connection to an Internet provider's computer server. From there, anyone is able to use their computer at home or in the office as a front-end to the whole system. It is as if you were directly connected to the Internet, but from the comfort of your armchair, mobile in the car, out in the garden shed – in fact, wherever there is a telephone connection.

The telephone link is the key to the whole exercise of course and this is always done with some form of modem at your computer end. In practical terms, it does not seem to matter what type of modem you have, although more about this later. However, there has to be some control over the transfer of information at both your computer *and* at the information provider's computer. This control is usually provided in the form of software which governs the protocols which both computers must follow, and manage the system to the extent that a user can only access the Internet if that user has got the proper privileges (which usually means that the user has paid the Internet access provider).

There are two very common software package-types in use which do all this. FirstClass Client is one of the varieties of SLIP (which stands for *serial line internet protocol*), and the other is one of the forms of PPP (which stands for *point-to-point protocol*). Your computer probably needs one of these to get on the Internet. Which one you use depends totally on your Internet access provider. There are other protocol governing packages but SLIP and PPP are by far and away the most common, simply because they are relatively easy to use and reasonably modern in their implementation.

Information which either of these two forms of protocol control methods need from you as a user varies, but generally you have to input the following at least:

- the server's telephone number
- your login name
- your password
- the login procedure – what information is passed between your computer and the provider's, usually in the form of a script of some description)
- your Internet address (generally called an IP address – in the form of a number like 123.456.789.123)

All of this can usually be stored by the SLIP or PPP package, so you only have to enter it once. Thereafter, when you want to make the connection you just run the package and it dials the provider's number and deals with connection details. Once it has done its dial-up job, it then steps into the background and invisibly controls data flow while you roam the Internet.

A last word about telephone dial-up connection lies with your modem. The faster it is the better – simply because data takes a finite time to travel and to a large extent the modem can cut down this time. Use the fastest modem appropriate, if only to save your telephone bills.

Top of the Class

A couple of months back (the January issue) we took a short look at FirstClass Client. It is an e-mail communications application which has (quite incidentally) been adopted by many hundreds of bulletin board services worldwide. At the last count almost a thousand BBSs use it as a high-quality front-end for their users to get access to, and numbers are growing by the day. It provides a graphical user interface, incredibly easy to understand and get along with.

When we took our last brief look we noted that a new version of FirstClass Client was due out which would support TCP/IP connectivity. Well, it is now out and we have been playing with it. Version 2.6 of FirstClass Client (that's the official name of the software you need on your computer) allows you to opt that communication is to be via TCP/IP, then enter the IP address (in the *Server* slot) and port (in the *advanced settings TCP port* slot) of a BBS using a new FirstClass Client settings file. FirstClass Client 2.6 is available for both Windows and Mac computers. Then, provided you are on the Internet (and a SLIP or PPP account is sufficient) you can access the BBS direct.

In effect, what it means is a brand-new service on the Internet, along with World Wide Web, FTP, Gopher, WAIS and the rest. And like those other Internet services, they cost only the price of your Internet connection – that is, what you pay your Internet provider, and the telephone call itself. Given that you have your Internet connection anyway, you can now access these BBSs for the cost of (depending on your proximity to your provider) a local telephone call.

Here are some of the first FirstClass BBSs which are on-line to the Internet. Most are Stateside, but the last is European. There will obviously be more, and hopefully some UK ones soon. We will keep you posted.

FirstClass BBS	*IP address*	*Port*
digitalNation	204.91.31.64	3004
InfiNet	204.96.111.157	4000
CyberDen	199.4.64.18	3000
Mt Parnassus	204.30.14.3	3000
Metronet	204.112.14.6	3000
magnet	193.80.248.21	3004

Credit Card Internet Security

First Data Card Services Group (FDC) of Omaha and Netscape (formerly Mosaic) Communications Corporation of Mountain View has announced that it will provide a secure way to conduct credit card and other electronic transactions on the Internet. The method uses Netsite Commerce Server software from Netscape Communications.

The two firms said the new software will let FDC and its member banks provide the first real-time online card authorisations. With real-time authorisations available, customers anywhere in the world will be able to purchase goods and services via the net, using any major credit card.

Contact: Netscape Communications, e-mail: **banking@mcom.com.**

Two-Way Voice Calls Over the Internet

An Ontario firm named microWonders is promoting a free Windows program that provides two-way voice communications over Internet connections. Named the Internet Global Phone (IGP), the program will run on any PC equipped with a SoundBlaster compatible sound card, speakers, and a microphone.

The program is expected to be of some interest to the many millions of Internet subscribers, and to the various governments and institutions that now underwrite the sprawling, worldwide network.

IGP uses voice compression technology developed at the Technical University of Berlin and made freely available over the Internet. The compression technology, called GSM, makes real-time voice connections practical over any common modem-based Internet connection from 14·4K-bit/s up. It also works over ISDN-based or LAN-based connections.

IGP source code can be downloaded from the DDJ Forum on CompuServe (GO DDJ) or via anonymous FTP from Internet at site **ftp.mv.com** (192.80.84.3) in the **/pub/ddj** directory.

The software implementation can be obtained via anonymous FTP from Internet site **ftp.cs.tu-berlin.de** in the **/pub/local/kbs/tubmik/gsm/** directory, or by e-mail: **jutta@cs.tu-berlin.de.**

BT Launches Internet Services

After months of speculation, British Telecom (BT) has finally announced BTnet, which it claims is the most comprehensive connection to the Internet.

Critics could accuse BT of merely leaping aboard the Internet bandwagon, but BT officials argue otherwise. They point to the fact that BTnet is the widest range of direct connection offered to the public to date, with everything from modem dial-up to high-speed broadband communications available.

BT is offering applications software to access the Internet for both IBM PC and Apple Macintosh computer users. Access is, available across modem, ISDN, private circuits, frame relay, and even switch megastream circuits in the UK. Across Europe, access is via PDN (packet data networks), as well as frame relay.

Standard facilities on BTnet include e-mail, a managed mailbox service for dial-up users, a Domain Name Service (DNS), and FTP (File Transfer Protocol) services. Future developments will include support for World Wide Web servers for customers, allowing information to be displayed on an information provider (IP) basis.

BT officials are stressing that the BTnet service portfolio is very much aimed at major companies, at least initially, with service charges starting at £499 for ISDN connection to the service and £3,000 a year for a subscription.

Whitehouse Web

Forget everything you saw on the BBC TV Sitcom *Two Point Four Children* screened during the Christmas period . . . this time it's for real!

The computer screen opens with a colour photograph of the White House, taken from Pennsylvania Avenue. A plaque at the top says, in ornate script, 'Welcome to the White House', and at the bottom, 'An Interactive Citizens' Handbook.'

Welcome to the White House's World Wide Web site, viewed through Mosaic. The hypertext Web site offers a single point to access much of the federal US government information available on the Internet.

The information on the White House includes a photographic tour of the public areas of the President's house and office, but not the private living areas. Clicking on an icon of Socks, the White House cat, produces a 'Meow, Meow, Meow' sound bite.

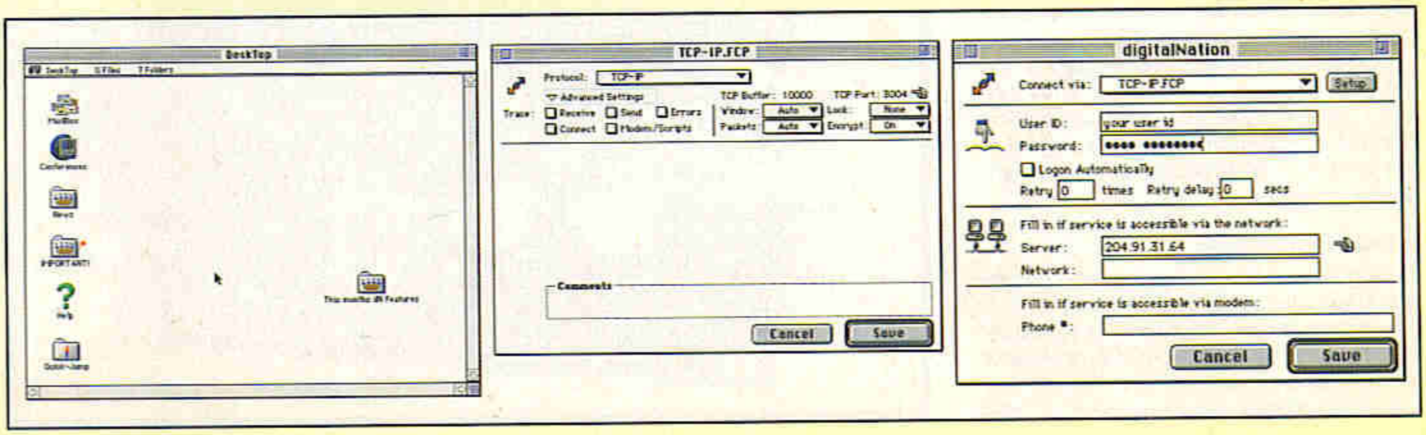
Net surfers have long been able to send e-mail to the White House, but the new WWW site marks a step up in sophistication and ease of use, at least for those who have high-speed Internet access. Mosaic is very slow for the large (and growing) number of people who access the net via PC and modem. Those without high-speed access can use text-only browsers such as Lynx to access the site.

There is more to come. Among the enhancements now under construction are the ability to fill out disaster relief forms from the Federal Emergency Management Agency, and after that, access to other government forms.

The White House site can be reached at: **http://www.whitehouse.gov.**

Site Survey
– the month's destination

Who could forgive us if we did not look at one of the FirstClass BBSs, having whetted your appetite's with details about how to reach them. Favourite is digitalNation, which actually has several BBS locations across the USA – the one listed (and shown below) is in Washington. It's a cool spot! For an even cooler interface though, download the *dN settings* file (held in the dN Settings folder within the *IMPORTANT!* folder on the desktop) and use it to reconnect to dN.



DSP
THE TMS320C26 STARTER KIT

Review by Dean P. Hodgkins BEng(Hons)

Until fairly recently, digital signal processing was beyond reach for most hobbyists, but that is about to change! Texas Instruments' DSP starter kit (DSK) makes real-time signal processing an affordable reality for all PC users. The kit comprises a PC linkable board, which contains a TMS320C26 digital signal processor, and all necessary software to get the board 'up and running', including an assembler and debugging tools – in short, this is a complete DSP development environment which provides designers with a fast and easy method of using real-time DSP for a multitude of applications.

Applications of Digital Signal Processing

Fast Fourier Transforms (FFT)

Fourier transforms convert data from the time domain to the frequency domain. They are extensively used in DSP, and algorithms which can compute a Fourier transform efficiently are called Fast Fourier Transforms. The TMS320C26 can compute an FFT very quickly due to its very short cycle time, and is thus ideal for use in spectrum analysers and instrumentation applications.

Control Systems

Control theory is another major application of DSP. In a control system, a sensor is used to monitor the system's operation. The signal from the sensor is 'fed back' to the system's manager (which may be analogue or digital) which determines any action to be taken to ensure that the system performs as specified. The TMS320C26 is capable of running very sophisticated control algorithms for applications such as noise filtering, etc.

Speech Processing

The speed with which a digital signal processor can perform calculations and bit-manipulations means that it is especially suited for implementing the complex algorithms which are required for speech processing.

DSP processors are widely used in the telecommunications industry; they are used, for example, in 'echo' cancellation (caused by the mismatch of transmission line impedances) applications, and in high-speed modems.

Image Processing

Modern image processing is placing more and more demands on DSP processors. The image processing required for applications such as CAD, and Virtual Reality, for example, involves thousands of complex calculations every second. A DSP processor has features designed to enable this type of calculation to be performed very quickly; the TMS320C26, for example, allows row by row matrix operations to be performed.

System Requirements

The DSP kit has been designed to use an IBM PC/AT or 100% compatible as its host system. The PC must have a hard disk, and a minimum of 640K RAM. All software is supplied on a 1·2M-byte 5·25in. disk.

The DSP processor board requires a 9V AC (@ 250mA) power supply with a 2·1mm power jack connector, and is interfaced to the host machine via an RS232 serial communications link.

The DSK Board

The board is fairly compact, mainly due to a large number of the components being surface mount devices. The main components can be divided into three sections:

(a) The on-board power supply, which makes use of LM7805 and LM7905 voltage regulators.

(b) The RS232 interface components, which include an RS232 line driver, an RS232 line receiver, and an analogue interface IC.

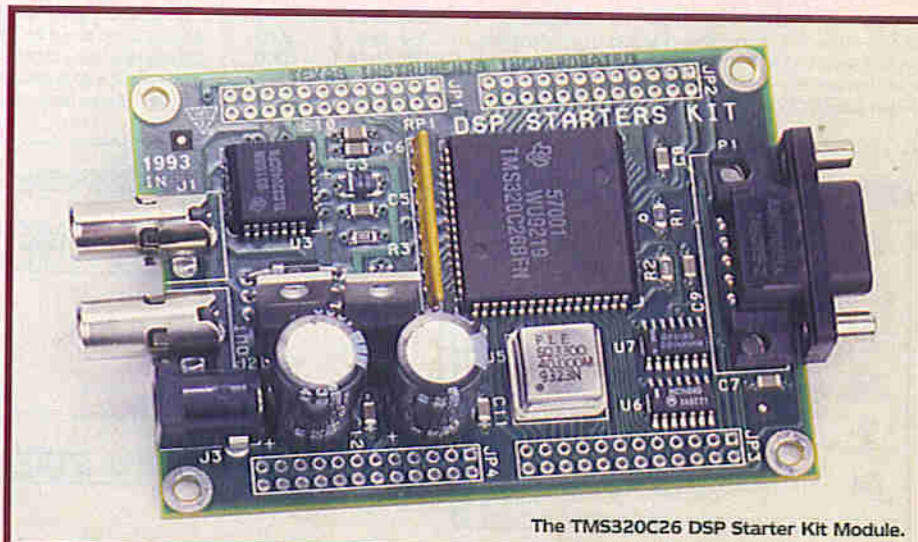
(c) The digital signal processor and system clock (a 40MHz TTL oscillator).

The interface circuitry and the processor will now be discussed in more detail.

The TMS320C26 Digital Signal Processor

This is the heart of the DSK; the TMS320C26 has an instruction cycle time of 100ns, and since many instructions require only one cycle, the processor can execute up to 10 million instructions per second. It is, therefore, capable of handling many real-time DSP algorithms.

The TMS320C26 has 1568 16-bit words of on-chip RAM, 256 words of on-chip ROM, and can directly address 128K words of external data/program memory (up to 64K words of each). The ALU (Arithmetic Logic Unit) and Accumulator have a 32-bit word-length, and the proces-



The TMS320C26 DSP Starter Kit Module.

sor has a 16 × 16-bit hard-wired multiplier, capable of calculating a 32-bit product in a single machine cycle! Other features include an on-chip timer and clock generator, a 16-bit parallel interface, 16 input and 16 output channels, and a global data memory interface.

The processor may be used alone, or it may be used in a multiprocessor system, with other devices in parallel, or with global memory space.

What makes this processor especially useful is its on-chip memory. Programs are downloaded from slower, external memory devices to the chip's (much faster) memory, from where they are executed. The processor's instruction set has special 'block transfer' commands which enable blocks of data from external memory to be loaded into its on-chip RAM very quickly.

The instruction set supports three addressing modes: direct; indirect; and immediate addressing – there are eight auxiliary registers and a dedicated arithmetic unit for the indirect addressing mode.

The Analogue Interface

The DSK uses a TLC32040CFN Analogue Interface Circuit IC for all analogue-to-digital and digital-to-analogue conversions. The TLC32040CFN has a 14-bit ADC and DAC resolution, and can support variable sampling rates, up to 19,200 samples per second. The IC has an antialiasing input filter, and a low-pass output-reconstruction filter.

Connecting the DSK

The DSP board is linked to the host PC by means of an RS232 cable, which connects to either communications port on a PC. The other end of the cable connects to the board via a 9-pin D-type socket. A standard RS232 cable may be used, in conjunction with a 25-to-9 pin adaptor, but since the DSP board only uses 4 out of the 9 pins, it is easy to make your own cable. We made ours from 4-core, screened data transmission cable. The board is powered by an external 9V AC supply, which must be able to supply at least 250mA. The signal input and output connections use standard 'phono' sockets.

The Development Process

The development process is shown in Figure 1. The idea behind this process is to be able to produce software which can be executed in a DSP target system. This is achieved by using the assembler and debugger software (included with the kit) to write, edit, test, and modify applications software for the DSP.

The Assembler

The assembler translates an assembly language source code file into a machine code file, known as the object code, which can be executed by the processor itself. The DSK assembler allows the user to specify 'directives' before assembly, so that code may be generated for an absolute address (an address which is permanently mapped to a memory location), hence avoiding the need for a 'linker' stage.

The Debugger

The purpose of the debugger is to allow the user to locate and remove any errors ('bugs') which may occur in their code. It has a window-based display which means that it is easy to use and can be quickly mastered by new users. The debugger has all the features that one would expect, including single-step execution, breakpoint setting, and run-time execution halt.

Using the DSK

Having connected the DSK module and turned on the power supply, we decided to run some of the demonstration software which was supplied with the kit; the first to be tested was a spectrum analyser program. The assembler was invoked to assemble the spectrum analyser program by simply typing 'DSKA DSK_SPEC'; the

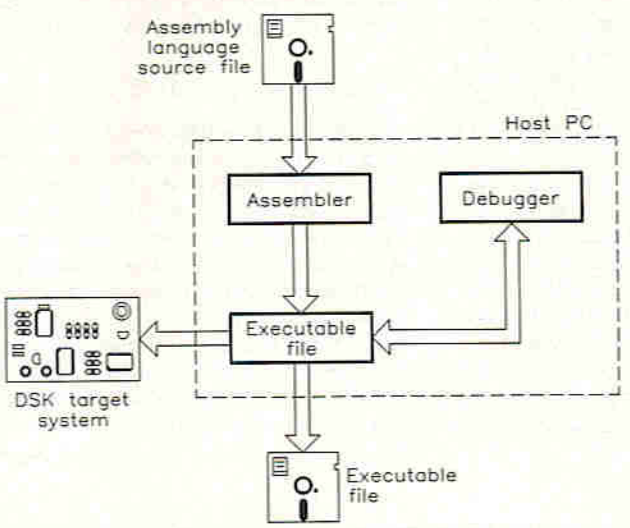


Figure 1. The software development process.

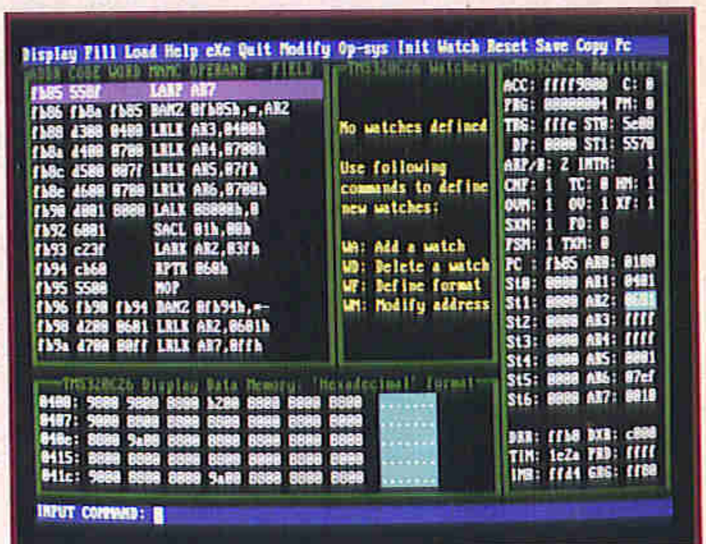


Photo 1. Debugging software, showing the spectrum analyser software about to be run.

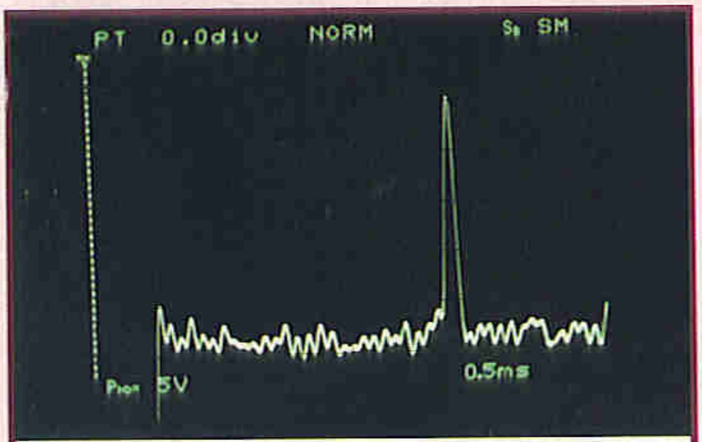


Photo 2. Oscilloscope screen, showing the results of the spectrum analyser program; the peak occurs at 10·83kHz, which was the frequency of the test signal applied.

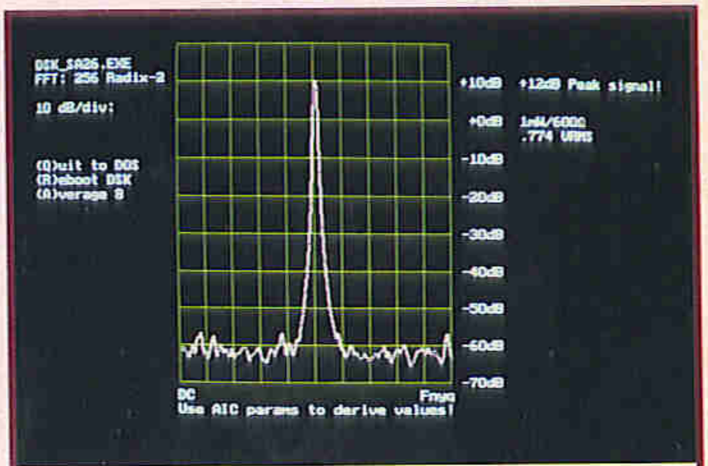


Photo 3. Spectrum analyser program; the peak again occurs at 10·83kHz, which was the frequency of the test signal applied.

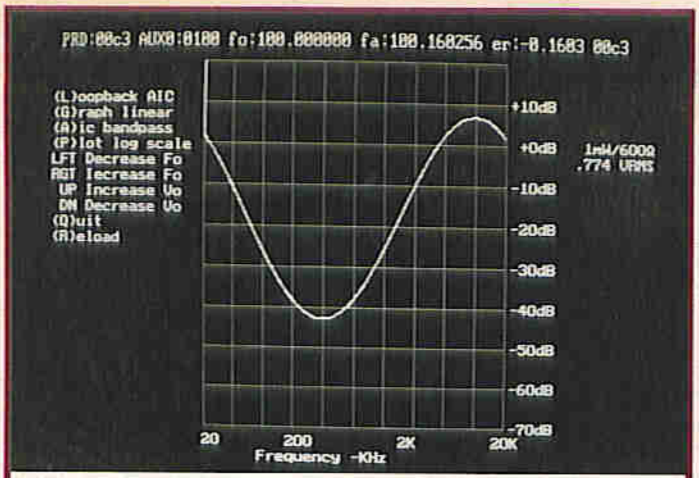


Photo 4. Audio Analyser program; the sine wave output is clearly visible.

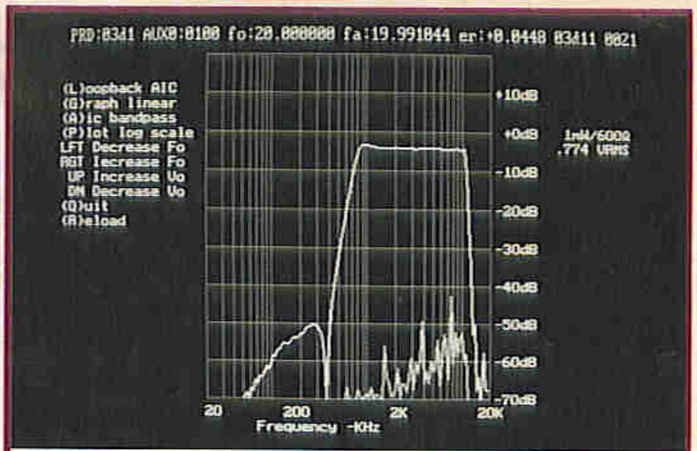


Photo 5. Audio Analyser program, showing the frequency response plot of the DSK's TLC32040CFN Analogue Interface Circuit's band-pass filter.

program assembled without any problems. The debugger was then loaded and used to execute the object code (see Photo 1). A pure sine wave signal of 10kHz was applied to the module by connecting a signal generator to the input socket. The results were displayed on an oscilloscope (see Photo 2), which had been connected to the module's output socket.

Not everyone has access to an oscilloscope, and so a second version of the spectrum analyser code has been included which makes use of the host machine's graphics display instead, as shown in Photo 3. The results obtained were identical in each case, but due to the extra code required to generate graphics on the host machine's display, etc., this program was slightly slower to run than the previous version. It does, however, include an extra feature: an averaging function, which allows the output to be averaged over 2, 4, or 8 complete frequency response measurements. This helps to reduce the effects of any noise which may be present in the system.

One other interesting demonstration program is the Audio Analyser; this allows the user to measure the audio frequency response of a loudspeaker, or similar, by turning the DSK into a DC-20kHz oscilloscope, with the PC's monitor being used to display the waveforms. It was written for the TMS320C26 DSP Starter Kit, but is easily modified to run on other devices. The Audio Analyser works by generating a 'precision' sine wave signal (by using a bit-reversed lookup table method) which is input to the audio system being tested (see Photo 4). The software alters the frequency of the signal over a specified range, and the output signal from the system being tested is fed back to the DSK, and 'recorded'. Once this process has been completed, the frequency response of the system is plotted (on a logarithmic scale). We measured the frequency response of the DSK's Analogue Interface Circuit's band-pass filter, Photo 5 shows the plot.

Another noteworthy detail about the demonstration software is the fact that it uses a very fast 115200 baud rate! This was achieved by adjusting the communications kernel, and using the TINT (Timer Interrupt) to control the RS232 sampling rate, allowing each RS232 sample to be resolved from 200ns to only 100ns. The documentation states that this feature has not yet been incorporated into the debugger, but is available in several new application software examples.

Several other small programs were supplied with the DSK, including a useful autotest program, which checks and tests the DSP processor in situ.

The software was easy to use, and the documentation supplied with the kit was concise, and clearly presented. Full details are provided on how to install the software, and how to link the DSK board to a host PC. RS232 pinout diagrams are given for construction of the link cable, and full circuit diagrams are included so the board can be easily modified and expanded.

Future Upgrades

At the time of writing, Texas Instruments had just launched (the official launch date was 1 June 1994) a new DSP Starter Kit, based around a TMS320C50 processor. This DSP runs at 40MHz, and has 10K words of on-chip RAM. The board features an EPROM, which enables the DSK to communicate with a PC.

For further details on either kit, contact Texas Instruments on (01234) 270111.

Please note that neither of these kits are available from Maplin.

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CIRCUIT DIAGRAM AND MANUALS for National NC-77X valved HF general coverage communications receiver. Tel: Godfrey (0181) 958 5113. 63 The Drive, Edgware, Middlesex HA8 8PS.

CIRCUIT DIAGRAM for Trio Tuner KT5500. Two vintage slow-motion dials c.1930 with Bakelite escutcheons or similar. H. N. Jeffery, Letcombe Regis, Oxon. Tel: (01235) 764995.

OPERATORS MANUAL or any information about setting up/ operating a Diablo 630 daisy wheel printer. A. Brett, 72 St. Neots Road, Eaton Ford, St. Neots, Cambs PE19 3BD. Tel: (01480) 213504.

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

THE BRITISH AMATEUR ELECTRONICS CLUB (founded in 1966), for all interested in electronics. Four newsletters a year, help for members and more! UK subscription £8 a year (Junior members £4, overseas members £13.50). For further details send S.A.E. to: The Secretary, Mr. J. F. Davies, 70 Ash Road, Cuddington, Northwich, Cheshire CW8 2PB.

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: (01427) 788356.

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 (0151) 648 5892.

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LEDs LIGHT EMITTING DIODES AND THEIR APPLICATIONS

Part Three – Clever Tricks

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

In this final part we discuss the operation of LEDs with respect to Pulsed Operation and Infra-red.

PULSED OPERATION

The concept of pulsed operation has already been mentioned in connection with the multiplexing of seven-segment displays. The idea is that an LED can be made to produce a greater intensity by driving it with a current far higher than normal. This will not damage the LED as long as the current is flowing for a fraction of the total time. This technique is also important in infra-red remote control transmitters where it is applied in order to maximise the range.

As with many semiconductor devices the limits on pulsed operation of LEDs are set by limitations on the current and the power dissipation; an LED data-sheet will typically show two maximum current ratings.

The first is the DC forward current which is applicable when an LED is operated in the conventional way. This rating has to be reduced at high ambient temperatures, otherwise the power dissipation will result in the maximum semiconductor junction temperature being exceeded, just as in a transistor. Information on derating is given as a graph of maximum forward current versus ambient temperature, as shown in Figure 18, or simply as an equivalent statement such as "derate linearly at 0·167mA per degree centigrade from 50 degrees centigrade". Most of the cooling of the LED junction is by means of conduction down the leads, and so the lead length and method of soldering can affect the thermal rating. This is the reason for the two alternative curves in Figure 18.

The second current rating is the peak forward current which relates to pulsed operation and may be from 3 to 20 times the DC forward current rating. The limit is set by the current carrying capabilities of the semiconductor and the bonding wires. However, the LED cannot be operated at these high currents continuously without causing overheating of the LED. If the current is supplied in short pulses the junction temperature does not have time to rise too far and can then cool down during the time the current is off. Quite a reasonable analogy is an RC filter fed with a square wave. This is shown more scientifically by a graph such as Figure 19.

Taking an example of a multiplexed five-digit seven segment display refreshed at 1kHz, each digit would be on for 1/1,000/5=0·0002s or 200μs. Figure 19 shows that the maximum safe current per segment would be 3·5 times the maximum DC current for this ambient temperature.

When calculating the series resistor for pulsed operation of an LED it is important to remember that the voltage drop across the diode can be significantly higher than the value at normal currents, due to the internal impedance of the LED. A graph of forward voltage against forward current is often included in the data sheet.

Although the intensity of an LED increases with the forward current, it does not do so in direct proportion. Surprisingly, for LEDs based on GaAsP, the light output increases more than proportionately, so that at high peak currents the LED becomes more efficient. The increase can be as much as 50% compared to the value at the normal DC current, which can be a distinct benefit in multiplexed applications. For instance in our example of a five digit multiplexed display the brightness of the segments would be decreased by a factor of five because each is only on for one fifth of the time, but increased by 3·5 times because of the increased current, and increased by 1·5 times because of the improved efficiency, giving an overall factor of 1·05 times the DC brightness! LEDs using other semiconductor materials show a slight drop in efficiency as the current increases.

INFRA-RED LEDs

Infra-red LEDs operate on the same principles as conventional LEDs, the only difference being that the radiation

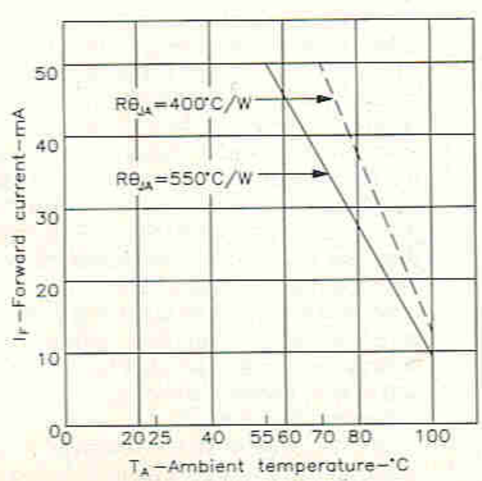

Figure 18. Temperature derating of maximum dc forward current.

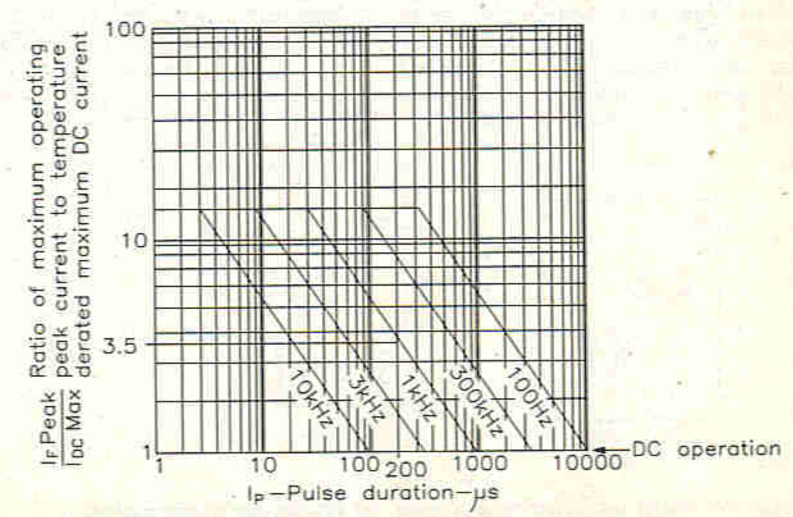

Figure 19. Curves for maximum current in pulsed operation.

emitted is in the invisible infra-red spectrum. Typically they are manufactured from GaAs or GaAlAs and operate in the frequency range of 820 to 950nm, which is known as the near infra-red. This range coincides with the region of maximum sensitivity for silicon photodetectors. This is an important consideration in many applications of infra-red LEDs where a cheap, sensitive detector is needed to sense the radiation from the LED (see Table 5 for typical specification).

One of the most familiar uses of infra-red LEDs is in remote control transmitters for televisions, VCRs and entertainment systems. Information is transmitted as a series of pulses, a method which allows high peak LED currents to be used in order to achieve a wide operating range. Often more than one LED is used for the same reason.

The other area where infra-red LEDs are very important is in optocouplers (see Table 6). These consist of an infra-red emitter and an output device encapsulated in a single package, often a 6-pin DIL type. The output device can take many forms from a simple photodiode to a triac or Schmitt trigger. However, in all cases it is controlled or activated solely by the infra-red radiation from the emitter, there being no electrical connection between thetwo. This electrical isolation between input and output is the main advantage of an optocoupler and is reflected in their alternative name of optoisolator.

In a simple optocoupler the relationship between the output signal and input current varies widely from device to device and is also a function of temperature. This restricts their use primarily to digital signals. However, special devices incorporating a second feedback detector are available which can be used for analogue signals.

A typical optocoupler with transistor output is shown in Figure 20a. In addition to the normal specifications for the maximum currents and voltages that can be applied to the LED and the transistor, two other important parameters are usually quoted.

The first is the isolation voltage which is the maximum voltage that can be safely applied between input and output. This is normally a few thousand volts but may be given as an RMS, peak or DC value. Note that where an optocoupler is providing safety isolation from the mains it must have an isolation voltage of at least 3000V DC. There must also be a separation of 6mm between PCB tracks carrying mains voltages and the low voltage circuits.

Colour/Type	LED Size (mm)	Peak Wavelength (nm)	Light Output (mW)	Forward Voltage (V)	Maximum Forward Current (mA)	Power Dissipation (mW)	Stock Code
Miniature IR Source	3	940	3·5 at I_F=40mA	1·6 at I_F=40mA	60	80	YY65V
High Power IR Diode	5	940	20 at I_F=100mA	1·7 at I_F=100mA	100	100	YH70M
GaAs IR Emitter	9·2	950	20	1·2 at I_F=250mA	250	300	KW66W
Reverse Voltage 5V max.							

Table 5. Infra-red LED selection chart.

		LED Emitter			Detector		
Type	Isolation Voltage (V)	Forward Voltage (V)	DC Forward Current (mA)	Peak Forward Current (mA)	Power Dissipation (mW)	Output Current (mA)	Stock Code
Opto Darlington Isolator	1,500 (DC)	1·5 at I_F=10mA	100	–	150	100	WQ70M
High Gain Optoisolator	3,000 (DC)	1·37 at I_F=0·5mA	0·5	20	–	60	RA59P
High Voltage Optoisolator	7,500 (AC)	1·15 at I_F=10mA	10	–	–	–	AY44X
Opto Triac Isolator	7,500 (Peak)	1·3 at I_F=30mA	30	60	–	100	QQ10L
Opto Zero-Crossing Isolator	7,500 (Peak)	1·3 at I_F=30mA	30	60	–	100	RA56L
Low-Current Optoisolator	–	1·3	1	50	150	50	CY94C
Dual Input High Gain Optoisolator	–	1·3	20	–	100	60	CZ64U

Table 6. Opto-coupler selection chart.

The second parameter is the current transfer ratio. This is the ratio between the transistor collector current and the LED current expressed as a percentage. It is measured in a test circuit similar to that in Figure 20b. The actual value can vary widely and so minimum and typical values are often quoted.

Perhaps the most important application of infra-red LEDs is in fibre-optic communications. The principle is to convert electrical signals into pulses of light by means of some form of LED and pass these down a thin transparent fibre. The light remains trapped in the fibre due to the phenomenon of total internal reflection discussed earlier. At the far end of the fibre a photo-detector converts the light back to electrical signals. The process is obviously much more involved in practice and really deserves an article of its own!

Low-loss optical fibres are manufactured from silica whose attenuation decreases with increasing wavelength up to about 1,500nm. Therefore although wavelengths of 820nm and silicon photodetectors can be used, better performance can be achieved using special LEDs and detectors which have been developed to emit at 1,300nm.

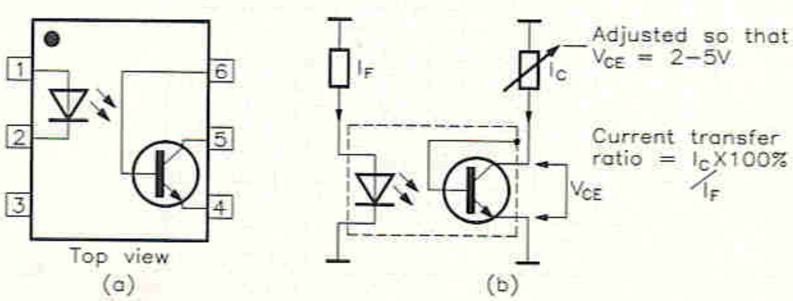

Figure 20. Single transistor opto-coupler. (a) Typical pin configuration. (b) Circuit to measure current transfer ratio.

LIGHT

Most people are familiar with the idea that light is a form of electromagnetic radiation. The complete range of electromagnetic radiation is known as the electromagnetic spectrum. Figure 21 shows how the spectrum is divided into bands according to the wavelength or frequency of the radiation. Each band is named according to the phenomena associated with it, although there is actually no fundamental difference in the radiation. Visible light occupies a very small section of the spectrum between wavelengths of 400nm and 700nm. This section has been expanded to show the correlation between wavelength and our perception of colour.

Like any type of electromagnetic radiation, light is a form of energy. It is therefore possible to measure the output of a light source in the usual energy units of joules per second or watts. The science

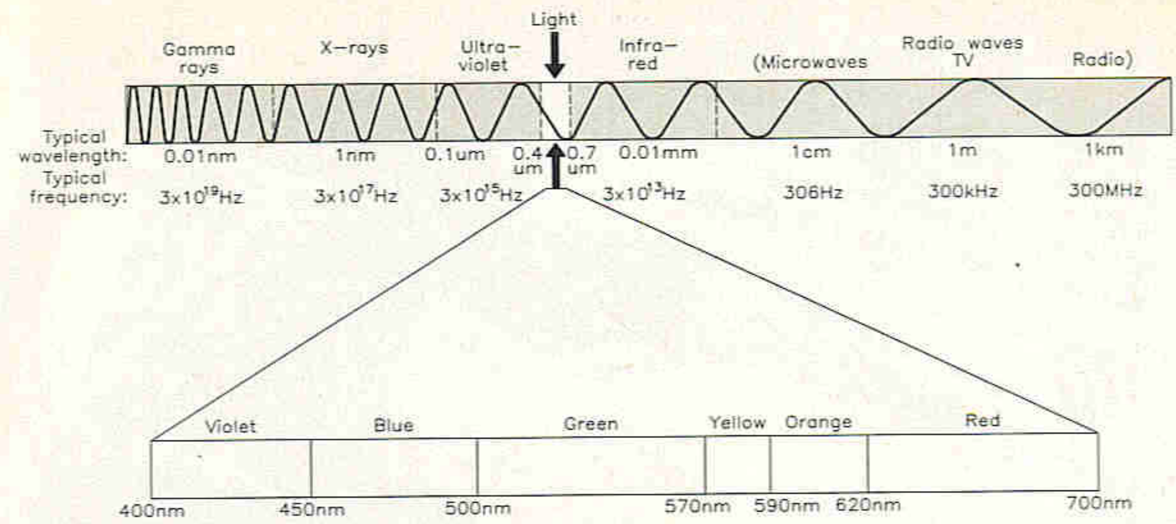

Figure 21. The electromagnetic spectrum.

of measuring light in this objective way is known as radiometry. However, it is often the subjective effect of light that is of concern, and this depends on the response of the eye. Unfortunately this is anything but linear as can be seen from the standard luminous efficiency curve for the eye shown in Figure 22. The eye is most sensitive to wavelengths of 555nm, corresponding to green light, which is not very surprising as we have evolved in a world full of green plants! Either side of the peak the response falls away rapidly to zero at the wavelengths corresponding to the limits of visible light.

The curve makes it plainly obvious why measuring light output in watts is not very useful. A source producing say 1W of light of 500nm wavelength would only be about a third as effective as a source emitting 1W at 555nm. To overcome this problem light measurements are often based on a unit of luminous power known as the lumen. At 555nm 1W of light radiation produces 680 lumens. However, at other wavelengths the conversion is modified according to the relative luminous efficiency curve, so our source of 1W at 500nm only produces a luminous power of $680\times0{\cdot}33=224$ lumens. This branch of light measurement which takes account of human vision is known as photometry.

A 6V 0·1A MES bulb has a light output of about 3 lumens. The electrical input power is 0·6W so the efficiency of conversion is 3/0·6=5lm/W, compared to the maximum possible efficiency of 680lm/W at 550nm. The reason for this very poor efficiency is that much of the electrical power is converted to heat rather than light. Of the light produced, a large proportion is in the longer infra-red wavelengths where the response of the eye is poor or non-existent. Household filament bulbs are slightly more efficient at about 10lm/W, while fluorescent tubes can achieve 70lm/W.

The luminous power falling on unit area of a surface is called the illuminance and is measured in lumens per metre squared or lux. Table 7 shows some typical values under different situations. When designing a lighting scheme for a building the output of the light fittings in lumens and their arrangement is used to calculate the illuminance at the working area. This is compared with accepted figures and the number or type of fittings revised if necessary. 500 lux is considered adequate for offices and classrooms whereas inspection of very fine detail may require 1,500 lux.

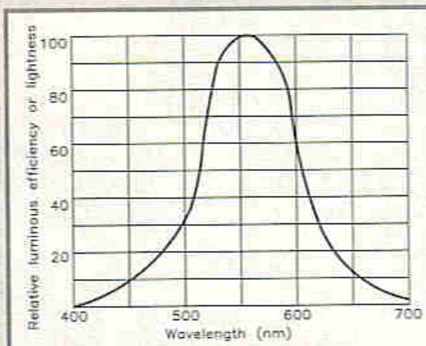

Figure 22. Spectral sensitivity curve for the eye under good illumination.

Light Source	Illuminance (Lux)
Moonlight	0·1
60W bulb at 1m	50
1W MES bulb at 0·1m	100
Fluorescent lighting	500
Bright sunlight	30,000

Table 7. Typical values of illuminance.

For many light sources the output in lumens is not a very useful measurement. A car headlamp might have the same luminous power output as a household bulb, but there is obviously a difference in the concentration of the light. There are two ways of measuring this concentration depending on the whether the light is coming from a point source or an extended source.

A point source of light is one whose dimensions are small compared to the distance from the observer, such as an LED viewed from a normal distance. In this case all the light reaching the observer effectively comes from one point and the applicable measurement of light concentration is luminous intensity. This is defined as the luminous power in lumens divided by the solid angle measured in steradians in which the light is being emitted, and has units of candela. Solid angles are a sort of three-dimensional form of a normal angle and measure the spread of the light. One steradian represents the spreading of the light from a source at the centre of a sphere of radius 1m over an area of 1m² on the surface of the sphere. For most light sources the luminous intensity is also a function of the direction of view, and this information is usually presented as a graph or polar diagram. This is discussed further in the section on selecting an LED.

In an extended source the area of the source becomes significant. The appropriate measure of brightness in a certain direction is then the luminance, which is defined as the luminous power in lumens divided by the solid angle in steradians and by the projected area of the part of the emitting surface being considered. Units are therefore lumens per steradian per metre² or candela per m². A perfectly diffused source will have a luminance that is the same whatever the direction from which it is viewed. However, the luminance of most practical sources varies according to the angle of view.

I hope this three part series has been of interest, and that the product information and ideas have been useful. All the parts mentioned are available from Maplin by quoting the Stock Codes mentioned. Given the amount of space, it is always difficult to fit in all the information about every device, so always refer to your Maplin Catalogue for a wider and more comprehensive selection of LEDs, Optoisolators and Infra-red Transmitting devices!

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by Ian Hickman

This project owes its advanced performance to the use of the latest LinCMOS™ technology. The completed unit checks components of all sorts both passive and active, and is safe to use on all normal semiconductor devices.

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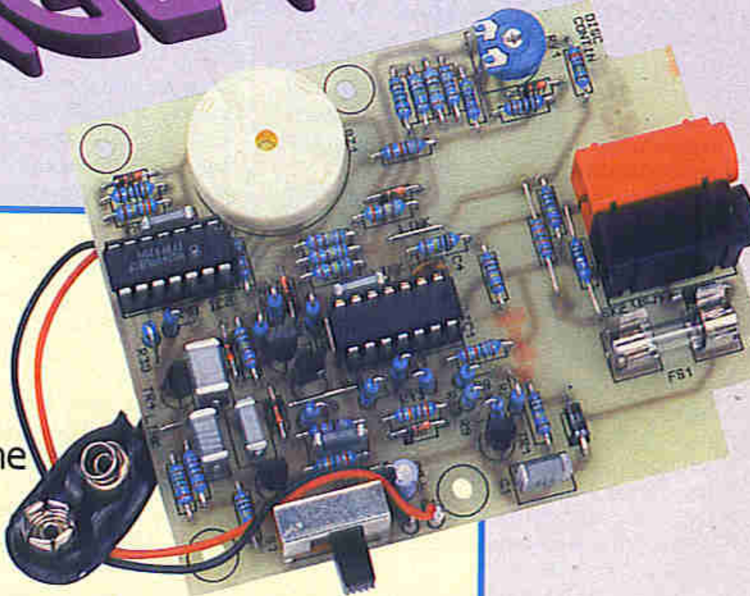
DISCRIMINATING CONTINUITY + LEAKAGE TESTER



APPLICATIONS

- Continuity testing
- Leakage testing
- Checks both passive and active components

FEATURES

- Uses latest LinCMOS™ Technology
- Uses Wheatstone Bridge principle
- Internal fuse protection
- 9V portable operation
- Watchdog function
- Minimal current consumption

2 PROJECT RATING

When servicing a piece of electronic gear, electrical equipment such as a vacuum cleaner, or even the car, a continuity tester is most essential. Until a few years ago, I used to use the low ohms range on a multimeter, and many readers probably do the same. However, an audible indicator is often more convenient, for instance in car maintenance when delving into the innards of the works under the bonnet, since the tester can be perched wherever convenient, rather than having to be within view. Continuity testers of this sort have been available for longer than I can remember, but some of them are in fact less useful than one might think. For instance, in the case of an electrical machine, one usually wants assurance that a connection is really sound, i.e. has a resistance of much less than an ohm: the same goes for car work, and even for electronics, where a poor signal earth connection on a Hi-Fi amplifier can be responsible for hum problems.

