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No. 68

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ELECTRONICS

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Versatile Xenon Strobe for You to Build

FREE – Win a Complete Satellite TV Receiver System!

Discover All About – Computer Techniques Modelled on the Human Brain!

AUGUST 1993
VOL. 12 No. 68

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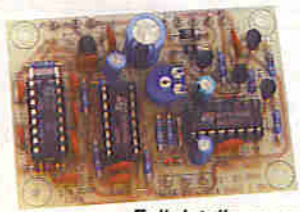

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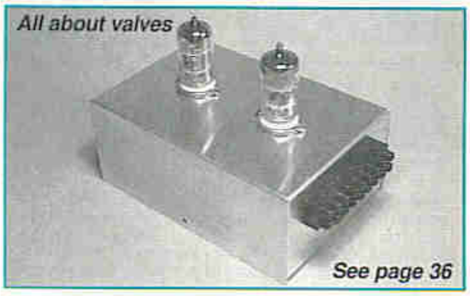

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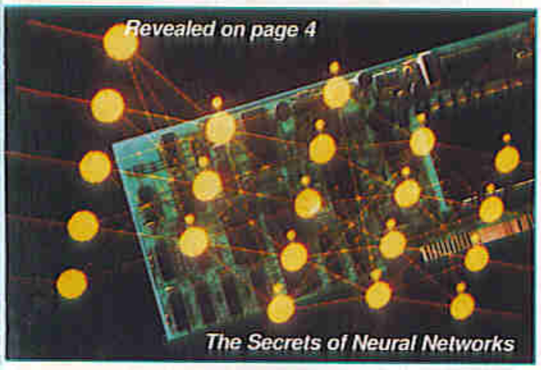

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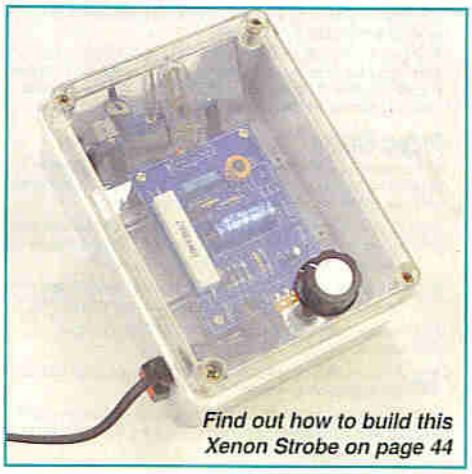

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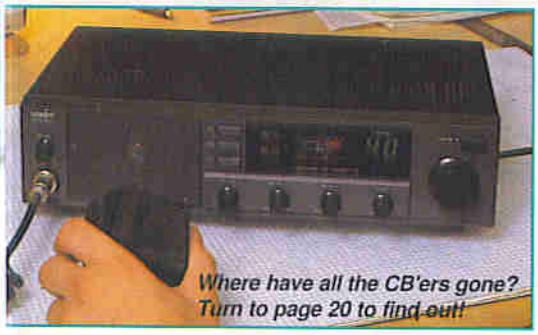

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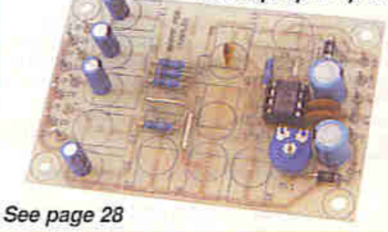

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ABOUT THIS ISSUE . . .

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

Just in case you're not already aware, leading semiconductor manufacturers Intel and Motorola have recently announced their latest super microprocessor offerings to the electronics and computing world. It is a sobering thought that a little over ten years ago, technology was a lot different. Many of you will remember (Sir) Clive Sinclair's ZX80 and ZX81 personal computers, which ushered in the domestic computer revolution in the early eighties. Prior to this time, most computer enthusiasts were also *very* keen on electronics; they had to be, as it was a case of building hardware themselves and adapting cast-offs from industry and commerce (remember teletypes!). Both the ZX80 and ZX81 were offered in kit form (as well as ready built) and were advertised in the electronics and computer popular press of the day. The ZX81 had 1KB of memory, whilst today 1MB is considered miserly.

During the '80s numerous home computers came and went; the Commodore VIC-20, Dragon 32, to name but two. However, by this time computer users were strongly discouraged by manufacturers from opening their machines and dabbling with the innards. This may well have helped to breed a particular type of computer enthusiast, those that knew very little of the world of electronics. However, as we approach the middle of the final decade of this century, the tables are turning once again. Computer users are fast becoming adept at throwing together their own custom machine from a wide choice of component cards. It is now easy to upgrade from a 386 to a 486 processor, or add a second hard disk, printer port or more megabytes of memory. It will be interesting to see what the next decade brings . . . .

In this issue there is a special feature on neural computing techniques; this new technology (if you can actually call it new, since it is modelled on the operation of the brain), can be used to solve complex problems. For example, image and voice recognition, otherwise quite difficult tasks with traditional computing techniques, can be realised relatively easily with neural networks. The processing elements work in a parallel fashion, simultaneously assimilating information, this coupled with a 'learning ability' achieves the desired result. Douglas Clarkson, discusses in depth the development and application of neural networks.

So until next month, I hope you enjoy reading this issue as much as 'the team' and I have enjoyed putting it together for you!

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Computing techniques, modelled on the human brain, are being used to solve complex problems

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Project Ratings

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

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

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

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

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

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

Ordering Information

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

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

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

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

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

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

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Prices of products and services available from Maplin, shown in this issue, include VAT at 17·5% (except items market NV which are rated at 0%) and are valid between 2nd July 1993 and 31st August 1993. Prices shown do not include mail order postage and handling charges, which are levied at the current rates indicated on the Order Coupon in this issue.

Technical Enquiries

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

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

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

Readers Letters

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

TECHNOLOGY WATCH!

with Keith Brindley

There is a battle brewing between two of the largest integrated circuit manufacturers, which looks set to change the face of consumer electronics. Whichever of these chip makers wins the battle, consumer devices such as televisions, videocassettes, mobile communications and, primarily computers, will be changed forever. This is all happening, although the poor-old consumer doesn't realise it yet and isn't being consulted about the changes likely to occur over the next decade.

The two integrated circuit manufacturers are Intel and Motorola. A bit of history, first.

Over the last ten years or so, most personal computers have used Intel microprocessors and associated peripheral integrated circuits. Personal computers based on the Intel 80x86 (e.g., 8086, 80286, 80386, and the latest – 80486) family of chips have dominated the computing arena. Some 90% of business computers worldwide have been based on Intel's range. As a result, Intel has made and sold literally millions of integrated circuits and has – as you'd expect – made a little bit of money in the process.

Sure, Motorola has its own family of microprocessors (the 680x0 range – 68000, 68020, 68030, 68040) which match – and indeed more than match in many cases – the Intel equivalents. But Motorola has never been able to crack Intel's domination of the market and, except in a couple of notable exceptions, hasn't had its microprocessors used in mainstream business computers. However, this hasn't stopped Motorola developing and making them. Instead of mainly supplying the personal computer market, however, Motorola makes its profits in many other fields – for example, communications and embedded controllers – as well as computers. More about this later.

Things are now set to change. Both manufacturers are in the latter stages of developing their next-generation microprocessor families. Intel's is called Pentium. Motorola's is the PowerPC. Note these names, they'll become increasingly important over the next few years. Both manufacturers have announced designs, although only Motorola to date has begun shipping. Indeed, the PowerPC has been used by Apple in a demonstration computer running at 80MHz, which by all accounts is a mean machine.

In reality, Motorola's lead to the marketplace needn't necessarily – by itself – be a particularly worrying aspect for Intel. Intel's base of personal computers should guarantee high sales, simply because already purchased software should run on Pentium-based computers. DOS, Windows, applications and so on will be transportable (within limits) between 80x86 computers and Pentium ones.

On the other hand, supplementary factors may well be worrying. For a start, IBM the makers of the 80x86-based personal computers which started all this revolution in computing intends not to use Pentium, instead opting for PowerPC. IBM is the world's largest manufacturer of personal computers, making about 10% of the world's supply on its own. Apple, the world's second largest manufacturer (also making about 10% of the world's supply) is to continue to use Motorola devices. These two manufacturers alone will shift millions of computers a year. There are unconfirmed reports coming out of Motorola that several other previous users of Intel's devices are developing PowerPC-based products, too. How many other previous users of Intel's devices, and how many other *new* microprocessor users go for the PowerPC are, as yet, unanswered questions no doubt on the lips of many Intel senior managers.

Another concern for Intel is Motorola's base in the markets *outside* computing. PowerPC is available as an embedded controller, so consumer products of all types will be able to use it. Ford, the car and truck manufacturer, for example, is to use the PowerPC family as an em-bedded controller in automobile systems. Motorola's experience in communications will ensure PowerPC is used there too.

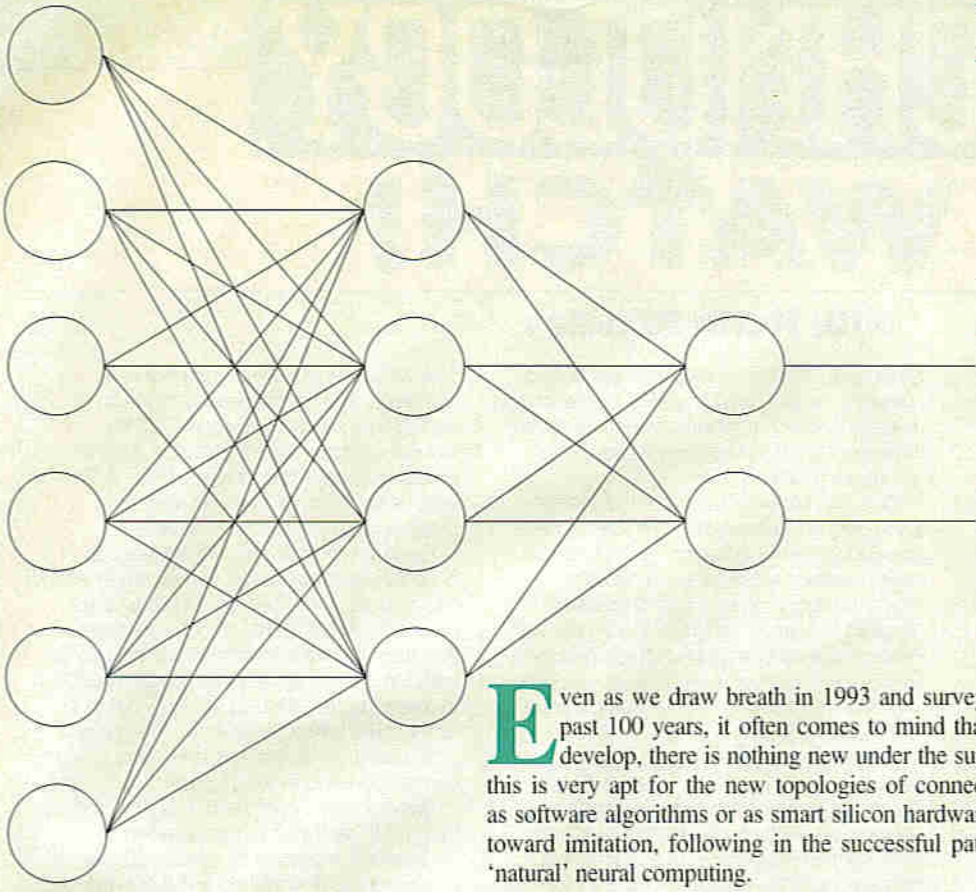
All this creates another worry for Intel – price. Motorola has initially pitched the PowerPC much lower than (down to a quarter of) Intel's Pentium price. Further, every time PowerPC doubles in sales, price falls 30%. Because Motorola will use PowerPC in other markets apart from computing, sales of PowerPC will be inevitably higher than Pentium's, so will probably always be cheaper. PowerPC was designed right from the start as a cross-application family of devices.

Concern for Intel also comes from a potential second-source manufacturer AMD, which looks set to be able to produce its own versions of 80486 microprocessors, and wants to make pentium equivalents as well. While Intel is seeking to quash AMD in a legal battle, AMD is still gearing up to production. If AMD succeeds, Intel prices (and therefore profits) will fall due to competition and market forces.

But possibly the biggest worry for Intel has got to be Pentium's introverted use. It's basically intended to replace 80x86 computers and so will do just that – nothing more, nothing less. It's a computer chip upgrade. PowerPC, on the other hand, is designed to run any operating system. As a result, workstation operating systems like Unix, as well as Apple's own system, will run on it. Indeed, as I write this, it looks almost certain (though unconfirmed) that Microsoft's new Windows NT operating system will be written to take advantage of PowerPC as well as Pentium. This is probably true (and maybe you'll already have seen reports which *do* confirm it) and logical. After all, Microsoft is already committed to developing its *applications* to run on PowerPC computers (just as it already produces versions for the Motorola-based Apple Macintosh). It would make sense for a software producer to produce *all* its software (and this includes Windows, of course) to run on *any* major computer platform.