Some continuity testers will indicate a connection as good, even if it has a resistance of several or many ohms. This is misleading at best, and in many circumstances worse than useless; a good continuity tester should indicate clearly whether a connection is well under 1Ω or not. The project described below does just this, and also provides useful information at the other extreme – indicating leakage in the range 1 to 10MΩ. In fact, used as described later in the article, it can check out a multiway screened cable, say, or a rack backplane, in less than half the time needed to test it using separate leakage and continuity testers. It achieves this by an ingenious arrangement of several overlapping bridge circuits. The Wheatstone Bridge is one of the earliest and still a fundamental example of the arrangements used in electrical measurements.

This project owes its advanced performance to the use of the latest LinCMOS™ technology (LinCMOS™ Texas Instruments), the TLC27L4CN quad op amp featuring exceedingly low bias current. This enables it to work from a source impedance of 1MΩ without incurring offset errors. In addition to testing for continuity and leakage, the completed unit checks components of all sorts both passive and active, and is safe to use on all normal semiconductor devices. It is protected against accidental connection to voltage sources up to and including 240V AC mains, and is unlikely to be inadvertently left switched on thanks to its 'watchdog' function. This, together with minimal current consumption, ensures exceptionally long battery life.

IMPORTANT NOTE:

This project is a general-purpose test instrument for checking continuity and leakage. It is not designed to test earth continuity, earth loop impedance or insulation on 230V AC mains installations systems or equipment for compliance with British IEE Wiring Regulations, nor on installations systems or equipment for this or any other mains voltage for compliance with any other specifications or regulations.

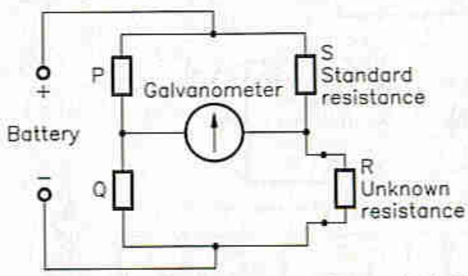
The internal 100mA F fuse protects against permanent damage due to accidental connection to DC or AC sources up to 240V. Instrument operates to specification after fuse replacement.

The Wheatstone Bridge

This instrument was invented by Sir Charles Wheatstone, who was born in Gloucester, in 1802, and died in Paris in 1875. Whilst still a minor, he set himself up in London as a maker of musical instruments, and in 1823 attracted scientific attention with a paper in the 'Annals of Philosophy' entitled *New Experiments on Sound*, followed by many other papers. As a professor at King's College London, in 1836 he exhibited experiments demonstrating the velocity of an electric current, leading to a joint patent with W. F. Cooke for an electric telegraph. Elected an FRS in 1836 and knighted in 1868, he is remembered first and foremost for the 'bridge circuit' named after him. The Wheatstone Bridge enables an unknown resistance to be measured by comparison with a known standard resistance, even though they may be of different values. The scheme depends upon the remarkable uniformity of drawn wire, not only the mechanical properties such as diameter, hardness etc. being constant along its length, but also its resistance.

The basic Wheatstone arrangement is shown in Figure 1, where P and Q are the lengths of wire either side of the tapping point leading off to the galvanometer. Due to the uniform resistance per unit length of the wire, when the ratio P/Q = S/R there is no potential difference between the terminals of the galvanometer, and hence no deflection – the bridge is said to be 'at balance'. Knowing the lengths P and Q (their actual resistance does not need to be known) and the value of the standard resistance S, the value of the unknown resistance R is determined. To achieve the high degree of accuracy of which the arrangement is capable, thanks to the great uniformity of the wire, a considerable length of it is needed, so that the distances P and Q can be measured with very high resolution.

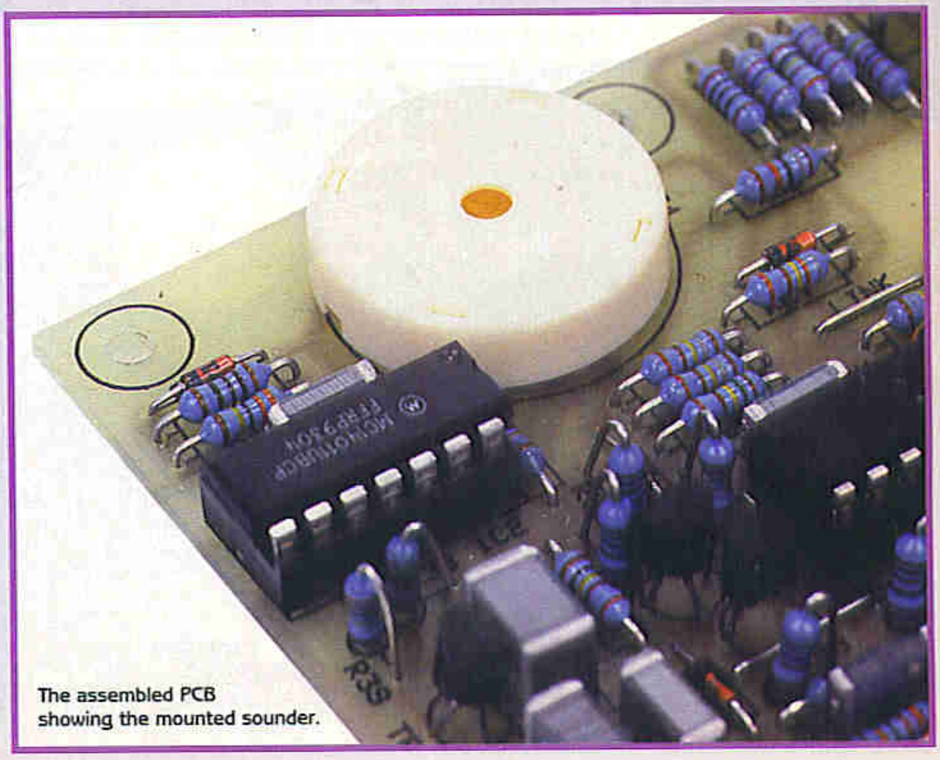
It as later realised that if the battery were replaced by an audio frequency generator and the galvanometer by a sensitive earpiece, the arrangement would work equally well. Furthermore, it was now possible to measure inductors or 'condensers', by using a known inductor or capacitor respectively at S. With this arrangement, the exact frequency of the audio generator did not need to be known. Later versions of the bridge enabled other arrangements to be used, e.g., an inductor could be measured using a capacitor as the standard, though in this case a good, pure sine source was necessary, as was a knowledge of its frequency. Indeed, one version (the Wien Bridge) was designed to measure not the value of a component, but rather the frequency of the AC source.



P and Q may consist of a single length of resistance wire with an adjustable tapping point for the Galvanometer. P and Q in the equation are then the lengths of resistance wire either side of the tapping.

At balance (no deflection on galvanometer): $R = \frac{Q}{P} S$

Figure 1. Circuit diagram of Wheatstone Bridge.



The assembled PCB showing the mounted sounder.

Specification

Supply voltage:	Internal 9V battery type PP3
Supply current:	530µA quiescent, 13mA operating
Typical battery life	
On but not sounding:	800+ hours
Sounding leakage tone – intermittent use:	150+ hours
Sounding continuity tone – intermittent use:	25+ hours

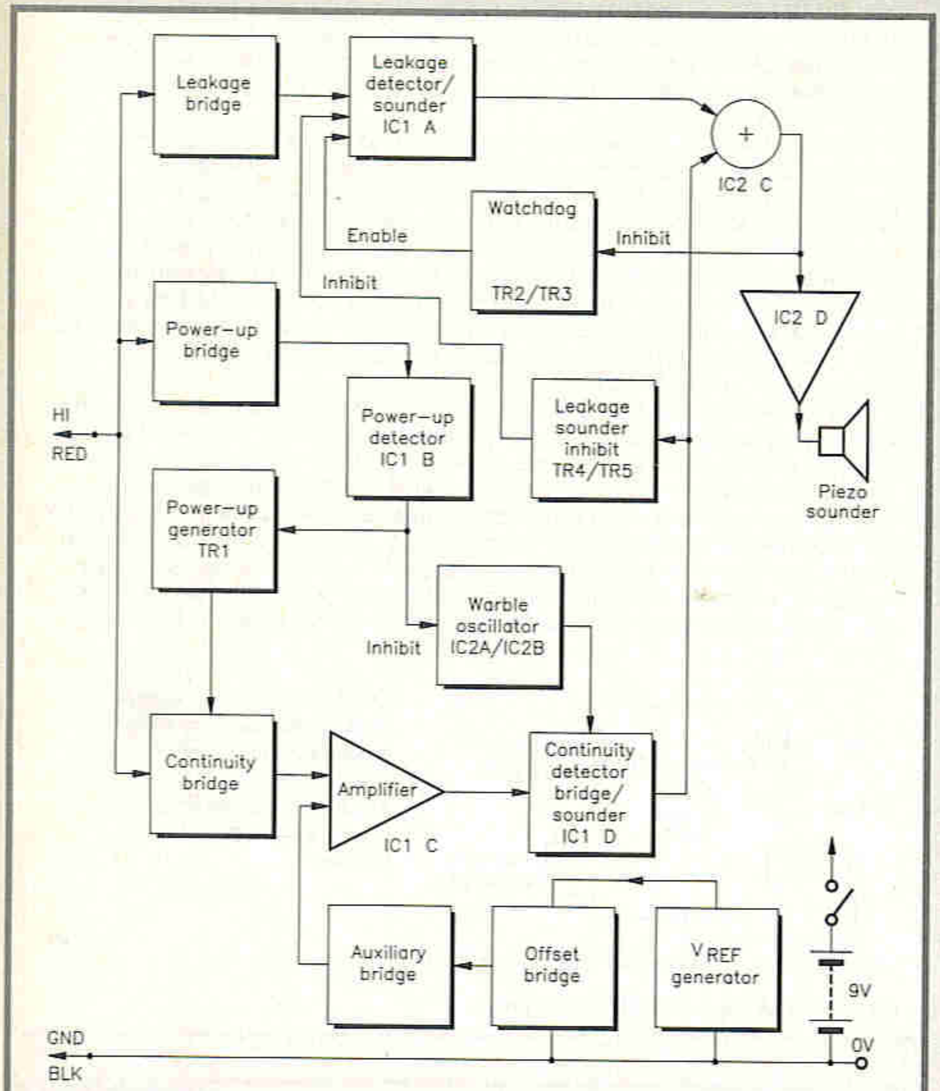


Figure 2. Block diagram of the Discriminating Continuity Meter.

Circuit Description

In addition to Figure 2, the block diagram Figure 3 shows the full circuit diagram of the Discriminating continuity and leakage tester, at first sight it seems rather complex. However, depending upon the resistance across the test probes, only the relevant part of the circuit operates, so the workings can be explained section by section.

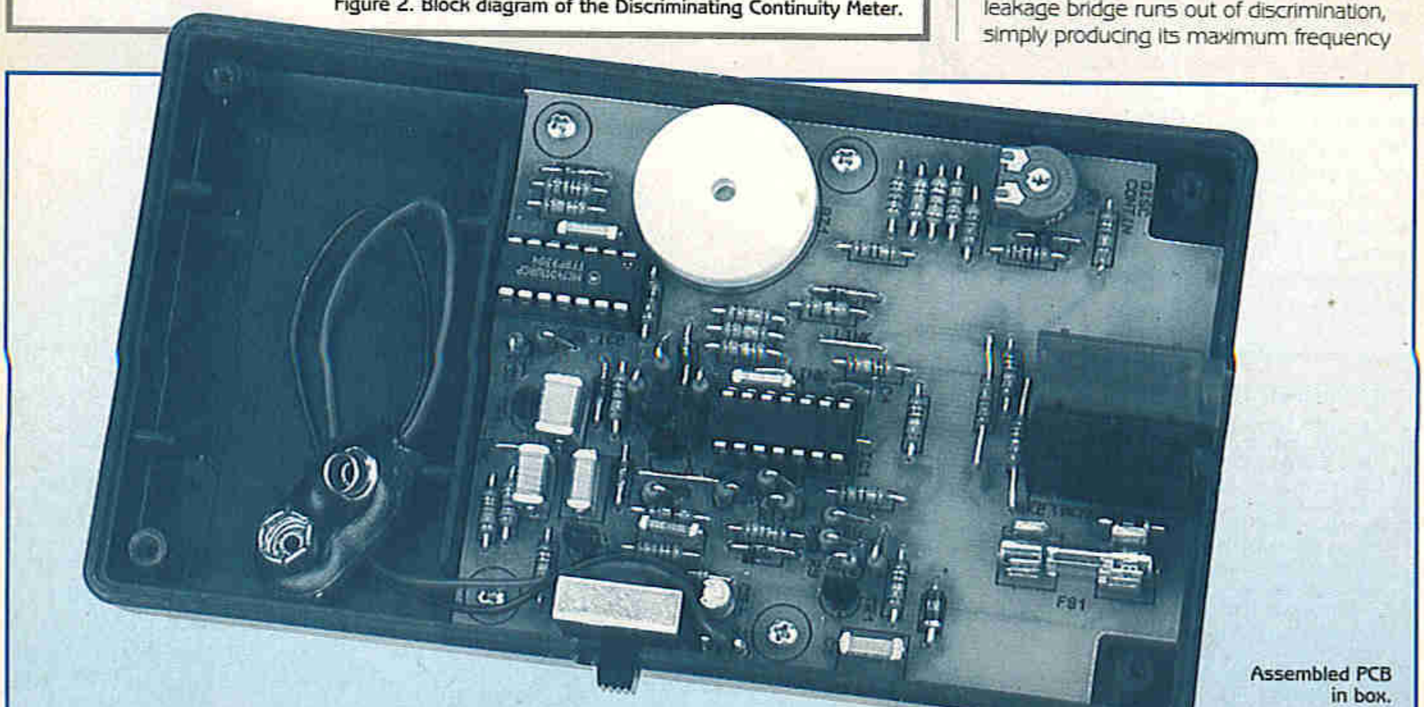
Leakage Measurements

The operation of the leakage detection circuitry, uses a bridge which consists of P, S, Q and R. Where P is 1M (R1), S is 1M (R11), Q is 1·018M which comprises of 1M (R13) plus 18k (R14), and R' (1·33MΩ) which consists of R (330k R4 and 1M R5) in parallel with the resistance across the test terminals. When the test leads are open circuit, the non-inverting (NI) input of IC1B is positive with respect to (WRT) its inverting input and therefore its output is at +9V so that TR1 is off, and the oscillator formed by IC2A and IC2B cannot run (being inhibited via diode D3). Furthermore, via R8 the inverting (I) input of IC1A is positive WRT its NI input, so its output is at 0V, connecting R12 in parallel with Q (R13 plus R14) and depressing the voltage at the NI input slightly.

If the resistance across the test leads falls to about 3MΩ, the voltages at the I and NI inputs of IC1A become equal, and its output voltage begins to rise. Positive feedback via R12 causes it to flip up momentarily to +9V, which charges up C2 via R15 and D5. This causes IC1A output to fall back to 0V, where it remains until C2 discharges sufficiently via R8 for the action to repeat. The result is a series of clicks from the piezo sounder BZ1 which is driven by IC2C and IC2D, the former being enabled on pin 8 since the output from IC1D is at +9V. As the resistance across the test leads falls below 3MΩ, the clicks merge first into a burp – then into a tone which rises higher, reaching a maximum with a resistance of about 50kΩ across the test leads.

The Power-up Bridge

For resistances below about 50kΩ, the leakage bridge runs out of discrimination, simply producing its maximum frequency



Assembled PCB in box.

tone. To measure resistances down in the ohms range, the bridge must be powered up to a much higher current. This permits a measurable (albeit still very small) voltage drop across the unknown resistor. The power-up bridge works as follows: where now P is 2MΩ consisting of 1MΩ (R11) and 1MΩ (R13), Q is 18kΩ (R14), S is 1MΩ (R1) and R is the resistance across the test leads (in parallel with R4 and R5). When R falls to about 9kΩ, the power-up bridge is in balance and the inputs of IC1B are at the same voltage. Its output starts to fall, turning on TR1, which powers up the bridge by supplying about 10mA to the external circuit via R2, F1 and R3. However, this raises the voltage at the NI input of IC1B, which therefore turns TR1 off again, the proportion of the time for which TR1 is on increasing as the resistance across the tests leads falls below 9kΩ. Meanwhile, IC1A is still running, producing the high leakage tone, so the 80mV at IC1B's I input is modulated by the switching action of IC1A via R12 and R13.

When the resistance across the test leads has fallen to a little under 8Ω, the voltage at

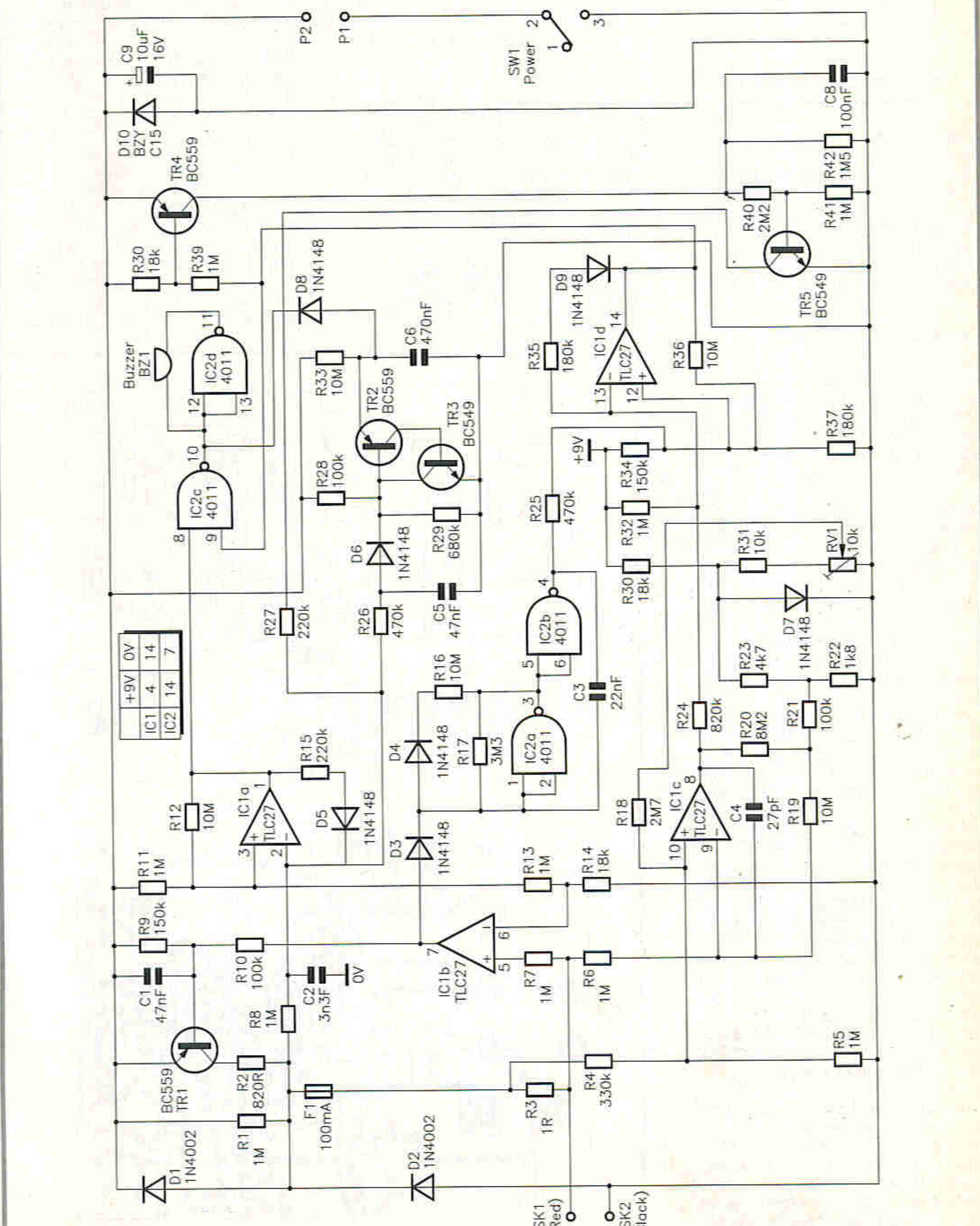


Figure 3. Circuit diagram of the Discriminating Continuity Meter.

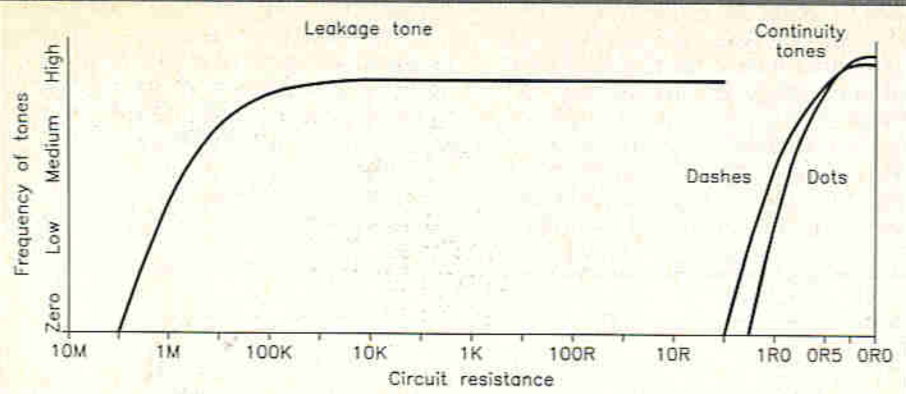


Figure 4. Graph showing frequency of tone versus resistance value.

IC1B's NI input is lower than 80mV, even with TR1 hard on permanently. The power-up bridge now consists of P, Q, S (R2 820Ω) and the external circuit, and it is out of balance such that TR1 is on permanently, since IC1B's output is stuck low. This removes the clamp via D3 from the oscillator IC2A, IC2B, which therefore commences to run.

Continuity Measurements

For values of resistance across the test leads of about 8Ω down to 3Ω, the high leakage tone continues to sound as before. At this point the continuity bridge comes into play, where P is 330kΩ (R4), Q is 1MΩ (R5), S is 1Ω (R3) and R is the resistance under test. IC1C is arranged to amplify the degree of bridge unbalance, since the bridge output is so small: when R = 3Ω the bridge is in balance with the voltage at point Y (the junction between R4 and R5), equal to that at point X (the junction between R3 and R6), whilst when R = 0Ω, point Y is a mere 7·5mV positive WRT X. On the other hand, the corresponding voltage change at IC1C's NI input is 22·5mV, so that the common mode input is much larger than the wanted change in bridge output voltage.

At 3Ω, the continuity bridge approaches balance, so the output of IC1C starts to rise from zero, towards +9V. The gain of IC1C is set at about × 820, the ratio of the effective negative feedback resistor at IC1C's I input to R6 – due to the 'tee' attenuator network, R19/20/21 are equivalent to a single 820MΩ resistor. The output of IC1C is applied to the lower end of one arm of a bridge comprising R24, R32, R34 and R37. When the output of IC1C rises sufficiently, the voltages at the inputs of IC1D approach equality, and it commences to oscillate in exactly the same way as described earlier for IC1A. As soon as IC1D starts to oscillate, its first negative going edge turns on TR4 which in turn charges up C8 and turns on TR5. Via R27, this pulls the I input of IC1A well below its NI input, inhibiting the leakage tone and leaving input A of gate IC2C enabled.

The 3Ω threshold for R at which IC1D commences to oscillate is set up by injecting an offset from RV1 into the NI input of IC1C via R18. To avoid the offset injection interacting with the large common mode input into IC1C, the offset is injected via an auxiliary bridge, where the ratio of R18 to the resistance seen looking into point Y is equal to the ratio of R19 to R6.

The offset injected via the auxiliary bridge is obtained from the bias bridge R22, R23, R31 and RV1, the voltage applied to which is stabilised by D7. Thus all told, the instrument incorporates no less than 'six' bridge circuits!

The Warble Tone Oscillator

With the continuity bridge fully powered up, IC1B output is at 0V, so D3 is reversed biased, allowing the warble tone oscillator IC2A, IC2B to run. This it does at about 4Hz, with an asymmetrical mark/space ratio, since on one half-cycle, C3 is charged via R17, whilst on the other it is discharged via R17 and R16 in parallel. When the resistance under test (RUT) equals 3Ω, IC1D can only oscillate when the output of IC2B is low, pulling down the threshold at IC1D's NI input via R25. Thus the piezo sounder BZ1 emits bursts of a very low frequency tone with short gaps in between. As the value of the RUT falls, the pitch of the interrupted tone rises, C8 keeping TR5 bottomed and hence the leakage tone oscillator IC1A muted during the gaps. When the RUT falls to about 1·5Ω, by which time the pitch of the interrupted tone (the 'dashes') has risen to a middling value, the output voltage of IC1C has reached a point where IC1D can oscillate (at a low-frequency) even when the output of the warble tone oscillator at IC2B is high. Thus there are now middling pitched dashes interspersed with low pitched dots. As the RUT falls below one ohm, the pitch of both dashes and dots rises, the former being the higher, as indicated in Figure 4. As with the leakage tone, so with the continuity tones:

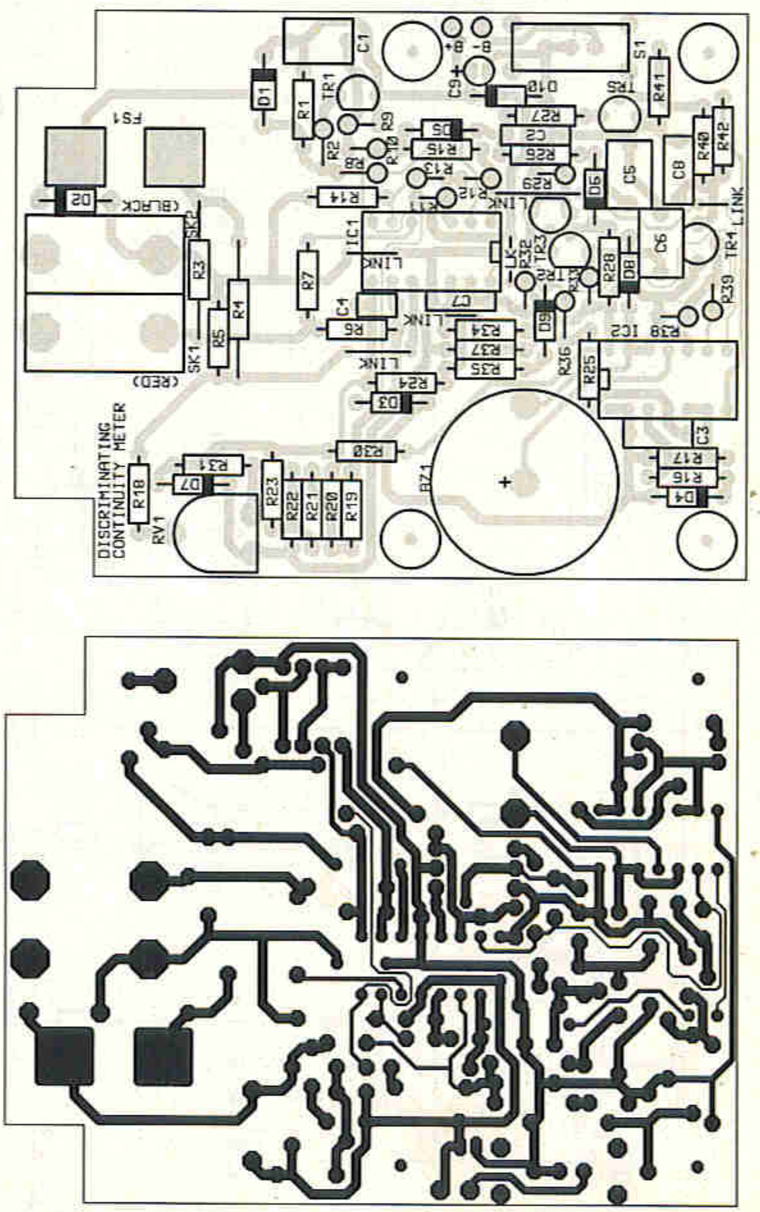


Figure 5. PCB legend and track.

as the RUT falls so their pitch tends to level off at some maximum value. The circuit is so arranged that this happens to the dashes tone first, so that about RUT = 150mΩ (milli ohms) the dots tone catches up, whilst when the RUT equals zero, the dots tone is actually higher than the dashes tone. Thus with practice, the sound the instrument makes will indicate to the user the approximate resistance between the test leads anywhere in the range 0 to 3Ω.

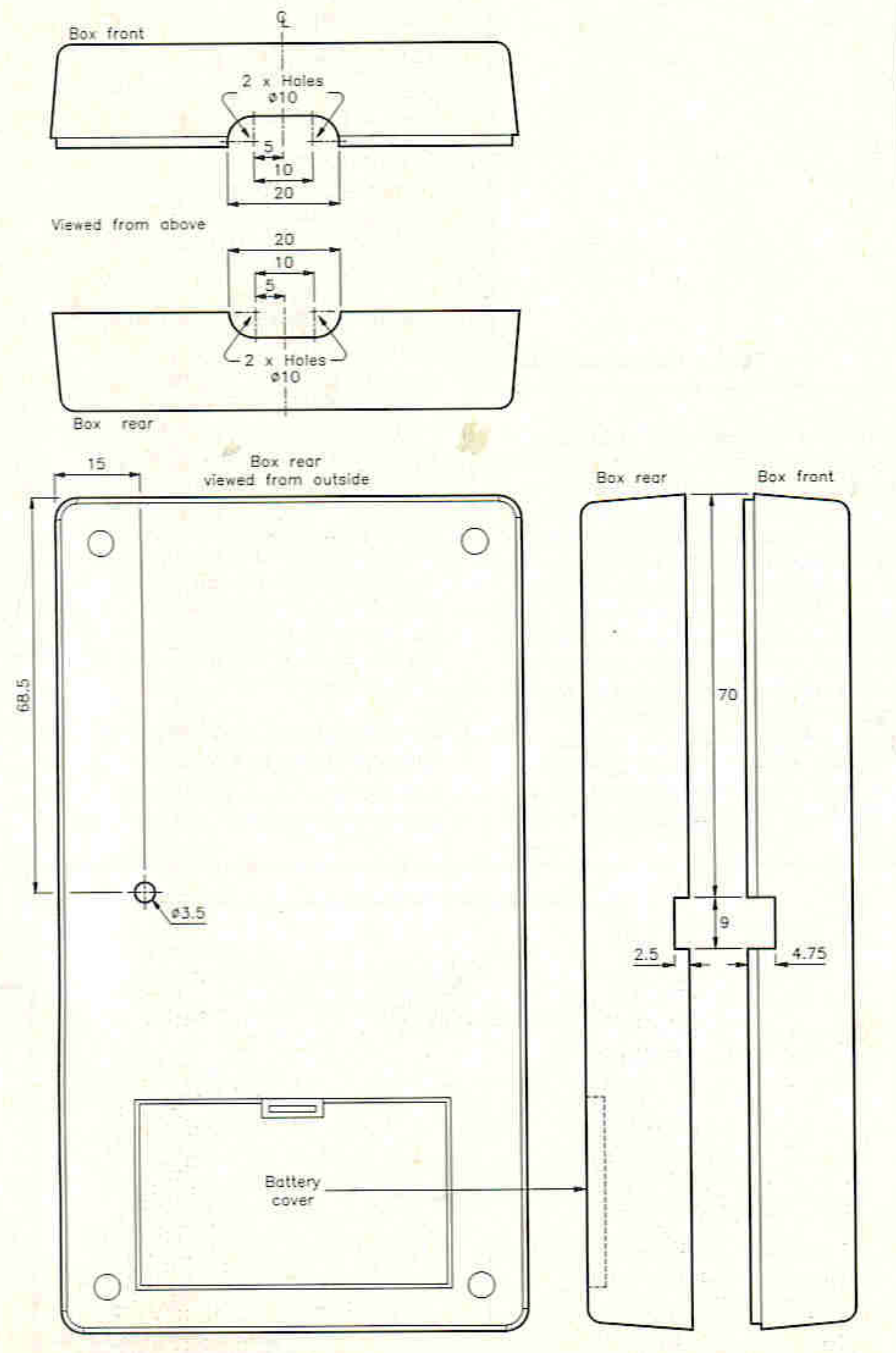
The Watchdog

One problem with battery instruments is that all too often it is found, when they are required for use, that they are inoperative, due to an exhausted battery. Usually, the reason is that they have been inadvertently left switched on. Incorporating a pilot light is hardly a sensible move, due to the current it would draw, but this instrument solves the problem by making use of the piezo sounder to draw attention to itself. If the continuity and leakage tester is left switched on but not in use, it will emit a characteristic chirp tone every twelve seconds or thereabouts. C6 charges up via R33 until the voltage at TR2's emitter exceeds that at its base, whereupon TR2 and TR3 act as a programmable unijunction transistor, momentarily conducting heavily and discharging C6 again. Via D6, C5 is also discharged, effectively grounding the right-hand end of R26. This activates the leakage tone oscillator IC1C, whose pitch falls as C5 charges up again through R26, resulting in a characteristic down-chirp, and alerting the user that the instrument is still switched on. Whenever the instrument is actually in use, indicating either continuity or leakage, C6 is repeatedly discharged via D8, disabling the watchdog chirp both during use and for 12 seconds afterwards.

Protection

The continuity and leakage tester is designed for use on 'dead' circuits, i.e. on circuits which are not powered up. Nevertheless, the instrument is protected against connection to live voltage sources, even AC mains, by virtue of its design. If the voltage at the test leads substantially exceeds +15V, then the fault current through D1 and D10 will blow the 100mA fast acting fuse F1. Similarly, the fuse will be blown by a negative voltage causing fault current via D2. This still leaves the NI input of IC1B and both inputs of IC1C connected to the input, but the series resistors R4, R6 and R7 are so high that the current is limited to a value that can be handled by the device's internal protection circuitry. Thus the instrument will sustain no permanent damage from connection to a live source, though replacement of F1 will be necessary to restore normal operation. Note that when replacing the fuse F1, it is *essential* to use an exact replacement rated for 230V AC mains operation. If a fuse designed for use on low voltage circuits is used, then if the unit is accidentally connected to the mains, the fuse may fail to clear the fault; it will open, but can sustain an arc, resulting in a fault current which must then be cleared by a fuse within the mains circuit itself. This can result in permanent damage to many of the components within the instrument.

Figure 6. Box drilling.



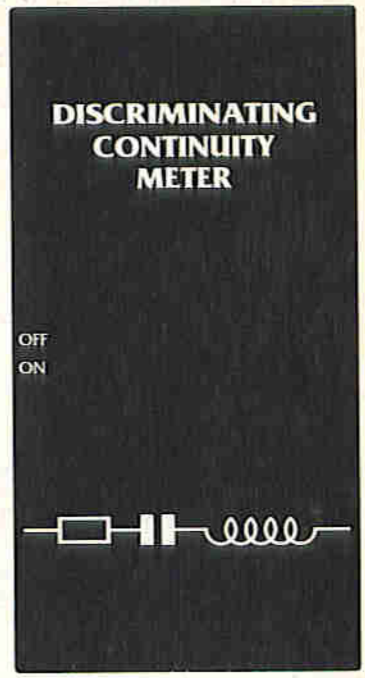


Figure 7. Front panel label, enlarge by 50% to obtain full size.

Construction

The PCB has a printed legend that will assist you when positioning each item, see Figure 5. As all components are mounted on the PCB, construction is straightforward. However, it is essential to make sure that all components are inserted in their correct

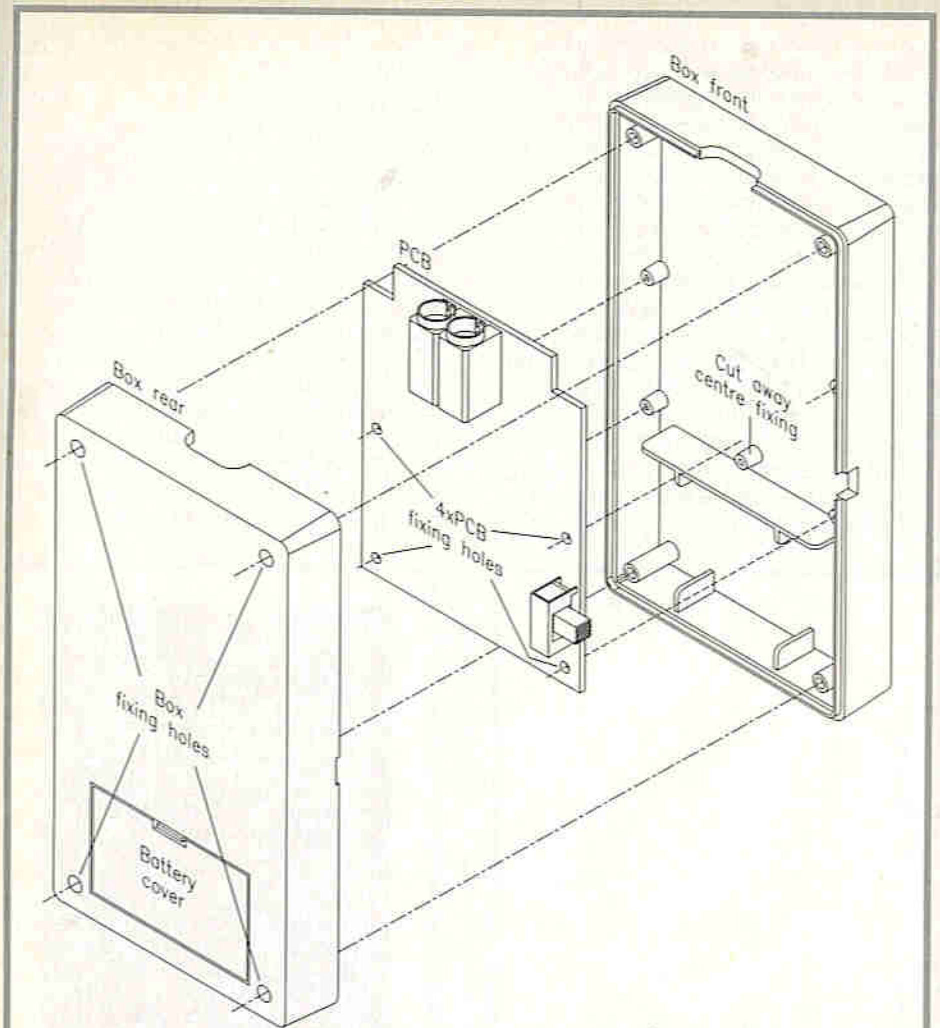


Figure 8. Exploded assembly.

locations and that polarised components such as the various diodes and C9 are fitted the right way round; mistakes can be costly to rectify. Use resistor or diode offcuts for links on the board. The order of fitting the components is not critical, but it is most convenient to mount the smaller components first, and then the IC sockets, do not fit the ICs themselves until assembly of the PCB is complete. The board should be given a final check-over with an eyeglass, looking for solder splashes between tracks, dry joints or other possible problems. When you are sure all is well, fit the ICs into their sockets.

Box Drilling

To complete the project; the drilling details of the case are given in Figure 6.

The front panel label (KP78K), which is included in the kit, is shown in Figure 7.

The exploded assembly details are shown in Figure 8, when complete, offer the unit up to the case.

Testing and Setting Up

There are two sockets red and black, and for most purposes these will be adequate for the two test leads, but an optional ground lead (BZ223A) as shown in Figure 9 can be connected if required.

Potentiometer VR1 should be set initially at mid travel. Fit a new 9V PP3 battery, switch on, and wait. The unit should emit a chirp every 12 seconds or so. Now connect a 3·3Ω resistor across the leads and adjust RV1 so that the high leakage tone is replaced by low dashes, then back RV1 off so that the dashes are just replaced by the high leakage tone. No other adjustments should be necessary, although it will be useful to find out just how high a resistance just causes the leakage tone to sound. This can be determined roughly with the aid of various standard resistor values in the range 1 to 10MΩ. Despite the use of 1% resistors throughout the circuit, some unit to unit variation can be expected, but a low pitched leakage tone should appear at somewhere between 2 and 8MΩ.

The test current is 10mA when the resistance of the circuit under test is 8Ω or less. When the resistance of the circuit under test is over 9kΩ, the test source looks like +4V behind 570kΩ. When the resistance of the circuit under test is between 8Ω and 9kΩ, the average test current is such as to drop 80mV across the circuit under test. Maximum power dissipated in circuit under test is less than 1mW when the resistance of the circuit under test is less than 8Ω and less than 10μW when the resistance of the circuit under test is greater than 9kΩ. With a 100kΩ resistor a high clear tone is emitted, and when the leads are shorted together a characteristic warble tone is emitted.

Using the Continuity and Leakage Tester

NOTE: HCT, MCT, LCT means high, medium or low continuity tone. HLT, MLT, LLT means high, medium or low leakage tone.

Continuity Indication

Warble tone of alternate dots and dashes. Pitch indicates resistance in range 0 to 3Ω approximately.

Leakage Indication

Steady tone. Pitch indicates resistance in range 3Ω to 3MΩ approximately.

On Indication

Momentary chirp tone once every 12 seconds approximately. Inhibited during continuity or leakage tones and for 12 second afterwards.

Simple Continuity and Leakage Tests

Using the test leads, a good connection will produce HCT, similar to the sound with the two leads touching: the dots are higher in pitch than the dashes. If the dots and dashes are of the same pitch, the resistance is in the range 100 to 250mΩ (milli ohms). At higher resistances, the dot pitch is lower or even zero. As the resistance approaches 3Ω, the dash pitch falls to zero and is replaced above 3Ω by the steady HLT. At higher resistances still, this falls, reaching zero at approximately 3MΩ, see Figure 4.

Simultaneous Continuity and Ground Leakage Checks

When testing a multiway cable with overall screen, a backplane in a rack or shelf etc.,

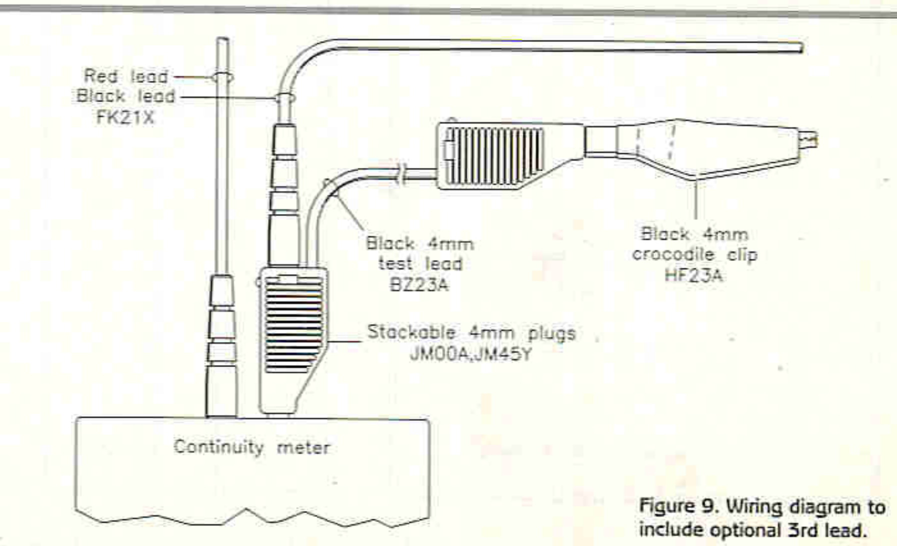


Figure 9. Wiring diagram to include optional 3rd lead.

connect the optional lead to the screen or shelf metalwork. Check continuity of each connection in turn, taking care to connect the red test lead to one end of a run before connecting the black test lead to the other end. Any leakage or short to ground will then be indicated by the leakage or continuity tone respectively. Then complete the test by connecting the black test lead to the other end of the run to check its continuity. Thus continuity checking also accomplishes ground fault checking simultaneously, with no extra time or effort.

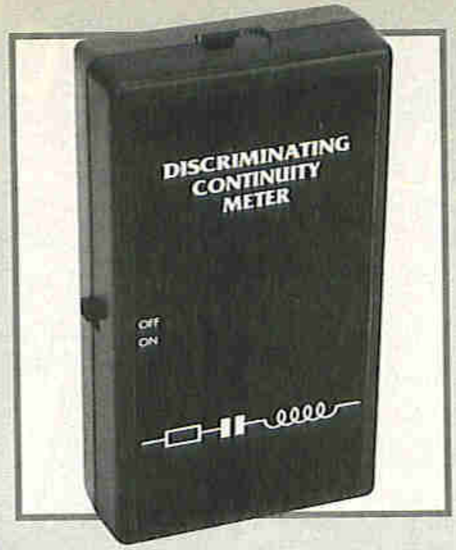
Component Testing

Nearly all components can be checked qualitatively as 'good' or 'bad'. In the case of resistors, the approximate value can often be estimated by reference to Figure 4.

Capacitors. On connecting the test leads across a capacitor, the following effect is produced:-

1nF – click. 10nF – brief chirp. 100nF – pronounced downward chirp. 1µF – chirp lasting about 1·2 seconds. 10µF – leakage tone gradually falling. For tantalum and modern aluminium electrolytics, the tone will fall to zero. Older aluminium electrolytics may 'stick' at LLT.

Discrete semiconductors of all types, diodes, bipolar transistors, FETs, SCRs, Darlingtons, LEDs, Triacs etc, can all be checked. Forward junctions e.g., red test lead to base of an NPN transistor and black to emitter, will result in HLT; black lead to collector likewise. Reversed biased junctions including silicon diodes and most LEDs will result in silence. For germanium diodes, expect silence, LLT or even MLT, according to type and rating. Note that many Darlingtons have a built-in base-emitter resistor, so expect HLT for this junction both ways round. Also expect HLT between collector and emitter one way round due to the Darlington's built-in inverse collector-emitter diode.



Other components. The tester can also be used to check bulbs, loudspeakers, relay coils and contacts, chokes, inductors and transformers (including winding to winding, screen and frame/clamp leakage).

Production Testing

For simplified continuity testing on the production line, warble tone = pass, anything else = fail.

Maintenance

Protect the instrument from damp, do not drop or immerse in liquids. Use only a good quality battery and remove it when exhausted, or as indicated by faint tones.

The internal fuse may blow if the test leads are connected to an AC voltage source, or to a DC voltage source negative WRT ground (GND), or to a positive source in excess of about +15V WRT ground (GND). Before attempting to replace the fuse, disconnect the instrument from any external circuit. Access for fuse replacement is by removing the top half of the case, which is secured by four screws accessible from the rear of the instrument. Use only 100mA F 20mm quick acting fuses to BS4265 or IEC127 standards, e.g., (CZ73Q).

DISCRIMINATING CONTINUITY AND LEAKAGE TESTER PARTS LIST

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

R1,5,6,7,8,11 13,32,39,41	1M	10	(M1M)
R2	820Ω	1	(M820R)
R3	1Ω	1	(M1R)
R4	330k	1	(M330K)
R9,34	150k	2	(M150K)
R10,21,28	100k	3	(M100K)
R12,16,19,33,36	10M	5	(M10M)
R14,30	18k	2	(M18K)
R15,27	220k	2	(M220K)
R17	3M3	1	(3M3)
R18	2M7	1	(M2M7)
R20	8M2	1	(M8M2)
R22	1k8	1	(M1K8)
R23	4k7	1	(M4k7)
R24	820k	1	(M820K)
R25,26,38	470k	3	(M470K)
R29	680k	1	(M680K)
R31	10k	1	(M10K)
R35,37	180k	2	(M180K)
R40	2M2	1	(M2M2)
R42	1M5	1	(M1M5)
RV1	10k Horizontal Enclosed Preset	1	(UH03D)
Test Resistor	3·3Ω	1	(M3R3)

CAPACITORS

C1,5	47nF Polylayer	2	(WW37S)
C2	3n3F Polylayer	1	(WW25C)
C3	22nF Polylayer	1	(WW33L)
C4	27pf Ceramic	1	(WX49D)
C6	470nF Polylayer	1	(WW49D)
C7	6n8F Polylayer	1	(WW27E)
C8	100nF Polylayer	1	(WW41U)
C9	10µF 16V Electrolytic	1	(YY34M)

SEMICONDUCTORS

D1,2	1N4002	2	(QL74R)
D3-9	1N4148	7	(QL80B)
D10	BZY C15	1	(QH18U)
TR1,2,4	BC559	3	(QQ18U)
TR3,5	BC549	2	(QQ15R)
IC1	TLC27L4CN	1	(AR57M)
IC2	HCF4011BEY	1	(QX05F)

MISCELLANEOUS

S1	R/A SPDT Slide Switch	1	(FV01B)
BZ1	PCB Piezo Sounder	1	(JH24B)
SK1	PCB Socket Red (4mm)	1	(JP22Y)
SK2	PCB Socket Black (4mm)	1	(JP20W)
	Single-ended PCB Pin (1mm)	1 Pkt	(FL24B)
	20mm Fuse Clip Type 1	1	(WH49D)
	100mA Fast Acting Fuse	1 Pkt	(CZ73Q)
	Plain HH2 Box	1	(ZB16S)
	Test Leads	1	(FK21X)
	PP3 Battery Clip	1	(HF28F)
	Front Panel Label	1	(KP78K)
	PCB	1	(GJ07H)
	Instruction Leaflet	1	(XV25C)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

	Patch Cord Black (100cm)	1	(BZ23A)
	Crocodile Clip Black (4mm)	1	(HF23A)
	9V PP3 Alkaline Battery	1	(ZB52G)

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 LT78K (Discriminating Continuity and Leakage Tester) Price £19.99

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.

Discriminating Continuity and Leakage Tester PCB **Order As GJ07H Price £3.69**

Discriminating Continuity and Leakage Tester Front Panel Label **Order As KP78K Price £2.29**

F100mA 20mm Quick Acting Fuse (BS4265 IEC127) Packet of 10 **Order As CZ73Q Price £1.70**

AN INTRODUCTION TO PROGRAMMABLE LOGIC

by Tony Williams
(Xilinx UK)

By the middle of the 1970s, TTL (Transistor Transistor Logic) had become the *defacto* standard way of building electronic circuits. A wide range of MSI (Medium Scale Integration) devices were produced to try and keep pace with quickly changing markets, and almost all electronic systems were being designed and built with them. Unfortunately, designing with TTL had a number of shortcomings that couldn't easily be solved. For example, even a small design change would require a large number of cut-and-straps, and possibly even a new PCB (Printed Circuit Board). With modifications in mind, engineers began designing boards with gates (and sometimes whole devices) unused in order to pre-empt the problems associated with hardware revisions. Buyers, trying to control their stock levels, objected to the increasing range of devices being specified by their design departments and projects would invariably slow down as design cycle times increased.

One solution to some of TTL's more onerous problems was to use PROMs (Programmable Read Only Memories) instead of large sections of asynchronous logic. Prior to this, the most common use for PROMs was in the computer industry where they were often used to hold program code or lookup tables. Using PROMs in a general logic design was a novel concept and although it was highly inefficient in terms of silicon, they had several big advantages over TTL. Firstly, a single PROM could replace several TTL ICs making designs smaller and more efficient. Secondly, a design change might only require the designer to alter the contents of a PROM instead of having to redesign or rebuild a section of the PCB. However, like TTL, PROMs had some serious drawbacks: the devices were too expensive and they often contained more functionality than the designer really needed.

Having identified the advantages that programmable logic could offer over TTL, several companies tried to develop new PLD (Programmable Logic Device) architectures that had none of the drawbacks of PROMs yet retained all of the benefits. These new developments fell into two groups: the PLA (Programmable Logic Array) and the PAL (Programmable Array Logic.)

Both structures contained a programmable AND array that generates *product terms* followed by a programmable OR array that generates *sum terms* – see Figure 1. This sum-of-products architecture is extremely flexible because any logic function of a fixed number of inputs can be expressed in this fashion. The PLA/PAL manufacturer also has the option to incorporate other features (such as flip-flops for example) that PROM manufacturers were not about to offer. However, the PLA's fully populated programmable OR array tended to be slower and more expensive than the PAL's sparsely populated equivalent and designers often found that the PAL's cost and speed benefits usually outweighed the slight loss of flexibility. Of all the small PLD architectures, the PAL has proved over the years to be the most popular and continues to replace discrete TTL solutions today.

One of the most successful variations on the PAL theme was the 22V10 device invented by Advanced Micro Devices. The 22V10 differed from ordinary PALs in that it had a varying number of product terms for each output, and a programmable I/O (Input/Output) structure. The programmable I/O meant that although 12 of the device's 22 pins could only be used as inputs, the other 10 pins could be configured as inputs, outputs or as bidirectional signals. Further, these pins could be set up as direct or registered connections and had the option to connect back into the AND-

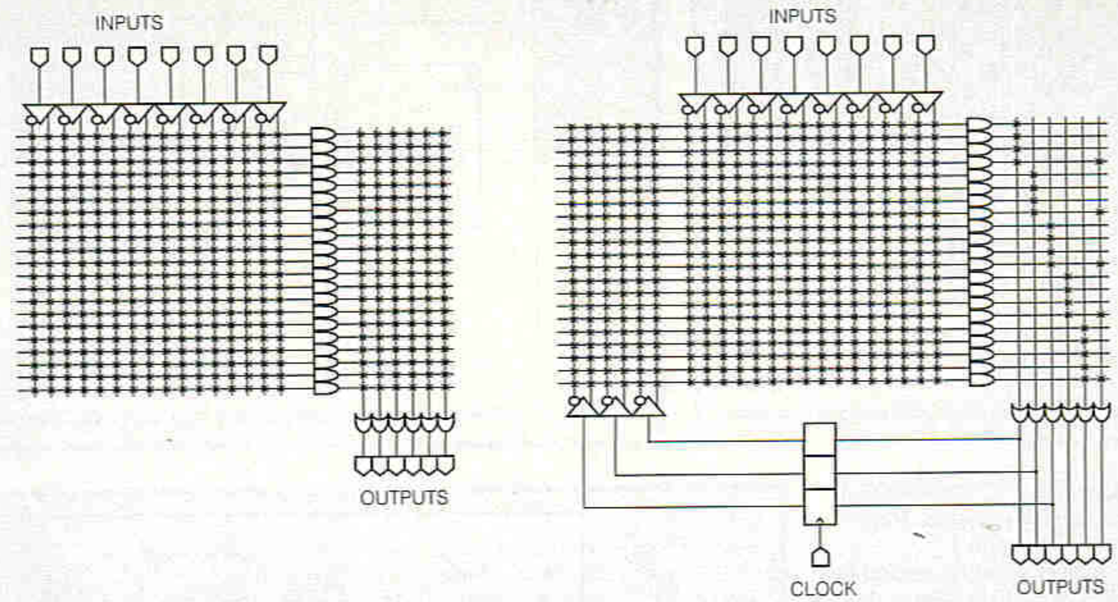


Figure 1. Common configurations found in PLA and PALTM programmable logic devices.

OR array. These features made the 22V10 the most generic logic device so far and companies started using them as their standard device for logic design.

However, despite their flexibility and ease of use, PLDs had two main weaknesses that made them less attractive than other custom logic solutions such as gate-arrays or standard cell devices. Firstly, a PLD could only replace a handful of TTL ICs whereas gate-arrays or standard cell devices could replace hundreds. Secondly, because of their bipolar fuse-link technology, PLDs consumed even more power than the TTL devices that they were supposed to replace.

Various manufacturers tried to address these problems by considering an alternative fabrication method known as CMOS EPROM (Complementary Metal-Oxide-Silicon Erasable PROM) and although these developments resulted in better PLDs, they still offered lower densities and consumed more power than existing gate-array and standard cell solutions.

The main problem facing designers who wanted to use custom logic devices was that they would only become economic as production quantities increased. The initial capital outlay required for the software tools and mask charges (combined with the additional burden of designing extensive test logic) tended to make custom logic solutions somewhat risky. In order to minimise this risk, designers had to spend long periods of time going through the design/simulate/revise cycle in the hope that the flaws in their design could be detected before they committed themselves to massive production runs. The long development times, high development costs and commitment to long-term production agreements tended to make custom logic solutions very unattractive, but there remained little or no choice for those applications requiring a high degree of integration, low power consumption and low to medium quantities.

It wasn't until the mid-1980s that the situation began to change as two new devices appeared that offered some alternatives in the high density programmable/custom logic marketplace. A new company, called Altera, launched its EP range of EPLDs (Erasable PLDs) that combined a PAL-like internal structure with the latest CMOS EPROM technology. The larger EP devices could integrate several PAL and TTL ICs and were often found in power or space sensitive applications where they out-performed the existing PAL/TTL solution. The Altera software also broke new ground in that it permitted the designer to use both the time-honoured text-based PAL programming language PALASM (PAL Assembler) and the very latest CAD (Computer Aided Design) tools such as schematic capture packages. This combination of technology and ease-of-use made Altera's EPLDs very successful and other companies have mimicked their architecture in their own programmable logic products.

The other device that appeared at roughly the same time was the FPGA (Field Programmable Gate Array.) These new devices applied CMOS SRAM (Static Random Access Memory) technology, widely used in the microprocessor market, to the programmable logic market and used a new type of architecture that more closely resembled gate-arrays than PLDs. This new approach yielded logic densities that were much higher than those available using PLDs and EPLDs but still weren't quite as high as those associated with custom logic. However, FPGAs could be manufactured using a relatively inexpensive standard CMOS process and offered markedly lower power consumption than both PLDs/EPLDs and custom logic devices. Today Xilinx Incorporated, the inventor of the FPGA concept, has three families of FPGAs and one family of EPLDs and has remained the FPGA market leader ever since it was founded in 1984.

Figure 2 shows how the various types of custom/programmable logic devices fit into the production marketplace. Although PLDs can be obtained cheaply in almost any quantity, they cannot be used in applications that require a high degree of integration. The exact reverse can be said of gate-arrays and standard cell solutions – for example these devices can only be obtained cheaply in large quantities and are only economic in designs that require large gate-counts. It can be seen then that FPGAs and EPLDs fit nicely into the remaining gap and offer the designer the opportunity to combine high levels of integration with low-to-medium production volumes.

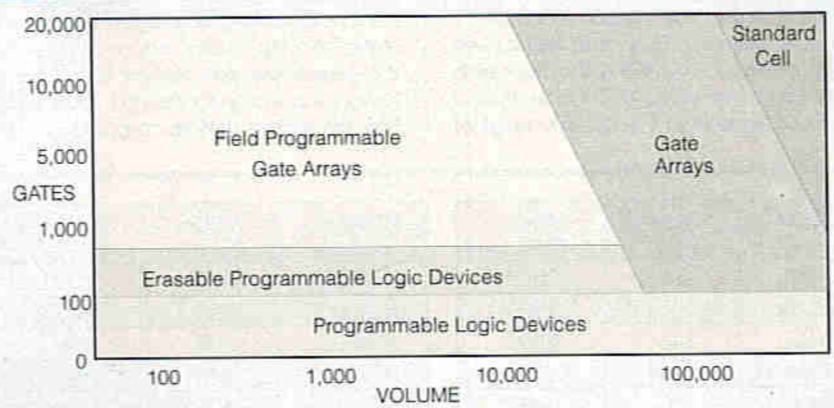


Figure 2. A comparison of the custom/programmable logic alternatives.

Xilinx Field Programmable Gate Arrays

All Xilinx FPGAs are based on an architecture known as the Logic Cell Array™ (LCA) which is a similar structure to that found in most gate-array products. An interior matrix of Configurable Logic Blocks (CLBs) is sur-

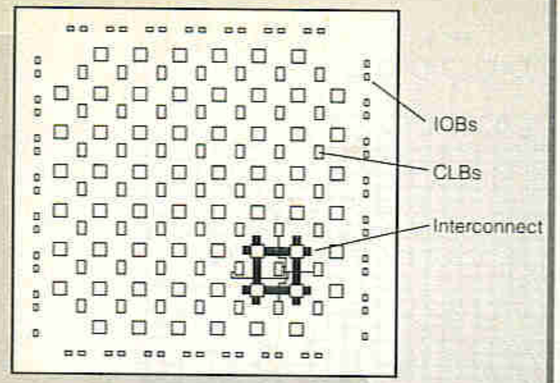


Figure 3. Xilinx's proprietary Logic Cell Array architecture.

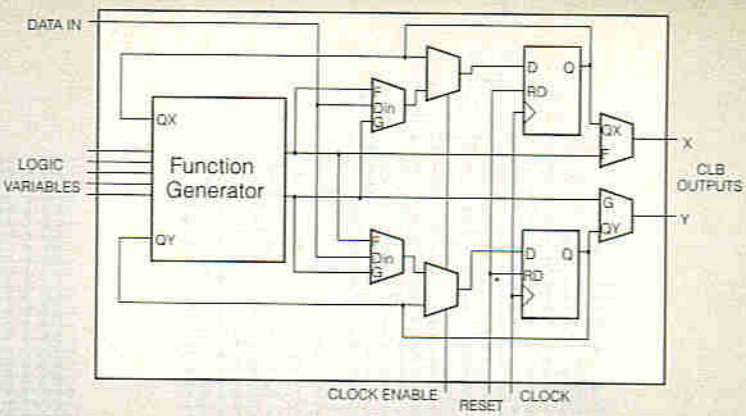


Figure 4. The internal layout of a configurable logic block (XC3000 family).

rounded by an outer ring of I/O Blocks (IOBs) and the space in between is occupied by interconnect resources – see Figure 3.

Each CLB is capable of implementing a small amount of logic and contains a programmable function generator and either one or two D-type flip-flops. Figure 4 shows how the CLB is arranged internally. Each IOB is attached to an external package pin and can be programmed independently to be a registered, latched or direct input, output (with 3-state control) or bidirectional signal. Figure 5 shows the internal arrangement of an IOB. The interconnect consists of a network of metal tracks that run horizontally and vertically in the rows and columns between the CLBs and IOBs. Programmable switches allow connections to be made to the interconnect, and cross-point switches at row, and column intersections allow signals to be switched from one path to another. Long lines run the length and breadth of the chip, bypassing the interchanges, to provide distribution of delay or skew critical signals. Finally, each CLB has a dedicated set of short metal tracks that allow it to pass signals to adjacent CLBs and IOBs with minimum delay – see Figure 6.

Xilinx supply the designer with a set of software tools that are capable of taking a design (entered at a desktop PC or workstation) and translating it into the configuration information required to program the FPGA. This ADI (Automated Design Implementation) software performs three main functions. First, the design is split-up into sections that are small enough to fit into individual CLBs – a process called *partitioning*. Second, the best possible location for each CLB is chosen in order to make inter-CLB connections as short and as fast as possible, *placement*. Finally, the software will make all of the required interconnections by *routing* the design.

Xilinx have three families of FPGAs that offer the designer the degree of integration applicable to his design. Of the three groups the XC2000 family is the simplest and contains two members – the XC2064 and the XC2018. XC2000 family CLBs are simpler than that shown in Figure 4 as they only contain one flip-flop and have a single function generator capable of taking up to four inputs. The XC3000 family contains five members and are the most widely used FPGAs in the electronics industry. (Note that Xilinx have recently introduced the XC3100 family which is an enhancement of the XC3000 family and contains six members.) The XC4000 range of FPGAs contains fourteen members and offers higher levels of integration than the 2K and 3K families.

The XC4000 devices contain both user programmable logic *and* dedicated logic functions (such as fast carry logic, wide decoders, static RAM etc.) which reduce the burden on the general-purpose resources and result in faster, more compact designs. Table 1 shows how the various devices compare.

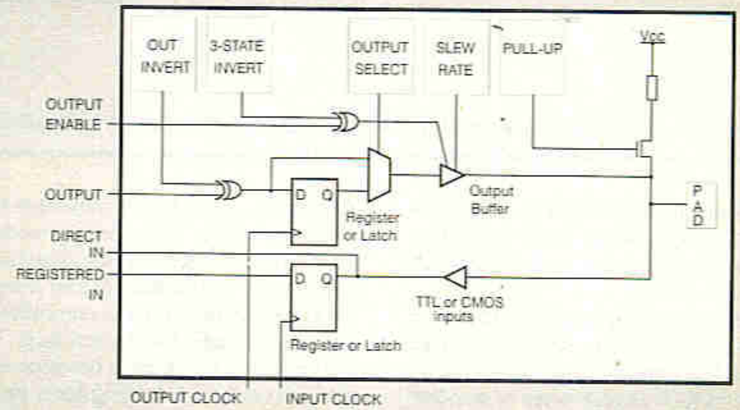


Figure 5. The internal layout of an I/O block (XC3000).

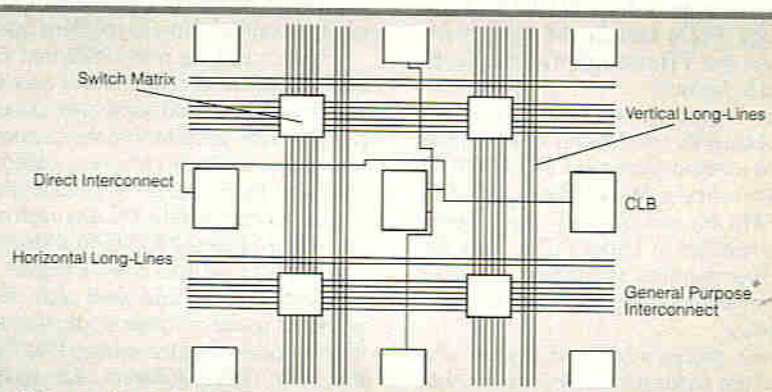


Figure 6. A sample of Xilinx FPGA routing services.

XC2000 series	CLBs	(Max.) Gates
XC2064	64	1200
XC2018	100	1800

XC3000 series	CLBs	(Max.) Gates
XC3020	64	2000
XC3020	100	3000
XC3042	144	4200
XC3064	224	6400
XC3090	320	9000

XC4000 series	CLBs	(Usable) Gates*
XC4003	100	3000
XC4005	196	5000
XC4008	324	8000
XC4010	400	10000
XC4013	576	13000

Table 1. A comparison of the three families of Xilinx FPGAs. (* Note: Conservative figures only.)

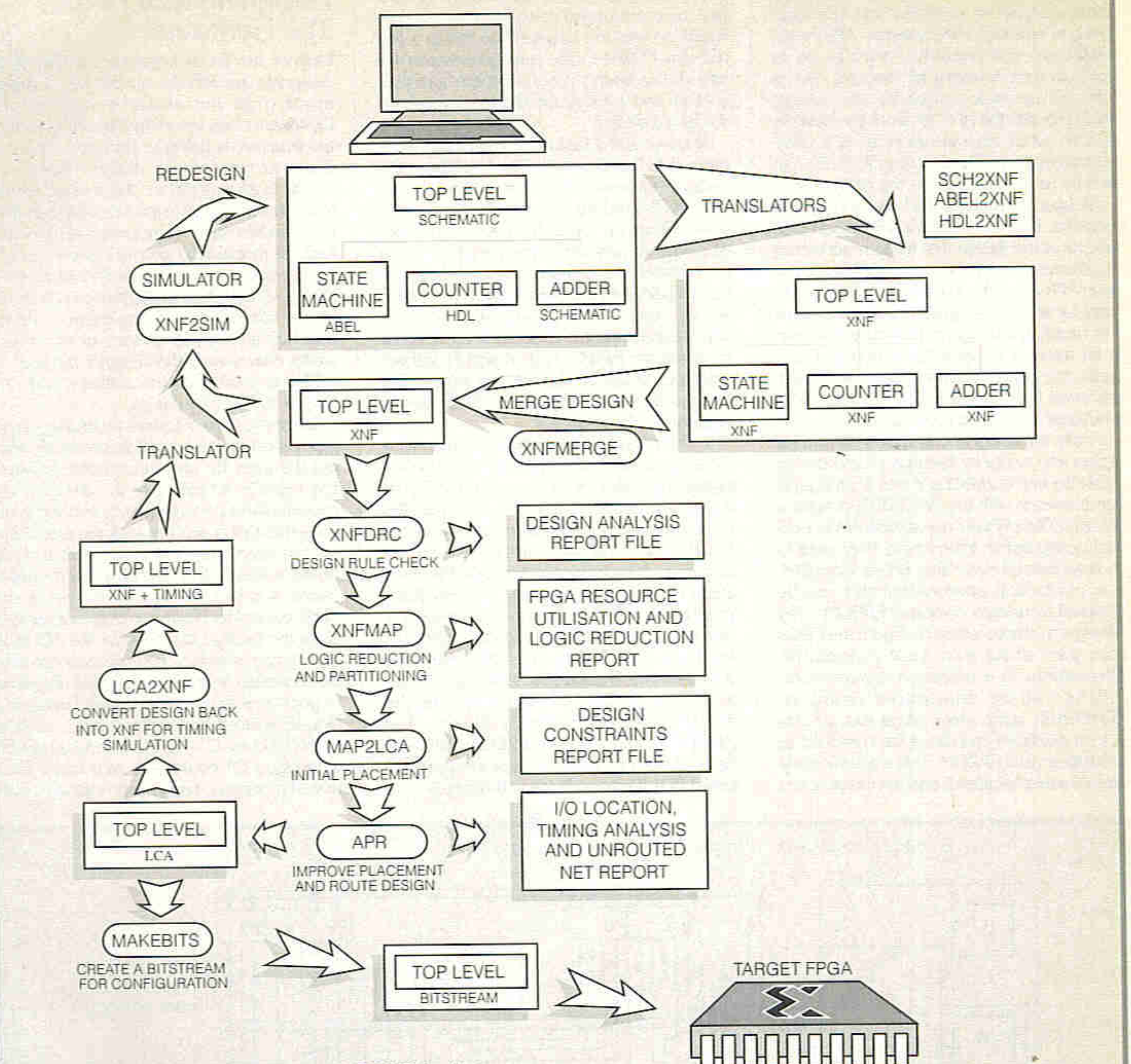


Figure 7. The Xilinx design flow (XC2000 and XC3000 families).

Designing with Xilinx FPGAs – The Software

The Xilinx software is intended for use with one or more third party design entry tools, such as schematic capture packages, simulators or HDLs (Hardware Description Languages). Most designs will contain sections that have been entered using different tools, and the first stage in the Xilinx design flow is to merge these elements together into a single common format called Xilinx Net-list Format (XNF). To achieve this, Xilinx sell a wide range of translators that convert a third party's own net-list format into XNF for processing by the Xilinx development tools. This approach allows designers to continue using familiar tools, removing the need to learn about other CAD-packages. Figure 7 shows the various processes that are applied to a design once the designer invokes the Xilinx ADI tools.

Since most designs are divided into sections, and not all sections are produced with the same design-entry tool, the appropriate translator must be applied to each section to produce a corresponding XNF file. These XNF files are then *merged* using a program called XNFMERGE to produce a single XNF file that describes the whole design. At this stage the XNF file can be used as the basis of a functional (or unit-delay) simulation, and the appropriate translator should be used to convert the XNF file into a format understood by the simulator. Simulation at this point is vital because this is usually the first time that all of the elements in the design have been brought together. Typically a designer will have to go around the 'simulate and redesign' loop several times before his design will meet its functional specification.

Once the design has been verified at the functional level a program called XNFDRC (DRC = Design Rule Check) tries to identify any elements of the design which may cause problems later in the process. These problems are reported to the designer who should make the indicated changes to his design.

A program called XNFMAP then *partitions* the design by redescribing it in terms of CLBs/IOBs and performs a logic reduction stage that removes any unused or redundant logic. This process generates a report file that describes where logic has been removed and how many of the FPGA's CLBs and IOBs have been used. (It's usually at this point that the designer finds out whether his design will fit into the intended FPGA.) The design is then *placed* by MAP2LCA, which tentatively allocates the design's CLBs and IOBs to resources on the FPGA. This program also creates a '*constraints file*', which holds the user's design constraints (such as locked I/O pins or CLB locations) for use in the next stage in the process.

The bulk of the work is carried out by a program called APR (Automatic Place and Route) which uses a complex optimisation algorithm called 'Simulated Annealing' to allocate the best possible location for every IOB and CLB – a task of daunting complexity due to the sheer volume of possible permutations. A good *placement* is one where the inter-CLB/IOB connections are the shortest (and therefore the fastest) and makes the job of routing the design very much easier. The *routing* phase aims to find the best possible set of links between CLBs and IOBs and results in a finished design in the guise of an LCA file.

Once a design has been routed it's then up to the designer to verify that the additional timing information introduced by APR hasn't created any new problems – such as set up and hold time violations for example. This is achieved by *back-annotating* the design, which rebuilds the XNF file from the design's LCA file (which now incorporates APR's timing information). The resulting XNF file can then be used to resimulate the design using a third-party simulator and the appropriate translator. Further simulation will reveal those aspects of the design that fail to meet timing requirements and the designer can either rerun APR – in order to achieve a better placement by altering parameters and constraints – or modify the design at the schematic level in an attempt to solve the problem. Once again, the designer can remain in the simulate/revise loop until the design meets both functional and timing specifications.

Finally, the designer can choose to turn his design into reality by taking a routed design (LCA) file and converting it into a *configuration bitstream* with the MAKEBITS program. Since all Xilinx FPGAs use static-RAM to hold their configuration information, they need to be reconfigured every time power is applied. In a production environment this can be achieved by using a dedicated EPROM or by having a microprocessor configure the FPGA as a part of its own boot procedure. Alternatively, in a prototype environment, FPGAs can be configured using an XCHECKER cable which plugs into a computer's serial port and allows the computer to simulate a serial EPROM. This is a particularly useful feature because it enables the designer to modify a design (at the schematic level say), reprocess it and download the new configuration into the target FPGA within a few minutes. FPGAs can be reprogrammed in this way without having to remove them from their sockets and without needing to power-down the target system.

Another useful feature of the XCHECKER cable is its *'readback'* facility. This allows the designer (or a microprocessor) to read back the FPGA's configuration data for verification. It also allows the designer to take a snapshot of all the signals within the FPGA and read them back into a computer for further simulation and debugging sessions. The XCHECKER software uses this facility to produce a logic-analyser-like display, which enables the designer to probe the FPGA's internal signals without having to design-in complex test logic. (Note that readback can be disabled should design security ever be an issue.)

It should also be pointed-out that Xilinx have a program called XMAKE which completely automates the process shown in Figure 7. XMAKE examines the design and applies the appropriate translators, merges the resulting XNF files and then executes the correct sequence of programs to produce a finished bitstream. XMAKE is usually the only Xilinx program that the designer has to be familiar with when processing a design from its highest level. (Note that the only difference between the XC2000/XC3000 family design flow (shown in Figure 7) and the XC4000/XC3000A family flow is that XNFDRC, XNFMAP, MAP2LCA and APR have all been merged into a single program called PPR (Partition Place and Route.))

Designing with FPGAs – The Hardware

One of the most important issues when designing for FPGAs is how well a design maps onto the device's architecture. Designers often ignore that the FPGA's internal structure is going to form the most fundamental layer of their design – that is, the actual implementation. Automated design tools are an attempt to insulate designers from such architectural complexities and include features that aim to identify those areas of a design that might cause problems in a real device. Of course, the designer can choose to ignore this advice and implement a design that has little or no chance of working in reality. Alternatively, the designer can use this facility to work with the software and produce a high quality design.

Given the state of today's technology, most designs can be processed automatically without the need for user intervention, however, the Xilinx ADI tools give the designer the opportunity to become heavily involved in the implementation process – to the extent that he can even specify the path that a signal takes through the device's interconnect matrix. It is rare that a designer should ever need to consider his design at such a low-level since the facility exists to steer the ADI tools at a much higher level – the process can even be controlled from the schematic diagrams. (A good analogy is the relationship between a high-level programming language – such as FORTRAN or C – and low-level assembly language.) Of course, as with most automated processes, anyone who interferes with-

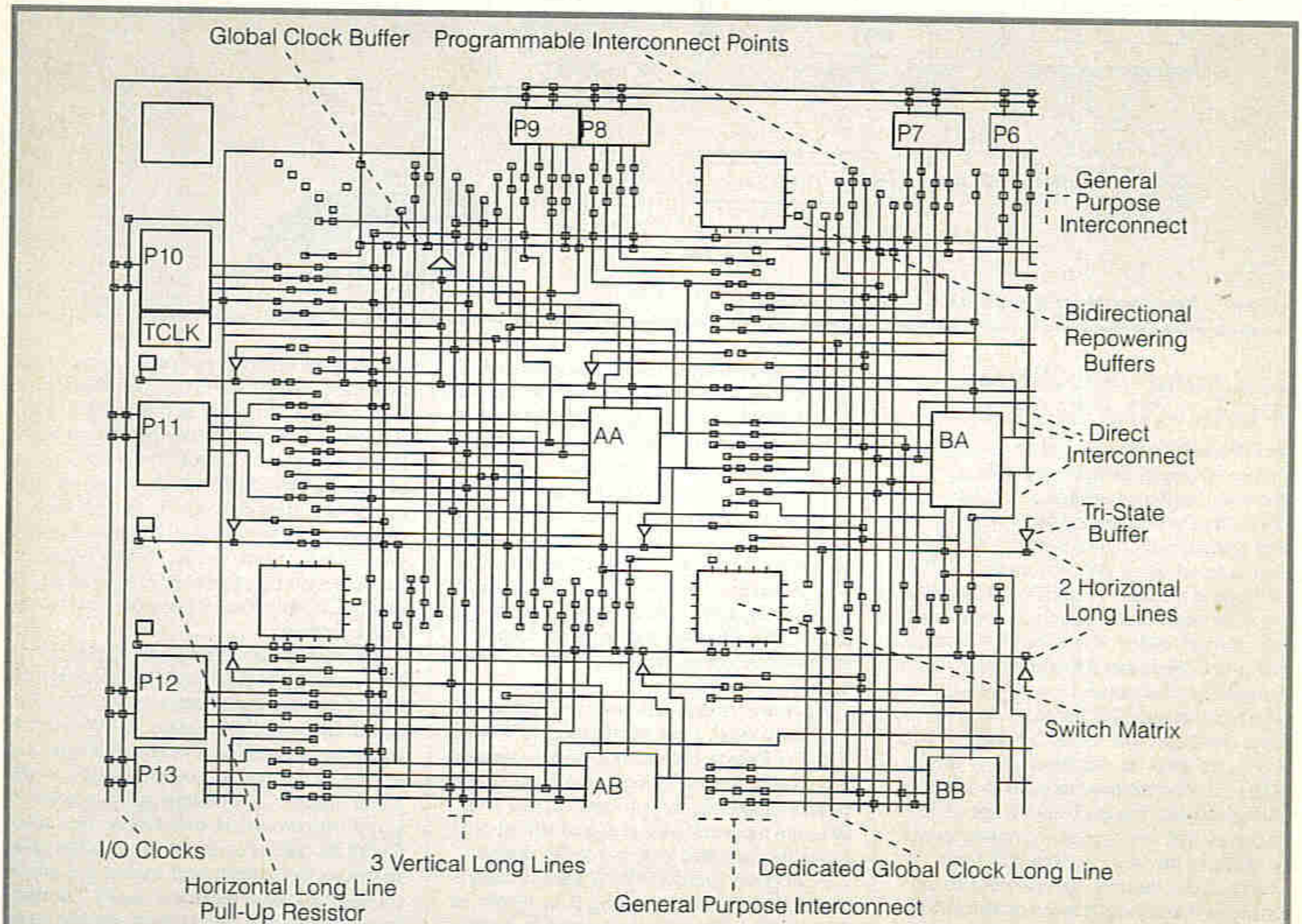


Figure 8. XC3000 internal architecture, as depicted by the Xilinx Design Editor (XDE).

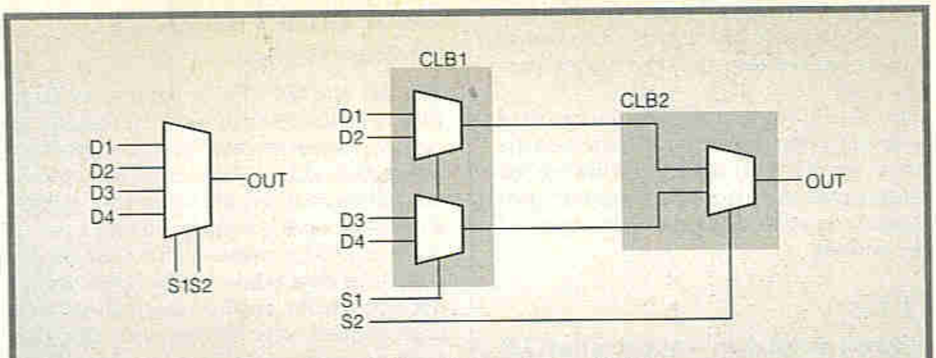


Figure 9. XC3000 implementation of 4-input-to-1-output multiplexer.

out fully understanding what he is doing can do more harm than good. The best way to achieve a good result is to design with the FPGA's architecture firmly in mind and the only way to achieve ultimate performance is to monitor and control every step of the implementation process.

It is beyond the scope of this article to discuss every facet of the Xilinx FPGA architecture (the Logic Cell Array (LCA)) but further information on the subject can be found in *The Programmable Gate Array Data Book* issued annually by Xilinx Incorporated.

The most fundamental components of any design are those found on the FPGA itself. These features include IOBs, CLBs, routing resources and other dedicated functions that are specific to a family of devices. The remainder of this section discusses some of the points that designers should consider when targeting a design for Xilinx FPGAs. References are made to the internal structure of the IOBs and CLBs found in all families and readers are directed to *The Programmable Gate Array Data Book* mentioned above, or to Figures 4 and 5, which describe the XC3000 family CLB and IOB. Figure 8 depicts the internal structure of a XC3000 family FPGA as shown by the Xilinx Design Editor (XDE). XDE allows the designer to edit his design in terms of the lowest level possible – namely, at the actual silicon. XDE is somewhat akin to programming in assembly language and would only be used to 'tweak' problematic designs, or as a last-resort method of improving on the ADI tools' placement/routing results.

Routing Resources

Figure 8 shows a magnified view of the routing resources that are available within XC3000 series FPGAs. The various types of interconnect are discussed below.

Direct Interconnect

All families have a set of short metal tracks that originate at a CLB's outputs and connect directly to adjacent CLB's inputs. These tracks are the fastest means of getting signals to nearby CLBs (<0·5ns). These connections are typically used for arithmetic carry propagation or as fast paths to IOBs.

General-purpose Interconnect

All families have a network of segmented metal tracks that span the entire surface of the LCA in a regular grid consisting of four (2K), five (3K) or eight (4K) individual tracks. Switch matrices located at intersections allow signals to be connected from one track to another and Programmable Interconnect Points (PIPs) allow connections to be made to CLB/IOB inputs and outputs.

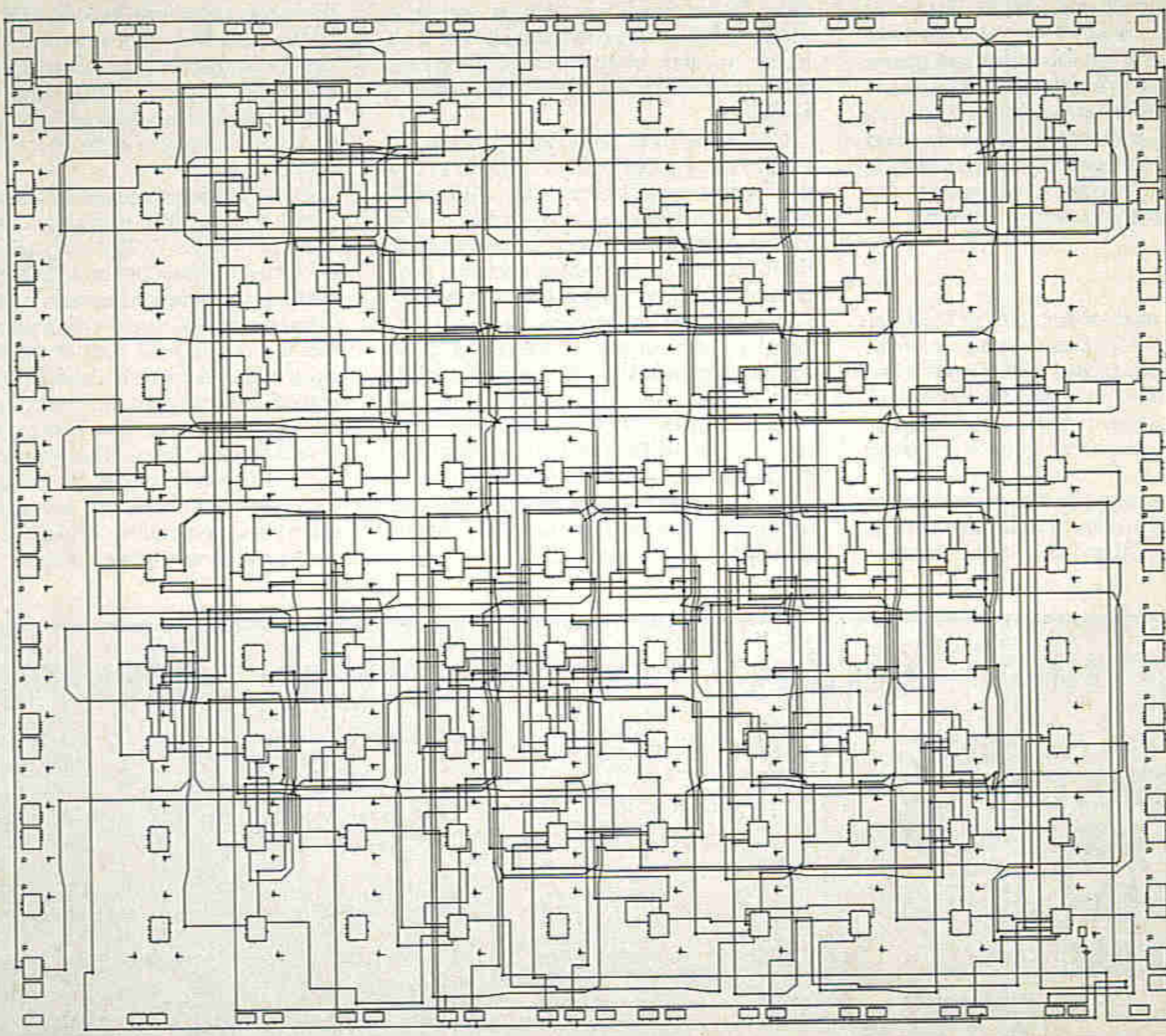


Figure 10. A printout from XDE, which shows how a design has been implemented within a XC3020.

Long Lines

All families have a set of long lines, long metal tracks that run horizontally and vertically across the entire LCA and distribute high fan-out, skew-critical signals. Typically, long lines are used for clocks, enables, resets, etc. Long lines are the fastest way to get a signal from a single source to many loads.

Clock Buffers

All families have a set of global clock buffers that use a dedicated set of long-lines to distribute any signal (typically a clock) around the whole device with minimal delay and skew. The 2K and 3K families have two global clock buffers and the 4K family has eight.

Bidirectional Repowering Buffers (BIDIs)

Signals that are widely distributed via the general-purpose interconnect can make use of bidirectional repowering buffers which add extra drive capability to high fan-out signals. It is not possible for the designer to specify (at the schematic level) where BIDIs should be used. That decision is left up to the automatic routing tools, which allocate BIDIs on a priority basis – that is highest fan-out signals first.

One of the most important routing-related factors is the speed with which the interconnect works. Even in 'slow' designs, signals will propagate through the routing network incredibly fast. Designers must be very careful to ensure that any asynchronous elements in their designs will not generate glitches or spikes because unlike TTL or discrete logic designs, there is very little track inductance and capacitance to swallow them up. Glitches become well-defined pulses that can cause unexpected clock transitions in even the slowest of systems. Xilinx advise that designs should be as synchronous as possible, and only to gate clock signals when absolutely necessary.

IOBs

IOBs contain input and output flip-flops that can be used for various functions such as pipe-lining, resynchronising I/O signals or as general purpose I/O registers. Making use of these flip-flops can remove a considerable burden from the other general-purpose resources.

The designer also has the ability to select whether an IOB's output buffer has a normal or fast slew rate (3K and 4K devices). Fast slew rate outputs are typically used to supply high-frequency signals or outputs that need to arrive at external devices in the shortest possible time.

It is often the case that FPGAs are mounted in packages that have fewer I/O pins than the device has IOBs. These extra IOBs are left unconnected and are available to the designer should he need to make use of the logic that they contain.

CLBs

Designers should always remember that CLB function generators have a limited number of inputs (2K = 4, 3K = 5, 4K = 9) and when a function requires more than this it will have to be allocated to several CLBs. The outputs of these CLBs must then be recombined (using another level of logic) to produce the desired result. Although there is nothing logically wrong with this procedure, additional levels of logic introduce extra delays that can have a serious impact on system clock rates. For example, a 4-input-to-1-output multiplexer requires 6 inputs (4 data and 2 data-select) and so cannot be directly implemented within a single 3K CLB. Figure 9 shows how such a function might be implemented. Designers for whom speed is an issue should be particularly aware of issues such as these.

It has already been mentioned that using direct interconnect is the fastest means of getting CLB outputs to adjacent CLB inputs. However, the fastest way to get a 3K CLB's outputs back to its own inputs is to use the feedback connections that exist within the CLB. These connections can be used in a variety of ways and allow functions like 2-bit binary counters, bi-directional shift-registers and LFSRs, etc. to be implemented within a single CLB.

One of the most novel aspects of the 4K CLB is that the designer can choose to use the function generators as a 16 × 2-bit or 32 × 1-bit static RAM memory block. The reason for this is that function generators are simply RAM-based lookup tables that are programmed (during configuration) with the correct bit-pattern to simulate combinatorial logic. A good example of the use of these memory blocks is in a microprocessor interface where sixteen 8-bit registers can be implemented in only four CLBs. Note that both 3K and 4K CLBs contain two flip-flops that share common clock, clock enable and reset/set signals, therefore flip-flops that use separate signals for these functions cannot be mapped into the same CLB.

Dedicated Functions

Tri-State Buffers

The 3K and 4K FPGAs contain Tri-State Buffers (TBUFs) which allow the designer to perform various tri-state related functions that would otherwise be impossible or impractical. TBUFs drive only the horizontal long lines and each long line is equipped with a pair of optional pull-up resistors. For example, bi-directional data buses (of the type found in microprocessor applications) can only be implemented with TBUFs. Also, functions such as wide-multiplexers or wired-ANDs (which don't easily map into CLBs and IOBs) can be implemented using TBUFs and the optional pull-up resistors.

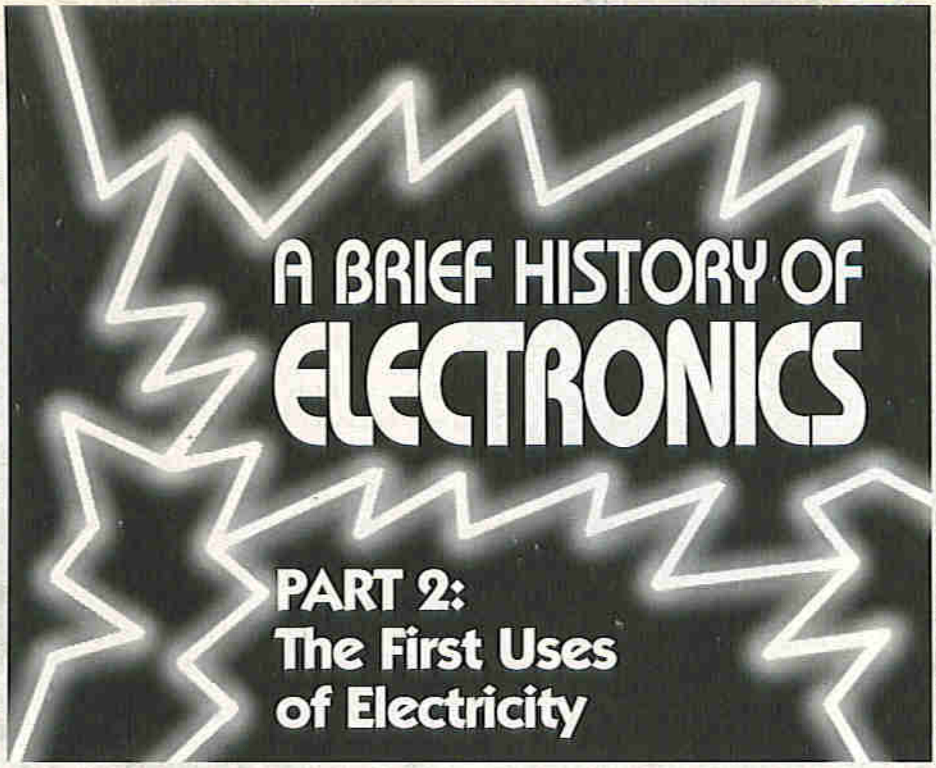
Fast Wide Decoders

One criticism of the 2K and 3K families is that their CLBs are very inefficient at implementing functions with many inputs (such as address decoding). The multiple levels of logic required to implement these functions use-up large numbers of CLBs and make designs slower. For this reason 4K devices come equipped with wide decoders that are capable of decoding a particular bit-pattern on their 60 (maximum) inputs. Up to 32 decoders sit around the periphery of 4K devices and they have their own set of dedicated long lines.

Fast Carry Logic

4K CLBs can generate the arithmetic-carry output for incoming operands, and can pass this extra output onto the next CLB above or below. (Note that this connection is independent of normal routing resources.) The addition of fast carry logic is one of the 4K's most important features, significantly increasing the speed and density of arithmetic and counter applications.