If Windows *does* become available on PowerPC it will, at a stroke, remove the very reason why Intel has dominated the personal computer market. If a user can run Windows (or whatever operating system he wants) and all his existing applications and software on a computer which is cheaper, faster, and what's more already available, why should he stick with an Intel-based computer? I don't know, does Intel?

by Douglas Clarkson



Introduction to NEURAL NETWORKS

Even as we draw breath in 1993 and survey the many milestones of technology of the past 100 years, it often comes to mind that, in terms of what man tries to invent and develop, there is nothing new under the sun. In the subject of artificial neural networks this is very apt for the new topologies of connective computing, currently being developed as software algorithms or as smart silicon hardware, and which are but the first faltering steps toward imitation, following in the successful path taken long-ago by nature, in developing 'natural' neural computing.

A Changed Identity

The study of neural networks has brought about a quiet revolution in linking various previously separate compartments of science. Scientific meetings on neural networks will now attract computer scientists, mathematicians, software engineers, psychologists and biologists, so that there is a more balanced approach to developing and exchanging theories.

This has resulted in a good combination of expertise for a number of reasons. Computer scientists were making limited progress in developing models of the brain, thinking it behaved like a massively complex digital computer. On the other hand, biologists had not been making significant progress in trying to assess collective neuron function, because they lacked the mathematical models needed to develop and structure ideas based on their observations of neuron activity of living systems.

A Brief History of Neural Networks

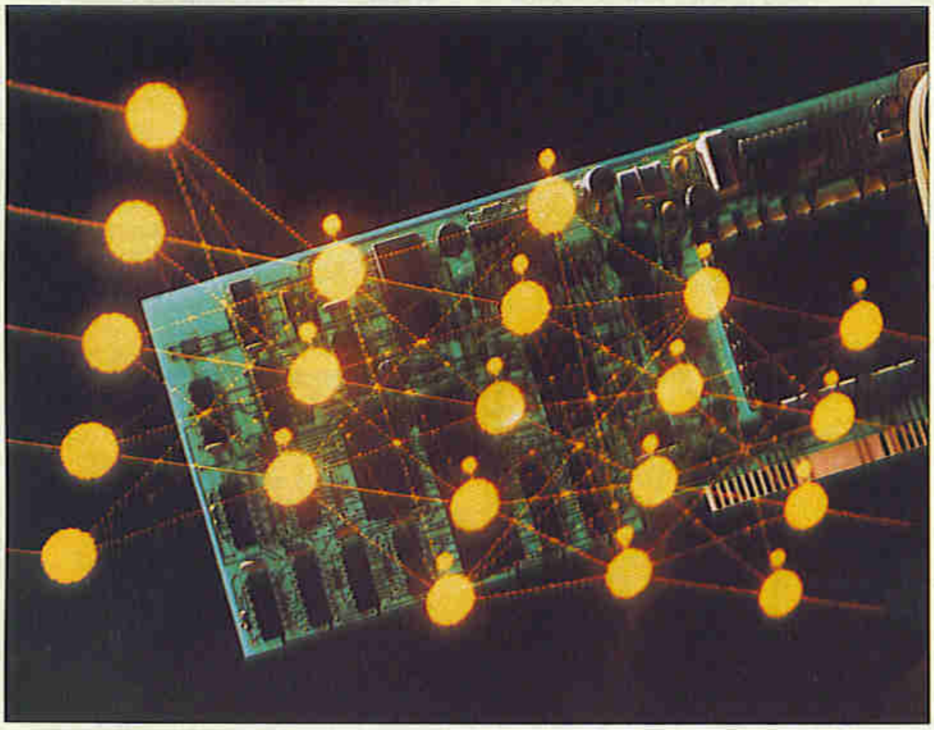
It was the paper 'A Logical Calculus of the Ideas Immanent in Nervous Activity', published in 1943 by McCulloch and Pitts, which established a formal structure for modelling the function of a neuron receiving impulses, and processing these within its own structure. Its definition of formal logic processes was also highly significant for other fields. This paper communicated its thoughts to a broad and energetic community, and stimulated development in digital computers, expert systems and artificial neural networks.

John Von Neuman found inspiration from this to develop one of the first digital 'electronic brains' in the guise of ENIAC. Marvin Minsky was able, in the summer of 1951, to construct an elementary 'neural computer' which could negotiate a 'maze' and subsequently he contributed greatly to the development of expert systems using rule based logic. Frank Rosenblatt, as a neuro-biologist, developed, in the mid-1950s, models of neurons which could facilitate vision. His 'perceptron' model of vision can now be recognised as the basic structure comprised of layers of a neural network. The 'perceptron' concept was implemented as a grid of 400 photocells which were linked in associative patterns.

There was, however, a missing link in the development of neural networks which became evident during the late 60s, and led to a reduction of their interest. This was brought about by the publication of the book 'Perceptrons' in 1969 by Marvin Minsky and Seymour Papert of the MIT Research Laboratory of Electronics.

However, a smaller field of researchers continued with their developments in neural networks. Teuvo Kohonen of the Helsinki Technical University in Finland developed, during the 1970s, adaptive 'self' learning networks. The lecture given by John Hopfield of Caltech to the National Academy of Sciences in 1982 did much to reawaken interest in neural networks. In particular he identified the potential that artificial neural networks have to be trained at the 'energy minimum'. While it was understood how they could be made to work to solve real problems (nature used them all the time), the technique for training artificial networks to do useful work failed to materialise.

It is often the case that one individual stumbles across a result which is the missing link to the next stage in development. Just as, within days of Roentgen's discovery of X-Rays in 1892, hundreds



Left: A neural network plug in PC card, Neural Technologies Ltd.

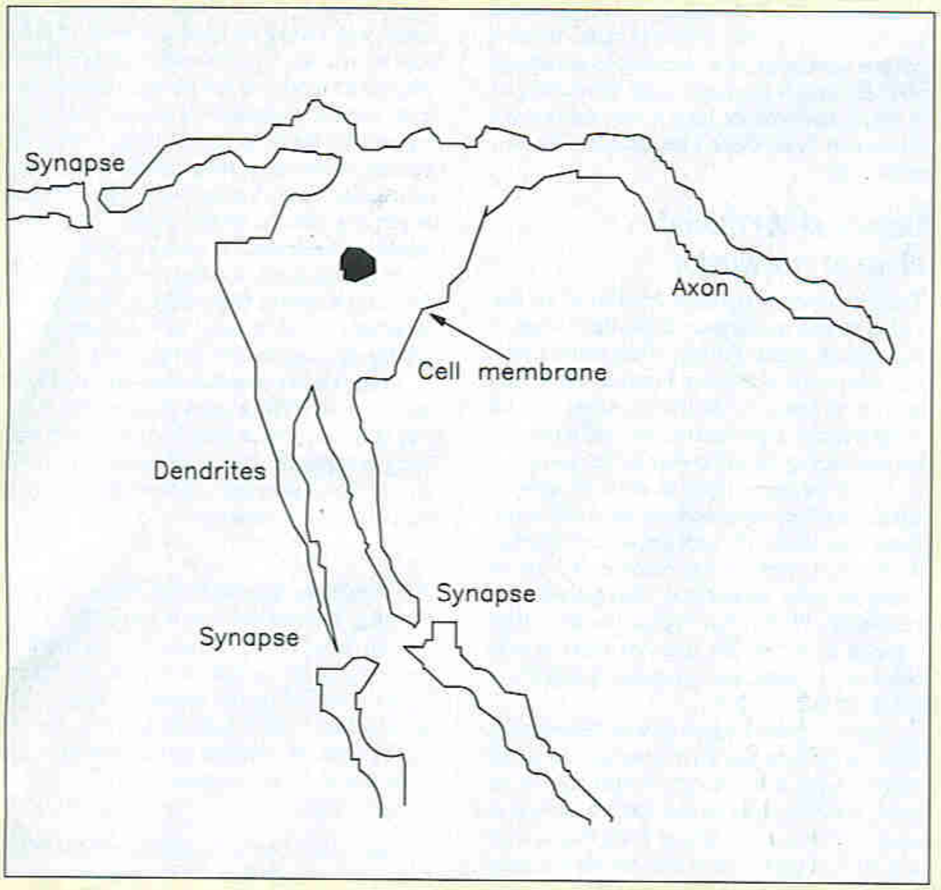


Figure 1. (Left) Simplified structure of neuron with attached dendrites and axon. The state of the neuron is communicated 'forwards' by the axon and is determined by complex synaptic interactions over the surface of the neuron.

Figure 2. (Below) A typical processing element of an artificial neural network. The series of inputs have their values modified by a series of weights and the sum of their products is processed by a 'transfer' function to give an output value.

of people across the world were duplicating his results, so, when an appropriate method of training neural networks to do useful work was established by Rumelhart, Hinton and Williams in 1986, literally hundreds of research groups across the world launched out on their own neural network projects.

This time, instead of trying to find out how to make them perform useful functions, developments were related to making them undertake useful work. As with a good many 'discoveries' in science, not only did several researchers in the field report similar methods independently, but an earlier researcher in 1974 had apparently stumbled on the solution and not recognised its significance. This began a phase of very rapid growth of the technology of neural networks, and indeed a phase which is very much on-going.

Parallel Processes

A simple assessment of the function of the human brain indicates that it is a massively parallel-connected system. The typical human brain contains around 100-billion neurons. Each neuron can have up to 10,000 links which connect to other neurons, and often over distances of several centimetres. A conventional digital computer undertakes to process its instructions exclusively *in series* in a very precise way. In many respects the accuracy of the digital computer is unsurpassed. The machine can more or less be guaranteed to control every state of the system it manipulates – there are no uncertainties.

The key to understanding natural systems of connected neurons, however, lies in their basic structure, as shown in Figure 1. The neuron receives inputs from synapses which connect to other neurons. The 'output' of a neuron is communicated along its 'axon' connection. Thus one axon can communicate to a number of separate neurons and also to several sites on the one linked neuron.

Active neurons release pulses of electrical activity at various frequencies. As a burst of activity propagates along an axon it terminates at a 'synaptic gap' and releases a packet of chemicals, which in turn stimulate propagation of the signal into the receiving neuron. In 'natural' neural networks neuron density is exceedingly high, but the speed of signal propagation is relatively slow.

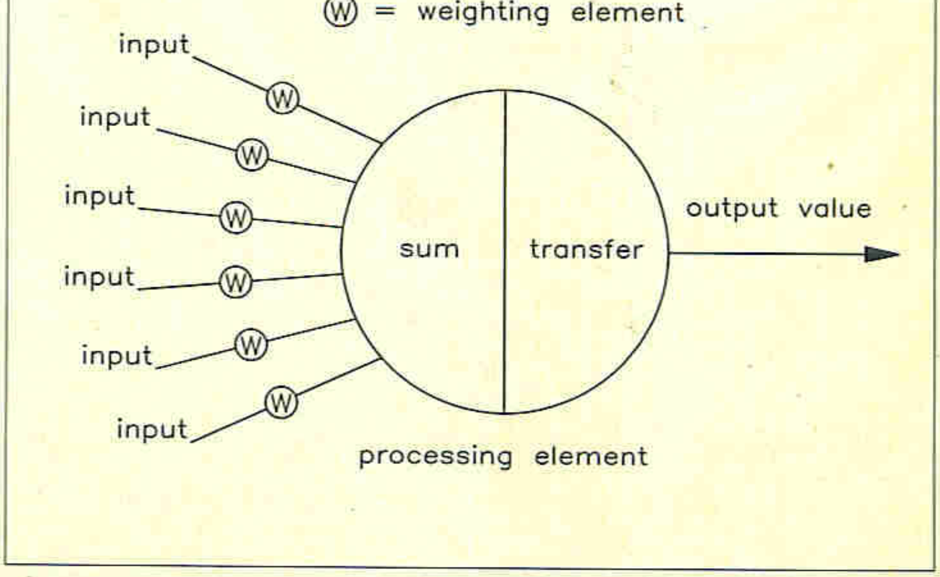
It has been shown that simultaneous synaptic activity can result in LTP – Long Term Potentiation. This implies that synapses which are active tend to develop and strengthen their activity. This process was first proposed by Donald Hebb, the Canadian Psychologist, in 1949. Numerous centres are seeking a more complete understanding of the role of chemical changes at synaptic 'intersections'.

Within the mammalian nervous system there are over 100 *different kinds* of such neurons. The human brain must, therefore, be considered to have an exceedingly high number of individual synaptic/connections. In total it is considered that each human brain can have as many as 100,000 billion synapses. While aspects of general organisation will be similar between individuals, the fine details of local connections must be strikingly unique. There is considerable debate regarding changes in synaptic linkages during the various lifestages of the human brain. There are at present no simple answers. We know more about the rings of Saturn.

What soon becomes apparent, however, is that there is a high level of interconnectivity in all sensory functions. Consider the act of sitting down and eating a meal with a knife and fork. Sitting at the table, the hands grip the knife and fork (holding, and sensory feedback on holding), a morsel of food is moved towards the mouth (vision system interacts with muscles of hand/arm and jaw/mouth), and the taste and smell of food is experienced (olfactory system). While all this is going on the diner can be viewing all that is happening in front of him and be listening to various conversations around the table. (And this is quite apart from the 'autonomic' processes also going on, like cardio-vascular activity, digestion, etc.) Our brains are therefore well connected – different senses are aware of each other.