Figure 10 shows a design that has been targeted at a XC3020 using the design flow shown in Figure 7. This diagram was produced by the Xilinx Design Editor and shows exactly how the design has been implemented within the FPGA. Closer examination reveals that the design uses both of the XC3020's clock buffers (located in opposite corners), a combination of long lines, direct connections and general purpose interconnects and even several tri-state buffers. This diagram should impress upon the reader the complexity of the operations involved in finding the optimum placement/routing required to give the fastest and most efficient results. E



A BRIEF HISTORY OF ELECTRONICS

PART 2: The First Uses of Electricity

by Ian Poole

FOR many years very few uses were found for the new discovery of electricity. It was Oersted's discovery of electromagnetism, more than any other for electricity being used for the benefit of mankind.

Until Oersted discovered the linking of electric currents and magnetism, there had been few ways of detecting currents. Leyden jars had been used to detect static electricity, and some chemical effects of dynamic electricity had been noticed. With electromagnetism, it was much easier to detect electricity, and this resulted in people investigating many uses for this new science.

First Uses

It was in the field of communications that electricity found some of its first uses. By simply connecting a number of wires between some form of transmitter and receiver and turning the currents on and off it was possible to send messages. The use of electrical forms of communication offered great possibilities, at the beginning of the nineteenth century communications were slow and often difficult. A system of semaphore towers was often used where messages might have to be passed over a known route. There was even a system where bonfires were set up along the English south coast to warn of an invasion by Napoleon. However, the most reliable method, of sending a message, was for it to be written on paper and sent by a horse rider or carrier pigeon. This was quite slow, especially when large distances had to be covered.

With the discovery of electricity a wide variety of systems were invented. Some pioneers managed to devise very ingenious systems even though they only had limited resources and knowledge. Although rather crude by today's standards these ideas were at the forefront of technology, in their time.

One of the earliest recorded ideas dates back to the mid-1750s. A proposal appeared for a system based around the transfer of electrostatic charges. The charge from a friction generator was transferred to one of a number of wires. This was carried along a wire to the remote end, where the charge attracted a small letter towards it, by successively sending a charge down different wires it was possible to make up a message.

In later years, after the invention of the battery, several ideas were put forward for the use of electrochemical effects as means of displaying when a current was flowing. In turn this could be used to indicate the message in some way or another. However, all these methods proved to be rather unworkable to give a permanent and usable system.

A further problem was that wire was not easy to manufacture; in turn this meant that it was very expensive. This alone meant that most of the multi-wire systems were not economical even from the start. Even when the wires had been manufactured they had to have insulation placed around them, and if possible they were bunched together in the form of a cable. Much of this was achieved with the use of pitch, but as the methods of manufacture were not well established it was a very time consuming job.

Sir Charles Wheatstone.
©Science Museum Photo Library.

Cooke and Wheatstone

Once electromagnetism had been discovered many attempts were made to try to devise a suitable and convenient electrical communications system. The first to proceed as far as a patent, was as the result of a joint venture between a physician named Cooke and a professor, at King's College in London, named Charles Wheatstone.

Cooke had seen a demonstration of a very early electromagnetically operated system devised by C. A. Steinheil. This was very ingenious and even included an alarm, to warn people of an incoming message. The receiver also employed electromagnets and ink to print the message onto paper. However, it was ahead of its time. It was far too expensive and complicated to catch on.

On seeing this demonstration, Cooke's imagination was fired up, and he started to devise his own system. It used five wires and a return to operate five needles, which were deflected by the current flowing in the wires.

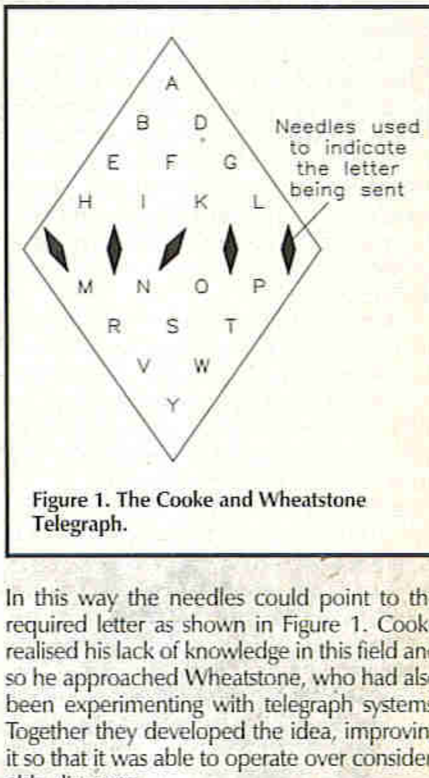


Figure 1. The Cooke and Wheatstone Telegraph.

In this way the needles could point to the required letter as shown in Figure 1. Cooke realised his lack of knowledge in this field and so he approached Wheatstone, who had also been experimenting with telegraph systems. Together they developed the idea, improving it so that it was able to operate over considerable distances.

On 10 June 1837, the patent for this idea was signed by William IV. Then on 26 July, the first full-scale experiment was undertaken between Euston and Camden stations, on the London and North Western Railway line, a distance of just under 3·6km. Although the experiment was a great technical success the company directors were not impressed, and the installation was dismantled.

It took a further two years before Cooke and Wheatstone gained another success. The Great Western Railway Company agreed to install a line between Paddington and West Drayton, a distance of 21km. Three years later the system was extended to Slough.

In addition to its primary use on the railway in giving communications between stations, a demonstration was also set up at Paddington Station. For the princely sum of a shilling the public were allowed to see the new invention which would allow messages to be carried at the speed of 280,000 miles in a second.

Whilst the Great Western Railway was pleased with the performance of the new system, it proved too costly to extend its use any further. As a result no more lengths were installed.

To reduce costs Cooke and Wheatstone modified their system. Using special operating codes they were able to reduce the number of wires from five to one, plus the return which could be achieved using the ground. Now the system gained a much wider acceptance. It was installed on a number of lines, but it did not gain anywhere near the acceptance they had hoped for.

Morse

The most successful telegraph system was invented by an American named Samuel Morse, he was a most unlikely candidate to make an invention of such importance, because he was an artist by profession, (possibly the best to come from the USA).

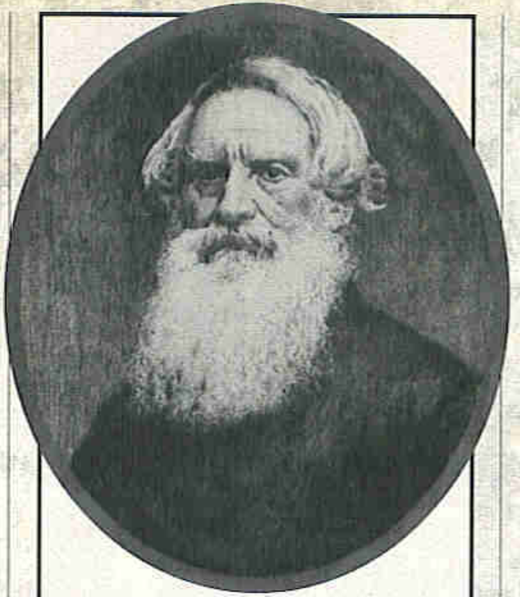
The story of the invention started after Morse graduated from Yale in 1810, initially he became a clerk for a book publisher, but he found the job uninteresting and he longed to become an artist. A year after joining the publisher Morse left to study the traditional style of painting being followed, in England.

After four years he returned to the USA, only to find that people in America did not want pictures painted in the style of art which he had studied. So he became an itinerant artist, producing some of his finest work. Slowly Morse's reputation began to grow and with more money in his pocket he decided to travel again, to learn more about the various styles used in Europe.

Morse had always taken an interest in the new science associated with electricity. He had read about electromagnets and some of their new uses, and started to think about how he might use them. It was on his return journey from Europe that he had time to reflect on the idea for a practical telegraph system.

On his return home, Morse was very busy with his painting and lecturing. This took precedence over his scientific thoughts, which were put to one side. This meant that it took Morse about three years to develop a prototype. However, when it finally became operational his enthusiasm grew, and in 1837 he put his painting and lecturing to one side to continue his work on the telegraph system.

Realising that he did not have all the resources he needed to complete a system which he would be able to demonstrate, Morse enlisted the help of some of his friends. One named Alfred Vail was very mechanically-minded and he took charge of this aspect of



Samuel Morse.
©Science Museum Photo Library.

the project. In fact many people think that it was Vail and not Morse who invented the Morse key.

Progress was swift and within a year they had developed a system of dots and dashes to represent the various letters and numbers which needed to be transmitted. This original code has many similarities to the one used today, and it was used for several years before the need arose for it to be changed.

It was realised that if this new telegraph system was to succeed then it needed the interest of large organisations and users. To achieve this they gave some demonstrations to the American Congress and several other organisations, but without success. Undaunted by their apparent failure they continued the search even coming to England to see if there was any interest here, but again they received little encouragement.

Morse Succeeds

Fortunately Morse did not give up. He forged ahead without the help of his partners and was successful in gaining a grant of $30,000 from Congress to set up an experimental line between Baltimore and Washington. The line was just over 64·4km in length, and even though he had to overcome a number of setbacks Morse completed the line in just under a year. Then on 28 May 1844 he sent his famous first message which read, "What hath God wrought?"

Now with his system operational, interest grew very fast. Many of the railway companies saw its possibilities and they started to have it installed. After only four years more than 5,000 miles of line had been set up and soon the Morse telegraph system became the standard system in use.

With its success in the USA, enquiries soon started to come in from other parts of the world. Many systems were installed in Europe and a few in other parts of the world as well.

Because Morse's system was becoming so successful, his former partners started to file lawsuits against him. Naturally they felt they had contributed to its development, and that they were entitled to a proportion of the proceeds. These legal battles took many years to settle, but finally Morse was successful, and was able to hold onto the patents.

A New Code

The original code which Morse derived had served its purpose well, but it had several limitations (see Table 1). Some of the letters included pauses, whilst others had dashes which were longer than others, and there was no provision for accents required by some European languages. These problems meant that the code was not always easy to use, to overcome this a new code was devised and introduced in 1851. It was based on the original one and bore many similarities to its predecessor. However, it was much easier to use, having standard lengths for all the dots, dashes and spaces. It is this code which is in use today and is called the International Morse Code (see Table 2).

Speech Over Wires

The telegraph system was a great success, but it did not include the vital element: the ability to send sounds over wires. This invention had to wait for a number of years, but when it arrived it was an instant success.

As most people know it was Alexander Graham Bell, a Scot, who invented the telephone. His mother and wife were both deaf, and he taught elocution, especially for deaf people. Before following this career, Bell studied anatomy and biology at University College in London. In addition to these studies, Bell had a keen interest in electricity, so that together all his knowledge stood him in good stead for his later researches.

In 1870 Bell's family moved to Canada for a more healthy lifestyle. Here he followed his father's career of helping deaf people to speak. Bell was very talented and soon found himself teaching others his methods which had proved to be so successful. Then in 1873 he was appointed professor of vocal physiology at Boston University in the USA. In his researches, Bell studied the make up of speech, even analysing the vibrations on an ingenuous con-

A	·–	M	––	Y	·· ··
B	–···	N	–·	Z	··· ··
C	·· ·	O	· ·	1	·––·
D	–··	P	·····	2	··––··
E	·	Q	··–·	3	···–·
F	·–·	R	· ··	4	····–
G	––·	S	···	5	–––
H	····	T	–	6	······
I	··	U	··–	7	––··
J	–·–·	V	···–	8	–····
K	–·–	W	·––	9	–··–
L	—	X	·–··	0	——

Table 1. The original Morse Code.

A	·–	M	––	Y	–·––
B	–···	N	–·	Z	––··
C	–·–·	O	–––	1	·––––
D	–··	P	·––·	2	··–––
E	·	Q	––·–	3	···––
F	··–·	R	·–·	4	····–
G	––·	S	···	5	·····
H	····	T	–	6	–····
I	··	U	··–	7	––···
J	·–––	V	···–	8	–––··
K	–·–	W	·––	9	––––·
L	·–··	X	–··–	0	–––––

Punctuation

Full Stop	·–·–·–	Equals sign (=)	–···–
Comma	––··––	Stroke (/)	–··–·
Question Mark (?)	··––··	Mistake	········

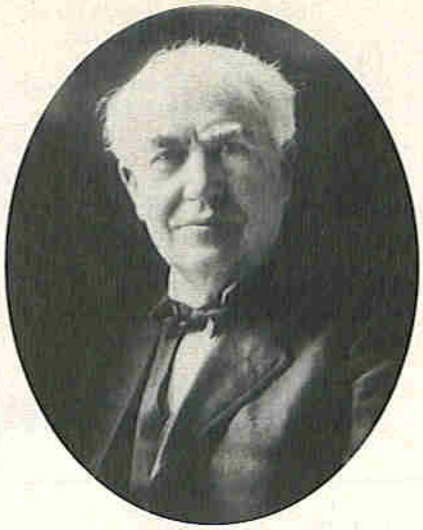
Procedural Characters

For procedural characters made up of two letters, they are sent as a single letter with no break between them.

Start of Work (CT)	–·–·–
Invitation to Transmit (KN)	–·––·
End of Work (VA)	···–·–
End of Message (AR)	·–·–·
Invitation to Transmit (K)	–·–
Invitation to a Particular Station to Transmit	–·––·

Table 2. The International Morse Code which is still in use today.

Alexander Graham Bell.
©Science Museum Photo Library.



Thomas A. Edison.
©Institution of Electrical Engineers.

Joseph Swan.
©Science Museum Photo Library.

traption he devised. The vibrations from a diaphragm were transferred onto a moving glass plate blackened with carbon. In this way the actual vibrations could be seen in a very similar way to the displays we see on an oscilloscope today.

Seeing the sound vibrations displayed in this manner Bell wondered if it would be possible to convert the audible sound vibrations into electrical vibrations which could be sent along a wire. For some years he had taken a keen interest in various forms of telegraph, and had even performed some experiments.

Bell continued his work with the deaf, but he still found time to develop his ideas for a telegraph system. To achieve this he received help from a fellow part-time enthusiast named Watson. It was Bell who devised most of the ideas, and Watson who built them up.

The next piece of the jigsaw fell into place when Bell started to develop an idea for sending several messages over a single telegraph line. He had the idea of using several reeds tuned to different frequencies. At the transmitting end they would interrupt the current at a certain frequency, and at the receiver only the corresponding reed would be activated. However, when setting up the system, Bell managed (accidentally) to send a sine wave along the line, and he quickly realised the implications of his discovery. He sketched out an idea for transmitting sounds along a wire and Watson helped to build it up. The following evening sounds were transmitted along a wire although at this stage they were not intelligible.

Unfortunately after this initial success, development had to take second place to teaching, and even developing the original multi-message telegraph system.

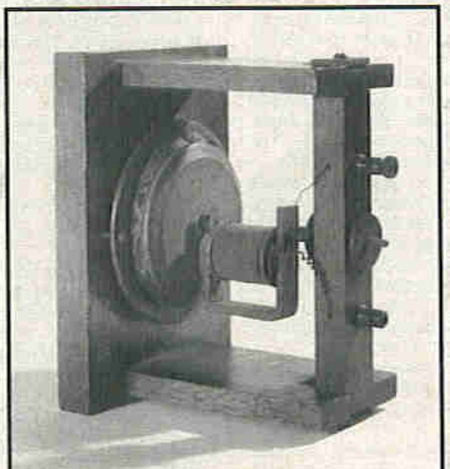
The First Message

However, in 1876, before Bell was 30 years old he was granted a patent for his idea. This gave the duo renewed enthusiasm for their telephone and it was only a matter of days after the patent was granted that intelligible sounds were transmitted. In fact, it was on the 10 March 1876 that Bell transmitted the first message over the phone saying, "Mr Watson, come here I want you". This was a cry for help because Bell had spilled some acid from one of the batteries over himself. This meant that the first telephone call was an emergency.

Bell's first transducers consisted of a parchment membrane with one end of a magnetised reed attached to the centre. This was held over a coil so that any vibrations in the parchment would be transmitted to the reed and induce a current in the coil. These first transducers were naturally lacking in performance. Bell realised this and put much work into trying to improve them. He even used a variety of new ideas, some of which seem far from ideal today. One involved hanging a wire from a diaphragm and dipping it into a weak acid solution. As the diaphragm vibrated so the amount of the wire in the water varied, changing the resistance and the amount of current flowing in the circuit.

Bell had now proved the viability of a telephone system, but he still needed to exploit it commercially. To interest people he gave a number of demonstrations. In one, he used an existing telegraph line over 100 miles long and managed successfully to send a message.

In 1877 the first commercial lines were opened in Boston Massachusetts, after this the growth in the use of telephones was phenomenal. The success of the initial system prompted many more to be set up over the whole of the USA. New companies were formed to run these operations, but it was quickly realised that an overall parent company was needed. After many reorganisations the American Telephone and Telegraph company (AT&T) was formed. Throughout the history of this company, research has been very important. In 1924 this lead to the formation of a new research wing called the Bell Telephone Laboratories. With its name shortened to Bell Laboratories this company was set to contribute more discoveries which would shape the whole world of electronics.



**An early Telephone (Bell's Gallows Frame Telephone).
©Science Museum Photo Library.**

The Telephone Develops

In the years following the introduction of the telephone, its use became even more widespread. The number of telephone calls made by people rose almost a hundred-fold in the years between 1885 and 1915. This dramatic increase called for many other improvements to be made in the telephone system. Expensive manual exchanges gave way to automatic switching centres. The first of these was invented by an undertaker named Strowger in 1889. His first system was very prone to giving errors, and as a result his engineers devised a dial system in 1896. This system remained in service for very many years until digital exchanges and push-button telephones started to arrive in the 1960s.

Whilst the Strowger system had gained very wide acceptance, another system was devised. Called the Crossbar system its invention is usually credited to Betulander, a Swede. This system was invented in 1919 and is based on a relay type switch. It was much more reliable than the Strowger system which used a pawl and ratchet system to move the wipers over the various contacts.

These new inventions enabled the real cost of owning a telephone to fall. Soon the telephone became the main form of communications used for everyday life. It did not take long for most businesses to have their own phones installed, and the number of private users rose rapidly as well. By the early 1960s most households and virtually all businesses had a telephone. This made the telephone one of the most revolutionary inventions of the last two hundred years or more.

Other Developments

The development of the telegraph and telephone were major stepping stones in the development of electronics as we know it today. However, there were many other inventions which also played a vital role as well.

Whilst they may not appear to have a link at first, their development was to play a vital role in the years to come. One of these was the need for clean efficient and safe forms of lighting.

At the beginning of the nineteenth century oil lamps and candles were the main forms of lighting. Around the early 1800s gas started to be introduced as it was more efficient. In fact, gas was particularly widespread as a form of street lighting, being used for many years in and around London.

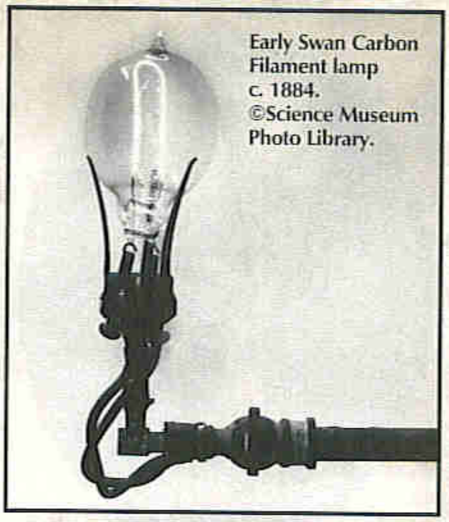
It did not take long for people to investigate whether electricity could be used. Initial attempts at using electric lighting involved the use of an electric arc between two electrodes. The first demonstration of this was made by Humphrey Davy just after the beginning of the nineteenth century. Using a large battery and two charcoal electrodes he succeeded in producing a brilliant light.

Although this demonstration proved the possibilities of producing electric lights, these early attempts were far from suitable for practical use. The electrodes burned away quickly and the resulting change in dimensions altered the arc. Despite these problems the basic principle that electricity could be used for electric lighting had been proved. Even so, it was many years before it was used in a practical form.

Of more interest to the development of electronics is the search for an efficient form of lighting for the home and office. This was seen by many as a very lucrative market. Consequently many inventors set about investigating the possibility of using incandescent lamps.

Although light bulbs are freely available today at very reasonable prices their development took many years, and was fraught with difficulties. The story starts around 1840 with the first investigations into incandescent lamps. These resulted in the first patents being issued in Britain, although people in many other countries were also trying to develop them.

One of the most important early problems which had to be overcome was finding a suitable method of obtaining a vacuum. Without this the filament would become oxidised very quickly because of the very high temperatures



Early Swan Carbon Filament lamp c. 1884. ©Science Museum Photo Library.

involved. The basic problem was overcome in 1865 with the invention of the mercury vacuum pump although it took a little longer to devise a method of evacuating and sealing the glass bulbs. This was only the first of many hurdles which had to be overcome.

Two Inventors

The composition of the filament itself was of vital importance. This determined the whole performance of the bulb from its light output to its life. Many people were involved in the quest to find a suitable filament, of the many people who were involved the two names which will be remembered most are Thomas Alva Edison and Joseph Swan.

Edison's work is well-known. Born in Ohio in 1847 he was a very gifted inventor taking out 1,093 patents during his life. Many of these were for devices which are still in common use today and they include the phonograph, a motion picture projector and the carbon telephone microphone.

Joseph Swan is not so well-known. He was a chemist from Newcastle who made contributions to science in a number of areas. He invented bromide photographic paper, and made some of the first man made fibres from cellulose.

Both of these men took up the search for making a usable incandescent lamp. However, Edison had the wider vision, seeing the enormous commercial possibilities. He was looking at a complete lighting system, including the generator, distribution system through to the lights themselves.

Much of the research put into these lights revolved around the filaments in the bulbs. A vast number of ideas were tried and tested. Carbon, platinum, titanium oxide, chromium, and a whole host of other substances were tried. In 1879, after a phenomenal amount of experimentation, Edison succeeded in making a bulb which lasted for two days, using a filament from carbonated cotton. Further developments lasted up to a week, and soon Edison was making bulbs on a commercial basis.

Swan also settled on carbon, but he manufactured his filaments in a different way by using his expertise in fibre technology. Swan's artificial fibres had a more uniform cross section than the cotton by Edison. This considerably improved the life of the filaments.

The key to success was in commercial exploitation of lighting in the home and offices. To achieve this Edison set up an experimental power station in his laboratory at Menlo Park in New York, to light Pearl Street. The system was opened with great ceremony in September 1882, with Edison himself turning on the lights.

The success of the system was soon proved and interest grew. By 1886 over sixty stations were operational, each supplying their own small areas.

Increasing Bulb Life

Despite all these successes problems with bulb life still troubled Edison and others, apart from the problem of filament life, another problem which was encountered was that of the inside of the bulb becoming blackened. To overcome this Edison tried a number of ideas, one of these was to place a second element into the bulb to repel any particles coming from the filament. Whilst this idea was never put into operation for normal light bulbs it was the vital link for the next era of electronics. E

DIARY DATES

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

29 January to 1 February. European Lightshow Exhibition, Earls Court, London. Tel: (01952) 290905.

3, 10, 17 & 24 February. 'Caught in the Net', Arts Theatre, 6-7 Great Newport Street, London WC2. Tel: (0171) 836 2132.

7 February. Weather Satellites, Sunbury & District Radio Amateurs, Wells Hall Old School, Great Cornard. Tel: (01787) 313212.

7 to 9 February. ISDN USER – Integrated Communications Exhibition, Olympia, London. Tel: (01733) 394304.

14 to 16 February. SMARTCARD – International Smart Card Exhibition & Conference, Olympia, London. Tel: (01733) 394304.

1 to 2 March. Electronic Books International, Wembley Centre, London. Tel: (0171) 976 0405.

3, 10, 17, 24 & 31 March. 'Caught in the Net', Arts Theatre, 6–7 Great Newport Street, London WC2. Tel: (0171) 836 2132.

7 March. Junk Sale, Sunbury & District Radio Amateurs, Wells Hall Old School, Great Cornard. Tel: (01787) 313212.

7 to 9 March. Computers in Libraries, Wembley Centre, London. Tel: (0171) 976 0405.

16 to 19 March. Computer Shopper Show, NEC, Birmingham. Tel: (0181) 742 2828.

18 March. Amateur Radio Open Event Station, Central Lancashire Amateur Radio Club, Maplin Electronics Store, Unit 1, Corporation Street, Preston. Tel: (01772) 258484 or (01772) 312912.

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

7, 14, 21, 28 April. 'Caught in the Net', Arts Theatre, 6–7 Great Newport Street, London WC2. Tel: (0171) 836 2132.

9 to 11 April. European Computer Trade Show, Business Design Centre, London. Tel: (0181) 742 2828.

22 April. Special International Marconi Day exhibition station at Puckpool Park, Wireless Museum, IOW. Tel: (01983) 567665.

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

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

8 May. Working Wartime CW Shortwave Station to Celebrate VE-Day, Puckpool Park Wireless Museum, IOW. Tel: (01983) 567665.

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

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

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

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

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

2 September. Wight Wireless Rally, Arreton Manor Wireless Museum, Newport, IOW. Tel: (01983) 567665.

5 to 7 September. International Conference on 100 Years of Radio, Savoy Place, London WC2. Tel: (0171) 240 1871.

10 September. Southend & District Radio Society 75th Anniversary Year, Radio & Computer Rally, The Cliffs Pavillion, Southend. Tel: (01702) 353676.

10 to 13 September. PLASA – Light & Sound Trade Show, Earls Court, London. Tel: (0171) 244 6433.

12 to 14 September. First IEE/IEEIE International Conference on Generic Algorithms in Engineering Systems – Innovations and Applications, Sheffield. Tel: (0171) 240 1871.

19 to 21 September. Computers in Manufacturing Exhibition, NEC, Birmingham. Tel: (01932) 564455.

20 to 21 September. Electrical Engineering Show, Hinckley Island Hotel, Hinckley. Tel: (01732) 359990.

4 to 6 October. Electronic Data Exhibition, ICC, Birmingham. Tel: (0181) 742 2828.

12 to 13 October. Electrical Engineering Show, Forte Post House Hotel, Basildon. Tel: (01732) 359990.

10 to 12 November. Design & Technology Education Exhibition, NEC, Birmingham. Tel: (01425) 272711.

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.

A readers' forum for your views and comments. If you would like to contribute, please address your replies to: **The Editor, Electronics – The Maplin Magazine, P.O. Box 3, Rayleigh, Essex SS6 8LR, or send an e-mail to: AYV@maplin.demon.co.uk**

AIR YOUR VIEWS

Dear Editor

Surrounded by Aliens

Dear Editor,
On the subject of sound reproduction, and surround sound, I do not understand how someone could believe that more than two speakers can be better than two. Humans have two ears, which can let us hear the exact direction of a sound from any direction, so that means that any place around the speakers and the listener can be fully emulated by speakers. So there is no need for more than two speakers, the people who design systems with more than two speakers must not be human, to have more than two ears. These 'surround systems' designers just want people to spend a lot of money on a system with no reason so they get royalties! I have heard '3D' stereo played once, but I am not a 100% follower of the idea, just a strong believer. It is a simple idea, which 'surround sound' designers do not seem to get.
I hope that everyone will remember that electronics is a part technology, the most important subject in the 20th century, for the future.
Stephen Bowyer, Stockport, Manchester.

Surround sound is a very broad term, encompassing many systems, so we must be careful of making generalisations – otherwise we risk automatic membership of the audio equivalent to the 'flat earth brigade'! Some systems work very well, others less so. It is, however, important to establish the aim of the system in question before picking fault with it. With any developing science it is important to keep an open mind, there are often many ways to achieve the same aim. Adopting a blinkered approach does not assist matters. Forget how a system achieves its aims, concentrate on whether it achieves its aims. Commercial systems designed and marketed over the years have largely fallen by the wayside (SQ, QS, CD4, et al) – generally due to fundamental flaws in the application of the theories of the way we perceive sound at the time they were developed. Because such systems didn't work very well, they did not achieve consumer acceptance. However, modern systems and techniques are much better at achieving their aims and this is borne out by consumer acceptance.
Our knowledge of psychoacoustics will continue to increase with time – much of the work is often undertaken by people without 'royalty motives'.
For a thorough discussion of the theories of surround sound recording and reproduction systems, it is well worth reading John Woodgate's series 'Surround Sound – Fad or Fancy?' in Issues 79 to 81 of Electronics. *This series is independent of 'royalty bias' and brings together a wealth of information from various authoritative sources – much of the reference information would be difficult for the casual reader to locate unaided. It also includes practical circuits to build and experiment with, good results can be obtained. Also well worth a read is the* New Stereo Soundbook *(WZ68Y) which covers many aspects of stereo and surround sound, I've read it myself so it comes with a personal recommendation. Be warned, however, it is an American book so you will probably want to read it in small chunks as the 'American English turn of phrase' can be somewhat grating at times.*

Disco Here Disco There

Dear Editor,
I have been a reader of *Electronics – The Maplin Magazine* for some time, have become a subscriber, and agree that it is the all round first class magazine in its field. Like many readers I find some issues more interesting than others. The February 1995 issue that I received a few days ago falls into the slightly less interesting category for me, which although not critical of the magazine, does inspire me to write.
I do a little disco work. Having started during the seventies, and bought my own equipment, mainly second-hand, then continuing through the eighties until retiring totally in 1987, when I got married. Reluctant to sell this equipment, I found people again asking me to provide entertainment, especially 60s and 70s type functions. I have since purchased two Compact Disc players, and am now gradually updating the now less popular vinyl. My current problem is that I wish to connect two CDs onto my existing mixer, but it is limited to only one auxiliary input. I am as a temporary measure, hoping to be able to duplicate the auxiliary channel, and add another, but I would really like another mixer. The one I have seen is about £200, but again am reluctant to buy, because at present, I only complete about four or five bookings a year. I would love to build one. You have published various circuits for mixers, but I have not seen one as such for Disco use. This is where you come in. I think that *Electronics – The Maplin Magazine* can do it. You have published some very good circuits in the past, which I do intend to build in the future. Although I do read some of the other electronics magazines, *Electronics* is the only one I subscribe to, so please don't let me down.
Warwick Ellis, South Humberside.

Ask six DJs what they want on a disco mixer and you will get six different answers. If we were to publish a complete budget disco mixer design, you can guarantee that it would satisfy only a percentage of DJs needs. To satisfy virtually everyone it would be very expensive. For this reason the best approach is a modular system so that the user decides what features are needed. This approach also means that you can spread the cost. The good news is that we have already published a complete range of Mixer Modules and a Modular Mixing System that should satisfy any DJs needs! All of these are listed in the Projects and Modules section of the 1995 Maplin Catalogue and are covered in detail in the Mixer Book *and back issues of* Electronics. *Some of the modules are available ready built to reduce some of the donkey work. Here are a few suggestions for further reading, these publications contain construction details and applications information for the relevant kits:*
- Mixer Book *(XL47Y)*
- *Issue 41/December-January 1991 (XA41U)*
- *Issue 42/February-March 1991 (XA42V)*
- *Issue 48/December 1991 (XA48C)*
- *Issue 60/December 1992 (XA60Q)*
- *Issue 61/January 1993 (XA61R)*
- *Issue 62/February 1993 (XA62S)*
- *Issue 63/March 1993 (XA63T)*
- *Issue 64/April 1993 (XA64U)*
- *Issue 65/May 1993 (XA65V)*
- *Issue 66/June 1993 (XA66W)*

Most of the facilities you listed in your (full) letter can be satisfied with the projects featured in the above publications. If you need help selecting which kits to use and how to connect them together call our Technical Help Line on Tel: (01702) 556001 (see page 2 under Technical Enquiries for full details).

STAR LETTER

This month, Mr R. A. Wallis, from West Yorkshire, wins the Star Letter Award of a Maplin £5 Gift Token for his very interesting letter regarding VideoPlus+.

£5 Gift Token

Dear Editor,
I am not sure whether VideoPlus+ comes within the scope of *Electronics*, but as a resident purchaser of a machine with this facility, i.e. a Panasonic NV-HD100B, I am intrigued at the wide variations in codes published in the *Radio Times* and other publications. Some codes have as little as two digits whilst adjacent programmes on the same channel might have as many as eight. In the last two days, I must have spent upwards of five hours or so using the remote control converting coding numbers into respective data, i.e. Day, Date, Channel, Time On, and Time Off, with, in most cases no relationship between one or the other. On what basis are these codes calculated or allocated? The controller takes no visible length of time to convert the codes into the respective elements.
Some insight into this subject, preferably a complete means of working out the codes myself would be appreciated either from yourself or from any other readers. If this is not possible, then just the basic insight into the subject will suffice. I am sure many other readers will have some interest in this apparent puzzle.

If the inventors of VideoPlus+ (a British idea I believe), anyone involved with VideoPlus+, or anyone else 'in the know' are reading, please drop me a line. Failing that, I'll get one of our intrepid sleuths on the case! As you suggest, I am sure many other people would like to know how the system works!

Older but Wiser!

Dear Editor,
Being at the +70 end of the age spectrum, many members of which are effected by cashflow, it is easy to sympathise with Jeremy Harper who complained about the price of the *Electronics* magazine (February 1995). And yet . . .
Pre WWII a wireless/mechanics magazine cost around 2d or 3d (that's about 1p) but spending money was about the same if you were lucky! Although an increase of around 200% (less by subscription), the current price of the magazine taking into consideration its contents is reasonable in relation to over 50 years inflation. The 1960s were probably the best years for the contents/price ratio of electronic magazines, but now many seem to have declined in their interest value whilst prices have increased. Over the years I have subscribed to many such ones, but have gradually cancelled them and now there are only two left, *Electronics* and one other, the latter soon to go.
Electronics with its well tried and new practical circuits often stimulating ideas removed from the original concept, its range of comprehensive theoretical articles, kit projects enabling simple and sophisticated electronics to be built, etc., maintains a sound basis for newcomers, the experienced and now even valve addicts with fond memories (and burnt fingers?). Arguable, but to me it represents the best contents/price ratio presently available in non-specialised magazines. Stick with it Jeremy, as by the year 2000 you may be earning £1,500 a month to pay for it!
N. L. Smith, Staffs.

Index Ideas

Dear Editor,
Having waited until December to read the December magazine, this letter is a little late! However, I have noted that the issue of publishing an index has cropped up. For those of us who take the magazine on subscription, I guess that keeping them is more likely than not. Mainly this will be because articles and projects are seen as of possible interest for some undefined time in the future. The projects, I would judge, have a design life in excess of 5 years. In these circumstances an information retrieval system in the form of an index is essential.
The nature of the index is, however, problematical. You could issue something annually to go with the December issue. Hard copy would be the best solution in this case, or you could start a cumulative index which would be better for people who became interested in the magazine in the last year or so. The snag with this is that the 'file' would need updating at regular intervals, and readers would have to request/buy the updated file from time to time, and would it need to go back to the year dot? A disk format would be the best medium here, but how many of your readers have PCs.
Peter Tyler, Lancs.

For anyone new to joining the debate on the Electronics *Index, here is the state play. The index is already available, it is currently 15 pages long and covers every issue from 1 to 82. The index is revised annually. The index is available from Maplin Regional Stores or by Mail Order, order as XU87U price 80p,* *see page 77.* *If you are only ordering the index, your don't have to pay the £1.50 handling charge normally levied on Mail Order purchases. It has been decided that the index will also be made available on the Internet, on various public BBS and on CashTel when it is upgraded. From the last readership survey, it was found that 81% of the readership were computer owners. 45% of the readership were IBM PC owners – the difference being spread across twelve other platforms. The highest user-base of any other platform being AppleMac at 8%. We will endeavour to make available as wide a range of file formats as reasonably possible to make life easy for people to use the information regardless of platform. All comments in this area are most welcome – watch this space for future announcements!*

THE MAPLIN MILLENNIUM 4-20 20W VALVE POWER AMP *Update*

The 'Millennium 4-20' Valve Power Amplifier project is now a year old and has proved to be very popular, receiving some good responses from independent testers.

During this time, one or two improvements/modifications have evolved. These have now been implemented in the relevant kits and literature, are detailed here.

THE modifications can easily be incorporated by constructors at the building stage, but if you have already finished a 'Millennium' you will be pleased to know that it is equally quick and simple to effect these changes without any major dismantling! The modifications concern three main areas: improving signal bandwidth and stability, signal earthing and the addition of the 115V US mains voltage option in the Power Supply Unit kit.

Revised EF86 (V1) Input Stage

Reviewers' findings suggest that the frequency response is unusually wide for a valve amplifier, in the order of 70kHz. This is perhaps too wide as there is sometimes evidence of a small amount of high-frequency oscillation in the noise floor. High feedback valve amps are best band limited, keeping the upper end down to 50kHz or so at most, to help avoid HF instability of this type.

Figure 1 shows the revised portion of the circuit, concentrating on the input stage around V1. The screen grid decoupling capacitor, C8, was originally taken directly to 0V. Normally this is satisfactory because the cathode is also decoupled to 0V. However, because, in this application, the negative feedback signal is developed across R3 and communicated through C4 & C5, some AC is present at the cathode as it is not fully bypassed, so that the screen grid 'sees' a small AC signal with respect to the cathode, slightly upsetting the valve's normal operation and this accounts for the small amount of HF oscillation.

In Mullard's original circuit of 1955, the screen grid decoupling capacitor is terminated to the cathode pin 3 instead, as in Figure 1. As a result there is no AC difference between the screen grid and cathode (as there shouldn't be) and so the stage is more stable. Future kits (LT45Y) will be supplied with Issue 2 of the PCB (GH60Q), now having this minor modification. It does not affect the layout of components on the PCB, which stays the same.

The modification can be easily applied to original version PCBs, however, which can then still be used. All that is required is to install C8 in the normal position on its legend, but only solder the lead at the R7 end, nearest the corner of the PCB, into the board. The other lead is bent around and directly wired to the PCB pin at V1 pin 3, nearby, covered with sleeving.

For Issue 1 PCBs that have already been installed into finished 'Millennium's', it is not necessary to remove the board completely. Simply cut the lead of C8 at the 0V end (nearest C4 & C5), close to the surface of the PCB, extend it with bell wire and cover with sleeving, then connect it to V1 pin 3.

To reduce the bandwidth, it may be possible to increase the value of the feedback network capacitor (C15 in Figure 1) slightly, from 330pF to perhaps 560pF (BX54J), although it has been suggested that this capacitor can make instability worse, not better. (R16 is meant to limit this effect.)

It has also been suggested that bandwidth could be limited in the preamplifier or at the input to the 'Millennium' amplifier. The optional C16 and R26 in the original circuit diagram can be used for this. Leave C16 at 220pF and increase R26 to 4k7Ω (M4K7).

In one example, 220nF capacitors (polyester type BX78K, or mylar type WW83E) were connected across each pair of speaker output terminals to reduce HF noise. RF, picked up by the speaker leads acting as aerials, could be observed on an oscilloscope. The capacitors reduce the level of RF returned to the amplifier by the feedback network, and ensure output loading is provided at high frequencies.

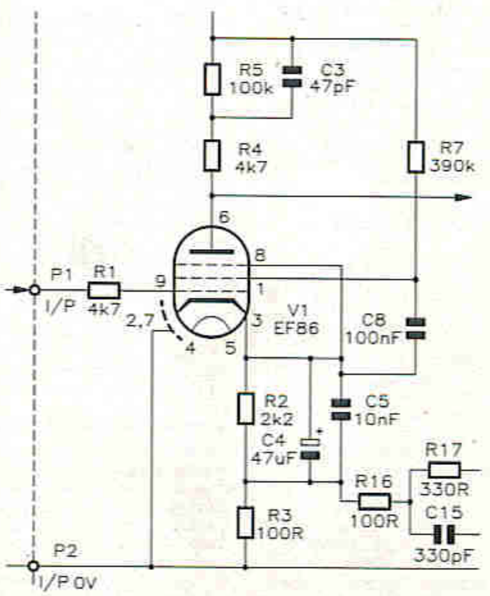
Revised Earth Wiring

This is an alternative earth wiring arrangement for a stereo configuration, where two amplifiers share one PSU and a common chassis assembly, as is the case for kit LK72P, for example. The modification serves to improve the stereo image, where a form of *crosstalk* between the left and right channels has been known to degrade the stereo image.

Some examples have shown a small difference signal occurring between the two speaker outputs, even when both inputs are identical (monophonic). While this can often be due to problems like phase errors, frequency response differences, or instantaneous drops in the commonly shared HT line, it can also arise in sympathy with current variations in the signal earth wiring for each amplifier module.

Figure 2 shows the earth wiring systems of a unit construction, stereo assembly version of the 'Millennium 4-20', configured as described in the original wiring instructions. The mains earth system connects the Millennium chassis with the chassis of other items of equipment in the stereo system, by the common mains earth wiring in the power leads. To reiterate the PSU module construction notes, a 100Ω resistor links the mains earth to the amplifiers' and PSU's supply and signal earth, to prevent a 'hum loop' forming

Figure 1. Small revision to the valve input stage V1 consists of relocating the 0V end of C8 to pin 3 of the valve.



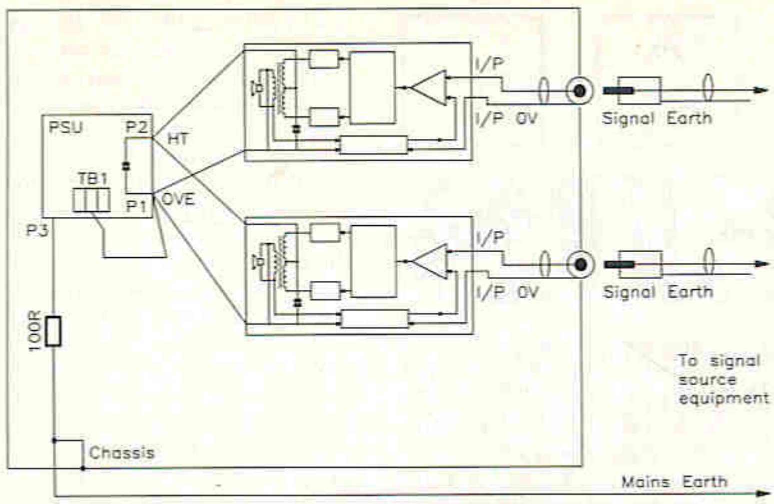


Figure 2. The signal and PSU earthing arrangement as described in the original instructions for a stereo assembly that shares a common PSU.

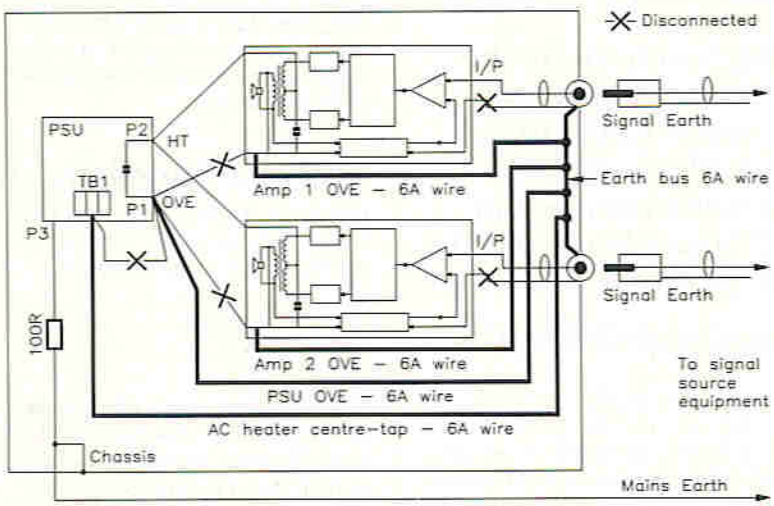


Figure 3. Improved earthing arrangement avoids difference errors between the two amplifier signals by locating the common earth point at the input sockets.

around mains and input signal earth connections.

Internally to the chassis, the Millennium's circuit earth is centred on a common point at the 'OVE' pin (P1) on the PSU PCB. The signal earth for each amplifier is derived separately for each input socket via the screen of its input lead (the bodies of the sockets are also isolated from chassis). This leaves the signal OV side of each socket 'floating' with respect to the other, allowing small voltage shifts that introduce the difference signal. It has been found that connecting each to a common signal earth point at the sound source equipment, via separate screened leads, does not sufficiently eradicate the problem. It is necessary to connect the OV screens of both input sockets directly.

During the original development, attempts to link together both input socket earths were abandoned due to the consequent introduction of 'hum loops'. However, it transpires that the key to overcoming this problem lies in physically *moving* the common earth point, from the PSU (the original point) to the vicinity of the input sockets. In addition, all earth returns are then made to *this point* by way of low impedance paths, using thick, multi-strand wire, for example 6A Green Wire (32 × 0·2mm strands, XR35Q).

Figure 3 shows the modified circuit earthing arrangement. New connections are shown as thick lines, representing the high current cable, or single wires stripped from 13A mains cable (i.e. XR09K, XR10L, XR11M: 40 × 0·2mm strands). *The original wiring (if already connected) is disconnected at points '–X–'.* To change existing wiring, proceed as follows:

1. Connect a new 'earth bus' between the screen solder tags (signal OV) of both input sockets using the high current wire, by as short a route as possible. The wire must also have approximately 1in. of insulation removed near the centre of its run. The copper screens of both input screened leads remain connected to the socket screen tags.
2. Remove (or omit, if building the PSU kit) the wire link between TB1 centre terminal (AC heater supply centre tap) and P1 ('OVE') on the PSU PCB.
3. Connect a length of high current wire between the TB1 centre terminal and the bared centre portion of the 'earth bus'. Twist the bared end around the 'bus' and then a lot of solder is needed, as it is soaked up by the high current wire.
4. Similarly connect a length of high current wire between 'OVE' (P1) on the PSU PCB and the bared centre portion of the 'earth bus'.
5. Remove (or omit) the black OV wires from the 'OVE' pins (P3) of both amplifier PCBs.
6. Connect a separate length of high current wire between the bared centre portion of the 'earth bus' and *each* amplifier PCB pin 'OVE' (P3).
7. Finally, disconnect the input lead screens from the 'I/P OV' pins (P2) of both amplifier PCBs. Wrap the loose copper screens to the cable sleeve with insulation tape. (If wiring a new kit, cut off the braid and insulate the remainder with tape.)

Stage '7' must be carried out otherwise a 'hum loop' is formed with the input lead screen and the new earth wire.

It may be worth considering physically moving the input sockets closer together, so that they are spaced approximately 1in. apart or so. This will make a very short 'earth bus' between them which can simply consist of bared high current wire.

This modification is important and necessary to achieve the best possible performance from a stereo 'Millennium' amplifier assembly that shares a common PSU.

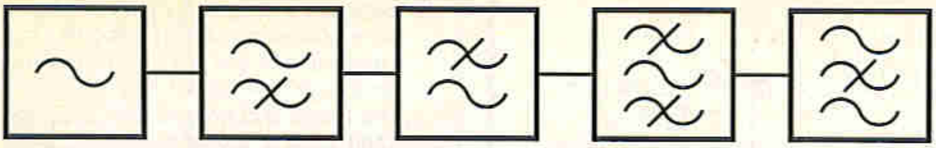
Dual UK/US Standard PSU

The revised Power Supply Unit now features a mains transformer having a dual-standard primary, that is, comprising two 115V windings. For operation in the UK or Europe at 230V AC, the primaries are connected in series. For the 115V US standard, they are connected in parallel. In addition, two alternative mains fuses and transient suppressor devices are included in the kit. For 230V, the 1A fuse and 250V suppressor are used. For the US version, the 2A fuse and 130V suppressor are used. Kit leaflet XU45Y has been updated showing these options in more detail.