While there are a great many mysteries in human learning, much of the human learning process is one of 'learn by experience'; the muscle control required for walking, the sounds required in talking, are all learned by trial and error. It is considered that part of the learning process relates to the relative extent of synaptic size. Thus synaptic links which fire frequently assume greater significance than those which fire infrequently. In general terms then the neural linkages become *modified* by the level of stimulation. This aspect of LTP (Long Term Potentiation) is being researched in various centres, and may bring major developments to the understanding of memory and learning.

Seen in perspective, therefore, digital computers are quite alien to mother nature in as much as it is not a structure which nature can implement as part of its process of incremental biological evolution. The irony of the situation, however, is that this



'unnatural' development *has* been developed using the cognitive ability of massively connected and trained neural networks in the human brain. It can therefore be considered as an 'outgrowth' of neural networks!

New Lamps for Old

The science of neural networks has a very basic message for a large section of the science community. For the biologist, it provides a formal framework for classifying and understanding neural activity and conditioning in living systems. For the computer scientist, it reveals problem solving techniques for complex data analysis, such as pattern recognition, which are more effective than the previous number crunching processes developed with digital computers.

Limits of Understanding and Acceptance of Neural Networks

If the understanding of the science of neural networks had matured *prior* to the full development of digital computers, then some of the problems experienced in finding what is the 'success' of neural networks could have been avoided. The so-called 'expert system', written according to well-defined rules and procedures, and programmed in a conventional way, is considered in various quarters 'acceptable'. Results equally as good, if not better, can be obtained using a neural network implementation, *but* this is identified in some areas as a 'problem', since answers are being produced which cannot be explained in terms of formal rule structures.

The eye of you, the reader, scanning these characters on the printed page, is not concerned about understanding 'how' the patterns of ink are scanned and recognised in the retina and brain. Where a pension fund manager is assessing an investment portfolio, which functions using the techniques of neural networks, the issue is very real and is a surprisingly acute factor when assessing the new technology.

Basics of Artificial Neural Networks

The generalised input/output function of the biological neuron readily gives rise to the concept, in the artificial neural network, of the artificial neuron. Such a unit is shown in Figure 2, where there is a set of inputs to the neuron, some rule for weighting each input into the unit, and a function for determining the output state of the neuron.

Of all the many types of artificial network which have been developed, the one which is predominantly used is the back propagation network. At meetings where people describe their use of neural networks, invariably it is this type which is referenced. While other approaches have been reported which provide solutions faster or with better performance, back propagation remains as it were in 'pole position'.

Figure 3 shows a simple forward feed network where links from one layer communicate to the adjacent layer. It consists of an input layer of six units, a 'hidden' layer of four units and an output layer of three units. A neuron in the hidden layer will have six inputs – each with its own weighting factor – and communicate its output to two neurons in the output layer.

The aim of training a neural network is to configure the weighting factors in the network so that it processes sets of data presented to it in an 'intelligent' way. During the training process the difference between the expected output and the observed output is minimised. In this process, however, there is no 'explicit' declaration of how the data is represented by the array of weighting factors. The training process itself, using, for example, the back propagation method, adjusts the weighting values as part of a 'turn the handle' process. Weights are usually set to random values prior to training.

In general terms, a neuron can be universally described according to the diagram of Figure 4. It is perhaps useful to show how the language of mathematics can describe things neatly.

In relation to a neuron in level [S], position j, it receives inputs from a series of inputs X_i (i = 1, 2 .. n) from the previous layer [S-1], with each input being multiplied with a weighting value W_{ji} (i = 1, 2 ... n). The neuron sums all these values to value I_j according to the notation:

$$I_j^{[S]} = \Sigma_i W_{ji}^{[S]} X_i^{[S-1]}$$

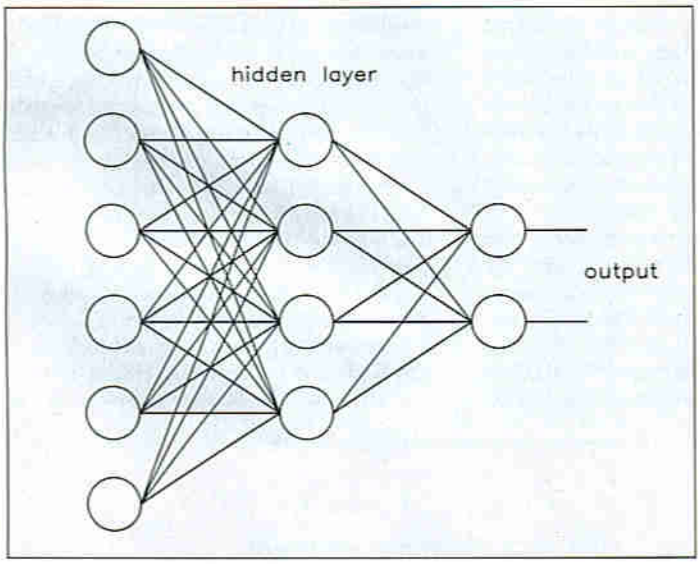
The weights are associated with the level [S] and the inputs from the previous layer [S-1].

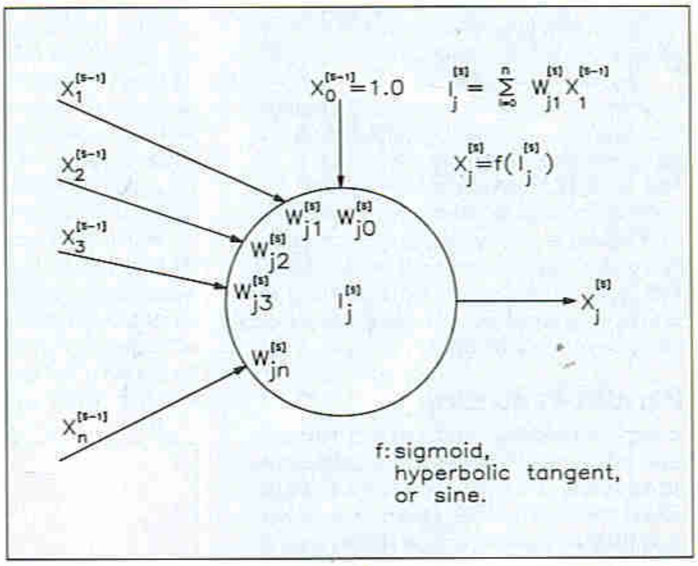
This value of the function I is calculated by summing all the contributions from the various inputs modified by the weighting factors. The actual output of the element Xj, however, is modified by a specific function f ( ), so that the output of the neural element is given by:

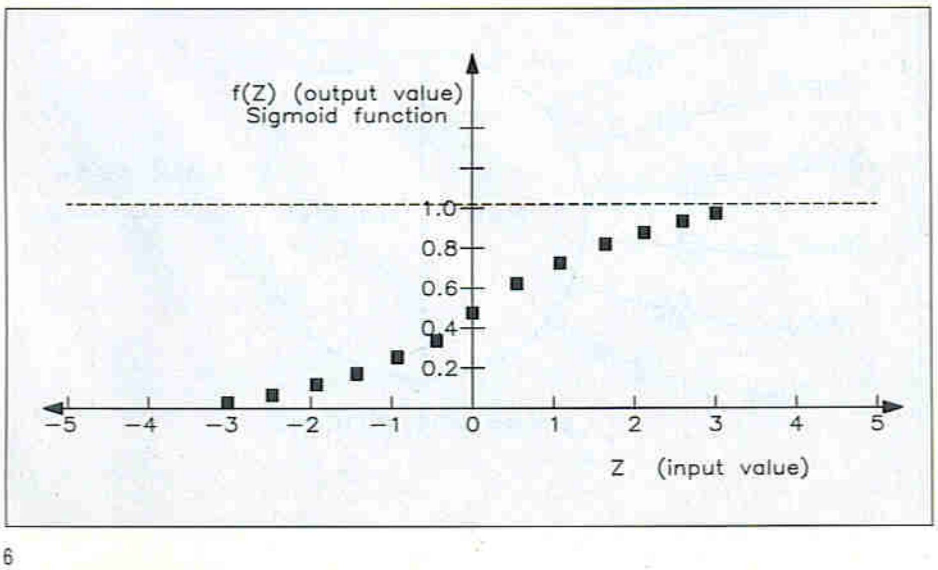
$$X_j^{[S]} = f(I_j^{[S]})$$

A range of functions can be used. A convenient one to use, however, is what is known as the sigmoid function, where:

$$f(z) = \frac{1}{1 + e^{-z}}$$







Above left: Figure 3. Diagram showing how processing elements are linked together in a forward feeding neural network. A neuron in a given layer is assumed to have specific weights and modify the output values from the previous layer, etc., etc. Problems of any complexity require a 'hidden layer', as shown. A network can have any number of layers but this need not necessarily improve its performance.

Above right: Figure 4. This is the formalised notation represented in simple terms in Figure 2. The outputs from the previous layer [S-1] are inputs to element in layer S. The weights are associated with element j. The sum of the products of inputs and weights is modified by a transfer function.

Left: Figure 5. Value of Sigmoid function for various input ranges. The function maintains output values between 0 and 1 whatever the value of the inputs. This is the most commonly used transfer function in back propagation networks.

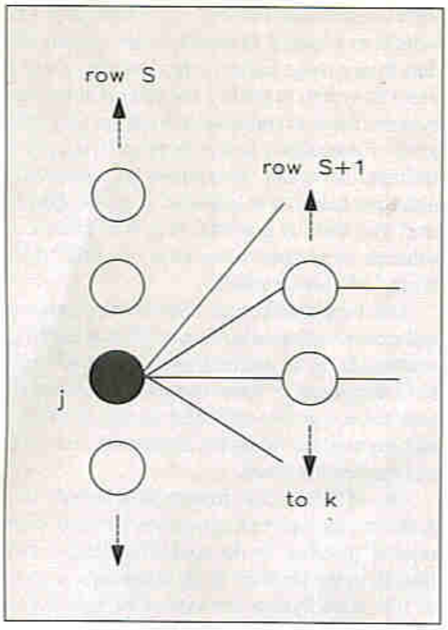


Figure 6. Indication of how element j in row S is 'processed' by back propagation where the weights of element j are altered by applying the delta rule after the error term from layer [S+1] is evaluated.

Figure 5 shows how this function translates values. Initially the network can be created with random valued weights close to 0 so that it is in an untrained mode.

A key concept of the function of such a network is its total error function. This can be considered to be given by:

$$E = \Sigma_{cj} (y_{j,c} - d_{j,c})^2$$

where y is the actual output value and d is the desired output value. The term j relates to the outputs of the network and c to the number of input/output pair of data presented to the network. Thus when a network is initially created, it will have a large error term which will be reduced with subsequent training.

This error term is a function of every weight in the system. Using standard mathematical techniques, expressions can be obtained for estimating the error term looking backwards in the network. The local error associated with element at level [S] and all the local errors at level [S+1] is given by:

$$e_j^{[S]} = x_j^{[S]} * (1{\cdot}0 - x_j^{[S]}) * \Sigma_k (e_k^{[S+1]} * w_{kj}^{[S+1]})$$

where the sigmoid function is used. Figure 6 shows element j in row [S] and the elements in row [S+1]. The reader need not be put off by such 'exotic mathematics'. Those wishing to follow this up more readily should look at references 1 and 2 given at the end of the article.

It is appropriate, however, to change weight values appropriately so that the network is moved towards minimum error. It can be shown that in that the appropriate change in weight element ji is given by:

$$\delta W_{ji}^{[S]} = lcoef * e_j^{[S]} * x_i^{[S-1]}$$

where lcoef is a learning co-efficient (and δ (Greek letter 'delta') = 'rate of change').

This, therefore, gives guidance on how best to change the weight value to achieve a more 'fit' network. This form of training therefore moves weights in the correct direction from a knowledge of the error function.

In summary, therefore, the process of back propagation can be presented:

(a) Present the input data to the network and calculate all values of outputs of elements, forming the output of the network. (This uses simple arithmetic as the output values of elements are fed forward through the network one layer at a time.)

(b) For each processing element in the output layer calculate the scaled local error and calculate the δ (delta) weight value. (This begins with the errors observed at the output layer, i.e. the differences between expected and observed values.)

(c) For each layer [S], starting at a layer below, the output layer and ending with the layer above the input layer and for each processing element in layer [S], calculate the scaled local error and then calculate the delta weight value.

(d) Update all the weights in this way in the network by adding the delta weights to the corresponding previous weights.

(e) Present input data and repeat process until the network 'converges' to a stable solution. A training set can be presented once and then the same training set presented numerous times.

A network will typically converge towards a solution. One of the problems, however, is that a network will seek out a local minimum of error rather than a 'global' minimum. In Figure 7, for example, features (a) and (b) are global minima while feature (c) is an obvious global minimum of the network. The network will function with higher performance when the global minimum is attained. One of the options which some packages provide is the introduction of a small random weight error to 'bounce' a network out of a local minimum.

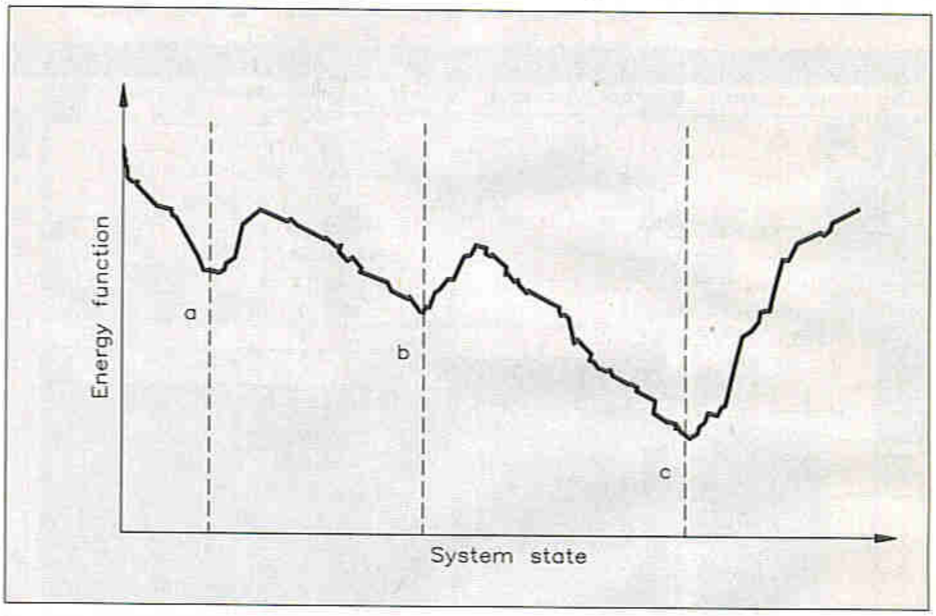


Figure 7. Example of a network with local minima (a) and (b) and a global minimum at (c). Most networks when trained will seek out the global minimum. The network will function best in state (c).

The concept of back propagation works reasonably well in practice, but it is not a mechanism which is considered applicable to 'natural' neural networks, for example in the human brain. The mechanisms involved in learning and memory have yet to be 'discovered'.

While it is possible to write programmes which can implement such neural networks, it is much more simple to use software packages configured for such systems. While simple networks can train in 'modest' times (several hours), relatively complex systems can require much more in the way of computing resources. Accelerator cards, such as the Balboa 860 SNAP Processor, can compute at over 1 billion, forward feed connections per second. This would be approximately 1 million times faster than a conventional PC. Thus, what the 860 SNAP could undertake in one hour, a humble PC (if it could structure the problem) would complete in 1,141 years!

Once a network is trained, however, it can produce results relatively quickly. It is the requirement for extensive processing power during training which is the demanding feature.

Learning by Example: NETtalk

The diversity of applications involving neural networks is remarkable. One of the early applications of neural networks, NETtalk, was to give considerable insight into the possibilities of the technology. The researchers, Sejnowski and Rosenberg (3), developed a network to vocalise speech. Their system interfaced to a DECtalk unit which vocalised speech after being provided details of stresses and component sounds (phonemes). The network would be trained on sets of words with a known vocalisation and then 'new' words would be presented to the network and compared against 'correct' pronunciation. Figure 8 shows the detail of the network used. The bottom input layer consisted of seven sets of 29 units, the hidden layer had 80 units and the output layer 26 units. Up to seven characters could be presented at the input layer. In all the system had 309 units and 18,629 weights.

The network was trained typically on 1,000 commonly used words. Figure 9 shows how the network achieved higher and higher scores for stresses and phonemes as additional training words were presented. Demonstration tapes of the output of NETtalk reveal that the network produced, initially, a babbling sound, but then, with progressive training, word boundaries become recognised and the prose progressively becomes more understandable.

The key feature which the network is demonstrating is that it is able to classify words correctly by optimising the weight values. This, in general terms, is what training of networks achieves. The alternative approach to this process would be to devise a look-up facility for every word. It can be appreciated that the neural network approach is a more 'universal' one, and one that could be applied to a range of languages or dialects.

Other Application Areas

Neural networks are being used worldwide in many thousands of different applications. A considerable number of these relate to aspects of pattern recognition. A range of projects have been undertaken to evaluate the use of neural networks for the recognition of addresses of mail items. Significant interest has been shown in Japan, for example, for the scanning of Kanji characters. One application at Carnegie Mellon University has used neural net-

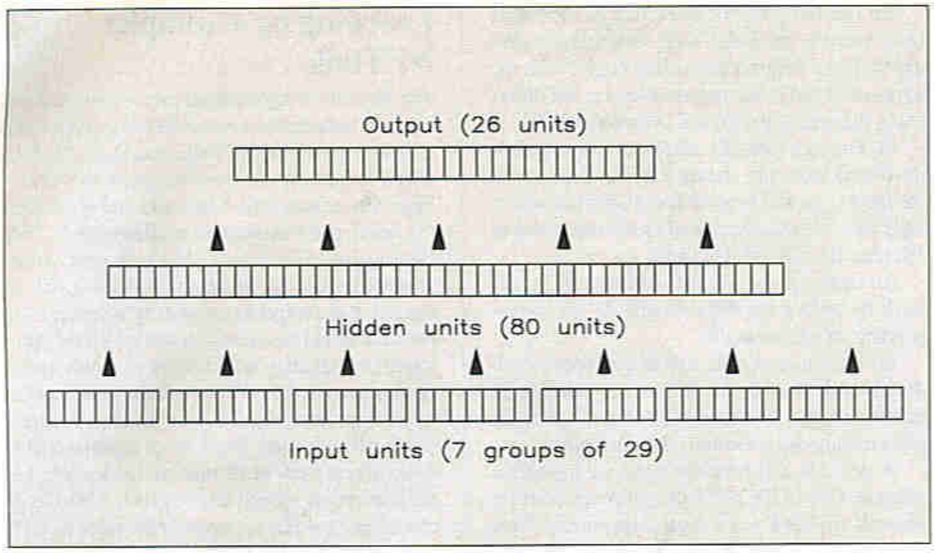
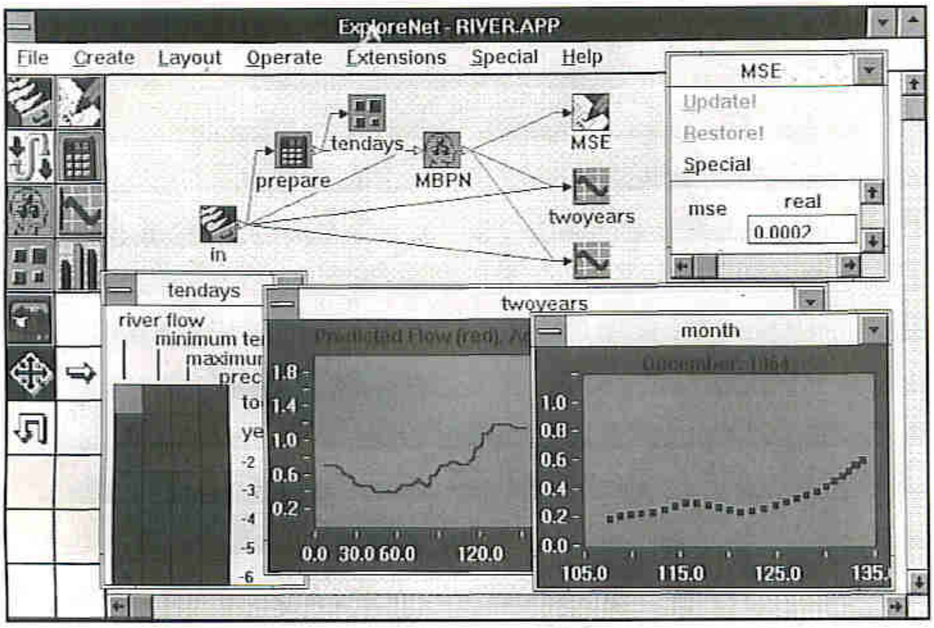


Figure 8. Outline of network used for NETtalk. An input layer of seven groups of 29 characterises the individual characters and an output layer of 26 units feeds directly to the DECtalk device to vocalise speech. The hidden layer allows sufficient complexity in the system to train with a high degree of success.



PC based neural network software, Neural Technologies Ltd.

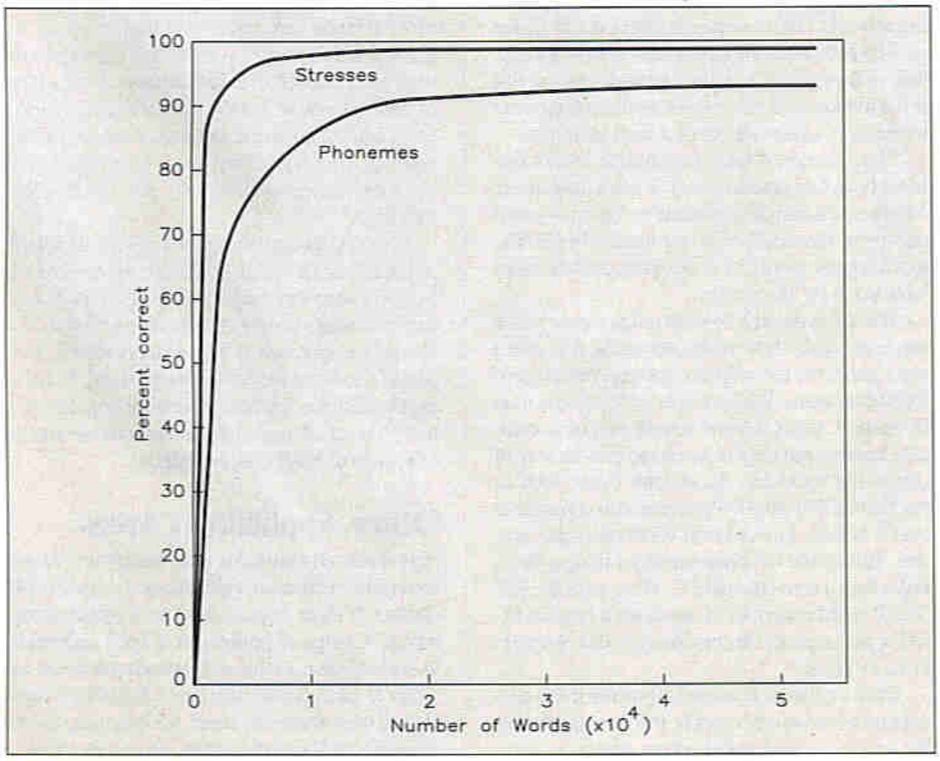


Figure 9. Indication of how the network performance improves with training set.

works to develop ALVINN (an autonomous land vehicle in a neural network). Video images and data from a range finder are processed by a neural network system to guide a test vehicle along road systems. Such an application requires a very great level of computing power to process images in realtime. An initial 'road following' speed of 1 metre per second was achieved. It can be appreciated that there is potential here for 'driverless' vehicles, or perhaps some level of safety 'monitoring' of moving vehicles.

Other applications can relate to more mundane and more commercially relevant fields of industrial automation. In an assembly line, neural networks have been used to detect components incorrectly assembled, e.g. tops on bottles missing or 'skew', and electronic components incorrectly inserted in a printed circuit board.

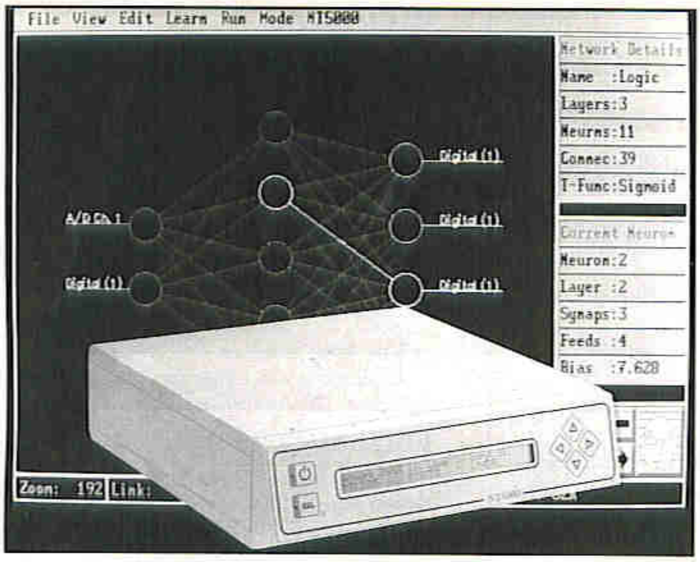
One of the attractive features of neural networks is that in such a pattern recognition problem, exact rules of 'pass/fail' do not need to be exactly specified. If, in the problem of the bottle tops, a series of 100 'good' bottles and a set of 50 'bad' bottles was used as part of an initial training set, then the network would be reasonably efficient at spotting 'bad' bottles. The same application tool could be used on another production line by merely presenting a different set of 'good' and 'bad' examples.