Performance

With the signal earthing changes, but without the change to C8, *Hi-Fi World* magazine have had the following results from one example of a stereo kit:

Power:	21W
Frequency response:	10Hz to 73kHz
Channel separation:	80dB
Signal to noise ratio:	100dB
Hum:	0·5 to 1·3mV
Distortion:	0·02%
Sensitivity:	230mV



FILTERS

Part 6: All-Pass Filters and Other Strange Beasts

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

Originally it was intended to cover design software in this part of the series, but the kindly Editor has pointed out that there is considerable interest in several special types of filters, so this time we shall be looking at all-pass filters, especially broad-band delay networks, wide-band audio 90° phase-shift networks and the –3dB/octave filter, which converts white noise into pink noise, or pink into red.

All-Pass Filters

It may seem very strange to refer to anything as an 'all-pass filter': you wouldn't want one in your coffee machine, after all. What has happened is that the concept of a 'filter' has been widened over the years, so that it is now even applied to file conversion software that, for example, allows formatted text prepared by one word-processor to be loaded correctly into another.

The meaning of the term 'all-pass' is that the frequency response of the filter is flat (ideally) over the frequency range of interest, not of course from the proverbial 'DC to light'. What is not flat is the *phase response*, which is designed to perform (with varying degrees of accuracy) what the designer wants. We have not considered the phase response of filters in detail in previous parts of this series, because for many applications, using continuous signals, it is not of great significance. However, not all signals are continuous, even in the analogue domain, and video signals form a very important example. Consider, for example, a narrow vertical white line on a darker background. The waveform of each line of the video signal then looks like a single isolated pulse, as shown in Figure 56. The spectrum of this signal (without the complications introduced by the sync pulses) consists, as usual, of a fundamental and a series of harmonics, with particular phase relationships. If we alter these phase relationships, by passing the signal either intentionally through a filter or simply through *any* circuit that introduces phase-shifts between the harmonics and the fundamental (termed 'differential phase-shift'), the pulse shape becomes distorted, as shown in Figure 57, and this makes the display look 'fuzzy'. Applied to a real picture, the subjective effect can be quite disastrous.

There is one special case where differential phase-shift does not cause the pulse shape to be distorted, and it is a very important case. This is where the phase-shift is precisely proportional to frequency, since this simply means that the pulse as a whole is delayed in time.

Transfer Functions, Again

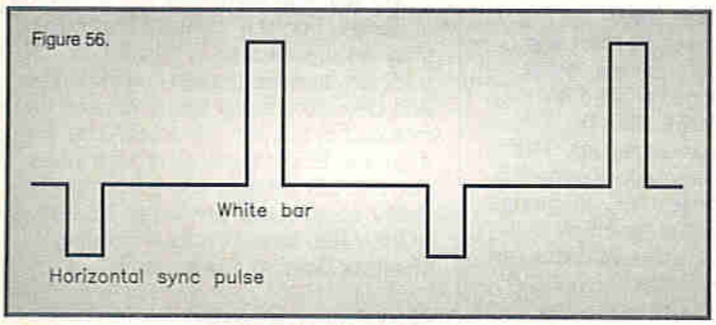
Way back in Part 1, we saw that the response of any linear circuit can be described by a transfer function:

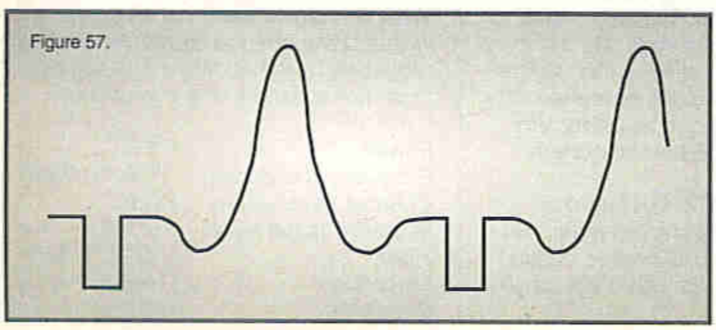
$$T(s) = \frac{N(s)}{D(s)}$$

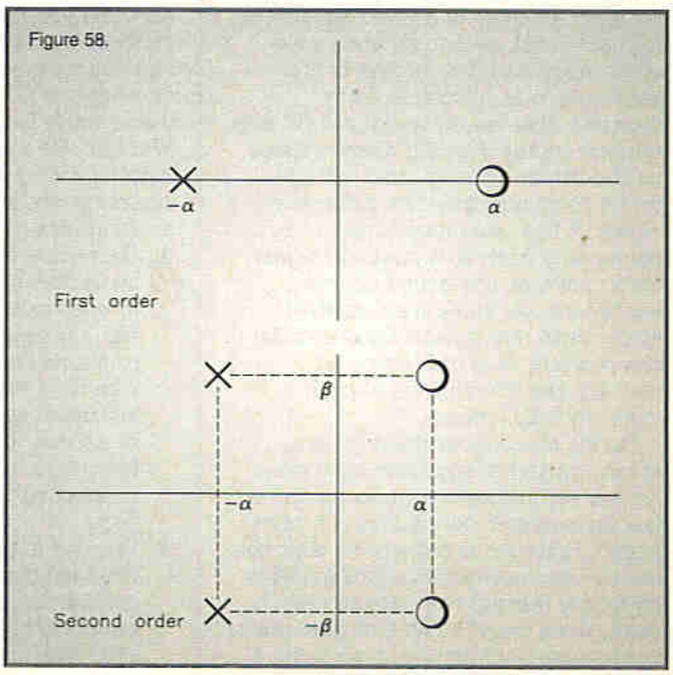
where s is the 'complex frequency', $\sigma + j\omega$, σ being related to the losses or damping of the circuit and ω being the physically-evident signal frequency.

For an all-pass filter, by definition, the modulus of $T(s)$ is constant, and is equal to the insertion gain or loss of the filter (that is the loss or gain in the flat part of the pass-band, which should ideally be all of it, of course). We have not considered filters with insertion gain, because it is usually simpler to keep the amplifying and filtering functions separate, and we have considered as satisfactory only those filters that have neg-

Figure 56. Video signal producing a narrow white vertical bar.
Figure 57. The same video signal passed through any phase-shifting filter.
Figure 58. Poles and zeroes of first- and second-order all-pass transfer functions.







ligible insertion loss. So we will continue to assume that $|T(s)| = 1$ for our all-pass filters as well.

For a non-oscillating circuit, the poles of $T(s)$, which are the roots of $D(s) = 0$, must have negative real parts, that is the resultant values of σ must be negative. So $D(s)$ must be the product of factors like $(s + a)$, where a is positive. In order that $|T(s)|$ is constant, $N(s)$ must then be the same as $T(s)$ but with a minus sign in every factor, i.e. $(s + a)$. The roots of $N(s) = 0$ are called the zeroes of $T(s)$ (because they also make $T(s) = 0$, if you think about it), and must therefore have positive real parts, each exactly equal in value to the negative real parts of the corresponding pole, as shown for first and second-order networks in Figure 58.

First-Order All-Pass Networks

The transfer function is of the form:

$$T(s) = \frac{s - \alpha}{s + \alpha}$$

so that the squared amplitude response is:

$$|T(s)|^2 = \frac{\sigma^2 + \alpha^2 + \omega^2}{\sigma^2 + \alpha^2 + \omega^2} = 1$$

and the phase angle is:

$$\phi(\omega) = -2 \arctan\left(\frac{\omega}{\alpha}\right)$$

For frequency (amplitude) response curves, we usually use a logarithmic frequency axis, but this distorts, usually unhelpfully, the shapes of phase response curves, so we often use a linear frequency axis, and we have to find ways of overcoming the resultant squashing of the low frequency end of the graph. The result for the above equation, with α (which is also the 'corner frequency' of the network, although it doesn't have a corner in its frequency response) normalised to 1, is shown in Figure 59. Note that, although the phase is not proportional to frequency, it is nearly so over part of the frequency range. In this range, the network introduces a more or less constant delay.

The delay introduced by the network, termed 'group delay' to distinguish it from another sort of delay which we are not concerned with, is equal to −1 times the rate of change of phase ϕ with frequency:

$$t_{gd} = \frac{-d\phi}{d\omega} = \frac{2\alpha}{\alpha^2 + \omega^2}$$

This function is shown, plotted on both linear and log frequency axes, in Figure 60. It may seem very strange, but the delay is a maximum at zero frequency, and its maximum value is $2/\alpha$.

Second-Order All-Pass Networks

Just as for first-order networks, we can identify a 'corner frequency', ω_r (in spite of there not actually being any 'corner' in the ideal frequency response) and we now have an additional parameter, the 'filter Q', Q. Then the transfer function $T(s)$ is given by:

$$T(s) = \frac{\left(\dfrac{s^2 - \omega_r s}{Q + \omega_r^2}\right)}{\left(\dfrac{s^2 + \omega_r s}{Q + \omega_r^2}\right)}$$

and the rather unwieldy expression for $|T(s)|$ can be easily seen to be identically equal to 1, proving that the network is indeed all-pass.

Figure 59. Phase response of a first-order all-pass network.
Figure 60. Group delay of a normalized first order all-pass network.
Figure 61. Phase response of second order all-pass networks of various Q values.
Figure 62. Group delay responses of second order all-pass networks of various Q values.

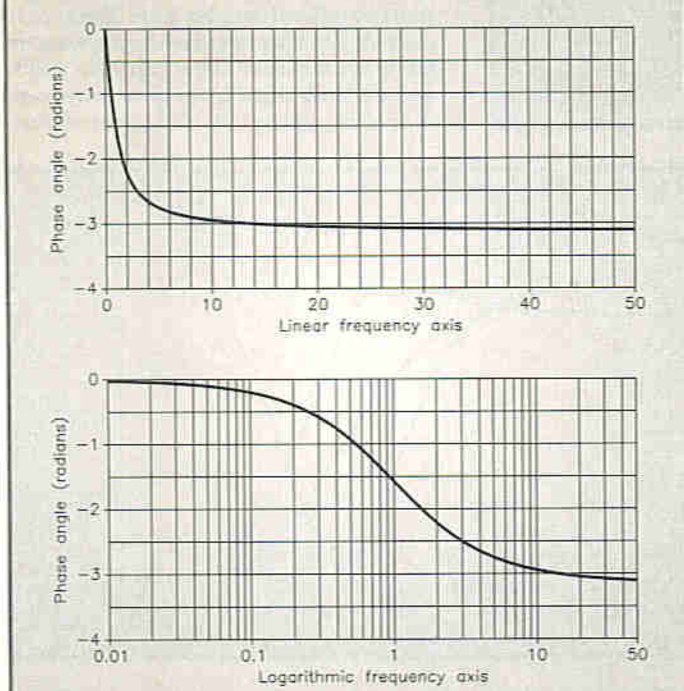


Figure 59.

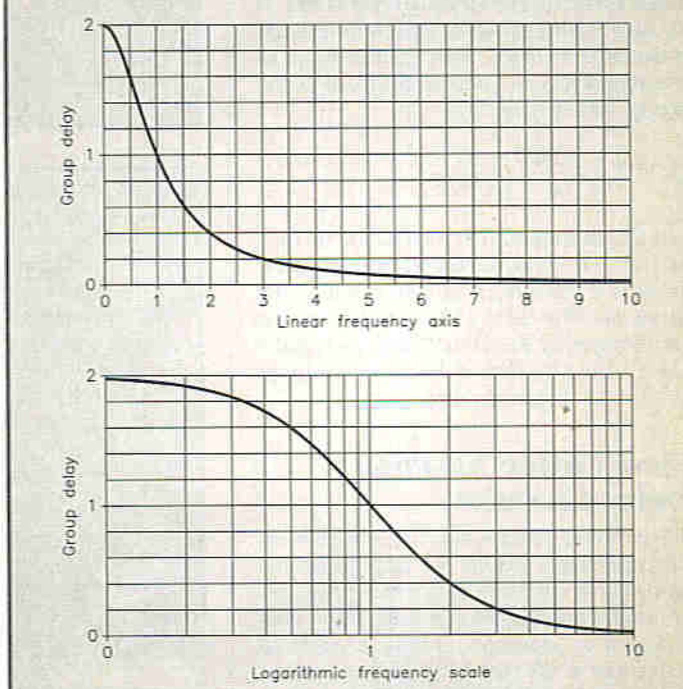


Figure 60.

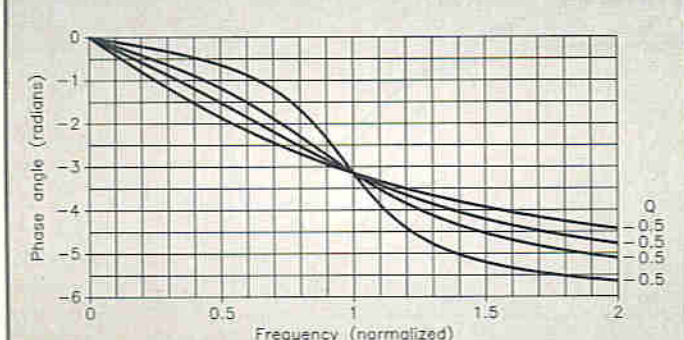


Figure 61.

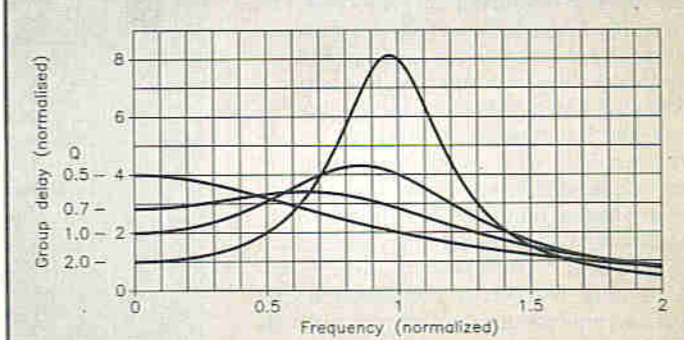
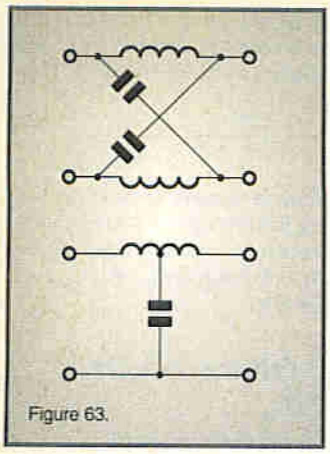
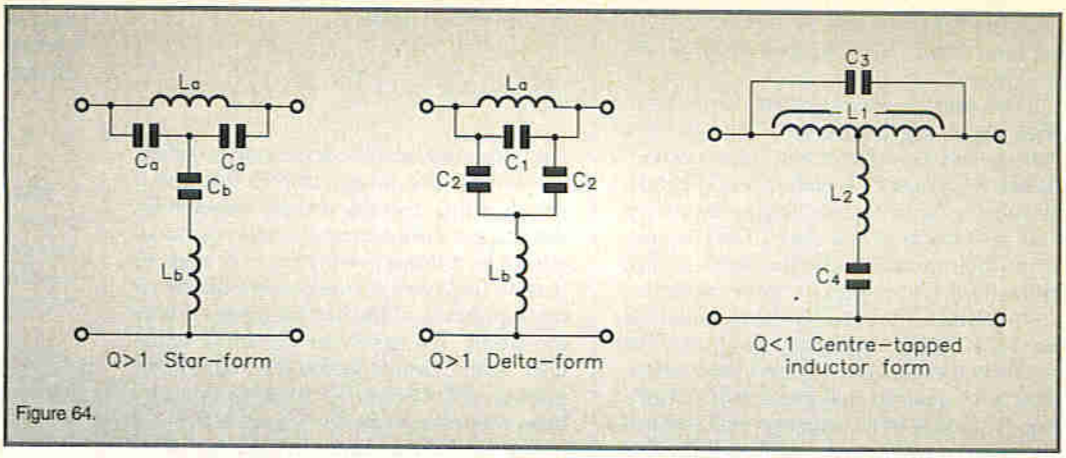


Figure 62.





The co-ordinates of the poles can be written $(-\alpha\pm j\beta)$, so that the co-ordinates of the zeroes are $(\alpha\pm j\beta)$, as shown in Figure 58. These are related to ω_r and Q by:

$$\omega_r = \sqrt{\alpha^2 + \beta^2}$$

$$Q = \frac{\omega_r}{2\alpha}$$

The phase response is given by:

$$\phi(\omega) = -2 \arctan\left(\frac{\omega\omega_r}{Q(\omega_r^2 - \omega^2)}\right)$$

and is shown in Figure 61 for various values of Q, ω_r being normalized to 1. The phase is zero at zero frequency and 180° at ω_r, and it tends to 360° at infinite frequency. If we let $\Omega = \omega/\omega_r$, which is the same as normalizing ω_r to 1 and writing ω as Ω, the group delay is given by:

$$t_{gd} = \left(\frac{2Q(\Omega^2 + 1)}{Q^2(\Omega^2 - 1)^2 + \Omega^2}\right)$$

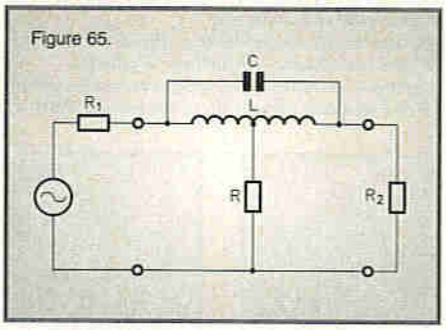
and this is shown in Figure 62 for various values of Q. If Q is much greater than ½, the delay is a maximum at a frequency just below ω_r. The delay at ω_r is $4Q/\omega_r$ and at zero frequency is $2/Q\omega_r$. These are equal if $Q = 1/\sqrt{2}$, but the flattest delay curve is given by $Q = 0{\cdot}67$ approximately.

First-Order All-Pass Delay Circuits

Before it was decided that Dr Georg Simon Ohm probably would not appreciate his name being spelled backwards for the unit of conductance, and the unit name was changed to 'siemens', it was possible to claim that a 2Ω resistor acted as a delay, since it had a conductance of half a mho. Being a German joke, this is no laughing matter [Mark Twain].

On a less serious note, Figure 63 shows two passive first-order all-pass delay circuits. The lattice form can also be drawn as a bridge, and many all-pass networks of this type exist. However, they require either a balanced source drive or a succeeding circuit with balanced input, which is usually inconvenient, so we shall concentrate on the unbalanced forms. These often contain centre-tapped inductors, in which the magnetic coupling between the two halves must be very close. This is best achieved by *bifilar winding*, in which the coil is wound with half the requisite number of turns, but with two strands of wire (insulated from each other, of course), and the two half-coils are

Figure 63. First-order passive delay networks – lattice and T-form.
Figure 64. Second-order passive delay networks.
Figure 65. Bridged-T second-order delay network, requiring only one inductor.
Figure 66a. Minimum inductance all-pass network as a delay network with $Q = 0{\cdot}7$.
Figure 66b. Minimum inductance all-pass network as a delay network with $Q = 0{\cdot}5$.



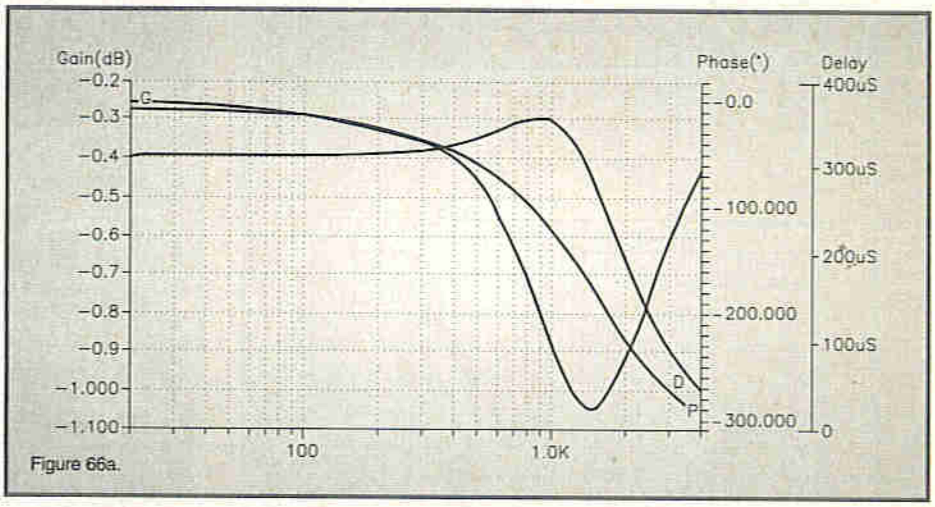
then connected in series-aiding (the start of one is joined to the finish of the other, and this joint forms the centre-tap). The component values for the T-network are:

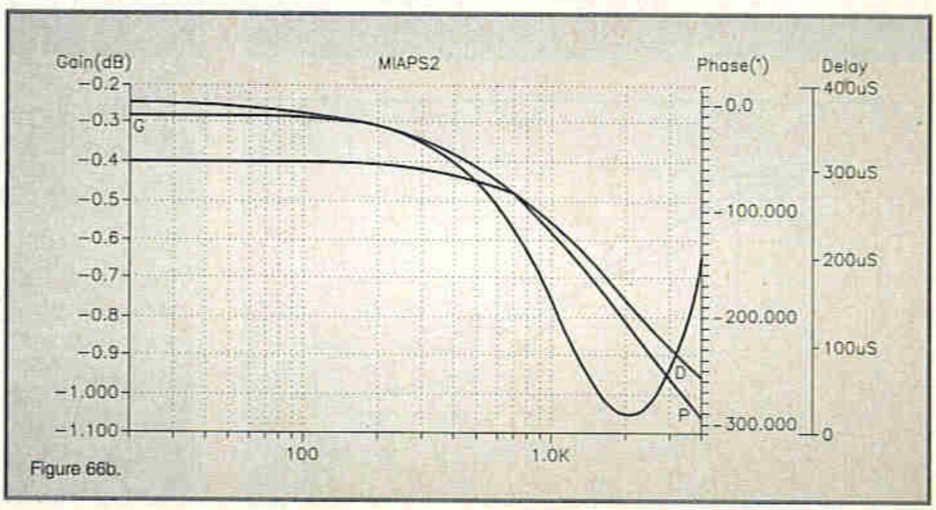
$$L = \frac{2R}{\alpha} \text{ and } C = \frac{2\alpha}{R}$$

Unlike most of the other passive filters we have looked at, this one works between equal source and load resistances R.

Second-Order Passive All-Pass Circuits

Figure 64 shows examples of second-order networks, which also work between equal source and load resistances R. The two circuits for Q>1 are obtained by applying the star-delta theorem to the capacitor triads, and the delta form often gives lower (and therefore cheaper!) capacitor values.





However, if $Q<1$, these circuits require negative capacitors in the shunt arm, which is something of a disadvantage, so the alternative circuit with the tapped inductor is used instead.

The component values are as follows:

$$L_a = \frac{2R}{\omega_r Q} \qquad L_b = \frac{QR}{2\omega_r}$$

$$C_a = \frac{Q}{\omega_r R} \qquad C_b = \frac{2Q}{\omega_r R(Q^2-1)}$$

$$C_1 = \frac{C_a^2}{2C_a+C_b} \qquad C_2 = \frac{C_a C_b}{2C_a+C_b}$$

$$L_1 = \frac{2R}{Q\omega_r} \qquad L_2 = \frac{QR}{2\omega_r}$$

$$C_3 = \frac{Q}{2\omega_r R} \qquad C_4 = \frac{2}{Q\omega_r R}$$

It can be seen immediately (!) that $L_1C_3 = L_2C_4 = 1/\omega_r^2$, so that both arms of the network are resonant at ω_r.

There is a simpler type of second-order network, which works between a (theoretical) zero-resistance source and an infinite load, and is shown in Figure 65. This is the bridged-T circuit that we met before as a notch filter, but with different component values the 'notch' can be of negligible depth. The component values are:

$$R = \sqrt{R_1R_2} \quad C = \frac{Q}{4\omega_r R} \quad L = \frac{4R}{\omega_r Q}$$

and the LC circuit is parallel resonant at ω_r. Actually, we usually start from the delay required at DC and low frequencies, and we saw previously that:

$$t_{gd(dc)} = \frac{2}{Q\omega_r}$$

so we can use this to get rid of ω_r, giving:

$$C = \frac{Q^2\, t_{gd(dc)}}{8R}$$

and, what is more interesting:

$$L = 2Rt_{gd(dc)}$$

independent of Q.

Examples, for Q values of $1/\sqrt{2}$ and 0·5, of the amplitude, phase and group delay responses of this type of delay network with a ratio of load to source resistance of 1000 are given in Figure 66. It can be seen that the amplitude response is quite flat in the frequency range where the delay is practically constant, but is not flat over a wider range. Also, the phase tends to be proportional to the *log* of frequency at high frequencies, whereas the constant delay at low frequencies implies that the phase is proportional to frequency in this range.

For use as phase-correctors for low- or high-pass filters, much higher Q values are usually required, because the delays introduced by these filters (except Bessel and low-order Butterworth filters) peak up considerably in the region of the corner frequency. Unfortunately, there is no precise design method for phase-correctors, so either trial and error has to be used or computer-aided design, which can give least-square error approximations, usually much better than the alternative.

Active All-Pass Networks

These are interesting because of the insight they give into what is going on, whereas the passive circuits defy intuitive analysis (to ordinary mortals, anyway). The fundamental approach of the active circuits is shown in Figure 67, where the box labelled *T(s)* is a passive filter. It can be seen that the unfiltered signal is subtracted from twice the output of the passive filter.

First-Order Networks

If *T(s)* is a first-order low-pass filter, with a transfer function of the form $1/(s+1)$, then the overall transfer function is:

$$\frac{-1+2}{(s+1)} = \frac{-(s-1)}{(s+1)}$$

which is a first-order all-pass function. It differs from the passive circuit in that this one gives a leading phase-shift, but rest assured that it does not predict the future by having a negative group delay! The pole co-ordinate and 'corner frequency' are given by:

$$\alpha = \frac{1}{CR}$$

and the phase response is:

$$\phi(\omega) = 2\arctan(\omega RC)$$

An example of this sort of network is shown in Figure 68. By making *R* variable, a variable phase-shifter is obtained (but there are better ones). The group delay is given by:

$$\frac{2RC}{(\omega RC)^2+1}$$

which is equal to $2RC$ at zero frequency.

If the *T(s)* network is changed to a high-pass filter, an all-pass network is still obtained, but this one has the same lagging phase shift as the passive circuit. The group delay is the same as for the leading phase-shift circuit.

It is also possible to make second-order active circuits, by making *T(s)* a band-pass filter, but the variations and complications are too diverse to go into in this article.

Figure 67. Basic active all-pass network.
Figure 68. First-order active all-pass networks.
Figure 69. Principle of producing a 90° phase difference over a wide frequency range.

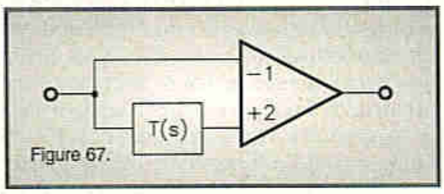


Figure 67.

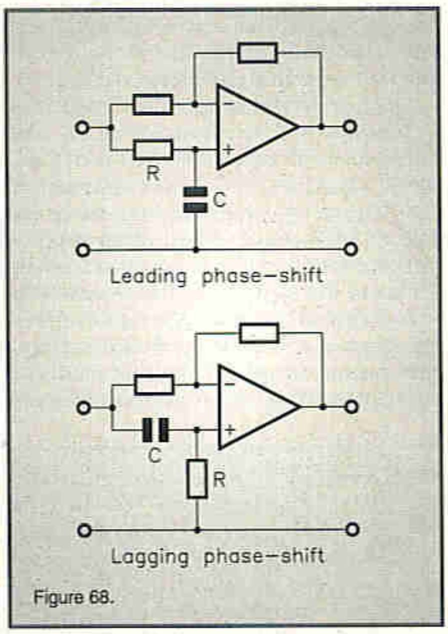


Figure 68.

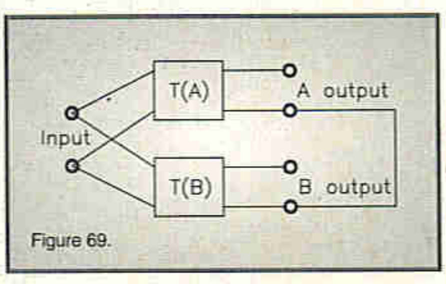


Figure 69.

Wide-Band Audio 90° (Quadrature) Phase-Shift Networks

These are a sort of 'opposite' to delay networks, in that we are trying to *stop* the phase varying with frequency and remain at 90°. It turns out that getting 90° in one go is more than a little difficult, but it is possible to make two all-pass networks whose phase-shifts differ by nearly 90° over a wide frequency range. This results in less complex circuits, because we do not usually care about maintaining any particular phase relationship between the outputs and the input signal, as long as the outputs differ in phase by as near to 90° as we can afford to get.

The basic concept is shown in Figure 69, where *T(A)* and *T(B)* are cascades of first-order all-pass networks. If you think that this implies quite a lot of circuitry, you would often be right: to get less than 1° error over a frequency range of 1000:1 requires ten sections. If 7° error is acceptable, as it may be for some surround-sound applications, the number of sections reduces to six, so the whole thing could be built with three dual op amps. It seems unlikely that anyone (except a coil manufacturer) would favour a passive solution, with six centre-tapped inductors. If we are going to make such a device for surround-sound, the working bandwidth is 20Hz to 20kHz.

There is no direct method of exact design by calculation. Books on filters design list the optimum pole locations (for various bandwidth ratios and tolerable errors), such as those originally published by S.D. Bedrosian in 1960. In our case, the optimum (least phase error) *T(A)* normalized poles are at −43·4, −2·02 and −0·12, while the *T(B)* poles are at −8·34, −0·49 and −0·023. The zeroes are, of course, at the corresponding positive points, since the networks are all-pass.

To denormalize the pole locations, we use a frequency scaling factor '2PIEF' of $2\pi\sqrt{20 \times 20000} = 3974$, and multiply all the above values by it. We then use one of the design equations for the all-pass circuit of Figure 68a:

$$A = \frac{1}{RC}$$

where A is the denormalized pole location, and either R or C can be chosen to be a convenient value (provided that it results in the other component also having a convenient value). The resistors R_1 in Figure 70 can also be chosen for convenience, and 10kΩ is often suitable. The op amps can be as primitive or as sophisticated as you like. The resultant amplitude and phase responses are shown in Figure 71.

–3dB/Octave Networks

The most common application of these is for the conversion of white noise into pink noise. White noise is so named by analogy with white light – it has equal energy or power in each unit bandwidth. Clearly the overall bandwidth cannot be infinite, since this implies infinite total energy. So all 'white' noise is in fact 'band-limited white noise'. This is the form of noise that is theoretically easiest to generate electronically. The thermal noise due to the vibration of atoms in any conductor at any temperature above absolute zero is white noise, but this is not often used as a source because it has very low energy at room temperature. At radio frequencies, the traditional source is a diode valve (tube) with a directly heated cathode: the anode current has a noise component which is predictable from the cathode temperature and thus (after initial calibration) from the filament current. The most convenient semiconductor source is a true Zener diode, which is one having a breakdown voltage less than 6·2V. Those with a higher breakdown voltage are properly called 'avalanche diodes' and have less useful noise characteristics. Strictly, the noise current component of a Zener diode includes a component inversely proportional to frequency, below some process-dependent corner frequency, so for the most accurate sources, the difference between the noise currents of two diodes of the same type (and preferably the same batch) is used as the source.

Continuing the analogy with the spectrum of visible light, red noise has a spectrum which falls at 6dB/octave, while that of blue noise rises at 6dB/octave. Blue noise is produced by an (ideal) FM receiver with no input signal and no de-emphasis. For electroacoustics, noise that has equal energy or power in each unit *fractional* bandwidth (such as each octave, $\frac{1}{3}$-octave or $\frac{1}{10}$-octave) is fairly representative of real audio signals, although as usually generated it has a significantly different probability distribution, but that may be a subject for the future. This sort of noise is called pink noise, and to produce it from white noise we need a special form of filter.

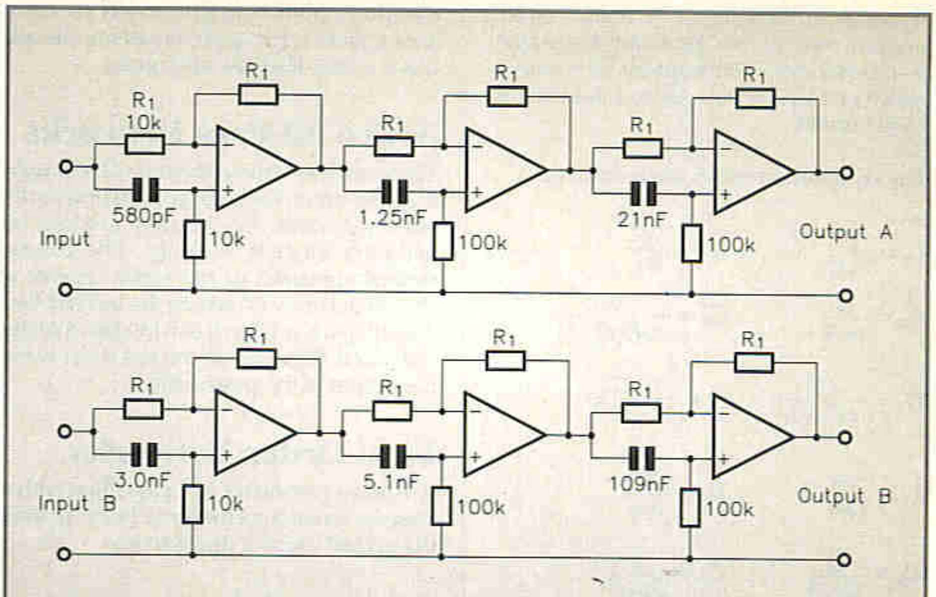


Figure 70.

Figure 70. 20Hz to 20kHz 90° phase-difference networks. With the same signal going in, the phase difference between the output signals is within 7° of 90° over the audio frequency range.
Figure 71. Amplitude and phase responses of the 90° phase-difference networks.

Since even a first-order filter has a stop-band slope of 6dB/octave, we clearly need some form of 'degraded' first-order network. There are two ways of approaching this. We can try to make an impedance that falls at 3dB/octave, which, when supplied with a constant current, produce a voltage falling at the same rate. This is called the 'two-terminal solution'. We could instead try to make a real filter, with distinct input and output terminals, so that feeding a white noise voltage in produces a pink noise voltage at the output. This is the 'four terminal solution'. I don't think there is much to choose between them but the two-terminal solution seems to be more popular commercially. So we will look at that form.

If we put a resistor in series with the Zener diode (or the output of the differences), we get a white noise voltage across it. If we connect a capacitor across the resistor, we get red noise. What we have to do is to put a resistor in series with the capacitor, to reduce the slope of the response curve. This gives us a response with a step in it. By connecting such RC circuits in cascade, we get a series of steps, which look as if we could get our 3dB/octave slope. But where should we put the corner frequencies of the RC networks? Quite a lot of mathematics is required to find the distribution giving the least-square error. (Squaring the errors allows us to treat positive and negative errors as equally significant, instead of tending to cancel in the calculations.) Good results can be obtained by distributing the corner frequencies as *geometric means* between the limits of the bandwidth of interest, however. Now, the concept of one geometric mean is fairly well known: it is $\sqrt{f_1 f_2}$. The idea of several geometric means perhaps belongs to the past, such as O-level maths of forty years ago. The n–1 geometric means between f_1 and f_2 are $\sqrt[n]{(f_1 f_2)^k}$, where k takes integer values from 1 to (n–1). For example, the note frequencies in the equally-tempered scale in music are found by inserting 11 geometric means in an octave – a frequency range of 2:1. Thus the ratio of the frequencies of any two adjacent notes (whether black or white) is $\sqrt[12]{2} =$ 1·05946 . . .

Applied to audio, our band limits are the usual 20Hz to 20kHz, but we have to widen this a bit, otherwise the errors at the band edges are rather too large. A range of 6·3Hz to 63kHz (1:10000) is suitable. Now, we do not want the impedance at the low-frequency end to rise indefinitely, because this would produce a very large output voltage at very low frequencies, which could overload subsequent circuits, so we start our network with a resistor rather than a capacitor. Nor do we want the response to continue at a constant level above the

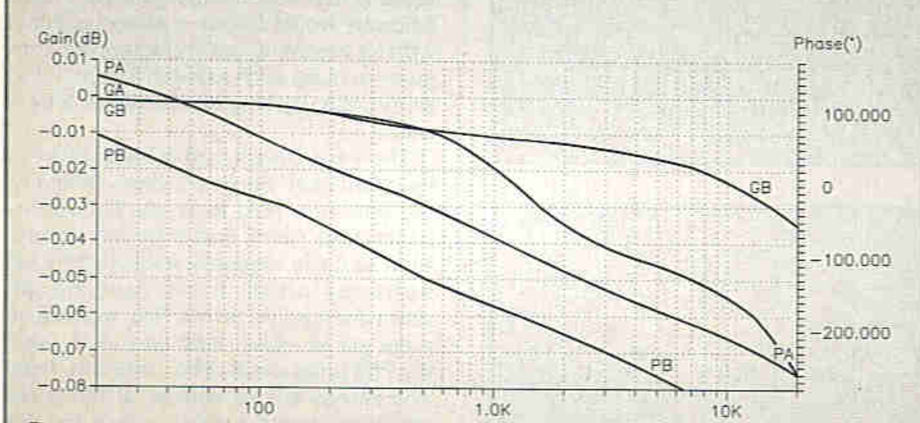


Figure 71.

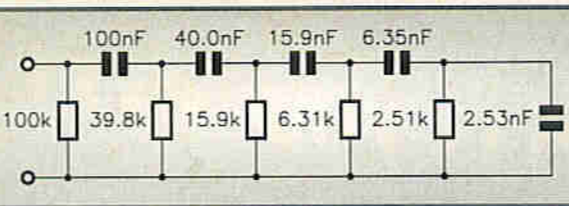


Figure 72.

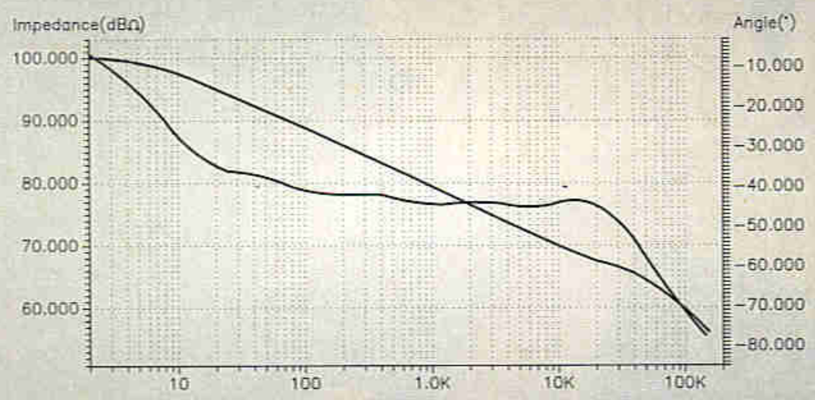


Figure 73.

upper band edge, because this stray energy also might produce unwanted effects, so we want our network to finish with a capacitor (with no resistor in series with it). This we can do by putting an odd number of geometric means in our range. Nine points give a quite accurate response. The ratio r between adjacent frequencies is $\sqrt[10]{10000} = 2{\cdot}512$, so the first geometric mean is at $6{\cdot}3 \times 2{\cdot}512 = 15{\cdot}82$Hz. At this frequency, we want the reactance of C_1 (see Figure 72) to be equal to the value of R_1, which is conveniently 100kΩ, so:

$$C_1 = \frac{1}{2\pi f R_1}$$

which comes to 100nF very nearly. The next value to find is that of R_2, which is equal to the reactance of C_1 at the next frequency, which is 39·75Hz:

$$R_2 = \frac{1}{2\pi f C_1}$$

This is 39·8kΩ, which is also equal to 100kΩ/r, so we can find all the resistor values by dividing the previous value by r. Similarly, the capacitor values are also in the ratio r, so the values are:

Component	Value
R1	100kΩ
R2	39·8kΩ
R3	15·9kΩ
R4	6·31kΩ
R5	2·51kΩ
C1	100nF
C2	40·0nF
C3	15·9nF
C4	6·35nF
C5	2·53nF

There is no point in specifying the values to more than three significant figures, because greater accuracy makes almost no difference to the results, which are shown in Figure 73. The response is within ±1dB from 20Hz to 20kHz.

Figure 72. Network whose impedance falls at 3dB/octave 20Hz to 20kHz.
Figure 73. Impedance and phase angle characteristics of the –3dB/octave network.

Next Time

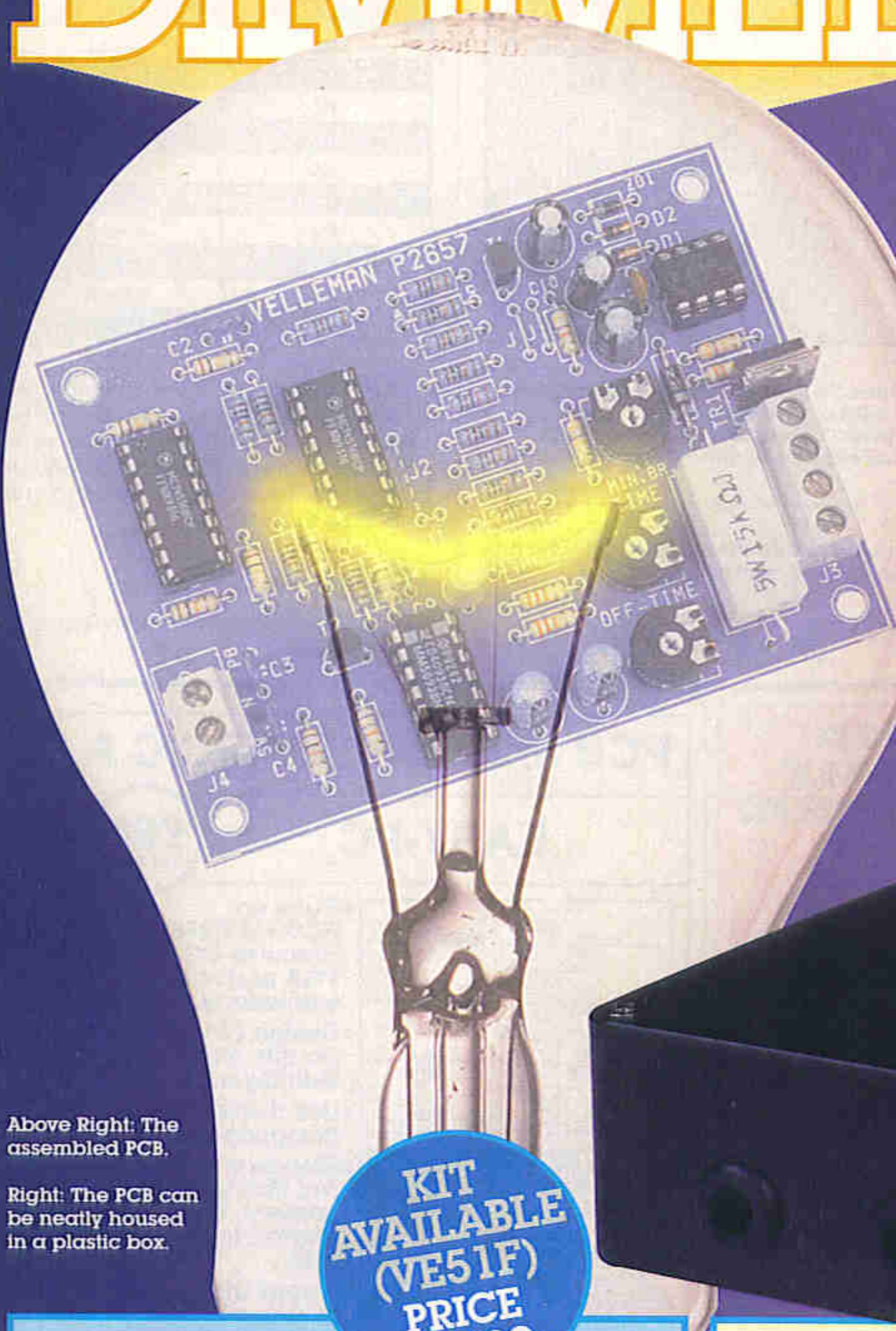
Next month, it will be time to look at filter design software.

Slow on/ Slow off DIMMER

3 PROJECT RATING

Text by Alan Williamson and Mike Holmes

The Slow On/Off Dimmer provides lamp dimming by means of a timer instead of the more usual manual control.



DIMMING times are adjustable over a wide range while the number of possible applications is increased by the following working modes:

Slow Dimmer. The lamp dims up or down, slowly, in response to operation of a switch. Both up and down times are independently adjustable from 2 seconds to 1 hour. Useful for bedrooms, slide/film shows, aquariums, etc.

Timer/Dimmer. In this case a switch can be operated to turn the lamp on at full brightness immediately. After staying on for a while, the lamp will then dim to off. Both the on-time and the dimming duration are adjustable independently from 1 second to 30 minutes. This is suitable for use in garages, on stairways, passages, and as a 'slumber switch', etc.

Above Right: The assembled PCB.

Right: The PCB can be neatly housed in a plastic box.

KIT AVAILABLE (VE51F) PRICE £15.99

Specification

Timing	
Slow dimmer mode:	2 seconds to 1 hour, adjustable
Timer/dimmer mode:	1 second to 30 minutes, independently adjustable
Supply voltage range:	220 to 240V 50Hz 110 to 125V 60Hz 24V AC 50 or 60Hz
Maximum load:	2A resistive (400W at 220V, 200W at 110V)
Dimensions of unit:	95 × 70 × 30mm

FEATURES

- ★ Two working modes: slow dimmer & timer/dimmer
- ★ 220 to 240V AC, 110 to 125V AC & 24V AC operation
- ★ Does not require separate PSU
- ★ Drives loads up to 400W

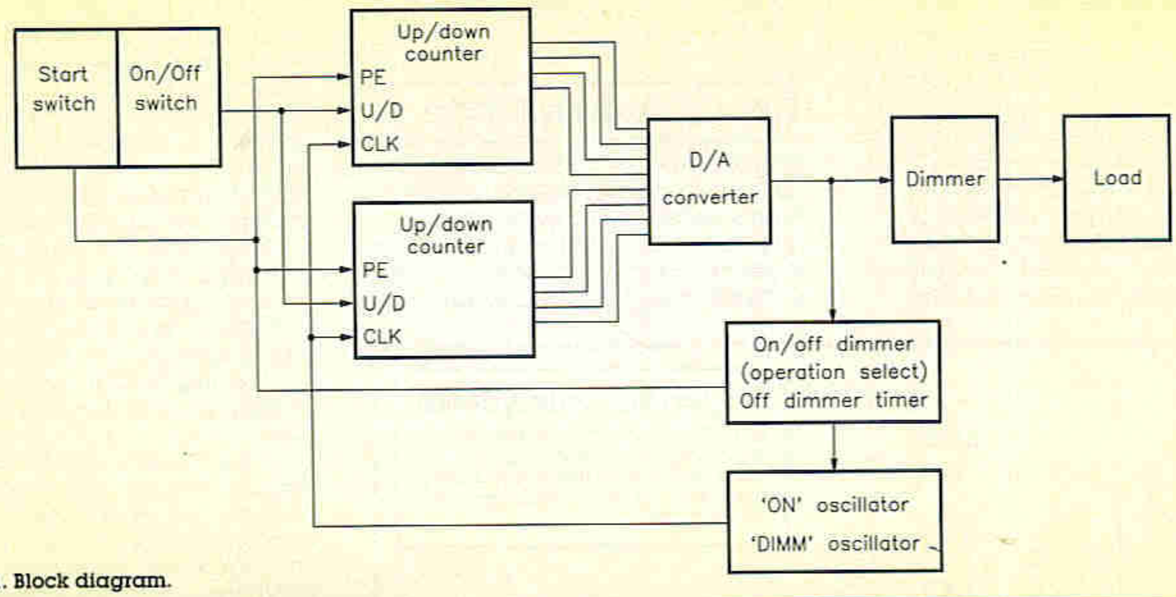


Figure 1. Block diagram.

Circuit Description

Figure 1 shows a block diagram of the Slow On/Off Dimmer, while Figure 2 shows the circuit diagram. In Figure 2, 'PB' (Push-Button) and 'SW' are the 'START' and 'ON/OFF' switches controlling the circuit. Capacitors C3 and C4 are included for switch 'debouncing', preventing noise from falsely triggering the unit.

IC3 & IC4 are CMOS 4516 programmable 4-bit up/down binary counters, which are cascaded and synchronously clocked to form one 8-bit up/down counter. The counter is started by the switches, and a clock input is supplied by a clock source comprising IC2a, b, c & d. IC2, a 4093, 2 input quad Schmitt triggered NAND gate, and the surrounding components around the gates, form two separate gated oscillator circuits, controlling the 'ON' and 'OFF' dimming times; the timing periods are determined by R6, RV3 & C8 and R5, RV2 & C7 respectively. The timing periods can be adjusted with the aid of RV2 and RV3, or by fitting different values for C7 & C8.

A control line, involving IC2a (as an inverter) and originating from SW (link J1) or IC4 Q3 (pin 2, link J2), selects one of the oscillators by disabling the other.

In either case a total count of 255 pulses is needed to completely cycle the 8-bit counter. During this time the counter will change over oscillators when it passes the 128 pulses point, if Timer/Dimmer mode is chosen, but will stop completely at 'terminal count' (i.e. at count 256 or 'carry out' (IC4 CO, pin 7, goes low). In the latter case IC4 CO will turn on T2, which will clamp the clock line to VDD and halt the counter.

The resistors R15 to R30 form a 2R2 ladder network, making up the D-to-A converter block shown in Figure 1. The output from this goes directly to IC1, which converts the analogue voltage into phase-angle control for triac TR1, which controls the mains current to the load. Capacitor C10 is used to average the D-to-A signal, and the resultant voltage applied to pin 6 of IC1.

Slow Dimmer Mode

In detail, then, closing SW will set IC3 & IC4 in an up counting mode; the IC2d oscillator will be enabled and IC2c oscillator disabled (link J1 fitted). IC3 & 4 will then count the clock pulses from IC2b.

Important Safety Note

Because of the variation of possible construction methods, and uses of the unit, ultimately determined by the constructor, full details of wiring connections are not shown in this article. However, for safety reasons it is essential that a suitably rated mains fuse and switch are fitted. Whilst by no means exhaustive, the following recommendations are made:

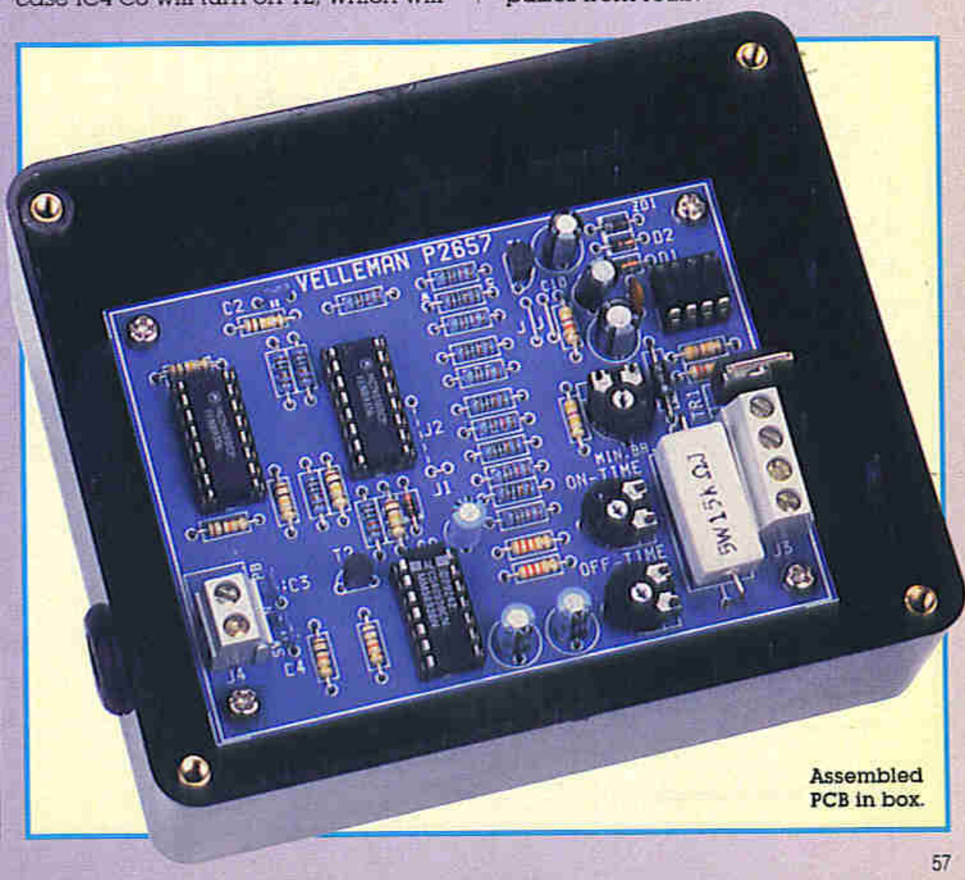
If the final unit is housed in a plastic case (as we recommend, see Optional Parts List), then Class II (double insulated) construction techniques must be employed and the mains connections must comply with Class II requirements.

If the final unit is housed in a metal case, Class I construction techniques must be employed; the case and any metalwork must be earthed.

Other precautions and steps necessary to comply with published safety standards must be employed to ensure safety of the user and servicing personnel.

Every possible precaution must be taken to avoid the risk of electric shock during maintenance and use of the unit. Safe construction of the unit is entirely dependent on the skill of the constructor.

For your safety, it is important that insulation is applied to all the exposed mains connections.



Assembled PCB in box.

When the maximum 'up' count has been reached, the Carry Out of IC4 switches on T2, inhibiting the Clock inputs of IC2 & IC3 thus preventing the counters 'rolling over' to 0000 0000 (binary).

Opening SW will enable the IC2c oscillator and disable the IC2d oscillator. IC3 & IC4 will also change to the 'down' counting mode, and the Carry Out of both counters will change state. T2 will then be switched off, allowing clock pulses from the oscillator to be received again; IC3 & IC4 will then count down to 0000 0000 (binary).

Timer/Dimmer Mode

IC4 & IC5 are programmable type devices, so that pushing PB will 'load' the preset number (binary 1111) on pins 3, 4, 12, 13 into the internal registers of both IC3 & IC4. Thereafter each clock pulse will decrement the counters until a count down of 0000 0000 is reached.

The high logic level from the Most Signifigant Bit (MSB), Q3 of IC4 is used to enable the IC2d oscillator (link J2 fitted); the 'on' time of the light before dimming is 128 clock cycle periods of the IC2d oscilator; the MSB output will then change state, and the IC2c oscillator will be selected.

Fitting a wire link in place of R30 and a diode in place of R23 in the timer application ensures that VDD (minus the diode voltage drop) is applied to pin 6 of IC1 (thus maintaining the light at maximum brightness), until Q3 of IC4 changes state.

IC1 is a TEA1007, a specialised dimmer chip. Pin 6 is the voltage control input; pin 5 of the IC is used to monitor the mains supply for synchronisation of the output (pin 2) which then drives the thyristor TR1 (the load is connected between P & N'); the preset RV1 is used to set the minimum brighiness, either to preheat level (to minimise thermal shock); or, (when used in communal corridors) set at a higher level as a security measure to discourage people lurking in the shadows.

A stabilised voltage supply for the circuit is derived with the aid of the components D1, D2, ZD1, T1, R4 & R14, with supply decoupling provided by C2, C5, C6.

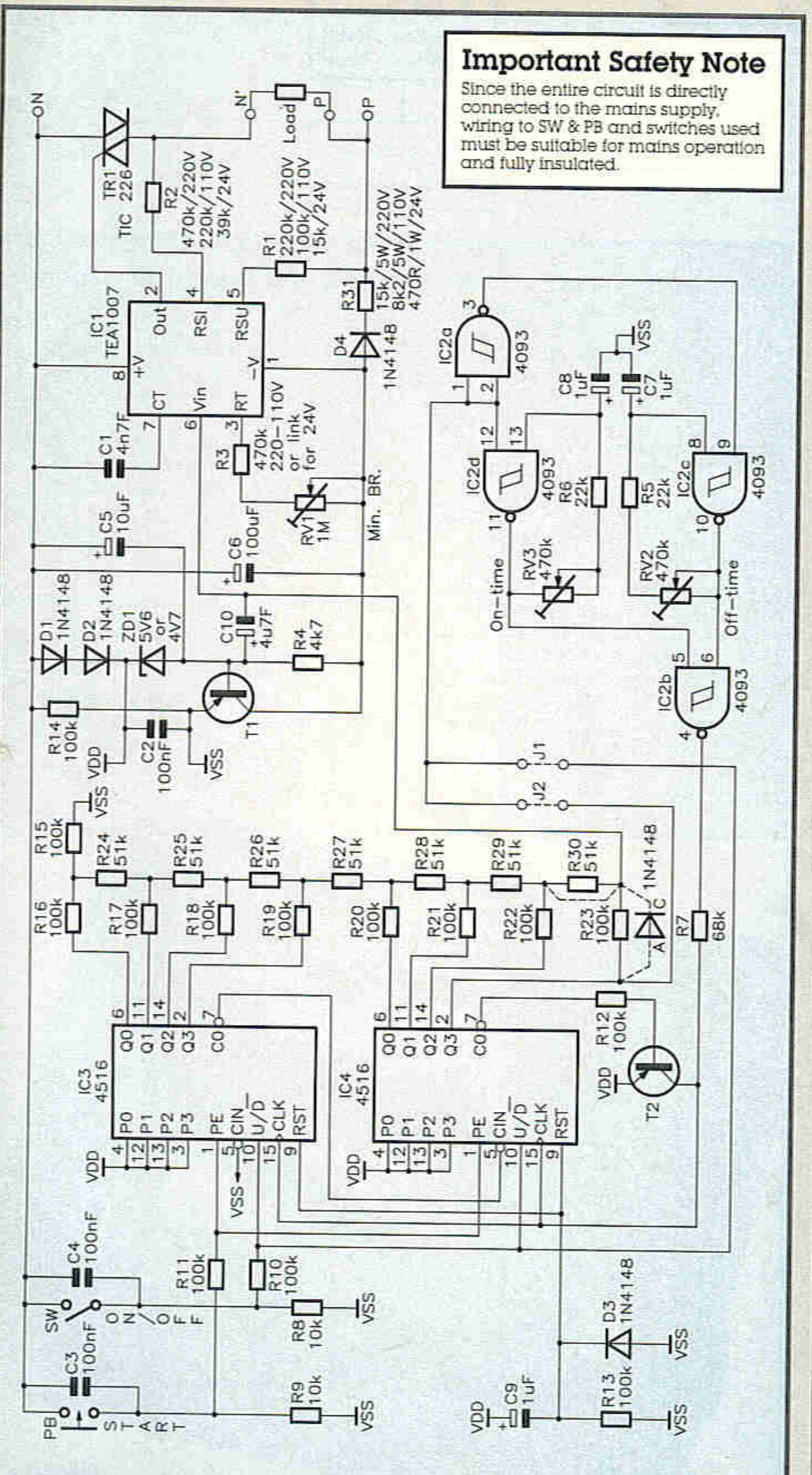


Figure 2. Circuit diagram.

Additional Construction Notes

The leaflet supplied with the kit provides more detailed instructions, but the following additional information is particularly relevant.

Except for initial setting up, on no account must power be applied to the circuit with the lid removed from the box, as mains voltage is potentially lethal. The mains must, therefore, always be treated with the greatest respect.

If in any doubt as to the correct way to build or use this unit, seek advice from a suitably qualified engineer.

Working Voltage

230V		115V		24V	
R1	220k	R1	100k	R1	15k
R2	470k	R2	220k	R2	39k
R3	470k	R3	470k	R3	Wire link

Dimmer Mode
Fit wire link J1
Fit R23, 100k
Fit R30, 51k

Timer Mode
Fit wire link, J2
Fit wire link in place of R30
Fit a 1N4148 type small signal diode in place of R23.

Note polarity: the cathode identifying band should face the legend marked 'C' (at the T1 side).

Table 1. Mode selection.

It is necessary to decide whether the unit is to operate as a timer or dimmer, and to follow the correct instructions as applicable. Another decision that will have to be made at this stage is what voltage the device is to run at, either 24V, 115V or 230V. Some resistor values will have to change depending on which voltage and operating mode is chosen, Table 1 shows these values.

Having completed the above, the next stage of construction can be carried out. Assembly is more detailed in the kit instructions, but the following sequence is recommended; start with the smallest components first, working up to the largest components.

Fit the wire links marked J, followed by diodes (note polarity), resistors, IC sockets, variable resistors, and capacitors (note polarity of all electrolytics). Also note that the values of C7 and C8 can be changed

Figure 3a. Surface pattress drilling details.

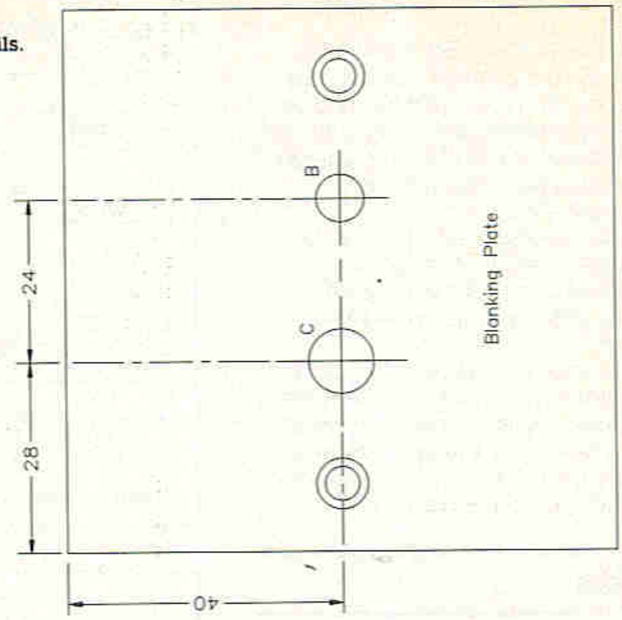
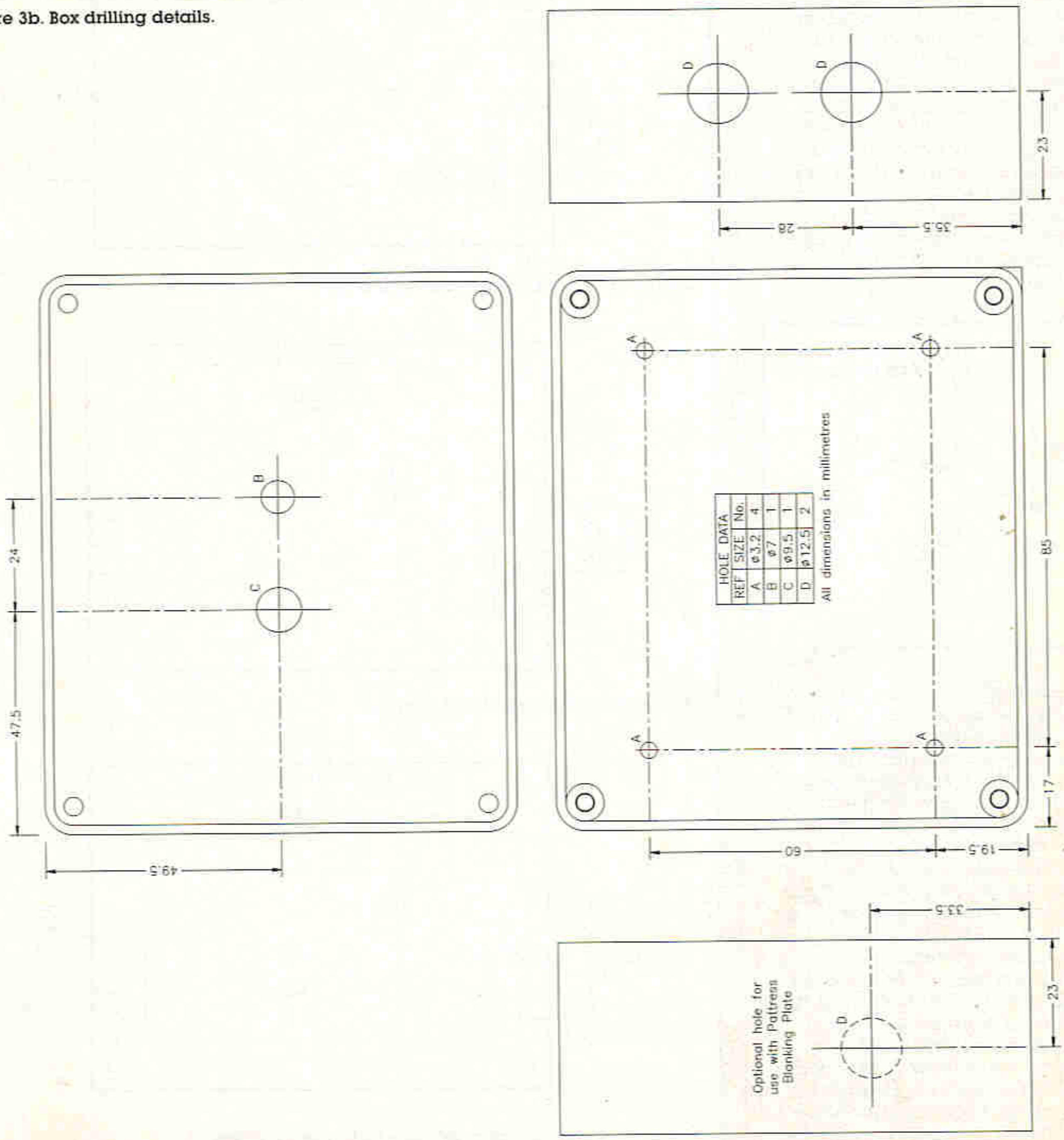


Figure 3b. Box drilling details.



to lengthen the on/off times, see Table 2.

Next larger items like the screw terminals can be fitted, followed by transistors and ICs. It is a good idea to leave the semiconductors until last, to minimise the risk of heat damage while soldering other nearby components on the PCB.

Finally, because the unit may be required to handle high voltages, spray the board with conformal coating after cleaning with PCB cleaner.

We advise that the unit should be enclosed in a plastic box for electrical safety, and Figures 3a and 3b show drilling details for the recommended box (see Optional Parts List), and also an optional surface pattress.

In Use

This device has so many potential uses I don't think that it is possible to mention them all here. With the two modes of operation the device can be used as either a dimmer or a timer, for applications such as:

Dimmer – Switching a light on and off softly, this could be useful for a bedroom, an aquarium, aviary or controlling a slide projector lamp, and bringing a small motor or fan slowly to full speed (maximum current 2A). The 24V capability is ideal for small lamps and motors of this type. See Figure 4 for modifications to 24V operation.

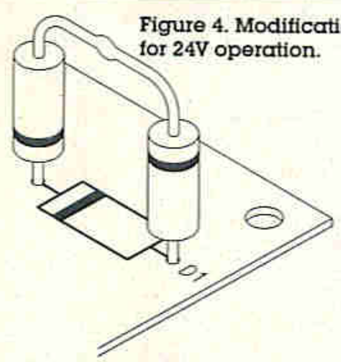


Figure 4. Modification for 24V operation.

Timer – Switching on fully and dimming over an adjustable period of time. This could be useful for bedrooms, stair-wells, passages, garages. Also to control an extractor fan for toilets so that when the door is opened the fan starts up for a set amount of time.

If it is necessary to change or lengthen the dimming times then C7 and C8 can be exchanged for larger values (See Table 2). If the device is used as a timer, several push switches can be connected in parallel, which would be useful if the device was to be used on a staircase (e.g., push switches at the top and bottom).

Figures 5 and 6 show application examples. Figures 5a to 5c are for a mains powered light dimmer, while Figure 6a and 6b show examples for 24V lamps. ▣

Slow on/Slow off Dimmer			
C7	Off-Time	C8	On-Time
1μF	2 sec to 30 sec	1μF	2 sec to 30 sec
10μF	30 sec to 5 min	10μF	30 sec to 5 min
100μF	5 min to 1 hr	100μF	5 min to 1 hr

Timer/Dimmer			
C7	Off-Time	C8	On-Time
1μF	1 sec to 15 sec	1μF	1 sec to 15 sec
10μF	15 sec to 2·5 min	10μF	15 sec to 2·5 min
100μF	2·5 min to 30 min	100μF	2·5 min to 30 min

Table 2. Modifying the on and off timing components.

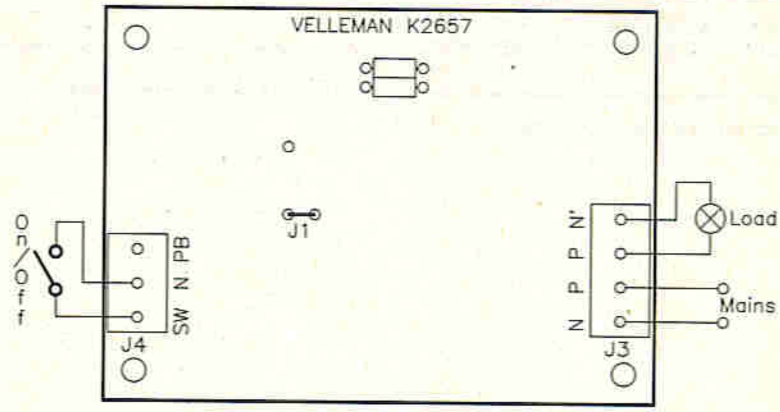


Figure 5a. Wiring for slow on/off dimmer.

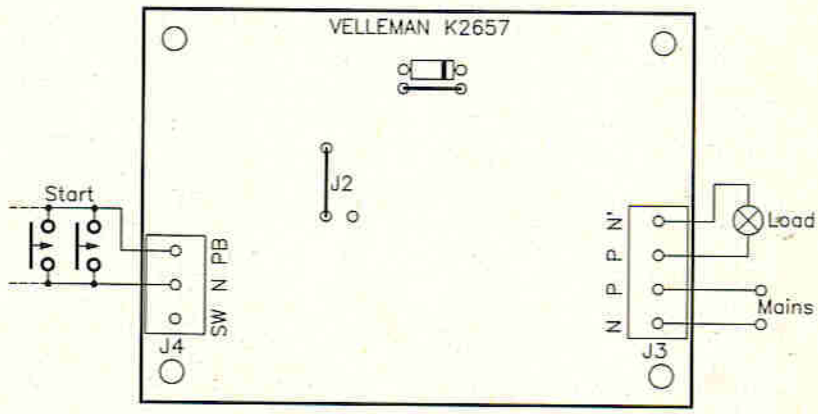


Figure 5b. Wiring for fast on/off timer.

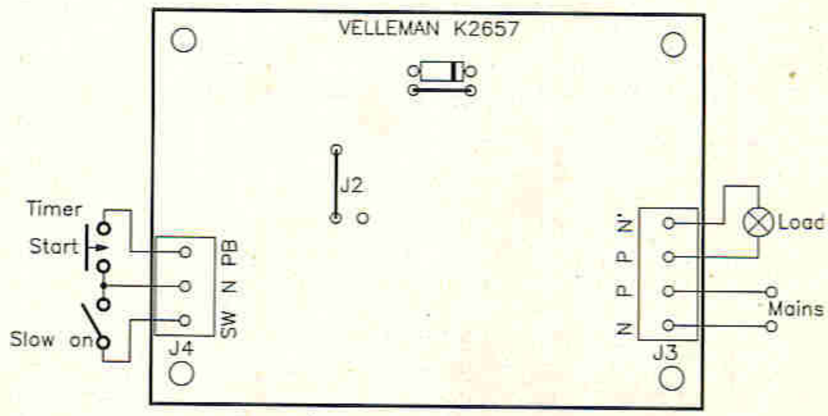


Figure 5c. Wiring for fast on/off timer with slow on option.

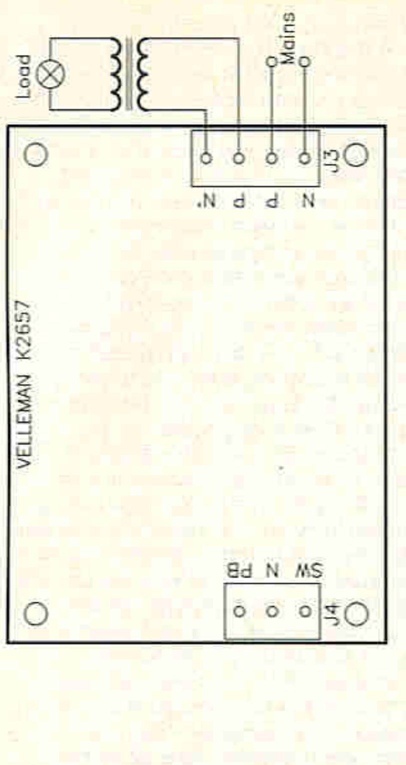


Figure 6a. Wiring for dimming a 24V halogen lamp without modification.

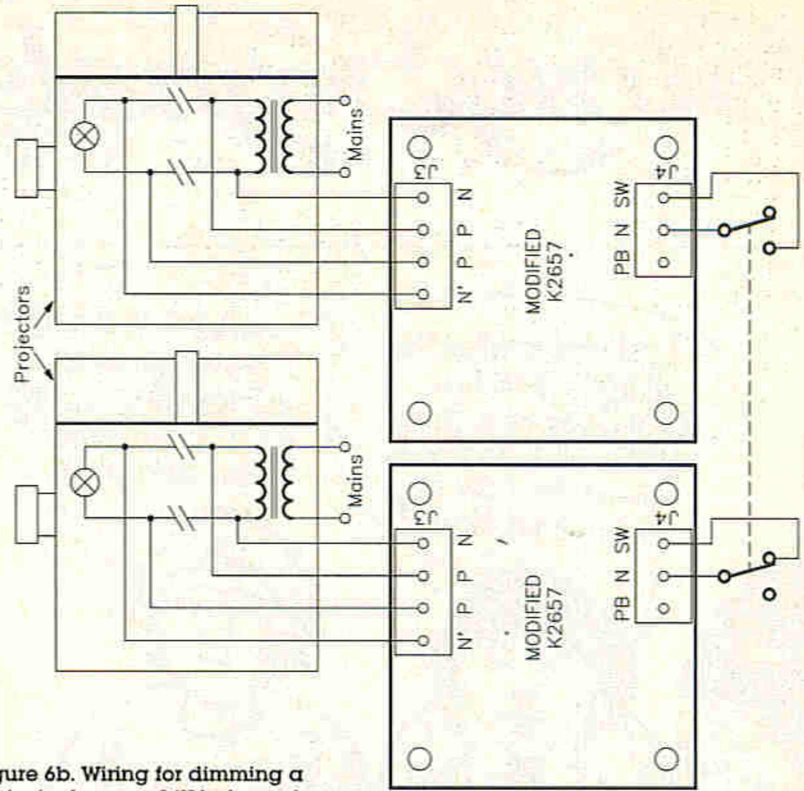
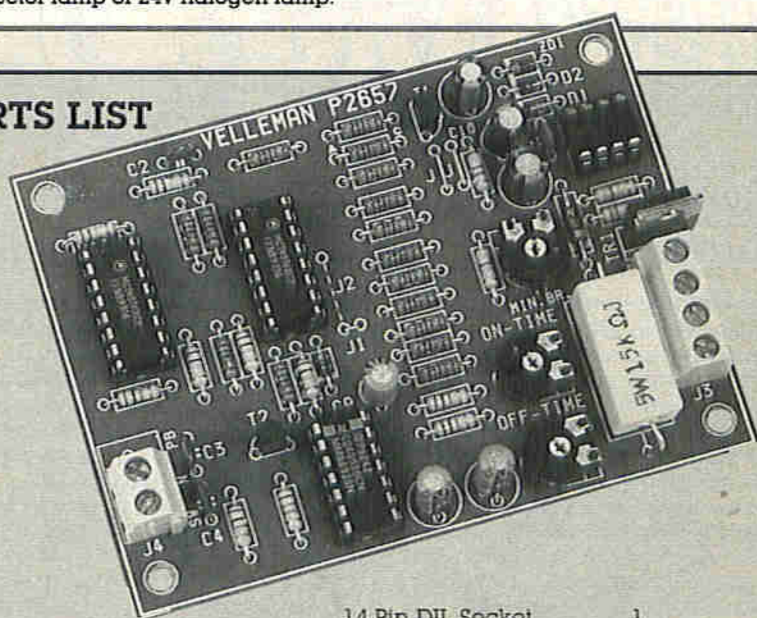


Figure 6b. Wiring for dimming a projector lamp or 24V halogen lamp.

SLOW ON/OFF DIMMER PARTS LIST



RESISTORS: All ⅓W (Unless specified)

R1*	220k	1
or	100k	1
or	15k	1
R2*	470k	1
or	220k	1
or	39k	1
R3*	470k	1
or	Link	
R4	4k7	1
R5,6	22k	2
R7	68k	1
R8,9	10k	2
R10-23*	100k	12
R24-30*	51k	7
R31*	15k 5W	1
or	8k2 5W	1
or	470Ω 1W	1
RV1	Miniature 1M Preset	1
RV2,3	Miniature 470k Preset	2

*See text

CAPACITORS

C1	4n7F Ceramic	1
C10	4µ7F Electrolytic	1
C2-4	100nF	3
C5	10µF Electrolytic	1
C6	100µF Electrolytic	1
C7-9	1µF Electrolytic	3

SEMICONDUCTORS

D1-3	1N914 (1N4148)	3
D4	1N4004-6	1
T1,2	BC557 (BC558, BC559)	2
TR1	TIC226 Triac	1
ZD1	5V6 or 4V7	1
IC1	TEA1007	1
IC2	4093	1
IC3,4	4516	2
	1N914 (1N4148)	1

MISCELLANEOUS

	8-Pin DIL Socket	1
	16-Pin DIL Socket	2
	14-Pin DIL Socket	1
	PCB	1
	Leaflet	1
	Constructors' Guide	1

OPTIONAL (Not in Kit)

PB	Push-Button Switch	1	(FH59P)
SW	Miniature Toggle Switch	1	(FH00A)
	Rotary Mains Switch	1	(FH57M)
	Knob K14 B	1	(FK39N)
	M3 Insulated Spacers	1 Pkt	(FS36P)
	ABS Box Type MB3	1	(LH22Y)
	Pattress Blanking Plate	1	(HL86T)

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 a kit form only.

Order As VE51F (Slow On/Off Dimmer Kit) Price £15.99

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

Stray Signals

by Point Contact

A Spark(l)ing Time was had by All

PC is writing this on 23rd December in the evening, nearing the end of the annual run-up to Christmas, and having just put the Ferranti TESVAC away. "The what?", I hear you say? Well, its a complicated story. A few months ago, PC started a contract of indeterminate length as an analogue electronics development engineer with a company producing products based on state-of-the-art electronic technology. As the end of the last working day before Christmas loomed, like in most firms, people gathered in little knots, discussing the weather, the economy, what they were going to do for Christmas – in fact, anything but work. Despite being a 'new boy' at the firm (although older than most of the other employees, including the bosses), this was PC's cue for providing a little light diversion. The necessary wherewithall had been prepared the night before, and people were soon gathering round gawping at a notice PC had pinned up, saying "Official CMOS Testing Station."

Test your CMOS here TODAY!

The TESVAC was switched on, and made its usual fiery buzzing noise, accompanied by a strong smell of ozone, as the corona discharge from the business-end of the hand-held, poker-like probe fizzed away. PC demonstrated that it was quite safe by drawing an inch-long spark to the tip of the index finger of his other hand, while the bystanders backed away nervously. Astonishingly, no-one offered their CMOS components for testing, which is perhaps as well, though one brave soul held out his forefinger, and was duly sparked.

The original purpose of the TESVAC was (as its name implies) for testing laboratory glass vacuum systems for leaks. Waving the business end over the glasswork pinpoints that annoying leak which prevents you achieving as strong a vacuum as you want or need. At low pressure, the breakdown voltage of air is greatly reduced, so the corona lights up the air inside the vacuum system in pretty purple streamers, emanating from the site of the leak. But all this was news to most of the engineers standing around, who had not led as varied a life as PC. Even so, when PC first came across the TESVAC (found by some apprentices on the rubbish dump of another firm, some years ago), it took him a moment or two to realise what it was. For it is clearly of a pretty ancient vintage, much more so than the Edwards' vacuum testers he had used at The Central Research Labs of the firm that made 'Everything Electrical', back in the '50s.

You Are What You Eat

We're all very conscious of what we eat nowadays, and rightly so. Apples with skin covered in pesticide residues may or may not be bad for you – who knows? – but one would feel happier eating apples not so treated, even if the price to be paid were the distinct possibility of coming across a maggot of the Codling moth happily chomping away inside your apple. And we could all do without rashers of bacon that have been pumped up to twice their size with injected water, and which sizzle back to their original shape as soon as they are put into the frying pan. Should we feel comforted and relieved to see that a food product contains only permitted additives, all of them bearing 'E' numbers? His 'A'-level chemistry of forty years ago being by now somewhat rusty, PC was nevertheless surprised and concerned that a leading brand of free-running table salt contained not only Sodium Chloride – common salt – but anti-caking agents, one of which is Sodium Hexacyanoferrate II, whatever that is. As a simple electronics engineer, PC is deeply suspicious of anything containing a cyano- group. At school, a common quip among lads in the maths and science sixth form (not appreciated by the arty types in history and languages) was that the ultimate cure for headaches was a dose of KCN. An ultimate cure indeed, being the Potassium salt of Hydrocyanic acid, or Prussic acid to you, the stuff of a dozen whodunnits. But doubtless PC's fears are unfounded, and Sodium Hexacyanoferrate II is totally harmless, even beneficial – still, one cannot help wondering. After all, not so long ago, carbohydrates were the curse of mankind, according to the nutritionists – the same ones, doubtless, who now urge us to eat them instead of other foods. And when first introduced to this country, smoking was hailed as beneficial in all sorts of ways, and much to be encouraged, especially amongst the young!

Tailpiece

In our democratic society, our elected representatives in Parliament not only cover political aspects from far left to far right, but are drawn from a variety of professions – for most had some other job before becoming MPs. Thus, there are ex-lawyers, doctors, trades union officials, barristers, etc, etc. But presumably there are few engineers, as pronouncements from various MPs make clear. One classic piece of misunderstanding is illustrated by a politician who was recently reported as claiming that it was a scandal that far more than half of the population earned less than the average wage! Us engineers realise that this is bound to be the case, simply because no-one can earn less than nothing, whilst for the really able (or lucky), the sky's the limit. This pulls up the average far more than the remuneration of the poorest paid workers can pull it down. Put more formally, the incomes of individuals is a case of a Rayleigh distribution, not a Gaussian normal distribution. PC half expected an astute member of the opposite party to reply, claiming that under their benign guidance of the economy, no less than half the population actually earnt more than the median!

Yours sincerely,

Point Contact

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

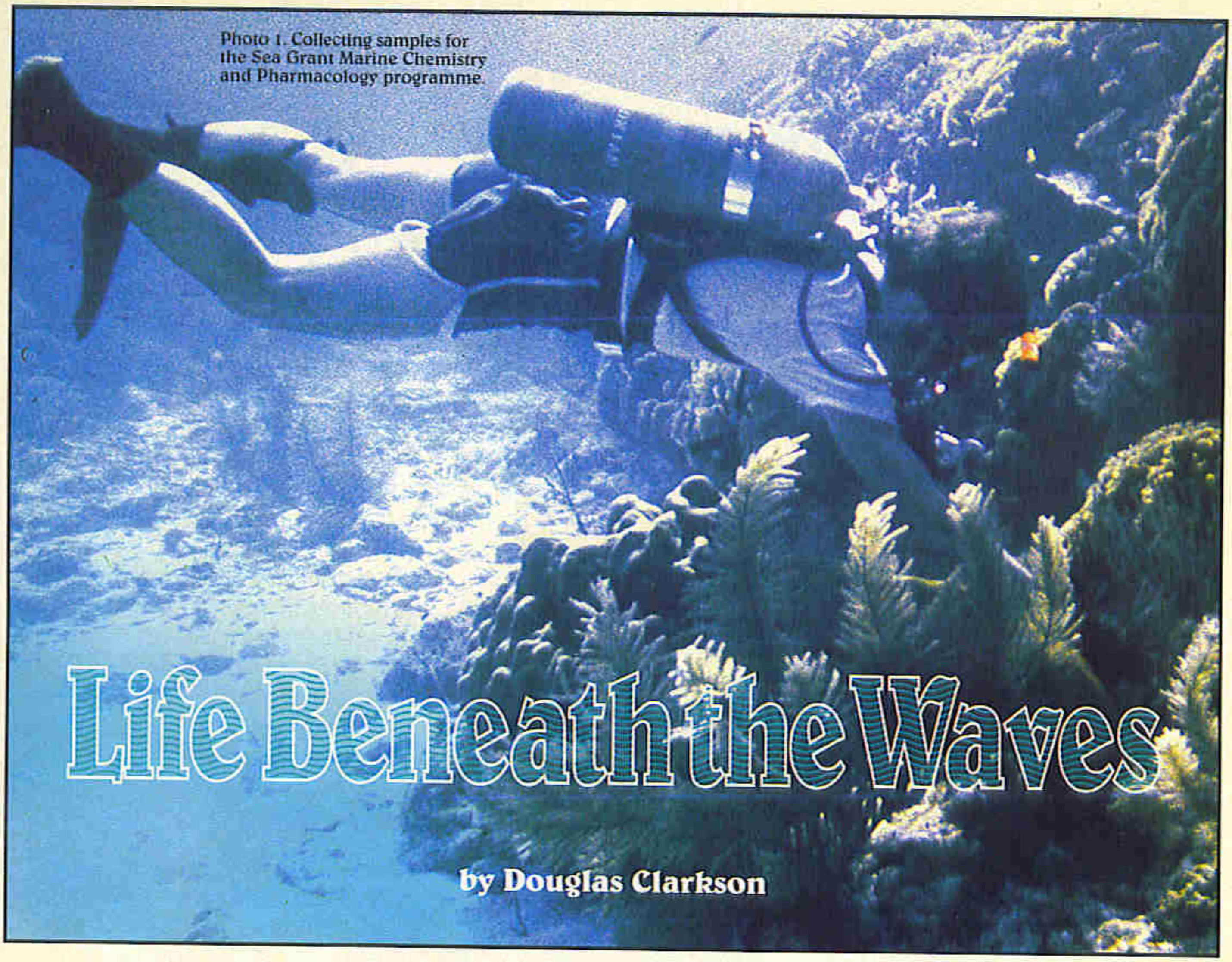


Photo 1. Collecting samples for the Sea Grant Marine Chemistry and Pharmacology programme.

Life Beneath the Waves

by Douglas Clarkson

The world's oceans are, in the final analysis, acting as a vast moderating influence on the climate of the land surfaces. While understanding the role of the oceans in maintaining a stable eco-system above the waves has developed considerably, new discoveries require a continual restructuring of theories of how the oceans determine the point of balance of so many vital systems of environmental equilibrium.

ONE key factor, for example, is how the world's oceans can absorb excess carbon dioxide which is released due to the continued practice of cutting down rain forests and burning fossil fuels. It is going to be vital to predict accurately global CO_2 levels and assess associated patterns of climate change. It may be that the very changes brought about by global warming significantly affects the rate at which CO_2 is absorbed by the oceans from the atmosphere. This could moderate the 'greenhouse' effect or accelerate it.

There are numerous long established research stations around the world engaged in 'Marine Research'. There is also a growing awareness of the importance of research related to the world's oceans. This is due to a mixture of both environmental and economic interests.

Modern technology has also revolutionised the way in which data can be collected and processed. Extensive satellite monitoring of sea temperatures and sea levels around the world can now be undertaken 'effortlessly' by satellite. However, marine studies also require study at the microscopic level in the ocean depths – so that the powers of investigation need to explore things on a vast scale, and also at the level of the smallest living organism in the deepest recesses of the oceans.

Ocean research is very much at the core of scientific research in the USA. It is realised that the deep ocean floor is littered with nodules of manganese and other metals; also, the ocean is a vast store of genetic diversity. While every effort should be made to preserve and conserve the genetic diversity of the world's tropical rain forests, there are equally strong, if not stronger arguments for maintaining and exploiting the genetic diversity of life in the oceans. Large research organisations, however, tend to grow from the smallest of beginnings – such is the history of the Scripps Institution of Oceanography.

The Scripps Institution of Oceanography: The Beginning

In 1885 William Emerson Ritter left his native Wisconsin to teach biology at the emergent University of California in Berkley. He introduced the concept of summer camps along the Los Angeles and San Diego shores to study marine life in the shore and rock pools. Ritter was able to persuade the local community, in particular E. W. Scripps a newspaper publisher, that a local permanent laboratory would be a good idea. The biological research enterprise was launched at La Jolla some 13 miles north of San Diego in 1903 with five professors and five graduate students and a budget of \$100,000. Some 90 years later, this embryonic facility had grown to a staff of more than 1,200, and a budget of around \$80 million.

The Evolution of Scripps

While the initial Scripps site existed as a scientific outpost in a largely underdeveloped sector of California, it is today encroached upon by urban sprawl. This in a way highlights the significant influence of man on the planet in general, to such an extent that emission of greenhouse gases and chemical pollution in the sea is now having a critical effect upon life everywhere. Present awareness of problems, however, is taking place against a significant lack of understanding of the impact of man's activities on the world's oceans; never before has there been such an urgent need to know more.

The present site at La Jolla consists of 65 buildings on a 230 acre site of Pacific shore. One of the more recent additions to the facilities is the Stephen Birch Aquarium-Museum – designed in order to give the public an appreciation of the diversity of life in the oceans – and the relevance of preserving it.

It is difficult to appreciate the range of research activities being undertaken within

Scripps on account of the scale of the organisation. Some activities within the major groupings are described to indicate the general nature of work undertaken.

Marine Physical Laboratory

A key research project undertaken by this group was LEADEX – LEAD EXperiment where the effect on local climate of 'leads' or breaks in the arctic ice was investigated. The arctic ice reflects back into space a significant amount of incident solar radiation. If the arctic ice began to shrink due to the onset of global warming, then this trend could be accelerated as higher levels of solar radiation were absorbed by seawater. A specialised multi-beam Doppler system operating at 195kHz was used to measure current flows within 'leads' which appeared in the arctic ice. This work has allowed a better evaluation of the effect of global warming on the arctic ice-pack.

Acoustic Daylight Imaging

While the waters of the world's oceans rapidly absorb light, below about 1,000 metres a permanently dark world begins, the same waters are filled with ambient acoustic noise produced by the continual activity of the breaking waves on the ocean's surface. The source of this noise is principally, the oscillation of bubbles in foaming water. Workers in this field draw a parallel between the scattered light of daylight and this 'ambient noise' which exists in the darkest and deepest oceans.

The Ocean Acoustics Group of the Marine Physical Laboratory at the Scripps Institution of Oceanography are developing systems that will process the reflected acoustic noise from objects in the sea, and reconstitute images from them.

Such a development has very significant implications for scientific programmes in deep sea studies and commercial applications such as bottom prospecting for mineral deposits and surveillance of offshore structures such as oil drilling and production platforms. There are undoubtedly major applications in naval technology where submerged objects such as submarines would be able to be detected. It may be the case in the future that the old adage 'run silent – run deep' may not be sufficient to escape detection.

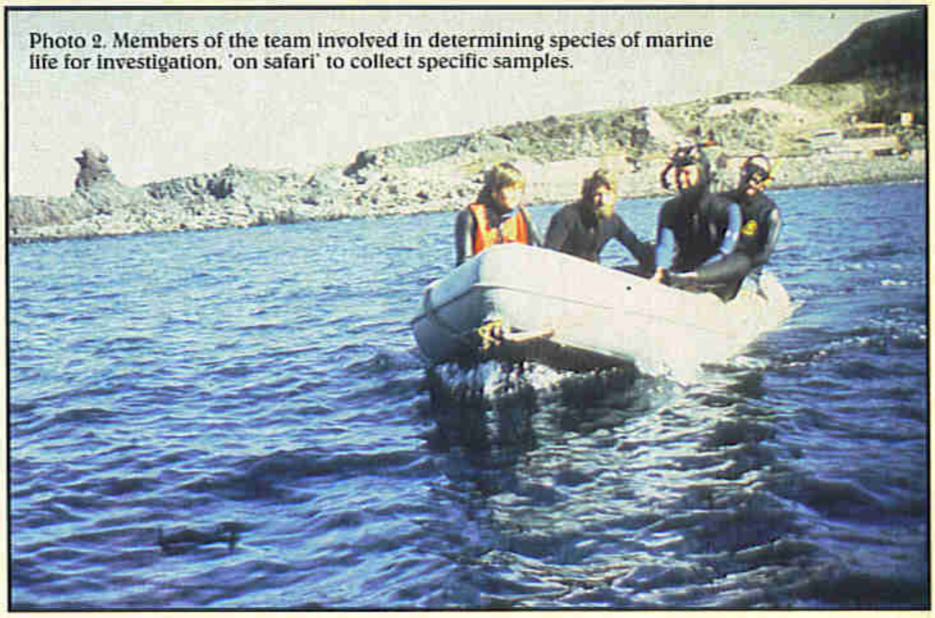


Photo 2. Members of the team involved in determining species of marine life for investigation, 'on safari' to collect specific samples.