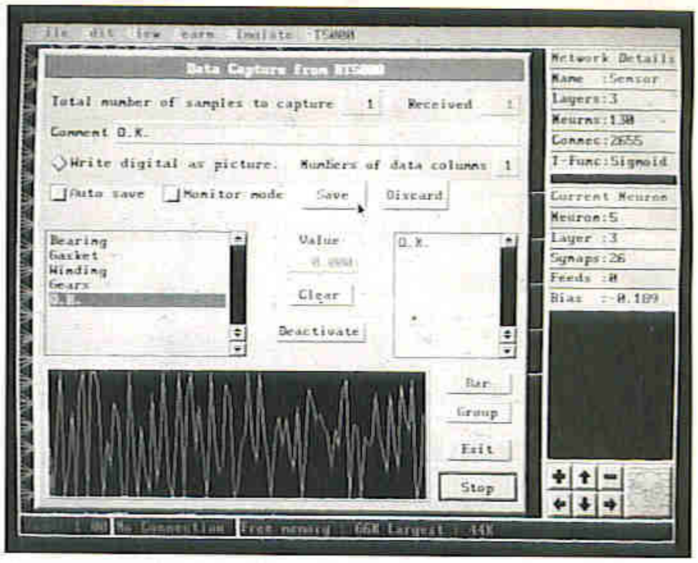
Much work has been undertaken in the use of neural networks in the processing of images of the human face. The WIZARD system can, for example, tell if a person is smiling or not. One application undertaken for BT was a neural network that could process a video image of the face and identify the eyes in order to present these in the centre of video phone monitor.

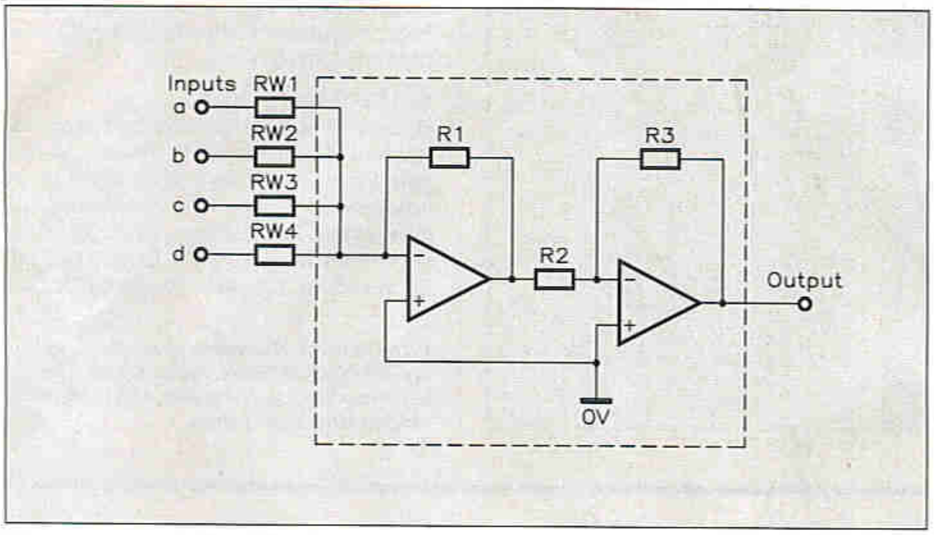
The financial market-place is known to make use of neural networks in a range of applications. One of these is loan 'scoring', where the risk of default is assessed, based on indications of a set of 'good' and 'bad' clients. One application developed by an American bank monitored the pattern of credit card use in order to detect card fraud. The basic concept used was that in authorised use a specific client's card has an 'individual' pattern of use. When the card is stolen and is used in an unauthorised way then the pattern of use changes. Trial use of the system in an 'off-line' mode has shown a high success rate of detecting card fraud. It would be very expensive, however, to implement such an 'on-line' system of credit card fraud detection.

Neural networks have been used with varying degrees of success in the financial markets. Where the market is 'stable' and predictions are made based against a background of such stability then relatively useful performance can be achieved. Where market conditions change then the rules which the previous data set obeyed have a reduced relevance and the performance of the network falls dramatically. When used in trading in gilts or currency markets, such networks require therefore to be trained on data which reflect relevant market conditions. There are tales of large amounts of money being made from relatively modest investments in neural network expertise. Such tales are usually second or third hand however, because it is highly unlikely that the institutions profiting from such technology are going to reveal the secrets of their success to their competitors.

One team at the Department of Computer Science at UCL, London, have developed a currency exchange rate prediction system using back propagation networks for such an aspect of time series prediction. Based on predictions of exchange rate of the $:DM, a profit element of 25% is claimed. This compares with a typical profit margin of 5% of a 'good' dealer. Do you want a copy of the program?







Above left: NT5000 neural processing unit, Neural Technologies Ltd.
Above right: On-screen shot of NT5000 data capture.
Figure 10. Example of how a dual operational amplifier can act as the 'core' of a neural processing element. Resistors would be attached to the inputs to allow the unit to function.

A significant number of neural network applications relate to the military sphere of activity. At the height of the cold war, for example, there was a significant input into developing neural networks in diverse fields such as sonar image signal processing and the identification of military vehicles by engine sound. It is reputed that neural networks do a very good job telling the difference between a whale and a Russian submarine. One application, which has recently been declassified, is the use of ground based multiple array mirror imaging systems which compensate for the distortion of the air. There are likely, however, to be a great many which the general public will never know about. . . .

A range of applications have been developed in the field of medicine. Neural networks are good at being trained on 'normal' data and 'abnormal' data and classifying data accordingly. Techniques of assessing ECG signals (from the heart) and EEG signals (from the brain) are fairly well developed. A system has also been developed to monitor intensive care data where after a system is presented with 'normal' data relating to a stable period of patient condition, it can recognise changes which may indicate deterioration in the patient condition. A system has also been developed for classification of skin pathology based on histological specimens.

Neural networks have been found particularly useful in the traditional area of expert system. Where a system is being classified on a rule based system after the fashion of a formal expert system this can be time consuming to configure. It has been found that neural networks can readily be used to 'classify' a problem into a neural network topology and a training set of data which when trained will function every bit as good if not better than the laboriously structured expert system. What might take three months to structure as an expert system has been successfully implemented using neural networks in significantly shorter time periods.

Hardware Representations

It is possible to illustrate principles of neural network technology using electronic circuitry. Figure 10 shows how a simple dual operational amplifier can be used as a neural network unit. The figure shows the unit without any weighting elements (resistors) connected. The values of R1, R2 and R3 would be equal. For positive input voltages, the output voltage would also be positive.

Figure 11 shows how 16 inputs feed into four such building block elements with their corresponding elements feeding forward to a single processing element with one output. The weights are shown as dotted lines and would in practice be implemented as resistors. In such an example large resistors would act to reduce the influence of inputs and smaller values increase the influence of inputs. In all the network has 16 inputs, 1 output and a total of 32 weights.

In order for the network to do useful work, however, it would have to be trained on a data set using computer techniques and then the required values set in the circuit. The circuit is, however, functioning exactly as a neural network would be expected to perform. The values of the resistors, however, would have to be set within bounded limits so as not to saturate the amplifiers.

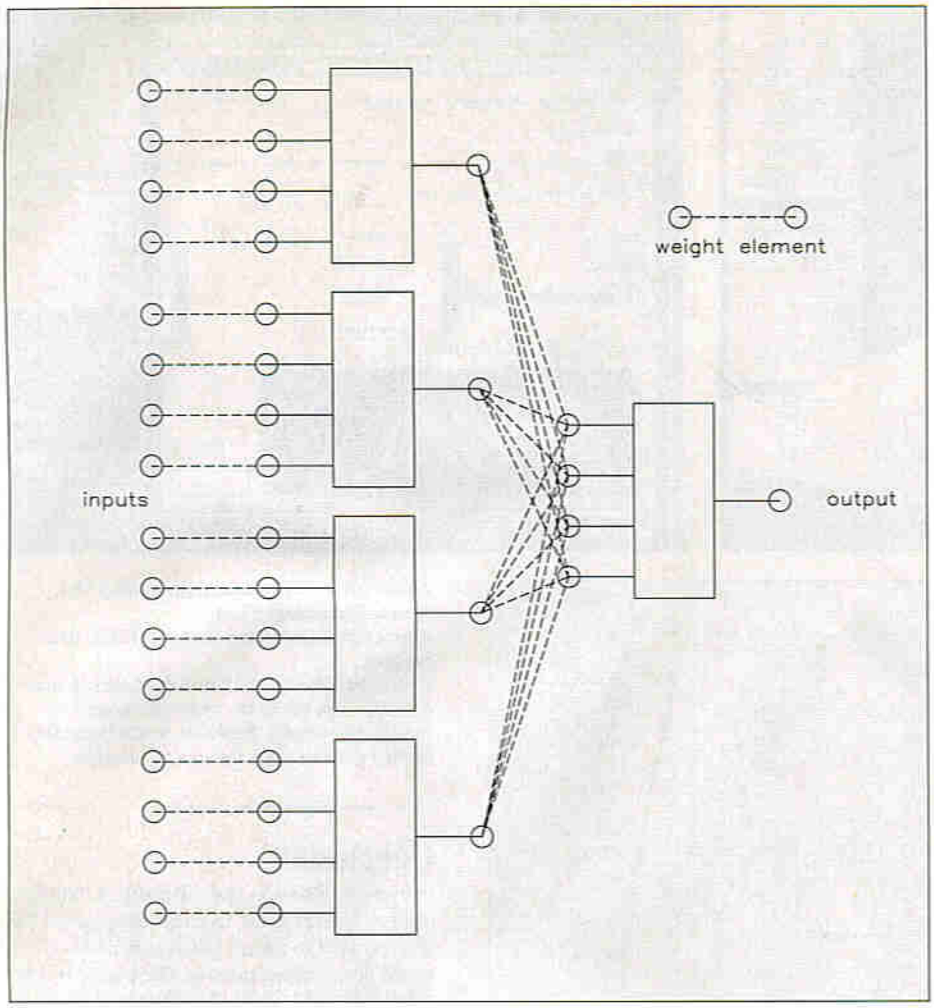
It is much easier, however, to simulate such a network using a computer model – a simple programming!

Conclusion

In trying to obtain an understanding of 'universal' computing techniques, to study conventional digital computers to the exclusion of neural networks would be a serious omission. There must be a balanced approach – using each flavour of computing where relevant and appropriate. At present, the bulk of routine applications relate to conventional digital usage. Some systems are being developed where a neural networks sub-system is incorporated into a conventional computing application.

There are obvious benefits for a range of industries to introduce such techniques and significant interest has been expressed in using such systems as 'safety supervisors' monitoring a large set of data streams such as in a power station or aircraft. It is also generally felt that industries can function with greater efficiency with regard to, for example, use of energy or reduction of 'scrap' output. Various companies have been able to reduce costs by critical factors using neural networks and so help maintain a competitive edge in demanding market-place conditions.

Casey Klimasauskas. Founder of NeuralWare Inc.



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2. Learning internal representations by error propagation, D. E. Rumelhart, G. E. Hinton and R. J. Williams, in Parallel Distributed Processing: Explorations in the Microstructures of Cognition, Vol. 1, D. E. Rumelhart and J. L. McClelland (Eds.), Cambridge, MA:MIT Press, 1886, pp318-362.
3. NETtalk: a parallel network that learns to read aloud, T. J. Sejnowski and C. R. Rosenberg, The John Hopkins University Electrical Engineering and Computer Science Technical Report, JHU/EECS-86/01,32pp.

Further Reading:

A Practical Guide to Neural Networks, M. McCord, Nelson and WT Illingworth, Addison Wesley. Neural Network Architectures, Judith Dayhoff, Chapman and Hall. Introducing Neural Networks, Alison Carling, Sigma Press. Neural Network Primer: Economies of a New Technology, Dr. Klaus Obermeir, Ellis Horwood.

Aknowledgment:

Photographs supplied by Neural Technologies Ltd., suppliers of neural network software and hardware for evaluation and implementation into real-world applications. For more information, please contact: John K. Davies, Tel: (0730) 260256, Fax: (0730) 260466. Neural Technologies Ltd., 7a Lavant Street, Petersfield, Hampshire GU32 3EL.

Left: Figure 11. Illustration of how the simple building block of Figure 10 can be incorporated into a functional neural system with 16 inputs, 32 weights and a single output.