Photo 3. The attractive soft coral Lophogorgia produces the compound Lophotoxin – a potent inhibitor of neuromuscular transmission which is widely used in medical research.

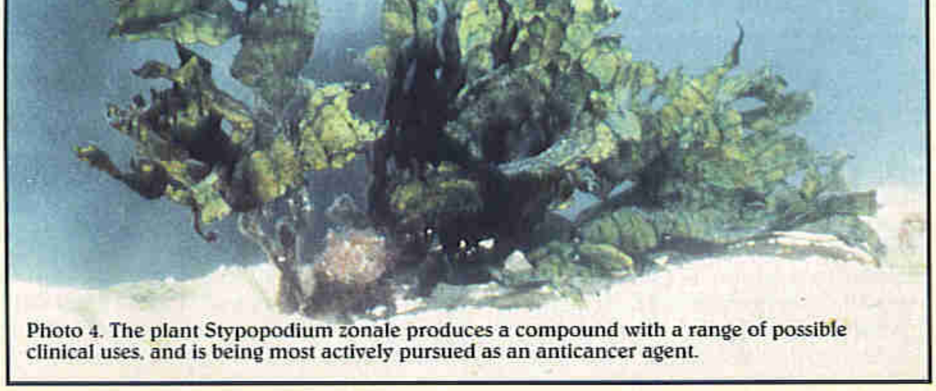


Photo 4. The plant Stypopodium zonale produces a compound with a range of possible clinical uses, and is being most actively pursued as an anticancer agent.

Physical Oceanography Research Division

One of the key factors very much determining states of balance of global weather patterns is air/sea gas exchange – extensively researched by this division. It is now understood that transport of inert climate-relevant gases such as carbon dioxide and methane is controlled by a very thin boundary layer only between 30 and 300 microns thick on the top of the ocean. This is the region within which gas exchange takes place.

While gas transport is increasing with increasing wind speed, the effect of wave size and wave action, and breaking waves and the presence of bubbles, has been difficult to determine. However, new techniques using tracer gas such as Hydrogen Chloride, in low concentration of one part per million, and very low levels of fluorescein in sea water, has allowed patterns of gas transfer to be measured accurately in real time. As the gas is absorbed across the water/air barrier, the chemical reaction between the HCl and the fluorescein solution produces light, which is captured using a charge coupled detector. Such a technique uses state of the art techniques of physics, chemistry and computer science.

Such work is important for predicting, for example, specific rates of gas exchange associated with specific types of surface wave, and also wind strengths. The refinement of such models will allow better prediction of rates of absorption of greenhouse gases, such as carbon dioxide and methane with changing weather patterns over the world's oceans.

Physiological Research Laboratory

Work in this group relates to increasing understanding of the physiological function of sea creatures. Topics being investigated include predicting the change in function of various species, e.g., tuna, if significant global warming takes place. Extensive work has been undertaken with monitoring the respiratory and circulatory system of trained sea lions.

Marine Life Research Group

Scientific observation of sea life needs to be undertaken over significant periods in order to differentiate between normal fluctuations and long term changes. This group has eval-

Photo 5. The Research vessel *Melville* carries out research in biological, geological, physical, and chemical oceanography.

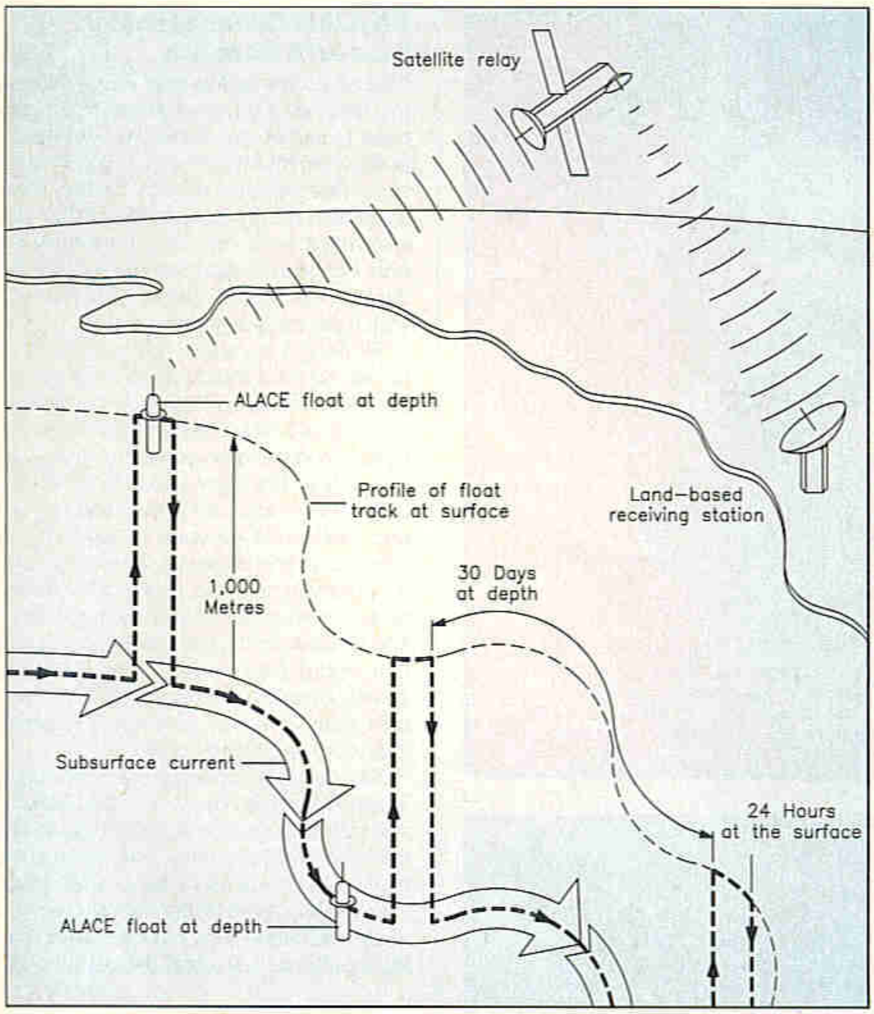


Figure 1. Operation of the ALACE drifter. Such units are submerged to a specific depth where they remain for about 30 days. When they surface again, they transmit their position via satellite to the receiving land station. Reproduced by courtesy of Scripps Institution of Oceanography University of California, San Diego.

uated extensive data over the past 45 years on the marine life of the waters of the California Current which has proved valuable in assessing fish stocks and associated conservation policies. A key finding is that between 1950 to 1991 there has been a 3cm rise in sea level – associated with an average 0·8°C rise in the upper 100m of the sea. This sea rise is associated with the expansion of water as its temperature rises. There is therefore, considerable importance in determining patterns of change in ocean temperatures.

Marine Research Division

This research is engaged in a broad range of research topics. Perhaps the most interesting relates to investigating the genetic diversity of life in the ocean for biotechnology – primarily as a new source of antibacterial agents and anticancer drugs. Special techniques are required for isolation and cultivation of such organisms. Development of skills has made it possible to isolate and culture over 4,000 different types of bacteria and fungi. Specific programmes are in hand with Bristol-Myers Squibb, to evaluate a range of marine organisms. To date several hundred such organisms have been investigated. It is now realised that such micro-organisms are an untapped biomedical resource and possibly the source of a significant number of the next century's new 'wonder' drugs.

Species in the sea face typically greater threats to existence than land based species. There is for example, more scope for access of predators to vulnerable species. This has led to widespread and sophisticated development of chemical messenger compounds as active agents to repel predators. Such compounds are being actively investigated by teams at Scripps for medical applications.

Photos 1 and 2 show activity in collecting samples as part of the Sea Grant Marine Chemistry and Pharmacology programme.

A highly developed set of compounds include neurotoxins – used by various aquatic species to paralyse their prey. One such compound, lophotoxin, derived from the soft coral Lophogorgia, shown in Photo 3, is being used by several medical schools to investigate neuromuscular disease. The compound tetrodotoxin (the puffer fish toxin) is a useful agent for the study of nerve transmission.

The brown seaweed Stypopodium zonale shown in Photo 4 produces the compound Stypoldione which is currently being evaluated by the Eli Lilly Company primarily as an cytotoxic anticancer agent.

The plant, Lufferiealla has been found to contain a compound with anti-inflammatory activity. Researchers at Scripps are investigating its use as a possible substitute for the steroid cortisone.

While very few terrestrial species produce compounds containing halogens such as chlorine, over 600 halogenated species have been identified and variously produced by marine bacteria, red algae and sponges. Such compounds have similar properties to synthetic herbicides and insecticides. There is considerable interest therefore in assessing the usefulness of such 'natural' compounds for use in place of today's polluting agricultural chemicals.

Climate Research Division

Almost everyone will have heard the phrase 'global warming'. The Climate Research Division at Scripps has a prime role of collating data to examine and predict climate variability on time scales of weeks to decades. One of the large multi-disciplinary projects relating to this topic is Sequoia 2,000 – a multi-campus University of California effort sponsored chiefly by the Digital Research Corporation. The project allows state wide data collection over networks and hardware and software tools for the analysis of large data sets. It is hoped that the model for climate prediction thus developed will identify cycles of natural variation, and also any long term contribution based on man's environmental impact through increases in carbon dioxide emissions.

Geological Research Division

The ocean floor provides a vast area for collection and examination of rock samples. Sea floor drilling programmes provide additional information about the age and distribution of the floor of the oceans. Experimental data collected by this unit in terms of physical structures provide insight into mantle and crustal evolution – both with regard to the upheavals of the past and future trends in crustal activity. One project undertaken recently by the group related to assessing indicators relating to the activity of Mount Pinatubo in the Philippines by examining lavas from recent and previous eruptions. While most of the work is based on academic research, it is linked in many places with evaluating oil and mineral wealth under the seas. This group at Scripps has recently structured a Micropalaeontological Reference Centre, based on deep sea sediment sequences recovered by projects, such as the Deep Sea Drilling Project (DSDP) and Ocean Drilling Programme (ODP). It is the function of this centre to make available to scientists round the world, specific extracts from the sequences. In time the amount of scientific interest in the samples is likely to sample the collection out of existence.

Marine Biology Research Division

This group undertakes research akin to that of the Marine Research Division, but with more emphasis on theoretical mechanisms and with less emphasis on technology transfer. Extensive work is undertaken in revealing details of DNA of genes in bacteria from a range of depths in the ocean, and relating this to environmental adaption and symbiosis with marine invertebrates.

Neurobiology Unit

The Neurobiology Unit at Scripps has extensively researched the nerve organisation in the legendary Coelacanth – the fish which lived in the world's deep oceans during the age of the dinosaurs. Such studies now provide details of the missing links of evolution which saw the development of land creatures from species that were once ocean bound. In many ways the Coelacanth's genetic make-up holds the key to various lines of evolution for land based creatures.

Deep Ocean Currents

An understanding of ocean currents is vital for proper development of models simulating and predicting patterns of global climate. Surface currents are now readily mapped using satellite tracked drifter buoys. There are, however, independent currents at greater depths below 100 to 200 metres which play a major part in determining patterns of intermixing of ocean waters.

The Scripps Institution of Oceanography have been assisting in developing and deploying devices code named ALACE (Autonomous LAngrangian Circulation Explorer). Each ALACE device is a neutrally buoyant float which drifts with the current at a preset depth down to 2,000m. Initially a device is programmed to submerge to a preset depth and remain at that level for a specific period – typically 30 days. At the end of its immersion period the ALACE unit rises to the surface and broadcasts a unique identification signal using its 80cm whip antenna. This signal is picked up by ARGOS system on board a NOAA polar orbiting satellite. Figure 1 indicates the various stages of deployment of ALACE devices.

After spending about a day on the surface the ALACE unit submerges again to its preset depth. Researchers collating data from the devices are able to measure the speed of currents at depth in the oceans. Around 300 such units are currently in use – principally in tropical Pacific and South pacific. Subsequently sensors for temperature and salinity have been fitted. Logged data is compressed in format by each ALACE's on board microprocessor for transmission via the ARGOS satellite link.

This development in 'intelligence' of autonomous units increases significantly the scope for data collection from the world's oceans, and is an indication of the trend for design and function of such systems.

Listening to Currents

Ocean scientists are now utilising ultrasound Doppler technology to accurately measure ocean currents. The new type of device is called a Acoustic Doppler Current Profiler (ADCP). Four beams are typically deployed. In Figure 2, two beams of ultrasound are shown. Micro-organisms (plankton) are moving from left to right in the ocean current. In A the plankton has a component of velocity away from the sound source which results in a decrease in scattered frequency. In B the plankton has a component of velocity in the direction up to the sound source resulting in an increase in scattered frequency. The degree of the frequency shift is directly proportional to the relative velocity of the plankton.

While the ADCP system provides information about the relative velocity of the current relative to the ship, there may be inaccuracy in determining absolute current measurements. Use is now routinely made of global positioning systems which provide an absolute reference of any net ship motion so that absolute current estimations can be made.

Research Vessel Melville

While an increased amount of research can be undertaken using satellite sensing and automated independent sensors such as ALACE systems, surface research vessels still play a unique part in ocean research.

First commissioned in 1969 and refitted in 1992, the vessel is 278 feet long with a displacement of 3,000 tons, and is one of the key vessels in the Scripps fleet (shown in Photo 5). Because of its specialist design, problems arose in the refit, and a planned phase of 12 months, in fact took 33 months and an Act of Congress to complete. The extensive recent refit, which increased the length of the craft by 10 metres, has added a range of features to the craft including a specially designed Sea Beam 2,000/SIO multi-beam echo-sounder, which can map a strip of seafloor 15 to 22km wide. A beam width of 90° is used for depths up to 11km, and a beam width of 120° for depths up to 4·5km.

Beneath the Antarctic Ice

An extensive amount of research work is undertaken by divers in order to locate and collect specific samples of plants or minerals and species of plants and sea creatures. Diving always has its risks though there is little doubt that it is diving under the Antarctic ice which is the most hazardous. One of the most experienced divers in the Scripps team is Jim Stewart who undertakes regular training courses in diving techniques and safety procedures at the McMurdo Station on Ross Island – some 750 miles from the South Pole.

The chief danger for divers in the antarctic is the severe cold. Water temperatures can fall to as low as −2°C. The rugged fabric covered neoprene diving suit is worn over a set of full body thermal undergarments. Heat loss through the head is minimised by a tight fitting neoprene hood, and to protect the hands two pairs of insulating gloves are worn.

The extreme cold can cause pressure regulators to freeze up – giving rise to a fault known as free flow where higher than normal demand air flow occurs, and which increases the chances of the diver running out of air. Divers carry two independent

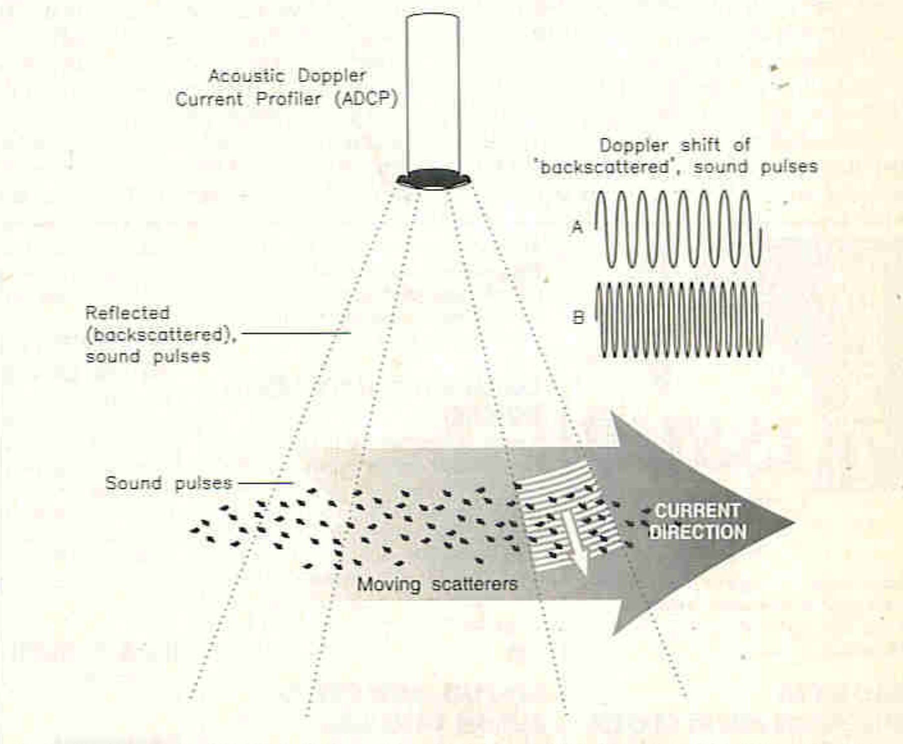


Figure 2. Function of Acoustic Doppler Current Profiler: Relative motion of plankton in the ultrasound beam changes frequency of signal and allows current velocity to be measured with considerable accuracy at various depths. Reproduced by courtesy of Scripps Institution of Oceanography University of California, San Diego.

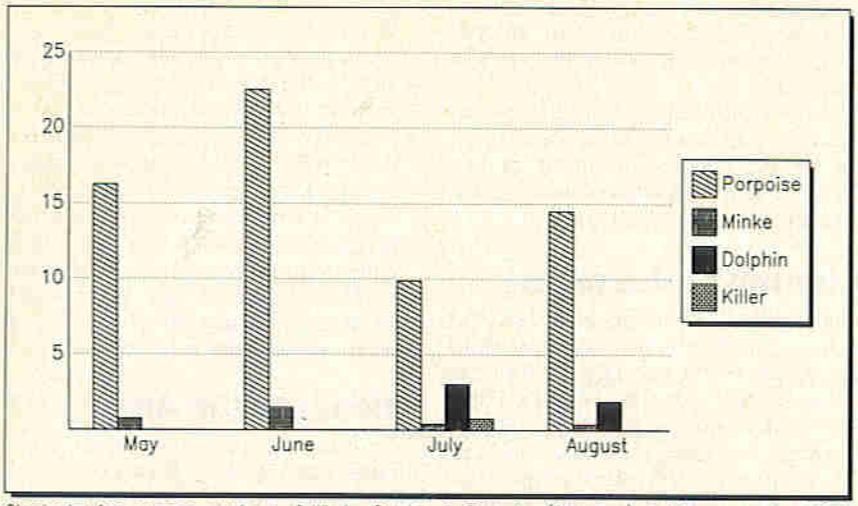


Chart showing average numbers of Whale, Dolphin & Porpoise (Cetacean) sightings per day, 1994.

Figure 3. Catacean Sightings. © Ian Birks. Reproduced by courtesy of Ian Birks.

scuba regulators, so that in the event of one freezing up the diver can switch to the auxiliary regulator.

The use of such a dry suit combination allows the diver to wear useful layers of insulation. If a tight fitting wet suit was used, exposure to high sub-zero winds above ground could lead to rapid hypothermia.

One of the most amazing features of the Antarctic Waters is the degree of clarity of the water. This is affected significantly by the level of plankton in the water. In high summer with 24 hours of daylight and under thin ice, plankton will suddenly blossom and visibility will fall to between 30 and 40 feet – increasing the chance of a diver becoming lost under the ice.

However, when the sun is low on the horizon and divers are working under five to seven feet of ice so that there is little plankton present, lights hung from the dive holes can be visible for as far as 1,000 feet; the water is almost as transparent as air.

In the words of Jim Stewart "If you were to freeze the top five feet of the Grand Canyon and cut a hole through the middle and then step through, that is how you would feel the first time you dived under the Antarctic ice."

Under the British Waves

While all aspects of marine life from plankton upwards are of key importance, interest in Britain has always been keen in observing 'cetaceans' which include Sperm whales, Minke whales, Pilot whales, Dolphins and Porpoises. The greatest diversity of such sea life exists in the waters of the north west of Scotland. The 'Sail Gairloch' sea survey project has been established from the Gairloch in Ross-Shire, Scotland, in association with Sea Watch Foundation, founded by the Head of Zoology at Oxford. Daily sailing can be chartered aboard the yacht 'Starchild's Dream', a 10 metre ketch able to navigate the unpredictable waters of the Minch and beyond. Sailing boats have a natural advantage in being able to get closer to such large sea mammals without disturbing them. Packs of killer whales also roam in these waters and can even target Minke whales. Their more common prey, however, will be seals.

Figure 3 shows the typical sighting activity over the 1994 summer season. The most commonly sighted species in any month is the porpoise. In previous seasons, sightings have been made of a 'Super Pod' of Porpoise with at least 300 within a half mile radius of the yacht. Sightings of Sperm whales have taken place off the Isle of Rona, to the south west. Minke whales appear to be more common during June and Dolphins and Killer whales during July.

There is therefore both a good chance of seeing 'something', as well as coming into contact with a range of species. Minke whales which can be over 30 feet long, provide the most memorable experience.

The skipper of 'Starchild's Dream', Ian Birks, a professional Offshore Yacht-master, is convinced that wildlife of the sea has to be effectively observed as part of the process of conserving this precious resource. To see such creatures in their natural habitat increases awareness of the futility of hunting them in commercial whaling. Hopefully the publicity from such initiatives as the Sail Gairloch Sea survey project will lead to better appreciation of the value of such creatures in the diverse ecosystems of the world's seas and oceans.

Conclusion

Just as life began in the ocean so too will it be the maintaining of life in the oceans which will lead to stability in ecosystems on land. Thus both large organisations and individuals have a role to play in increasing awareness of the importance of stewardship of the oceans, and all that they contain.

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Acknowledgment

Photographs illustrated in this article are reproduced by courtesy of the Scripps Institute of Oceanography, University of California, San Diego.

NEWS Report

Wind-Tunnel Moves to BRE

A dispersion modelling wind-tunnel and two leading wind-tunnel experts have transferred to BRE's Cardington Laboratory from the former Warren Spring Laboratory.

Dispersion of pollutants by prevailing winds must be considered when assessing the polluting potential of industrial discharges. There are considerable practical and economic benefits to be gained by using wind tunnel modelling to provide reliable estimates of dispersion. It allows effective planning of plant design to reduce risk and of siting to minimise pollution problems. It also enables an informed choice to be made between the use of discharge stacks or abatement plant for pollution control.

The wind-tunnel, one of only a few of this type worldwide, has a working section 22m long, 1·5m high and 4·3m wide. The wind speed range is from 0·2 to 10m per second with a typical operating speed of 1m per second. The tunnel should be operational by Spring 1995.

Contact: Building Research Establishment, Tel: (01923) 894040.

Radio Maplin

On 18th March, 1995, the Preston shop will be breaking new ground for Maplin Electronics, by hosting an Amateur Radio Open Event Station, run by Central Lancashire Amateur Radio Club.

This will involve communications across the globe using several Amateur Bands from within the shop.

Plus, there will be a selection of equipment supplied by Waters & Stanton on show, including short-wave listening equipment.

Anybody interested in Radio Electronics, please come and visit us during the day and have a go!

Contact: Alan Milburn, Tel: (01772) 258484, or Peter Sinclair, Tel: (01772) 312912.

Cordless Mouse?

Logitech has announced, what the company calls, the industry's first budget cordless PC controller. Known as the Trackman Live!, the unit is a mouse-like device that operates over a radio link with a range of around 30 feet.

Contact: Logitech, Tel: (01344) 894 300.

Government Warning: Mobile Phones May Seriously Damage Your Health!

On 4th January 1995, the Department of Health issued a circular advising hospital managers to ban cellular phones from areas of their facilities containing sensitive equipment, following tests carried out by the department proving that electromagnetic fields generated by portable phones could, in certain circumstances, interfere with medical equipment, with "potentially serious consequences for patients".

Cases have occurred where a ventilator attached to a patient suffered interference, and another patient's computer-controlled infusion drip system appeared to have been reset, following use of mobile phones nearby.

Although the circular stops short of issuing a ban on cellular phones within hospitals, it recommends that mobile phone use should be deterred in areas such as intensive care units where problems could occur, and that staff be advised of the possible risks involved.

Cellular phones may pose a risk even when not in use, as they regularly poll the network to advise the network of their location, so that incoming calls can be handled appropriately.

Ian Volans of Mercury One-2-One, one of the network operators which helped the department to draw up the guidelines, advises that "In our user's guide, we say that the operation of any radio transmitting equipment may interfere with inadequately shielded medical devices. It is better to be safe than sorry."

The circular notes that, while a National Health Service quality standard for new equipment sets limits of interference susceptibility, existing equipment, which will remain in use for many years, is unlikely to meet this new standard and may suffer interference from mobile phones used nearby.

Contact: Department of Health, Tel: 0171 210 5983.

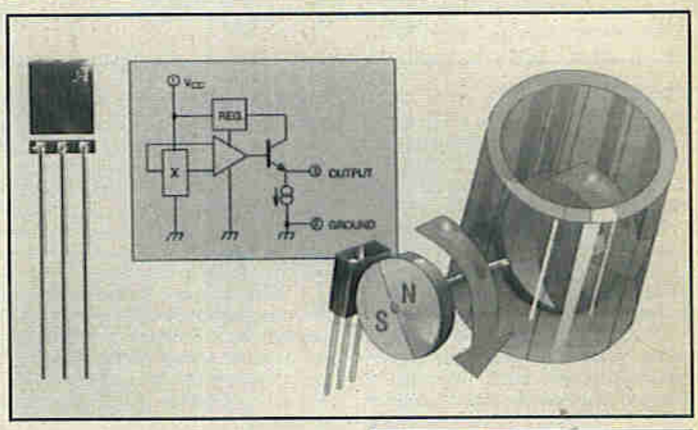
Young Engineers for Britain 1995

The Engineering Council's 'Young Engineers for Britain' regional and national finals and the Young Engineers clubs' regional and national awards, organised by the Standing Conference on Schools' Science and Technology (SCSST), will be joint events from 1995.

'Young Engineers for Britain' strengthens links between education and industry, by encouraging engineering project work by students and young people undergoing training and each year attracts 1,000 entries from 11 to 19 year-olds competing for the title of 'Young Engineer for Britain'.

The SCSST's Young Engineers clubs are now operating in 500 schools, with a nationwide membership of 10,000 students. Its regional and national awards are judged on a wide range of criteria including quality of project work, ingenuity, design excellence and marketability.

Contact: The Engineering Council, Tel: (0171) 240 7891.



High Temperature – Hall-Effect

A new generation of high-sensitivity linear Hall-effect sensors from Allegro MicroSystems produces a voltage output that is proportional to the incident magnetic field.

The A3506 and A3507 sensors are monolithic integrated circuits which each incorporates a quadratic Hall element, temperature-compensation circuitry, a signal amplifier, and a ratiometric rail-to-rail output stage.

The devices include on-chip processing circuitry which provides an output signal at a level that minimises the need for external amplification, allowing direct connection to analogue/digital converters or microprocessor inputs.

Contact: Allegro, Tel: (01932) 253 355.

Chip on Glass

Citizen has developed a 4·7in. Dual Scan Colour STN (Super-Twisted-Nematic) Passive Matrix graphic LCD. Based on the company's 'Chip-on-Glass' technology, the new 4·7in. version is suited to portable applications that require a small-sized LCD, but also the resolution benefits of a larger panel such as Personal Digital Assistants (PDA) devices and palmtop PCs.

Contact: Citizen, Tel: (01753) 584 111.

BBC Radio 4 Produce First Dolby Surround Drama: 'BOMBER'

On 18th February 1995, BBC Radio 4 broadcasts its first Dolby Surround drama, entitled *Bomber*, this dramatisation of the Len Deighton novel traces the story of a Lancaster raid over Germany during the Second World War, the programme being transmitted in four episodes during the same day, corresponding to the actual time that the operation took place. Listeners with Dolby Surround audio systems will have the atmosphere further enriched by means of the multi-channel soundtrack.

The Dolby system, generally associated with pictures, is also suited to radio, with BBC Radio 1 having already given such broadcasts, in productions including *Batman: Knightfall* and *The Adventures of Superman*.

Other programme formats currently using Dolby Surround include video, television, CD and computer games, and these may be experienced on a widening range of playback equipment, including a/v amplifiers, TV sets, midi systems, and other home entertainment systems, numbering over 15 million worldwide.

Contact: Dolby Laboratories, Tel: (01793) 842100, BBC Radio 4, Roger Danes, Tel: (0171) 765 4759.

SMC and AT&T in Wafer Fabrication Alliance

Standard Microsystems Corporation (SMC) has entered into a co-operative wafer fabrication alliance with AT&T Microelectronics that provides additional submicron fab capacity to AT&T and guarantees a portion of fab output to SMC.

Following installation of the SMC-purchased equipment, which comprises steppers, etchers and metrology equipment, the line will be capable of producing device geometries from 0·9µm to 0·45µm. The first production wafers from the line for SMC's use are expected by the end of calendar year 1995.

Contact: AT&T Microelectronics, Tel: (01344) 865927.

Microsoft Target Computer Illiterate

You might think everyone in the world except a hermit living in a cave knows the name Microsoft, but the software company has launched a US$100 million worldwide ad campaign that it says is aimed at increasing brand awareness.

Mike Maples, Microsoft executive vice president, said the campaign is particularly aimed at people who are not computer literate. According to Maples; "I think there's a large part of the population (at least two-thirds) that aren't computer literate, and those are the people who we're trying to lure into computing and Microsoft products".

Contact: Microsoft, Tel: (01734) 270 000.

TI Announces US$100,000 Design Competition

Texas Instruments (TI) has launched the 'TI DSP Solutions Challenge', a worldwide contest for electrical engineering students with a prize of US$100,000 to be shared by the winning team of students.

Open to students from countries around the world, the contest will award prizes for student design projects that develop new or innovative uses for Texas Instruments' digital signal processor (DSP) line of integrated circuits and peripheral products.

Digital signal processors (DSPs) are high-speed, maths-intensive, programmable integrated circuits that are revolutionising electronics in the 90s much like the microprocessor revolutionised computers in the 80s. The DSP, which can add and multiply tens of millions of complex formulae per second, is 10 to 50 times more powerful than other computer central processing units (CPUs).

Digital signal processing is the technology that will enable the electronics industry to develop radically new products and systems in industries such as cellular communications, computer storage devices (hard disk drives), modems and personal computer (PC) multimedia.

The judges will look for designs that address complete digital signal processing solutions. A typical system might include components such as a digital signal processor, analogue input/output devices, memory application-specific system peripherals, glue logic and software to pull the whole design together.

The deadline to submit a final project, which includes a detailed description diagram of the hardware or software design, is 31 December, 1995. Judging will be completed and the grand prize will be awarded in April 1996.

Contact: Texas Instruments, Tel: + 33 93 22 2427.

Ghost Busting

Successful tests of a new technique to improve television picture quality to viewers affected by ghosting has been carried out by the Independent Television Commission (ITC).

At a demonstration in Enfield, North London in November, the ITC showed experimental equipment which can be added to an existing television receiver to reduce picture 'ghosting'. The ITC hopes tests with a prototype could lead to the introduction of the 'ghost-canceller' within three years. This could be in the form of special television sets or add-on units which would greatly reduce the effects of ghosting.

Ghosting on television reception can occur in built-up and hilly areas. Enfield is ideal for a demonstration of this type, as particular problems with ghosting have been experienced in this area since the erection of Canary Wharf.

The experimental system requires a Ghost Cancellation Reference (GCR) signal to be inserted into the transmitted television signal. Existing televisions should not be affected by this, but special circuits need to be incorporated in the receiver to remove ghosting. The GCR signal has been included experimentally on selected ITV programmes in the South of England and S4C in Wales since January 1994, and has recently been tested on Channel 4 Transmissions from Crystal Palace.

The development work has led to the international standardisation of the GCT signal. Other European broadcasters are expected to begin testing the system soon and the ITC is working with the European Broadcasting Union on its evaluation.

Subject to broadcasters agreeing to transmit the signal permanently, the first European consumer ghost cancellers could be introduced by Philips in 1996. An add-on unit is predicted to cost approximately £200 and in 1997 integrated television sets are expected to become available at an additional cost of between 25 and 50% per set.

Contact: Independent Television Commission, Tel: (0171) 255 3000.

Bookham Wins Innovation Award 1994

Bookham Technology, winner of this years NatWest/Sunday Times Innovation Award, has announced the development of optical circuit manufacturing technology, known as ASOC (Active Silicon Integrated Optical Circuits).

With the development of ASOC, Bookham has optimised the production method of optical chips. The technology is based on the same processing techniques as those used in the manufacture of silicon electronic chips, but combined with silicon micromachining and innovative integrated optical designs, that provide a low-cost solution.

The advantage of ASOC not only refers to the cost of manufacture, but also to the simplification of the packaging procedures which is considered to be one of the major bottlenecks in the opto-electronics industry at present. Using ASOC, the micromachined features of the chips are aligned to the optical elements, allowing accurate alignment of fibres and lasers down to less than one micron.

Contact: Bookham Technology, Tel: (01235) 445 377.

DSP Chip to Add Speech to PCs

DSP Group has announced a new family of application-specific digital signal processors (DSPs) for adding speech processing to personal computers and telephony products. The first two products are a messaging co-processor, and simultaneous voice-over data technology, both of which employ DSP's Truespeech compression technology.

Truespeech, developed by DSP Group, is a speech compression technology which enables speech to be used in personal computers and telephony without requiring large computer memory or telephone line bandwidth.

In July last year, Microsoft announced that it would include Truespeech in the Windows 95 operating system. According to DSP, this move is expected to make Truespeech widely available in IBM PC-compatible computers. In addition, DSP says Truespeech has been endorsed by a number of major semiconductor manufacturers, including Intel, Motorola, AT&T, Texas Instruments, and Analog Devices.

Contact: DSP Group, Tel: +408 986 4475; e-mail: brindfleisch@dspg.com.

National Lottery Numbers Program

New from COSMI UK is Justlotto, a low-cost Windows program for PC users, that aims to predict the winning National Lottery numbers. The program is based on the mathematical iterative 'Link Number' theory, and analyses previous weeks' winning combinations to detect number patterns, improving accuracy of predictions with each week played.

The programmer has studied results of Lotteries from around the world, revealing that playing every week with a randomly-marked ticket only produced 2 or 3 small wins a year – not even breaking even! Justlotto has been developed specifically for the UK National Lottery, and aims to increase this low return.

Justlotto is available in selected branches of WH Smith, Woolworths, Tesco, Beatties, Comet, Byte, Staples and MVC (Music Video Club), retailing at £19.99.

Contact: COSMI UK, Tel: (01923) 284930.

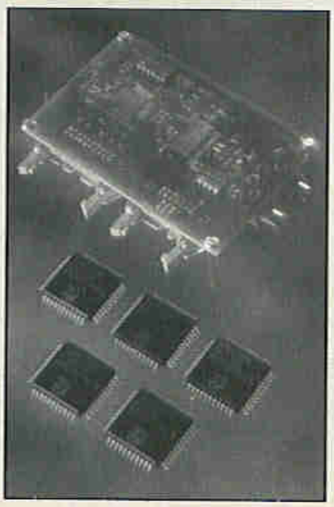
Cyrix Announce 586 Plans

Cyrix has revealed details about its first M1 architecture product, a 586 microprocessor that is both superscalar and superpipelined. The company says the chip is targeted to be the fastest x86 CPU (central processor unit) for personal computers.

Superpipelining divides the pipeline into seven stages, a design Cyrix claims provides for higher frequencies and better performance. Superscalar means the M1 architecture comprises two separate instruction pipelines, allowing the chip to execute two separate sets of instructions in parallel.

The chip includes a 64-bit data bus and a single 64-bit enhanced x87-compatible floating point pipeline. The on-chip floating point unit (FPU) uses a four-instruction queue and four independent 64-bit write buffers.

Contact: Cyrix, Tel: +214 994 8387.



Low-Power MPEG Decoder

To facilitate the rapid growth of digital audio in applications such as digital radio, video disk, digital video broadcast CD-I and multimedia computing, Philips Semiconductors has introduced a high-performance decoder for MPEG-1 data-compressed audio signals.

Incorporating master and slave MPEG data inputs, automatic sample frequency and bit-rate detection, full MPEG-1 layer 1 and 2 decoding, advanced error protection and audio post processing, the SAA2500 Audio Source Decoder offers the highest level of functional integration currently available in a MPEG decoder.

Packaged in a 10mm square 44-pin quad flat pack and drawing only 26mA from a 5V supply, it also provides a combination of small size and low power consumption which is unique in this market, making it ideal for use in battery-powered portable equipment.

Contact: Philips Semiconductor, Tel: +31 40 724 825.

INTRODUCING THE

TERMINATOR 10

ELECTRONIC MULTI-TEST SCREWDRIVER

IDEAL FOR

* Detecting output from transmitters
* Tracking cables and locating faults
* Detecting emissions from TV sets
* Detecting static from computer monitor screens
* Testing for radiation leakage on microwave ovens
* Testing fuses (out of circuit)
* Passive no contact testing
* Testing lamps or bulbs

KEEP ONE IN THE CAR, YOUR TOOLBOX OR INDOORS, NEAR THE FUSEBOX.

First Choice for: * Electricians * Electronics enthusiasts * Electrical engineers * Mechanics * Hobbyists * DIY'ers * Householders * Motorists

There are so many uses for the Terminator 10 Electronic Multi-test Screwdriver, and it can be used in so many applications instead of a sophisticated test meter. How often have you wished to test a fuse or bulb, but not had your test meter to hand? This no longer need be the case! You will find this ingenious Electronic Multi-test Screwdriver so useful, you will wonder how you managed without it.

Use the Terminator 10 Electronic Multi-test Screwdriver for the following:

Fuse and bulb tester, self powered continuity tester, short circuit tester, cable break detector, TV screen or computer monitor static tester and microwave oven leakage detector and much, much more . . .

It's so easy to use . . . Touch both ends of the Terminator 10 to self check. Then to test the continuity of, for example, a fuse, take the fuse out of the appliance or plug, touch the cap of the screwdriver with a finger of one hand and hold one end of the fuse with your other hand, then touch the free end of the fuse with the blade of the screwdriver. If the fuse is OK, the red LED inside the screwdriver will illuminate.

The Terminator 10 Electronic Multi-test Screwdriver is supplied complete with two AG3 type button cells. Battery life is approximately 5 hours of continuous use. Also supplied is a 13A fuse for testing.

Dimensions 136×20mm (including handy pocket clip).

Order Code 50562

(Terminator 10 Electronic Multi-test Screwdriver)

Warning: the unit is *only* suitable for use as a continuity screwdriver and is not suitable for direct connection to AC mains supply. Never use this screwdriver to work on live apparatus.

Electrical faults are a common cause of accidents, fires and personal injury. Faulty appliances should be properly repaired of disposed of safely. When in doubt, always contact a qualified electrician.

Subscribers' special introductory offer price **£5.49**, for ordering information see separate leaflet included in this issue. If the offer leaflet is missing call Customer Services on **(01702) 552911** and have your Subscriber's Customer Number handy. Please note this offer is only available to current subscribers to *Electronics – The Maplin Magazine*. Offer ends 28th February 1995 and is not eligible for further discount.

Note: If ordering by mail order, normal handling charges apply. This product is not shown in the 1995 Maplin Catalogue. Subject to availability.

This neat and compact amplifier module contains two TDA1514A, high quality power amplifier ICs which are compatible with a wide range of the source material, including compact disc.

FEATURES

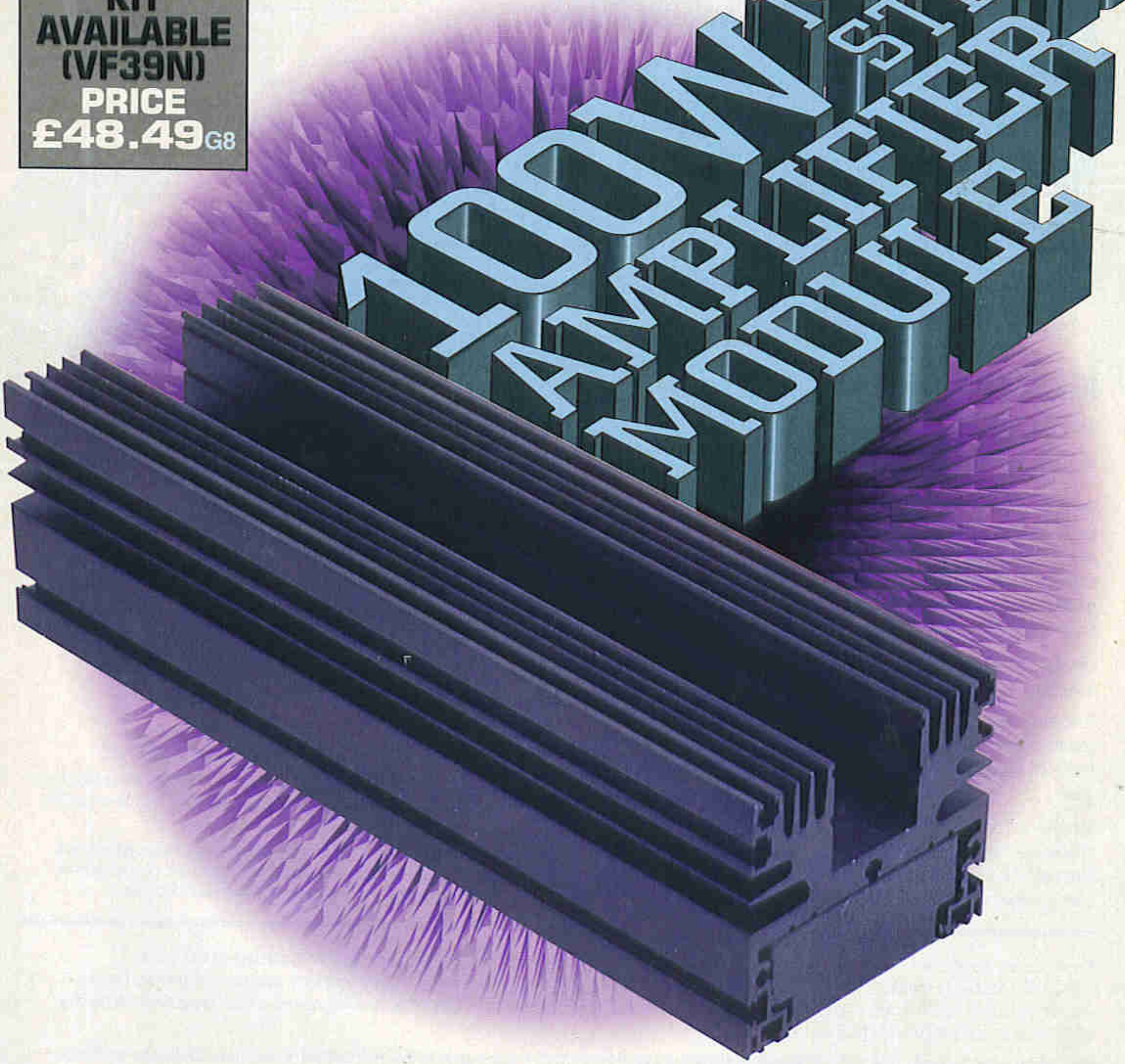
- 2×50W into 4Ω, 2×40W into 8Ω
- 100W into 8Ω (Bridged Mode)
- Overload and short circuit protection
- Selectable input level
- Thermal protection

2 PROJECT RATING

Text by Alan Williamson and Mike Holmes

KIT AVAILABLE (VF39N) PRICE £48.49 G8

100W MONO/STEREO AMPLIFIER MODULE



A ready-built Gold Line version of this amplifier is available which is known as the AMP100; Stock Code VF46A.

Circuit Description

A block diagram of the unit is shown in Figure 1, and the circuit diagram in Figure 2. The circuit could not be simpler, each channel contains a monolithic operational power amplifier IC and a hand full of passive components.

Protection of the circuit is provided by the fuses F1 & F2 in the supply lines. In the event of wrong polarity connections, the diodes D1 & D2 will conduct and blow the relevant fuse; this method of polarity protection is preferred to a series connected diode (because there is no voltage drop); this is an important criterion, as an efficient PSU means that more energy is delivered to the speaker without waste. The capacitors C16 & C17 increase the PSU common mode rejection, while capacitors C8 to 11 increase the differential rejection.

The TDA1514A is supplied in a 9-pin SIL plastic package (SOT131A). The IC features protection against AC and DC short circuits when used with symmetrical supplies. The IC also includes an output mute circuit preventing clicks and bangs during switch on and switch off, eliminating the possibility of damage to delicate tweeters. The amplifier is also protected against thermal runaway and includes SOAR (Safe Operating Area Region) protection making the device almost indestructible.

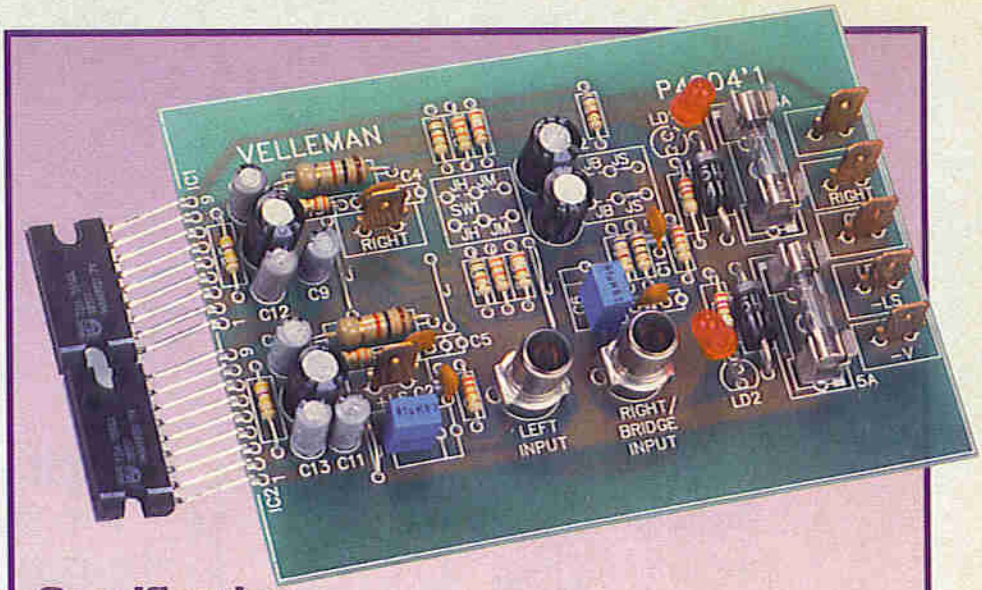
The left and right channels are identical, therefore only the right channel will be described.

The input impedance of the amplifier module determined by R1; the capacitor C6 AC couples the signal to the amplifier as well as determining the low-frequency cut-off point; the capacitor C1 limits the upper bandwidth of the amplifier.

Different sensitivities for the amplifier can be selected by fitting a wire link, or optional switch; the gain being determined by the total impedance of the feedback resistor(s) R7 // R9 // R11 divided by the value of R3 plus 1.

The resistor R18 is used to provide a minimum load for the amplifier should the speaker become disconnected.