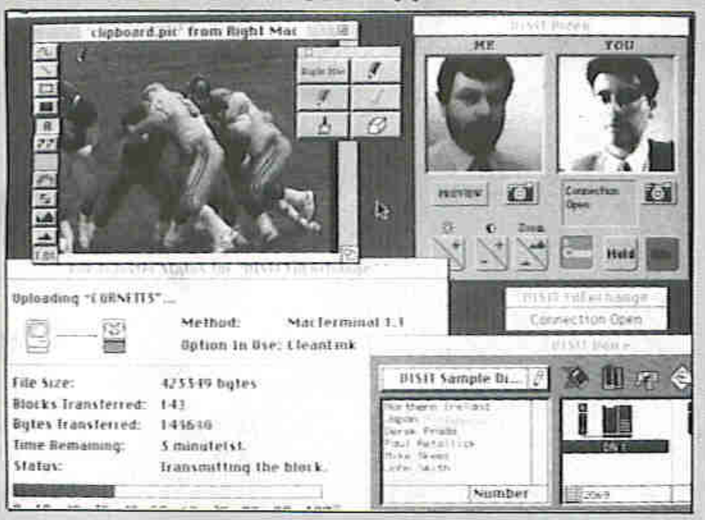
MAPLIN'S TOP TWENTY KITS

POSITION			DESCRIPTION OF KIT	ORDER AS	PRICE	DETAILS IN		
1.	(1)	♦♦	L200 Data File	LP69A	£ 4.75	Magazine	46	(XA46A)
2.	(4)	♦	TDA7052 1W Amplifier	LP16S	£ 4.95	Magazine	37	(XA37S)
3.	(2)	♦	Live Wire Detector	LK63T	£ 4.75	Magazine	48	(XA48C)
4.	(7)	♦	1/300 Timer	LP30H	£ 4.95	Magazine	38	(XA38R)
5.	(5)	♦♦	Courtesy Light Extender	LP66W	£ 2.95	Magazine	44	(XA44X)
6.	(6)	♦♦	Car Battery Monitor	LK42V	£ 9.25	Magazine	37	(XA37S)
7.	(8)	♦	Stroboscope Kit	VE52G	£14.95	Catalogue	'93	(CA10L)
8.	(3)	♦	MOSFET Amplifier	LP56L	£20.95	Magazine	41	(XA41U)
9.	(9)	♦♦	Lights On Reminder	LP77J	£ 4.75	Magazine	50	(XA50E)
10.	(11)	♦	IBM Expansion System	LP12N	£21.95	Magazine	43	(XA43W)
11.	(12)	♦	UA3730 Code Lock	LP92A	£11.45	Magazine	56	(XA56L)
12.	(17)	♦	Remote Power Switch	LP07H	£ 5.25	Magazine	34	(XA34M)
13.	(14)	♦	LM386 Amplifier	LM76H	£ 4.60	Magazine	29	(XA29G)
14.	(13)	♦	TDA2822 Stereo Amplifier	LP03D	£ 7.95	Magazine	34	(XA34M)
15.	(18)	♦	SL6270 AGC Mic Amplifier	LP98G	£ 8.75	Magazine	51	(XA51F)
16.	(16)	♦♦	I/R Proximity Detector	LT00A	£10.95	Magazine	54	(XA54J)
17.	(10)	♦	Mini Metal Detector	LM35Q	£ 7.25	Magazine	48	(XA48C)
18.	(15)	♦	LM383 8W Amplifier	LW36P	£ 7.95	Catalogue	'93	(CA10L)
19.	(-)	NEW ENTRY	Universal Mono Preamp	VE21X	£ 5.95	Catalogue	'93	(CA10L)
20.	(-)	RE-ENTRY	Beginners AM Radio	LP28F	£ 8.95	Magazine	42	(XA42V)

Over 150 other kits also available. All kits supplied with instructions.
The descriptions are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate project book, magazine or catalogue mentioned in the list above.

NEWS Report

Multimedia has Multiple Supporters



Northern Telecom are marketing the first desktop multimedia communications system commercially available in the UK. This combines personal desktop videoconferencing with other collaborative applications and runs them simultaneously, allowing users – who may be thousands of miles apart – to communicate visually and verbally. NT estimates that the overall market for such systems will be worth £1·2 billion worldwide by 1997 – a message not lost on Motorola, who have developed a 32-bit microprocessor for notebook computers, communication devices and home entertainment systems.

DEC is also aiming to be a major multimedia player, and has produced a system which allows high-speed multimedia data networking over ordinary cable television lines, putting implementers in direct competition with local telephone companies. The system is based on the Ethernet standard, and enables multimedia data to be carried at 10Mbps over television coaxial cable channels, providing up to eight times the capacity of T-1 lines.

Voltage Protection Devices, and a Word of Warning

Almost as if waiting for our recent article on Domestic Power Problems to hit the news-stands, two manufacturers have just launched two voltage protection devices.

Expanding upon their array of high voltage capacitors, ACAL Electronics now include a range of ceramic disc devices suitable for high voltage protection. Comprising both x and y rated types as well as standard high voltage capacitors, the range is claimed to provide designers with high tolerance components for demanding applications, such as radio frequency interference filtering and decoupling in power supplies. The devices may also be specified for low-voltage applications such as telephone, lighting ballasts and motor controls, to withstand transient voltages and energy surges as directed by IEE standards.

Meanwhile metal oxide varistors from Harris Semiconductors can be used to protect sensitive electronic equipment from mains-borne voltage surges. Providing 100% secondary surge protection for up to 40,000A, the new devices are expected to be used where power transmission lines enter a building containing sensitive equipment. They can be built into distribution panels, motor controls, or can provide stand-alone protection for equipment including computers, industrial motors, communications and other equipment. Devices are rated at between 130V and 750V AC, and are designed to work in the temperature range −55 to 85°C.

And finally, within ten days of submitting his manuscript on Domestic Power Problems to the Maplin Editorial Office, the author, Stephen Waddington, suffered damage to the hard disk on his own personal computer. While working away from home without mains protection, a spike damaged the drive, leaving the stepper motor dormant and the magnetic media ruined. Only delicate repair work managed to resurrect the drive mechanism, but all data was destroyed and the disk had to be reformatted. A case perhaps of not practising what one preaches – you have been warned!

What's in a Word?

So you thought that ATM stands for Automated Teller Machines. Yes, but it's now also an acronym for Asynchronous Transfer Mode. Likewise, reports 'Computergram', DTP – better known as Desk Top Publishing – can now also stand for Distributed Transaction Processing.

HDTV on the Agenda

Staying with infotainment, EC foreign ministers have had another stab at agreeing Commission proposals for the high definition television action plan. With most delegations agreed on the merits of EC involvement (not so the UK) the ministers agreed to hold further negotiations this month. For the UK, the stumbling block is a general reluctance to subsidise development on an analogue HDTV system (HD-MAC). Here the UK is supported by Bill Gates of Microsoft, who is keen to develop software for HDTV – but only if it is in digital mode. Hewlett-Packard is also keen to get moving on digital HDTV, just as soon as the US Federal Communications Commission (FCC) has decided on one of the present five different standards proposals put forward. HP will support rapid deployment of digital HDTV encoder equipment to broadcasters based on the standard presented by AT&T.

Virtual Reality – The Good . . .

Virtual Reality – the union of computer and audio-visual 3D simulation – has realised a host of applications in recent years. Engineering Consultants Mott MacDonald have latterly broken new ground by employing computer animation to help visualise complex fire and smoke situations.

A major extension to work is now planned, moving from conventional computer simulations to a more realistic 'virtual world'. This will help engineers to study real-time walk-through simulations, observing the spread of fire and movement of smoke in tunnels, buildings and oil platforms. The ultimate aim is to enable rescue workers to train safely in the virtual world using simulated fires and casualties.

. . . and the Bad

At the time of going to press, electronic games giant Sega were under fire for a tasteless application of Virtual Reality in their latest release, 'Night Trap'. The 'game' centres on the player moving around a three-dimensional world, with the sole objective of murdering five partially-clad young women. The horror is made all the more vivid by the use of real digitised actors, rather than cartoon-type figures. It seems that Sega has relinquished all social responsibility in a cynical attempt to gain a greater share of the youth computer games market.

From Trash to Transmission Line

Household rubbish now dumped in America's overflowing landfills may soon be used to generate electricity, with the help of an agreement between the National Renewable Energy Laboratory (NREL) and four US companies.

Research is aimed at developing a process that turns combustible garbage into thumb-sized pellets. The pellets are subsequently mixed with coal and burned in domestic-type boilers to produce electricity. An important step in manufacturing the refuse-derived pellets is the addition of lime, which acts as a bonding agent and holds the refuse together.

Under the research pact, Otter Tail Power Company will burn pellets at its power plant in Big Stone, South Dakota. The pellets will be supplied by Green Isle Environment Services and XL Disposal. NREL and Argonne will supervise the combustion tests and help analyse the results. A critical part of the work will be the examination of emissions generated by burning refuse.

If test results are promising, the NREL aims to develop a strategy to encourage electricity producers to try the pellets. More widespread use of the technology would help curb the millions of tons of municipal solid waste added to landfills every year. Perhaps UK generating companies should also take note.

PICTURE CAPTION CHALLENGE

No, it is not BT trying to outglare the Blackpool Tower. But what is happening? As usual no prizes – just a chance to exercise your deductive skills.

* Now why should someone have left a sparkler down here?
* BT's back-up lighting, should the power fail.
* The Old Testament story of the Burning Bush, brought up-to-date.
* Ouch!

OK – give up? It's actually modern technology being brought to a century-old structure as BT installs optical fibre cable 500ft up in the air to the top of the famous Blackpool Tower.

Events Listings

Now Open: The Mediterranean Air War. RAF Museum, Hendon, London. Tel: (081) 205 2266.

Now Open: 'Flight' Aeronautics Gallery, and 'The Secret Life of the Fax Machine'. Science Museum, London. Tel: (071) 938 8000.

Till 31 July: 'I used to be in Pictures'. An exhibition of autographed memorabilia of Hollywood stars working between 1915 and 1935. MOMI, South Bank, London. Tel: (071) 401 2636.

Till 3 October. The Electric Guitar 1930-1970. Design Museum, London SE1.

8 July. Radio Spectrum Review Stage 3 Seminar. Lord's Cricket Ground, London. Tel: (071) 215 2157.

25 July. 'All Formats Computer Fair'. National Motorcycle Museum, Birmingham. Tel: (0608) 66382.

14 and 15 August. Vintage Model Rally. Old Warden, Bedfordshire. Tel: (0442) 66551.

6 and 7 November. The 7th North Wales Radio and Electronics Show, Aberconwy Conference and Exhibition Centre, Llandudno. Tel: (0745) 591704.

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

Design by Alan Williamson
and Tony Bricknell
Text by Alan Williamson
and Martin Pipe

INFRA-RED DOOR LOCK

FEATURES

* Infra-red controlled
* Uses simple-to-install solenoid-controlled door catch mechanism
* Sensor can be installed away from the receiver for flexibility
* Uses same controller as Compuguard car alarm
* Output for switching external loads
* Adjustable 'on' time for external output

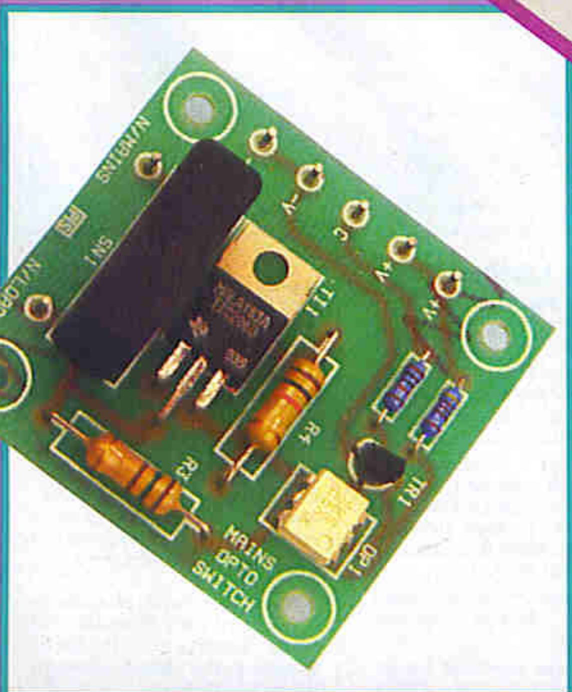
APPLICATIONS

* No more keys to worry about when your arms are loaded!
* Open your door while you arm your compuguard!
* Security systems

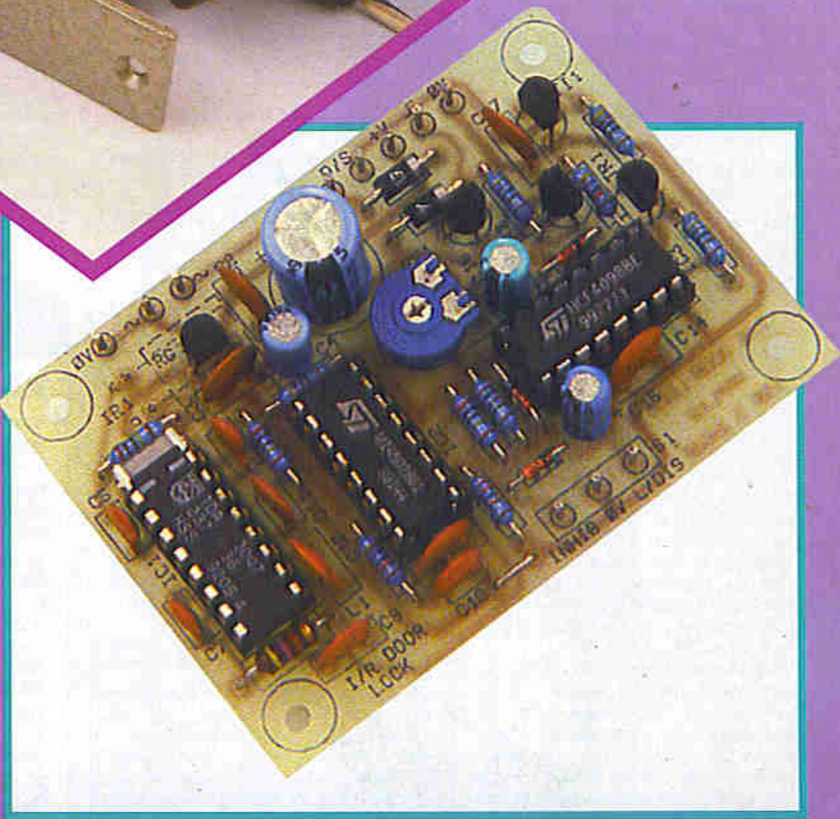
KIT AVAILABLE (LT32K) PRICE £24.95 A

Solenoid door lock mechanism and power supply for the Infra Red Door Lock

3 PROJECT RATING



The Opto Switch PCB, used to control an auxilliary load.