The resistor R13 and capacitor C4 form a 'zobel network' which is a low-pass filter and has a two-fold function, the first is when driving the amplifier at or near full power into a speaker, the inductance of the voice coil may generate a high voltage on the fall of the signal, which could damage the output stage of the amplifier; the zobel network helps to cancel the reactive element of the speaker, so the amplifier is presented with a resistive load. The second function of the zobel is in the unlikely event of the amplifier having RF on the output, the zobel will filter out the high-frequency



Specification

RMS output power:	2×50W/4Ω; 2×40W/8Ω
RMS mono-bridged power:	100W/8Ω
Total music output:	200W
Harmonic distortion:	0·01% at 1kHz
Signal-to-noise ratio:	102dB (A-weighted)
Stereo channel separation:	85dB
Damping factor (at 100Hz):	>1000 nominal
Input impedance:	22kΩ
Input sensitivity:	330mV, 550mV or 1V selectable
Short-circuit and overload protection:	10 minutes maximum
Thermal shut-down protection:	1 hour maximum
Supply voltage:	±28V DC maximum
Consumption 2×4Ω or bridged mono 8Ω:	4A maximum
Consumption 2×8Ω:	2·5A maximum
Dimensions:	210×84×64mm

Includes speaker 'pop' suppression at switch on and switch off, and protection against wrong polarisation by means of fuses.

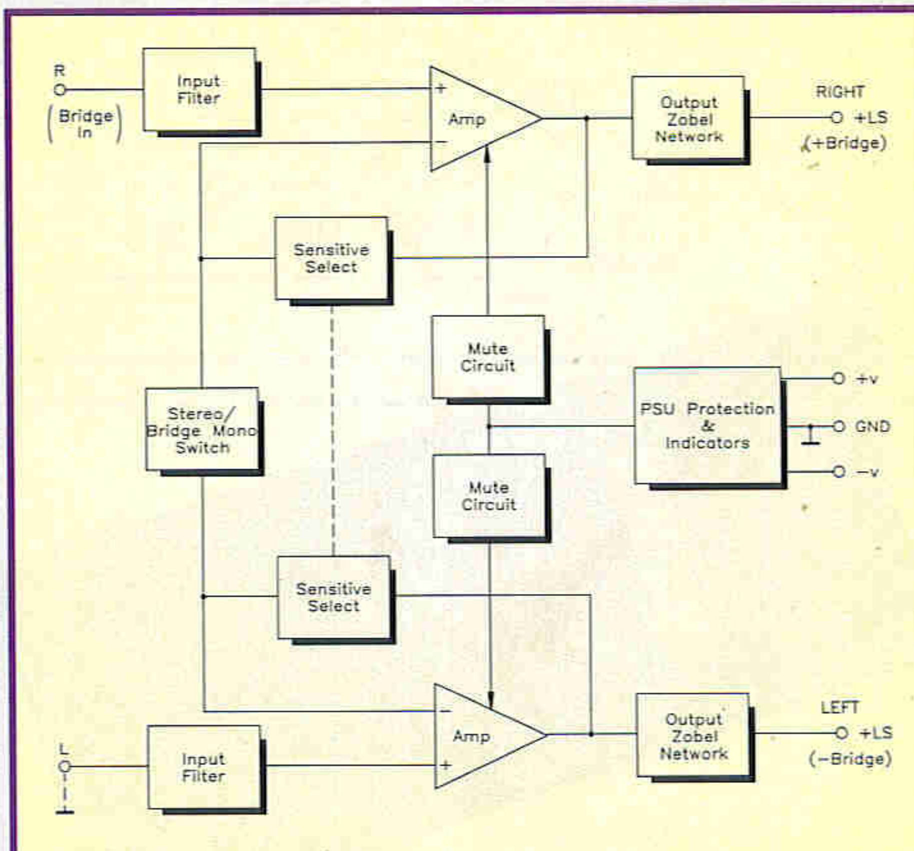


Figure 1. Block diagram.

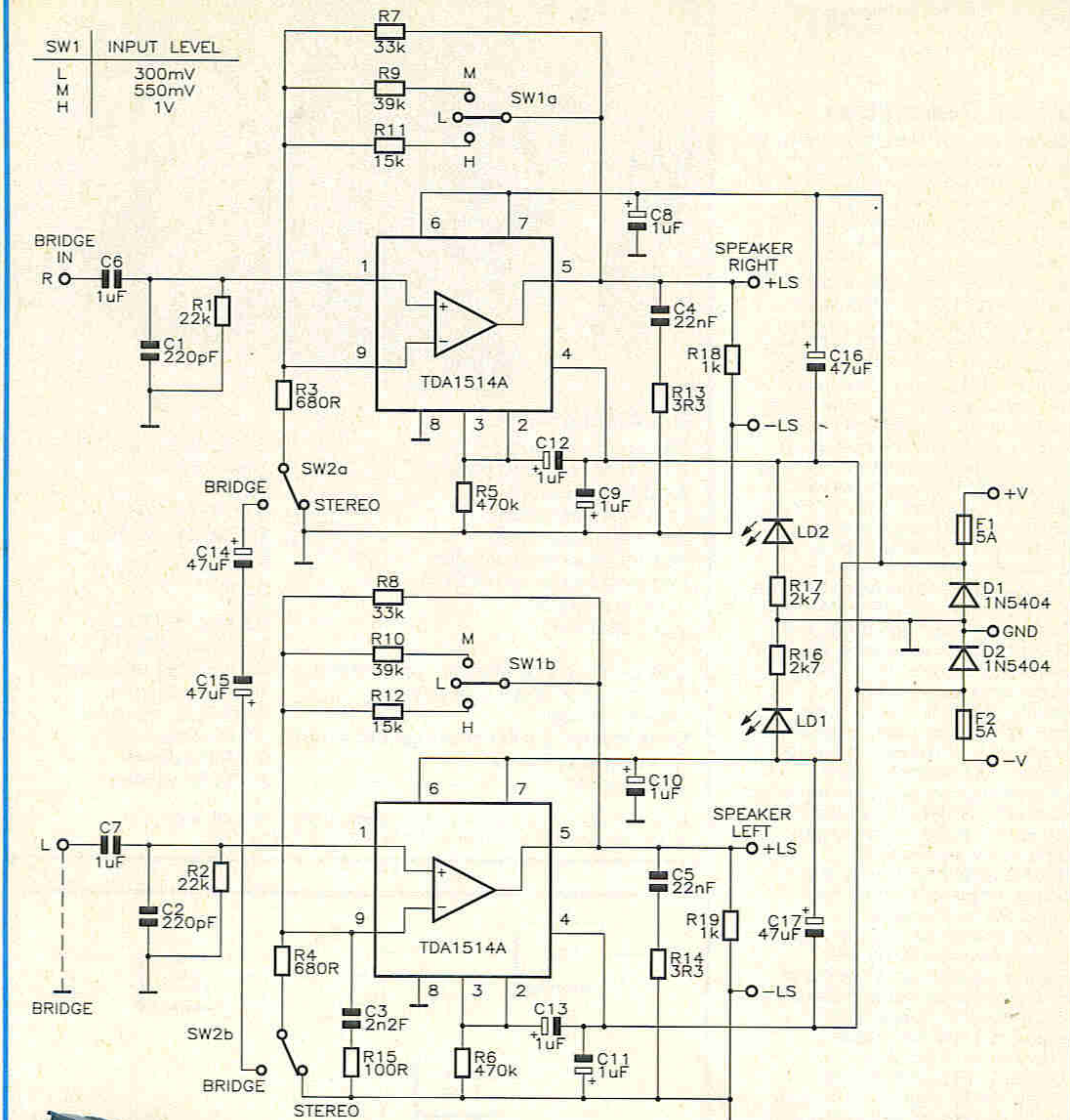
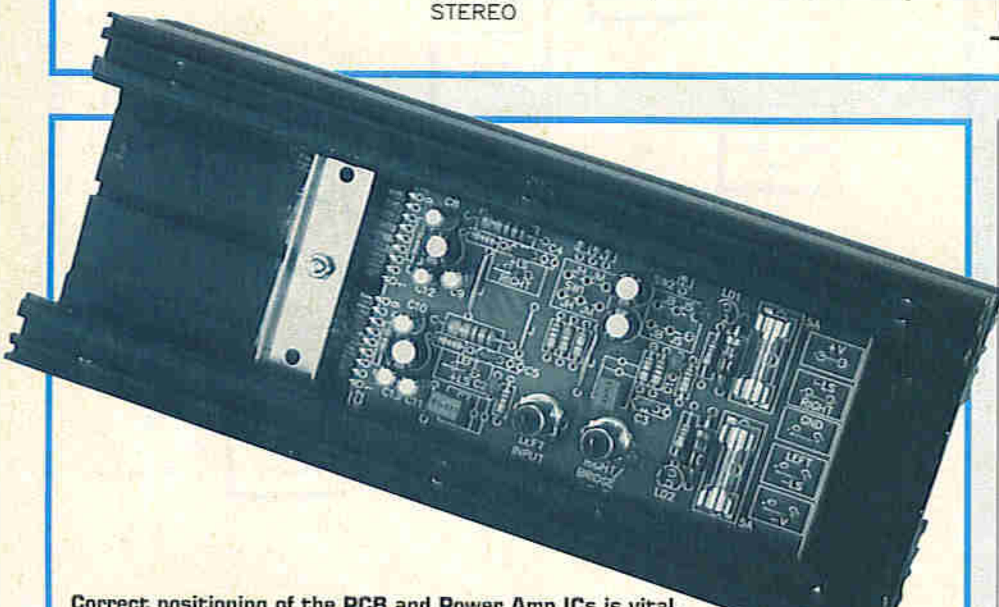


Figure 2. Circuit diagram.



Correct positioning of the PCB and Power Amp ICs is vital.

preventing 'burn out' of delicate drive units.

The LEDs LD1 & LD2 are the supply rail indicators, the resistors R16 & R17 limit the current through the LEDs.

Bridged Mono Operation

The switch SW2 selects between stereo and bridged mono use; in bridged mono, the non-inverting input to the left-channel amplifier is connected to 0V; the voltage at the inverting input of the right-channel amplifier is applied to the inverting input of the left-channel amplifier via R3, C14, C15 & R4; the output signal of the left-channel is 180° out of phase to the right-channel output;

this arrangement will double the output VOLTAGE swing to the load, which will then be connected between left and right +LS outputs (speaker + to the right-channel to maintain absolute phase).

Additional Construction

More complete instructions are provided in the leaflet supplied with the kit, but the general recommended sequence follows. Begin by fitting wire links marked 'J'. Links are used to set the input sensitivity of the amplifiers; fit a wire link in JH for a sensitivity of 1V, or JM for a sensitivity of 550mV, or leave both link options 'open' for a sensitivity of 330mV. An optional *three position* switch (FH05F) may also be mounted in place of the JM & JH links.

To configure the unit for dual-channel stereo or bridged mono, install the JS wire link for stereo operation, or the JB link for bridged mono operation. Alternatively, an optional switch (FH04E) could be fitted instead, but you should know that for bridged operation the left-channel input is shorted to ground – preferably using a shorted phono plug, but it could be permanently linked on the PCB in place of the phono socket – but the amplifier shouldn't change modes while switched on! If you hard-wire the phono input you won't be able to use the left channel in stereo.

Fit the resistors, starting with the smallest first, then the diodes, ensuring correct orientation. Fit the capacitors, observing correct polarity for the electrolytics, followed by the

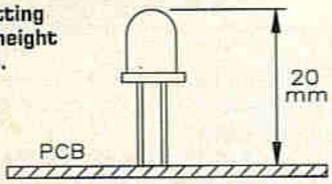


Figure 3. Setting the correct height for the LEDs.

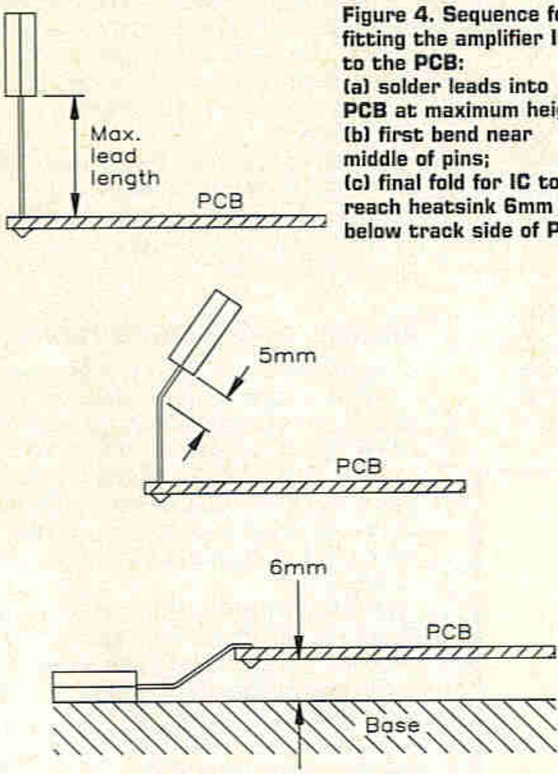


Figure 4. Sequence for fitting the amplifier ICs to the PCB: (a) solder leads into PCB at maximum height; (b) first bend near middle of pins; (c) final fold for IC to reach heatsink 6mm below track side of PCB.

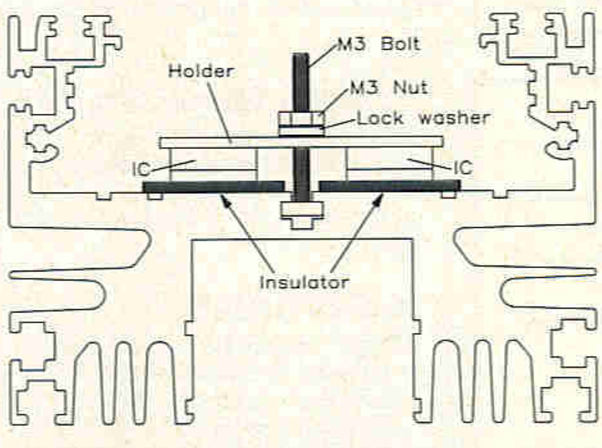


Figure 5b. How the amplifier ICs are clamped to the heatsink.

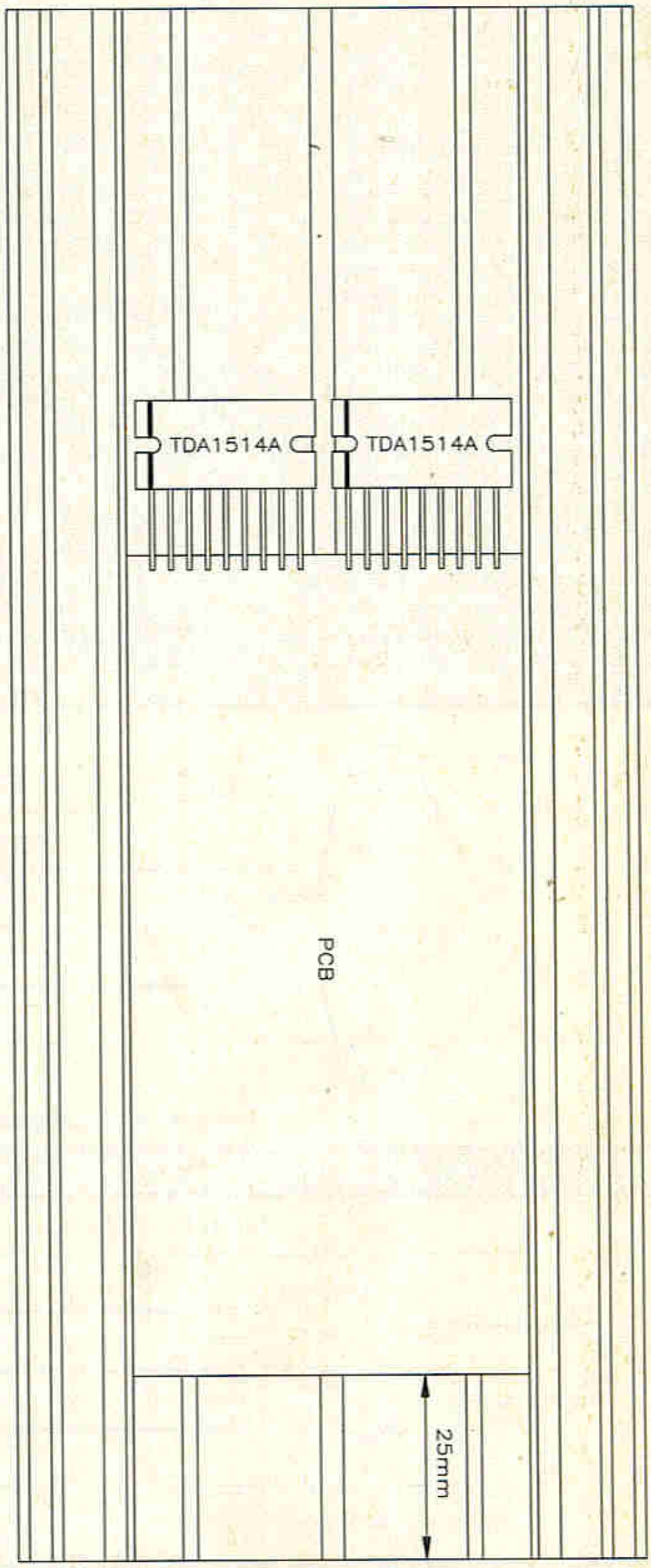


Figure 5a. Locating the PCB and ICs on the heatsink.

fuse sockets and fuses. The blade connectors can be installed next. These are the standard automotive ¼in. size for normal car type connectors.

Fit both phono connectors for stereo operation, or the right-channel connector only, and fit a link marked JC in place of the left phono connector, for bridged mono operation. If switches are used instead of the links, both connectors can be fitted, but that the left-channel phono connector *must* be shorted out when used in bridged mono mode. Lastly, fit LEDs observing correct orientation and height, see Figure 3.

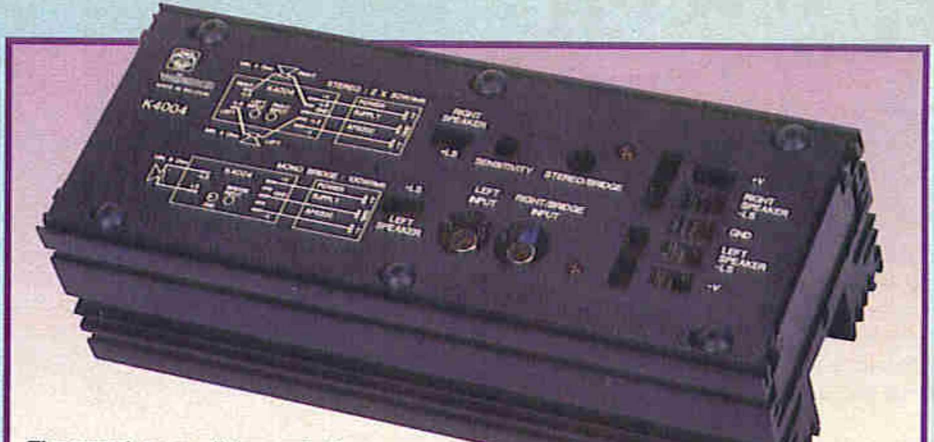
Thoroughly check your work for misplaced components, solder whiskers bridges and dry joints.

Fitting the Power Amplifier ICs

Mount both ICs onto the PCB at maximum height, with the metal mounting face towards the edge of the board; see Figure 4a. The leads should protrude no more than 1mm on the track side. Next, bend the ICs as shown in Figures 4b & 4c (this method differs from the kit leaflet instructions – follow *these* instructions).

Slide the PCB into the side channels of the heatsink and position as shown in Figure 5a. Apply a small amount of thermal paste to both sides of the mica washers, then fit underneath the ICs.

Slide the M3 hexagon headed bolt down the centre channel of the heatsink (between the ICs) and fix the amplifier ICs in place with the



The complete amplifier ready for use.

mounting bracket, lock washer and nut. Double-check that the PCB is still in the correct position; the edge of the PCB should be 25mm from the edge of the heatsink; refer to Figure 5a. Check that the amplifier ICs leads are *NOT in contact with the fixing bracket or heatsink.*

PSU Requirements

Suitable PSUs for the kit or the Gold Line versions of this amplifier are the Gold Line APS100 (VF50E); or the Gold Line APS200 which will require a transformer, Stock Code DH71N.

Testing

Connect a symmetrical output PSU (±28V DC maximum) to the module, see Figure 6a for connections. The Gold Line APS100 or the APS200 plus a DH71N transformer would be ideal. *IMPORTANT: Never switch on the supply before connecting to the amplifier.*

On switching on the power supply, both LEDs on the amplifier should illuminate, indicating that both supply rails are established.

Check the DC offset at the output of the speaker terminals, which should be less than ±1V (see Figure 6a for connections). Switch off the power supply and disconnect the wiring to the amplifier.

Attach the stick-on label to the rear panel, and trim around all the holes using a sharp knife. Fit the front panel to the module and fix in place using the six M5 bolts.

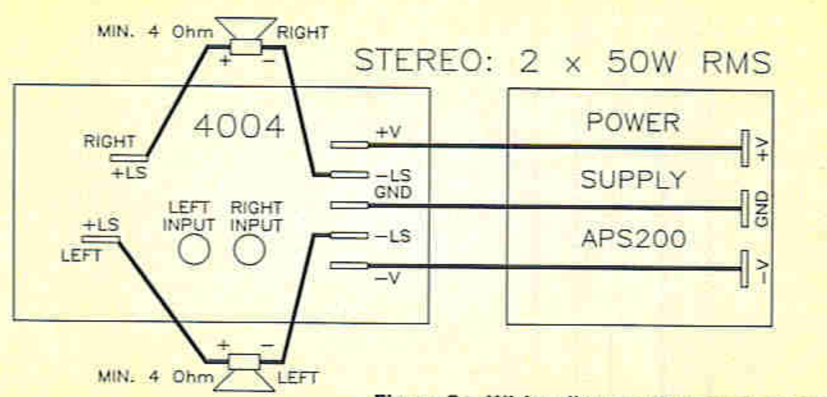


Figure 6a. Wiring diagram for stereo option.

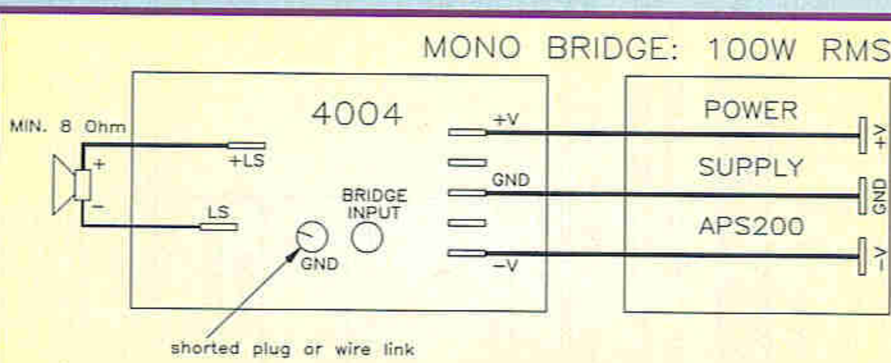


Figure 6b. Wiring diagram for bridged/mono option. Note that the left- channel input must be shorted to ground either by a shorted phono plug or the socket replaced by a wire link on the board.

Usage and Connection

If the intended use for the amplifier(s) is varied, it may be desirable to fit switches (not supplied but available as Stock Codes FH04E and FH05F, see optional parts list) for sensitivity and Stereo/Bridged-Mono operation. This can be done easily as there are holes already cut in the front panel for this purpose.

All PSU connections should be made using 1·5mm² (minimum) insulated wire. Terminate the wire using the spade connectors (not forgetting the insulating covers).

Stereo Amplifier

Again refer to Figure 6a for the connection of the power supply and the speakers; note the speaker polarity. Minimum speaker impedance is 4Ω.

Bridged Mono Amplifier

Refer to Figure 6b for the connection of the power supply and speaker; again noting the speaker polarity. In this configuration, the minimum speaker impedance is 8Ω.

IMPORTANT

Always connect the input(s) and output(s) of the amplifier before switching on the power supply.

If the amplifier is to be used as a free standing unit, it can be mounted in position by fitting M4 hexagon head bolts in the side channel of the heatsink.

MONO/STEREO AMPLIFIER PARTS LIST

RESISTORS: All ¼W (Unless specified)

R1,2	22k	2
R3,4	680Ω	2
R5,6	470k	2
R7,8	33k	2
R9,10	39k	2
R11,12	15k	2
R13,14	3Ω3	2
R15	100Ω	1
R16,17	2k7	2
R18,19	1k 1W	2

CAPACITORS

C1,2	220pF	2
C3	2n2F	1
C4,5	22nF	1
C6,7	1μF	2
C8-13	1μF PCB Electrolytic	6
C14-17	47μF	4

SEMICONDUCTORS

D1,2	1N5404	2
IC1,2	TDA1514A	2

MISCELLANEOUS

LD1,2	5mm Red LED	2
F1,2	5A 20mm Fuse	2
	5mm PCB Lucar Blades	7
	PCB Phono Sockets	2
	PCB	1
	Leaflet	1
	Finned Heatsink	1
	Pressed Rear Panel	1
	Stick-on Label	1

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
The above items are available in kit form only.
Order As VF39N (Mono/Stereo Amplifier Kit)
Price £48.49 G8

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

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by Bryan Hart

POWER MANAGEMENT IN SEMICONDUCTOR DEVICES

Part 2: Resistor-Limit Curves and Their Use

In Part 1 of this two-part article we explored the way that the power rating of a semiconductor was specified on a data sheet and saw how to interpret the information for two industry-standard transistors, the BC107 and the 2N3055.

In this part we show how to use a graph to select a load resistor which ensures that the power-rating of the devices is not exceeded. Alternatively, the graph can be used to choose the rating of a device so that it is capable of driving a given load.

The origin of a set of universal 'resistor-limit' curves used in this procedure is discussed, briefly, and their application to the following three frequently-encountered circuits studied: Zener-diode shunt stabiliser; Class A common-emitter amplifier; Class B audio-frequency power amplifier.

D.C. Power Relationships

In Figure 11, 'X' represents a device having three terminals but the discussion that follows also includes the case of a device that has only two.

The quiescent, d.c. or bias values of I and V are I_Q and V_Q respectively, so the power dissipation, P_Q in X is given by their product.

$$P_Q=I_QV_Q \qquad (7)$$

But, by Ohm's Law:

$$I_Q=\frac{V_{CC}-V_Q}{R} \qquad (8)$$

Substituting this value of I_Q in (7) we obtain,

$$P_Q=V_Q\times\left(\frac{V_{CC}-V_Q}{R}\right) \qquad (9)$$

If we choose V_Q at something less than V_{CC}, say mV_{CC}, where m is a fraction lying between 0 and +1, (9) can be modified to (10).

$$P_Q=m(1-m)\times\left(\frac{V_{CC}^2}{R}\right) \qquad (10)$$

We can also show that the power, P_R dissipated in R and the power, P_S supplied by V_{CC} are given by:

$$P_R=[(^1/_m)-1]P_Q \qquad (11)$$

$$\text{and } P_S=\frac{P_Q}{m} \qquad (12)$$

From (10) we can see that the dissipation in X does not exceed the rating P_D if:

$$P_D\geq m(1-m)\times\left(\frac{V_{CC}^2}{R}\right) \qquad (13)$$

Alternatively, if X is not to exceed a stipulated P_D we must choose R so that:

$$R\geq m(1-m)\times\left(\frac{V_{CC}^2}{P_D}\right) \qquad (14)$$

This last relationship is the basis for the construction of a set of resistor-limit curves considered next.

Resistor-Limit Curves

Take the case for which the equality sign in (14) applies. Then a plot of R against m for a pair of values of V_{CC} and P_D is a parabola (see Figure 12), that has its vertex at $m=0{\cdot}5$, $R=V_{CC}^2/4P_D$.

Because of the symmetrical nature of the curve, it is only necessary to plot the section for m=0 to m=0·5.

For m=0·5 to m=1 we can use the same horizontal scale 'folded-back', as shown in Figure 13. By doing this we obtain an expanded m-scale and easier plotting for a given size of graph paper. To satisfy the condition imposed in (14) we must operate either on the curve or in the shaded region above it.

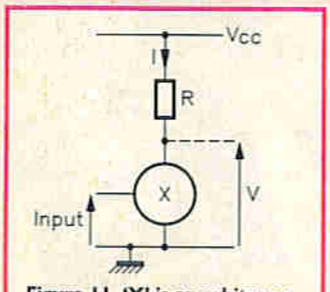

Figure 11. 'X' is an arbitrary three-terminal device.

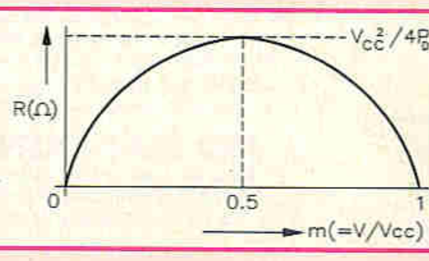

Figure 12. The 'resistor-limit curve' for Figure 1 is a parabola.

Of course, Figure 14 is for just one pair of values of V_{CC} and P_D. In general, we are more interested in a set of curves (Figure 14), showing R vs m for a given V_{CC} and various fixed values of P_D. Figure 15 is one such family, plotted to scale, for V_{CC}=15V and power levels not exceeding 1W. To avoid a display that is too cluttered, the chosen values of P_D correspond only to those of practical low-power devices.

A value of R for a value of P_D lying between the curves can be estimated by interpolation. The formula to use for this is given in (15). It follows from (10) for constant values of m and V_{CC}.

$$RP_D=\text{constant} \qquad (15)$$

The choice V_{CC}=15V is made because it is an industry standard for analogue circuit design. For operation at other values of V_{CC} we can still use Figure 15 but must use also an appropriate R-multiplier, given in Table 1.

V_{CC} (V)	R-multiplier
3	0·04
5	0·11
10	0·44
12	0·64
15	1
V_X	$(V_X/15)^2$

Table 1. Appropriate R-multipliers for different supply voltages.

DC Power and AC Power

Up to this point in the discussion, we have considered only d.c. power dissipation in X. Before we use Figure 15 on some practical examples, we must investigate the effect of a.c. power dissipation.

Suppose an audio-frequency input signal causes a sinusoidal current of peak value I_P to be superimposed on the bias level I_Q. Then the total terminal current, i, is shown in Figure 16(a) and the resulting total terminal voltage, v, in Figure 16(b), in which $V_P=I_PR$.

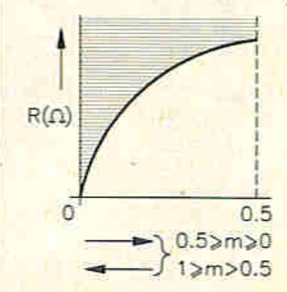

Figure 13. A satisfactory value of R falls in the shaded area above the half-parabola.

The mean signal power, P_O, developed in R is the a.c. power averaged over a whole number of cycles. Since we have sinusoidal variations:

$$P_O = I_P V_P/2 = V_P2/2R \qquad (16)$$

Now the mean voltage across R in the presence of the signal is V_Q and the mean current supplied by V_{CC} is I_Q. These are the same as the values of no a.c. input signal. Hence, the mean power supplied by V_{CC} is unchanged at $P_Q = I_Q V_Q$. From the Law of Conservation of Energy, it follows that the mean power P_d dissipated in X is given by:

$$P_d = P_Q - P_O \qquad (17)$$

The total power, P_t, dissipated in R is the sum of the d.c. power and a.c. power.

$$P_t = P_R + P_O \qquad (18)$$

Equation (17) tells us that the power dissipation in X is a maximum at the quiescent value P_Q when the sinusoidal signal is *absent*. Thus if we use Figure 15 to ensure that P_Q does not exceed the device rating P_D under quiescent conditions then X cannot over-dissipate when a signal is present. (It is assumed that $I_P < I_Q$, so X always conducts.)

This conclusion also holds for non-sinusoidal variations provided they are 'area-balanced', e.g., a square waveform or a symmetrical triangular waveform. (Note, though, that (16) requires modification for non-sinusoidal signals.) We now consider the application of Figure 15 to two design examples.

Design Example 1

Figure 17 shows a simple Zener diode shunt stabiliser supplying a load current I_L. The abbreviated specification for D_Z is:

$V_Z = 5{\cdot}1V$ at $I_Q = 5mA$; r_Z (slope resistance) negligible.

$P_D = 0{\cdot}5W$ at $T_A = 25°C$; $T_{JM} = 175°C$

Problem: Select values for R from the E24 resistor range, which guarantee that D_Z will not over-dissipate (even if the load current $I_L = 0$), for $T_A = 25°C$ and $T_A = 50°C$.

Solution (a): By definition, $m = (V_Z/V_{CC}) = (5{\cdot}1/15) = 0{\cdot}34$.

The intersection of the line $m = 0{\cdot}34$ and the curve $P = 0{\cdot}5W$ gives $R = 100\Omega$. For $R \geq 100\Omega$, when tolerances are allowed for, we choose $R = 120\Omega \pm 5\%$, 1W.

Solution (b): Using the method of Part 1, we find that $P_D = 416mW$ for $T_A = 50°C$. In this case we need

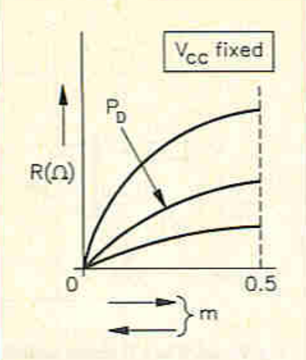

Figure 14. A family of limit curves.

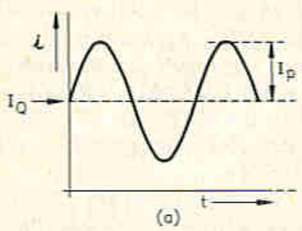

Figure 16. (a) i is the instantaneous terminal current, when a sinusoidal signal is present.

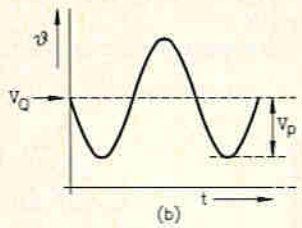

Figure 16. (b) v is the instantaneous terminal voltage.

to interpolate on Figure 15 and the resistor value found for solution (a). To do this we make use of (15) and the resistor value found for solution (a).

Thus

$$R(\Omega) \times 0{\cdot}416 = 100 \times 0{\cdot}5 \qquad (19)$$

From this, $R = 120\Omega$. Allowing for tolerances, $R = 130\Omega \pm 5\%$, 1W.

A practical Zener diode has a finite R_Z and a tolerance on the value of breakdown voltage. The inclusion of these affects the detail but not the procedure for the calculations.

Design Example 2

Figure 18 shows a basic Class A audio amplifier stage in which, for simplicity, base and emitter bias components are omitted.

Problem: Calculate the minimum acceptable value of R_C in the E24 range, if the ZTX310 is not to over-dissipate at $T_A = 50°C$ (ZTX data is: $P_D = 300mW$ at $T_A = 25°C$, $T_{JM} = 125°C$).

Solution: Using the method of

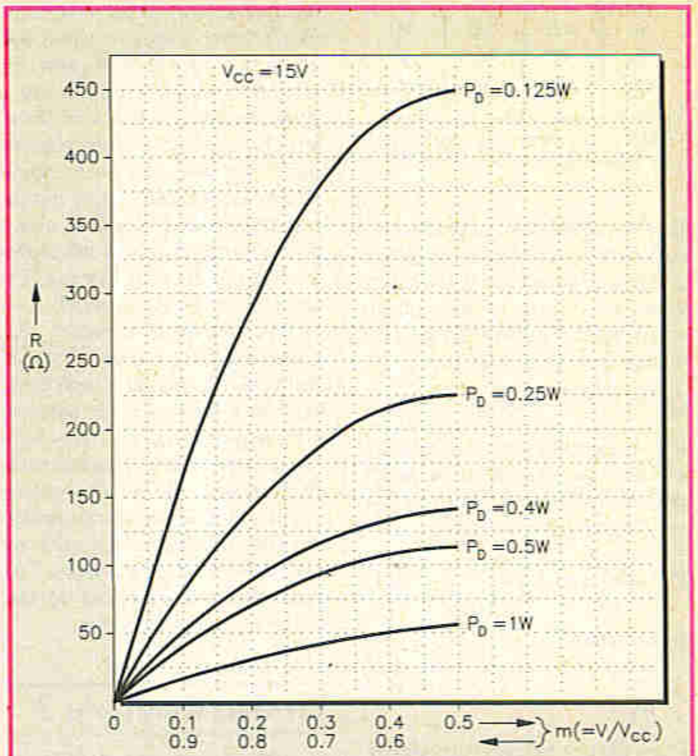

Figure 15. Resistor-limit curves for $V_{cc} = 15V$.

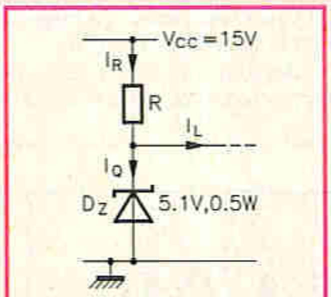

Figure 17. Shunt stabiliser for Design Example 1.

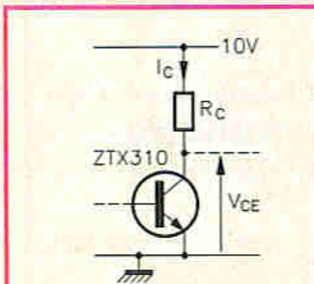

Figure 18. Class A audio amplifier stage for Design Example 2.

Part 1, we find that $P_D = 0{\cdot}225W$ at $T_A = 50°C$. The value of m is not set in this circuit, as it was in Design Example 1. A safe design must therefore assume the existence of the worst-case condition $m = 0{\cdot}5$, which maximises R.

In Figure 15 on the curve for $P_D = 0{\cdot}25W$ at $m = 0{\cdot}5$, the resistor value is 225Ω. Using (15) to find R_C for $P_D = 0{\cdot}225W$, we obtain $R_C = 250\Omega$. However, this is for $V_{CC} = 15V$. Referring to Table 1, the R-multiplier for $V_{CC} = 10V$ is 0·44. Hence, $R_C \geq 111\Omega$. The power rating for R with $m = 0{\cdot}5$ is, from

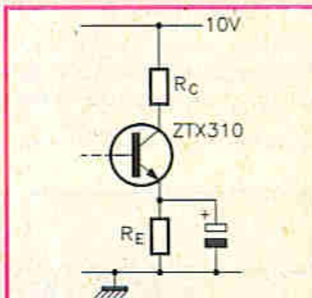

Figure 19. Amplifier stage with emitter bias resistor.

(11), 0·225W. However, if the base current of the transistor causes the potential difference across R_C to be almost equal to V_{CC} the power rating of R_C is four times greater than for $m = 0{\cdot}5$. Hence the required choice is $R_C = 120\Omega \pm 5\%$, 1W. If an emitter bias resistor R_E is present, as in Figure 19, the transistor does not over-dissipate provided $(R_E + R_C) \geq 111\Omega$.

Class B Amplification Application

Figure 20 is the circuit of a Class B amplifier stage supplying audio-frequency signal power to a load represented by a resistor, R_L. The operational amplifier A, connected in the inverting configuration, drives a complementary emitter-follower power output stage via a bias/driver network, details of which are omitted because they are not relevant in the present discussion. The conduction state of the output transistors Q_N, Q_P is shown in Table 2.

v_o	<0	=0	>0
Q_N	×	×	●
Q_P	●	×	×

Table 2. Transistor conduction state for Figure 20. ●=ON; ×=OFF

Overall feedback, provided by resistors R_X, R_Y minimises the crossover distortion that results when the polarity of the output, v_o changes. The low-frequency voltage gain, G, is given by:

$$G=(V_O/V_I)=-(R_Y/R_X) \qquad (20)$$

If V_O is a sinewave of amplitude V_P and average value zero, the mean power dissipation, P_d, in either Q_N or Q_P can be shown to be:

$$P_d=(4/\pi^2)n\times\left(\frac{1-n}{R_L}\right) \qquad (21)$$

By definition:

$$n=\frac{\pi V_P}{4V_{CC}} \qquad (22)$$

From (21), it follows that neither transistor exceeds a specified power rating P_D if we choose R_L so that:

$$R_L\geq(4/\pi^2)n\times\left(\frac{1-n}{P_D}\right) \qquad (23)$$

This relationship is similar in form to (14), if we substitute m for n and take account of the scale factor $(4/\pi^2)$, which is approximately 0·4. Thus the curves of Figure 15, which were derived from a consideration of d.c. power alone, are also applicable in calculations involving the mean a.c. signal power developed in the output transistors of a Class B audio power amplifier. Table 1 still applies for V_{CC} not equal to 15V but (11) and (12) are no longer valid.

The output power, P_O, dissipated in R_L can be calculated from (16). P_O increases with n and reaches a maximum for $n=(\pi/4)$ corresponding to $V_P=V_{CC}$. However, the maximum dissipation in Q_N (or Q_P) occurs when n=0·5. In power calculations we first calculate n. If n<0·5 we use n=0·5 in graphical work. This procedure is clarified in the following design example.

Design Example 3

Problem: For the circuit of Figure 20, P_D=0·25W for Q_N, Q_P and v_o is a sinusoidal waveform with a mean value of zero. Find the minimum acceptable values of R_L if V_P lies anywhere in the range (a) 0V to 5V and (b) 0V to 10V.

Solution (a): Using (22), the maximum value of n is 0·26 (i.e. $\pi \times 5/4 \times 15$). Since this is less than 0·5, we use n=0·26.

On Figure 15, for m (=n)= 0·26 and P_D=0·25W, we find R_L=175Ω. Applying the correction factor $(4/\pi^2)$, we obtain the result R≥70·9Ω. Using (16), P_O=0·176W for V_P=5V. A satisfactory rating for R_L is thus 0·25W.

Solution (b): From (22), the maximum value of n is 0·52. As this exceeds n=0·5, we use n=0·5.

On Figure 15, for m (=n)=0·5 and P_D=0·25W we find R_L=225Ω. With the scale factor included, this gives R_L≥91·2Ω. Using (16), P_O=0·548W for V_P=10V. An appropriate rating for R_L is 0·6W, or 1W.

Comment: An alternative, but related problem might be as follows. What power rating is required for Q_N, Q_P if R_L=25Ω and V_P lies anywhere in the range 0V to 15V? In this case we multiply the given R_L by $(\pi 2/4)$ to obtain 61·7Ω. Locating the point R_L=61·7Ω, m=0·5 on Figure 15 we find it lies just above the curve for P_D=1W. Hence the required rating is 1W.

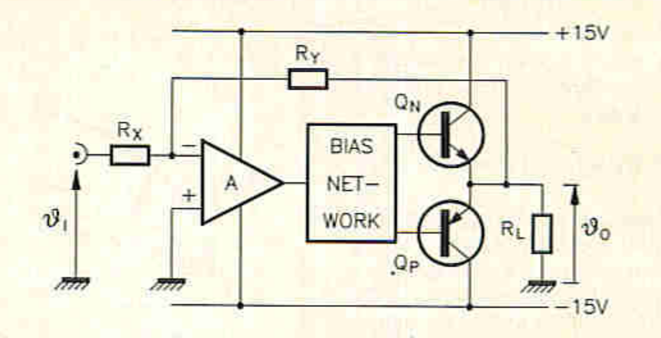

Figure 20. Class B audio power amplifier stage for Design Example 3.

Conclusions

The three design examples that have been studied illustrate the usefulness of the universal resistor-limit curves of Figure 15 in circuit aspects of the power management of semiconductor devices.

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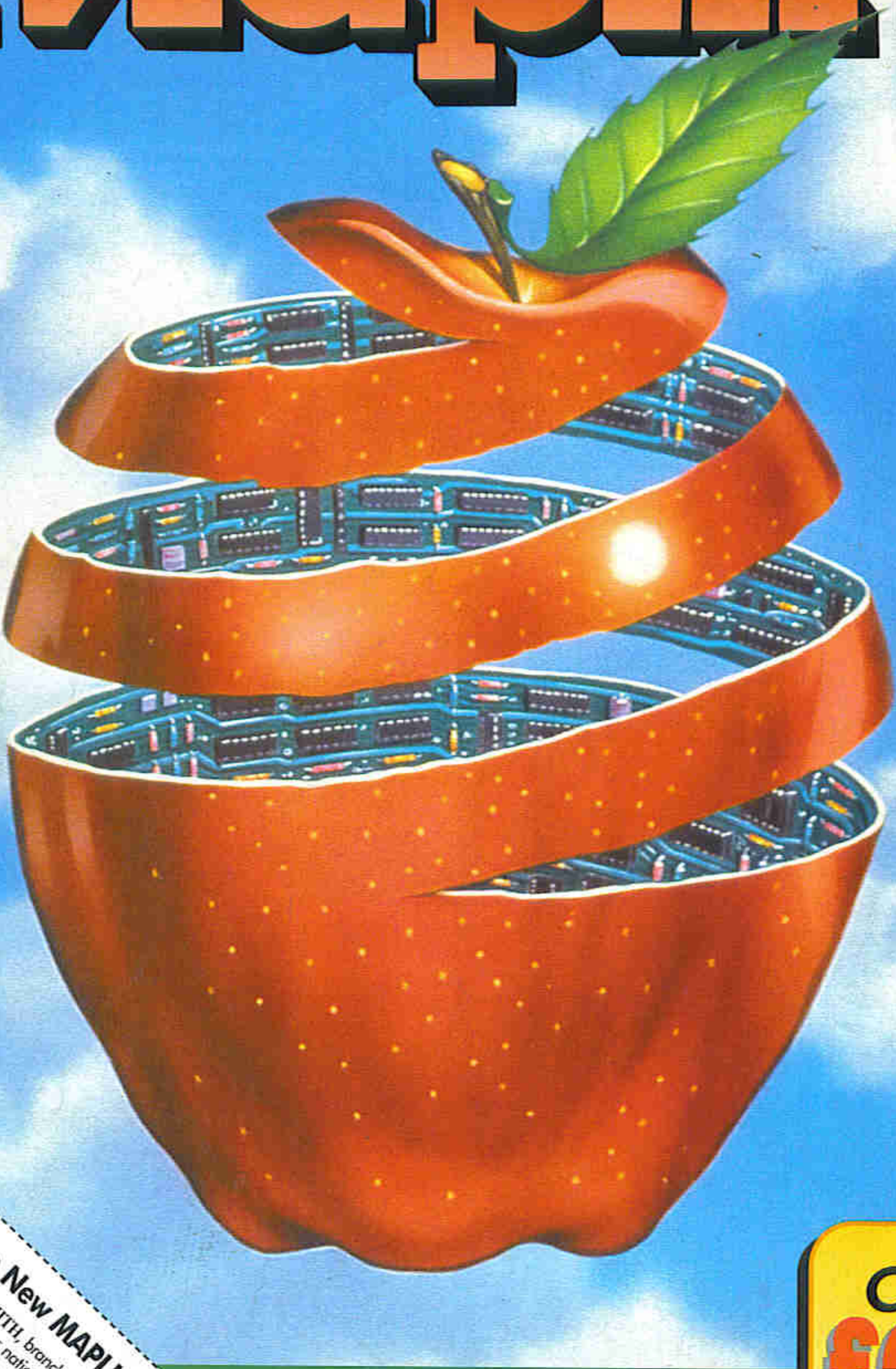

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