The Infra Red Door Lock PCB.

Have you ever been in the following situation? Your hands are full of shopping, it's dark and the porch light is off. The kids are playing you up and, during the struggle to get the key into the door, you drop the weekly groceries, breaking the eggs and glass jars. If this wasn't bad enough, milk from the split containers causes the labels to peel off from the tins, and ruins anything else that may have been salvageable, and in a burst of frustration and anger, you shout at the kids.

Well, this project will solve all (sorry, nearly all) of your problems. It will unlock the door, and can turn on the (porch or hall) light for a few minutes (with the addition of a relay, or the LP55K Mains Opto Switch Kit) by a simple press of a button. The remote control is the one used with the Compuguard car alarm system; if you already have Compuguard fitted to your car, set the same codes for both items and you will only need the one transmitter!

This project has many other applications – opening garage doors, for example.

Circuit Description – The Infra-red Transmitter

The infra-red transmitter, shown in Figure 1, outputs an amplitude-modulated carrier. As you can see from the circuit diagram in Figure 2, this carrier is generated by op amp IC2 (LF351) and associated circuitry.

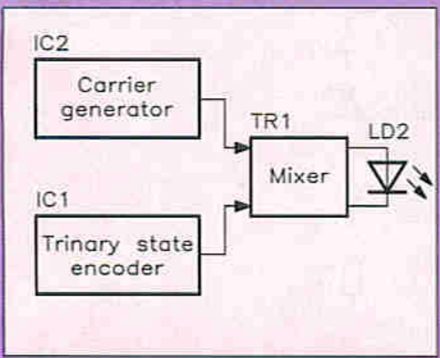


Figure 1. Infra-red transmitter block diagram.

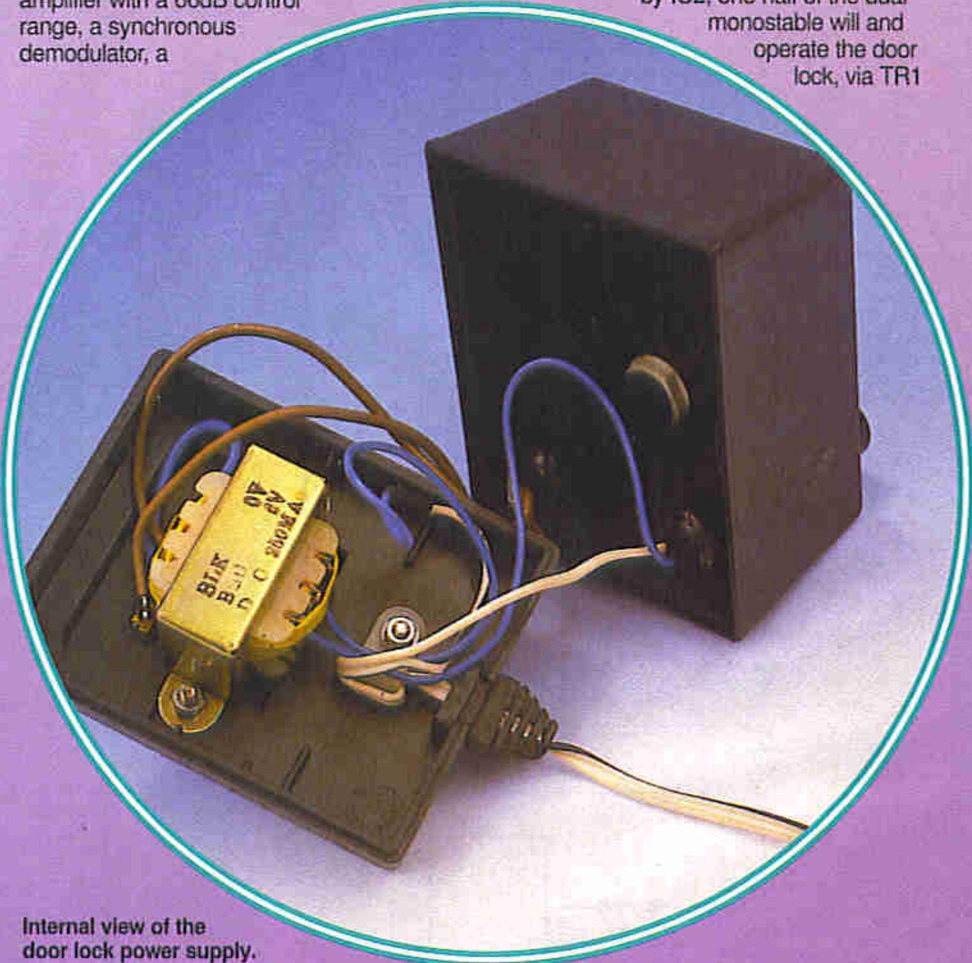
IC1 (M145026) provides a stream of data corresponding to the conditions set on pins 1 to (high, low, or floating). This data is used to modulate the carrier and is transmitted from LD2, via TR1.

Circuit Description – The Receiver

The receiver is shown in block form in Figure 3, and Figure 4 shows the ciruit diagram. Information received by the infra-red diode, IR1, is processed by the receiver IC1 (TDA3047), which contains an HF amplifier with a 66dB control range, a synchronous demodulator, a reference amplifier, an AGC detector, a pulse shaper, an input voltage limiter and a Q-factor killer. It strips off the carrier, leaving only the bare digital data stream.

This data stream is then passed to IC2, the companion to the remote control encoder in the transmitter, which will only respond (via pin 11, which becomes active) if the information contains the correct address, as set in the transmitter. There are 6,561 different codes possible, only one of which will trigger the device – security is therefore assured.

IC3 is a dual monostable; once triggered by IC2, one half of the dual monostable will and operate the door lock, via TR1



Internal view of the door lock power supply.

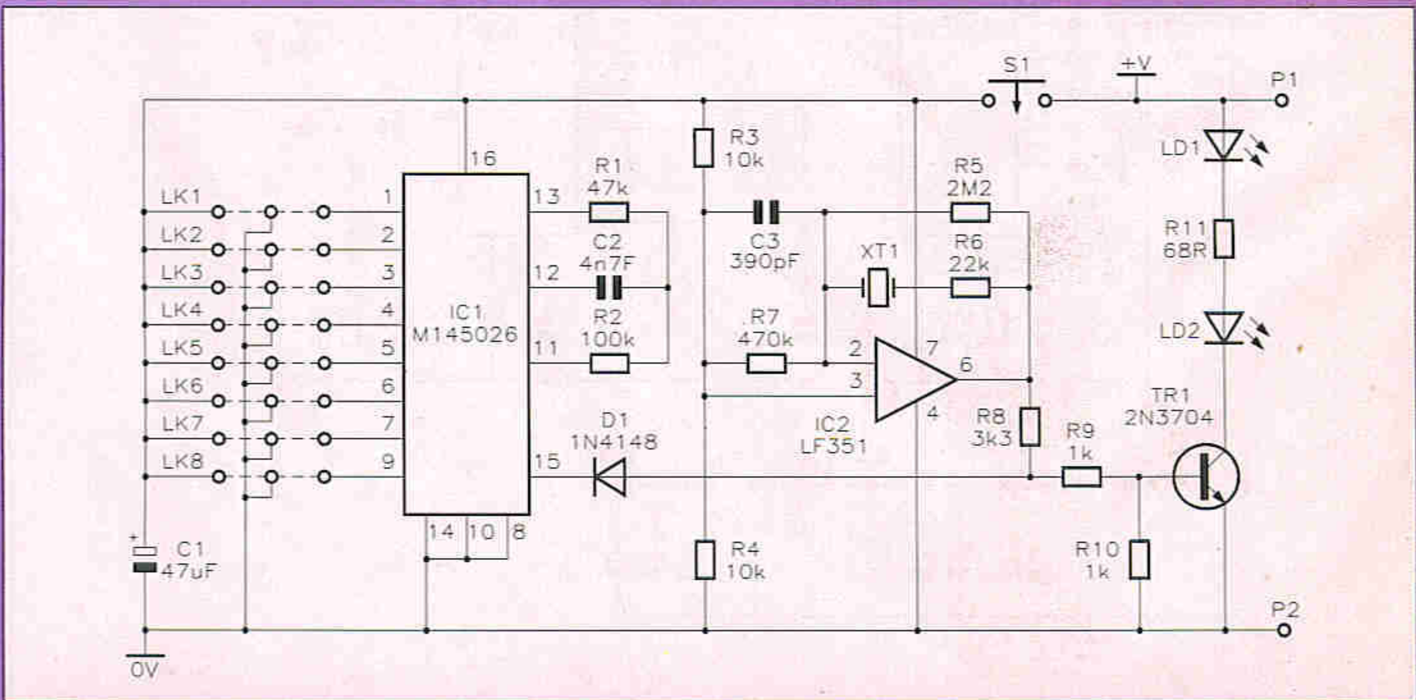


Figure 2. Infra-red transmitter circuit diagram.

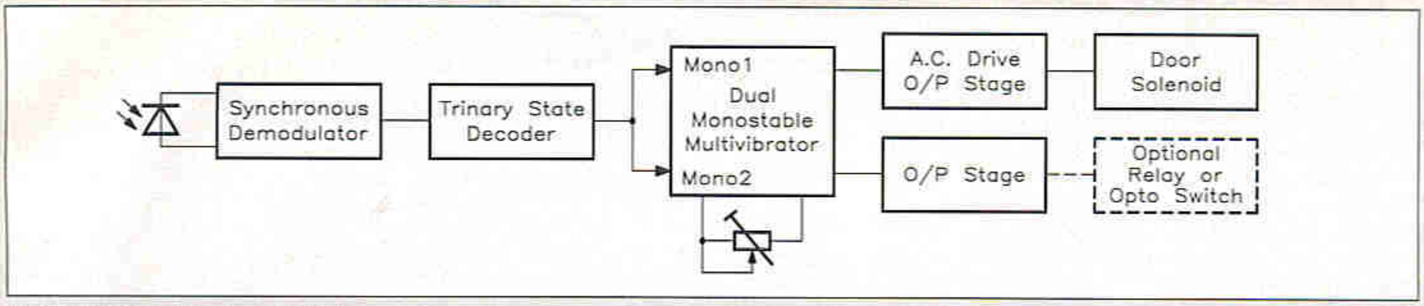


Figure 3. Infra-red receiver block diagram.

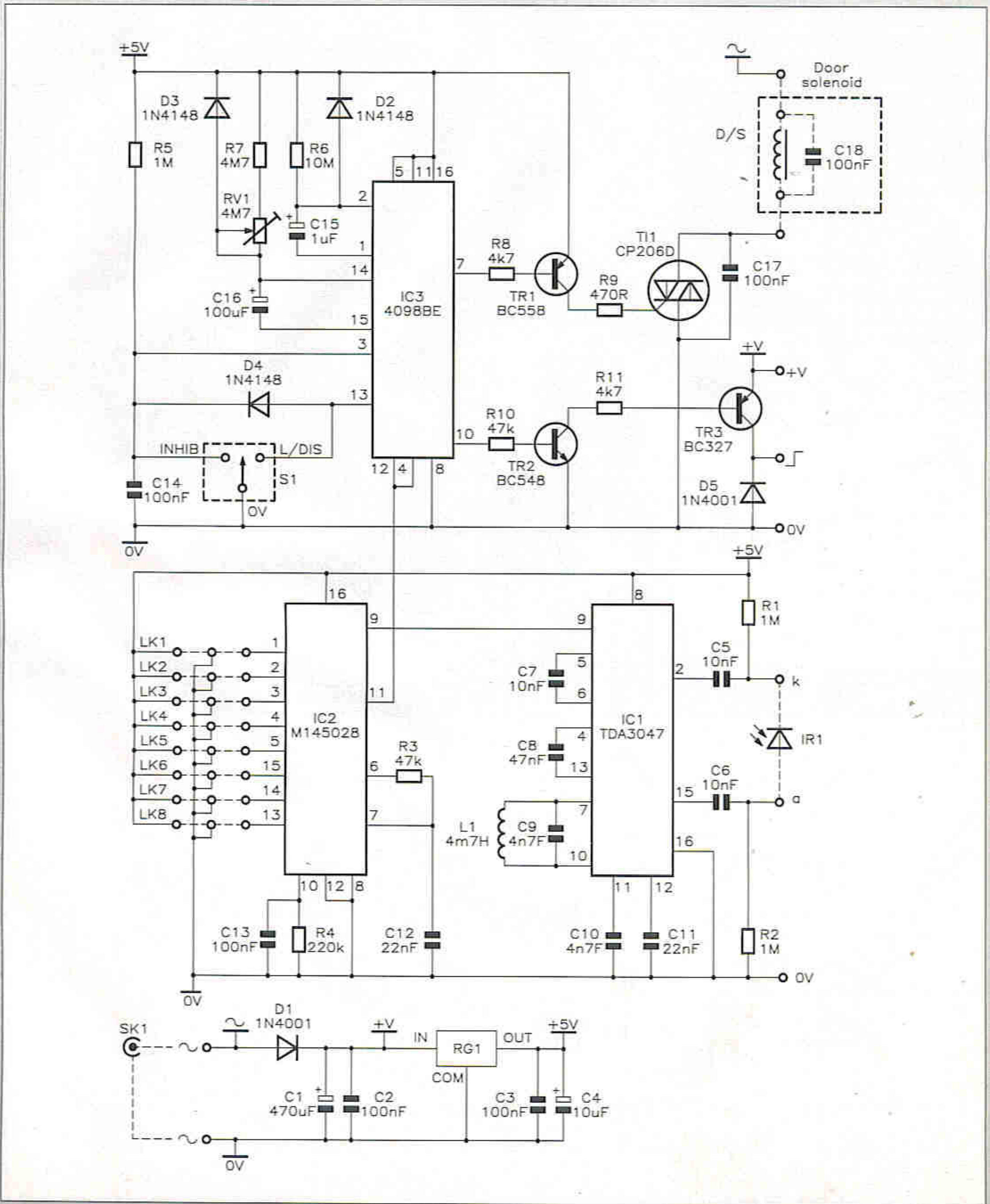


Figure 4. Infra-red receiver circuit diagram.

and TI1, for 3 seconds (determined by the time constant of R6 and C15) – enough time to open the door. The other half of IC3 has a variable timed output (determined by R7, RV1 and C16) ranging from 1 to 2 minutes. TR2 and TR3 are used as a voltage level shifter, which would be useful to turn on a porch or hallway light – but not directly; the LP55K Mains Opto Switch Kit or a relay should be used as an 'interface' – more details on this later.

Constructing the Infra-red Transmitter

A fibreglass PCB has been chosen for maximum reliability and stability. To allow the PCB to fit into the key-ring remote case, no IC sockets have been used, so please double-check the orientation of the ICs before fitting, as removal after incorrect insertion will almost certainly damage both the PCB and the chip! For further information on component identification and soldering techniques, please refer to the Constructors' Guide included with the kit.

Figure 5 shows the PCB, with printed legend, to help you correctly locate each item. The sequence in which the components are fitted is not critical; however, the following instructions will be of use in making these tasks as straightforward as possible.

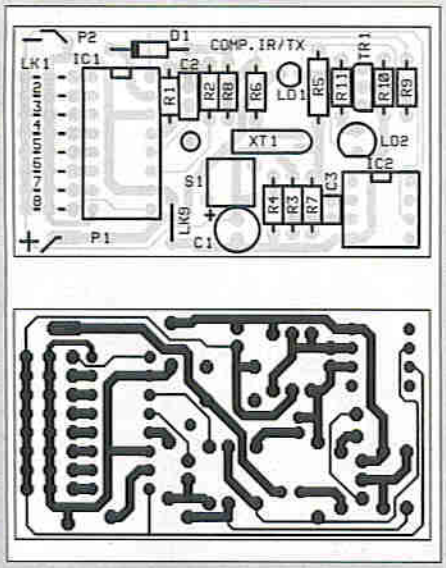


Figure 5. Transmitter PCB legend and track.

Start by fitting resistors R1 to R11, taking note that R5 is a larger, metal film resistor. Using offcuts from the leads of these resistors, insert link LK9. LK1 to LK8 set up the code transmitted. With reference to Figure 6, there are three ways of connecting the links (well, two ways, the third is to leave them out!). The purpose of these codes is to make your transmitter 'unique', so that only you will be able to open your door.

Insert S1 and XT1, bending the crystal flush to the PCB as per the legend.

Insert and solder C1 to C3, taking care of the orientation of C1. The polarity of this capacitor is shown by a plus sign (+), matching that on the PCB legend. However, on the actual body of most electrolytic capacitors the polarity is designated by a negative symbol (–), in which case the

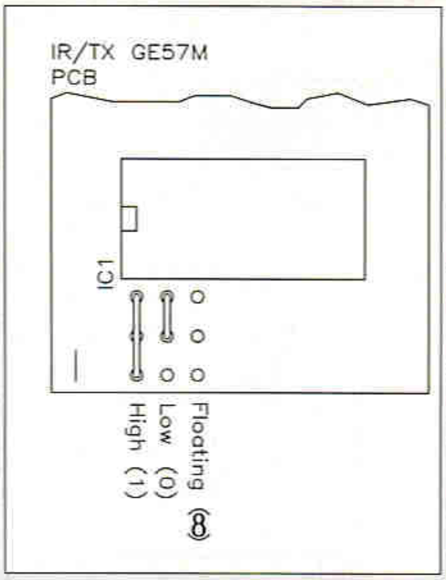


Figure 6. Three ways of fitting transmitter links LK1 – LK8.

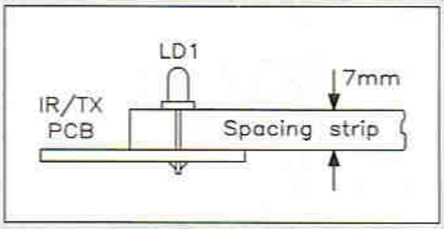


Figure 7. Inserting LD1 at a height of 7mm.

lead nearest to this symbol goes in the hole nearest the edge of the PCB.

With reference to Figure 7, insert LD1 at a height of 7mm. The best way to do this is to cut a thin strip of card 7mm wide, and place this between the legs of LD1 and the PCB whilst it is soldered. Bend the legs of LD2 at 90° as shown in Figure 8, and insert into the PCB at a height of 3mm.

Identify the two battery clips. The positive terminal (a small metal plate) is soldered into the slot labelled '+' or 'P1'. The negative terminal, or 'spring', is prepared as shown in Figure 9, before being soldered in the hole marked '–' or 'P2'. The spring may need bending slightly to allow it to fit snugly inside the box.

Insert diode D1, taking care of its orientation. The band at one end corresponds to the thick white line on the legend. TR1 is inserted matching its package outline with that of the legend. Install the ICs, making sure that all the pins go into the holes, and that the pin number one marker or notch at one end of the IC package matches up with the white block on the legend. Take *great* care while soldering the ICs in place, allowing several seconds between solder joints for the IC to cool down! As a guide, do the four corner pins first, ensuring that the IC is flush with the board. You can solder the remaining pins at your leisure, with long pauses in between.

Boxing Up the Infra-red Transmitter

If the remote key-ring box comes with two switch actuators fitted, then these need to be removed by pulling/breaking the actuator shaft. File the lower of the two inserts out to the dimensions shown in Figure 10. A 5mm hole also needs to be cut in the top end of the box for LD2, as shown. This is best achieved by carefully filing each half of the box with a round file, making frequent checks by placing the PCB inside the box to ensure that a correctly sized cut-out is achieved.

With reference to Figure 11, cut the flexible membrane into two pieces, 7·5mm and 10·5mm long. Remove the paper backing and stick them into the upper (small) and lower (large) recesses respectively.

Double-check your PCB to make sure there are no dry joints or short circuits, and assemble the box around the PCB, inserting the battery (not supplied in the kit) taking care of its polarity (marked on the bottom of the battery compartment). The whole assembly is screwed together, with the single screw provided.

The only thing left to do now is to depress the larger membrane, upon which the red LED, LD1, should flash very quickly.

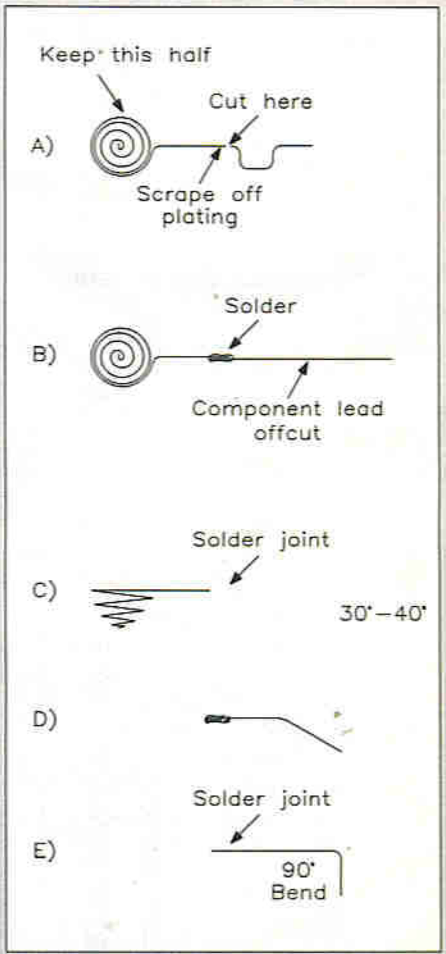


Figure 8. Battery terminal spring bending.

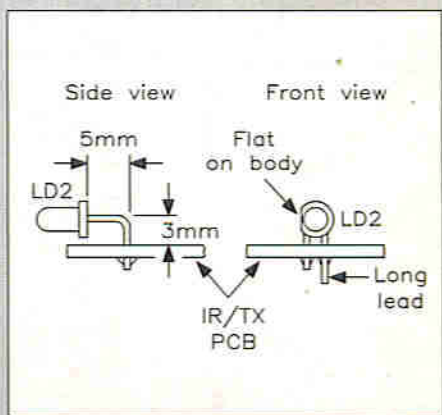


Figure 9. Fitting LD2.

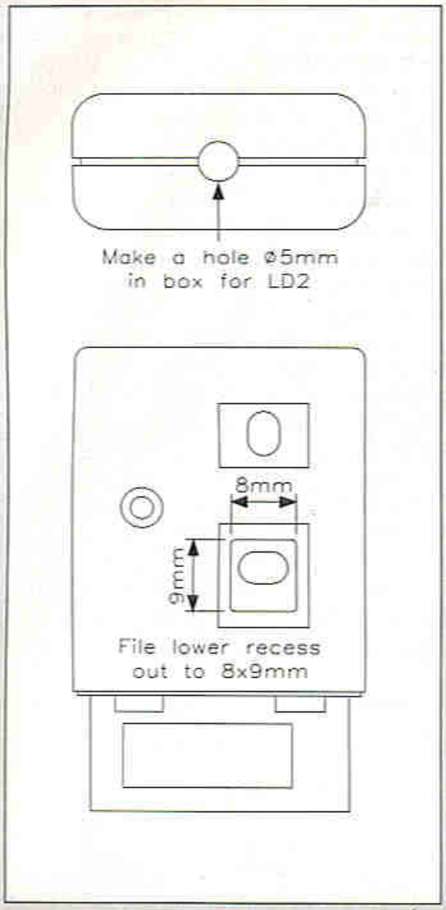


Figure 10. Filing dimensions for transmitter box.

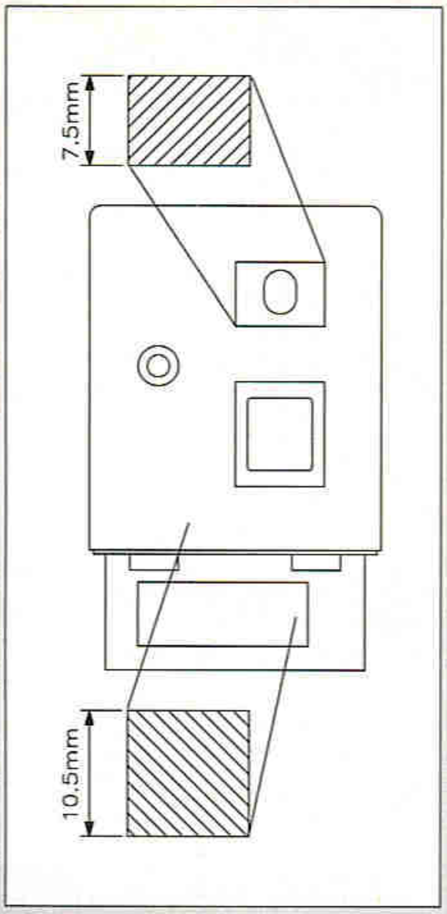


Figure 11. Fitting the membrane to the transmitter box.

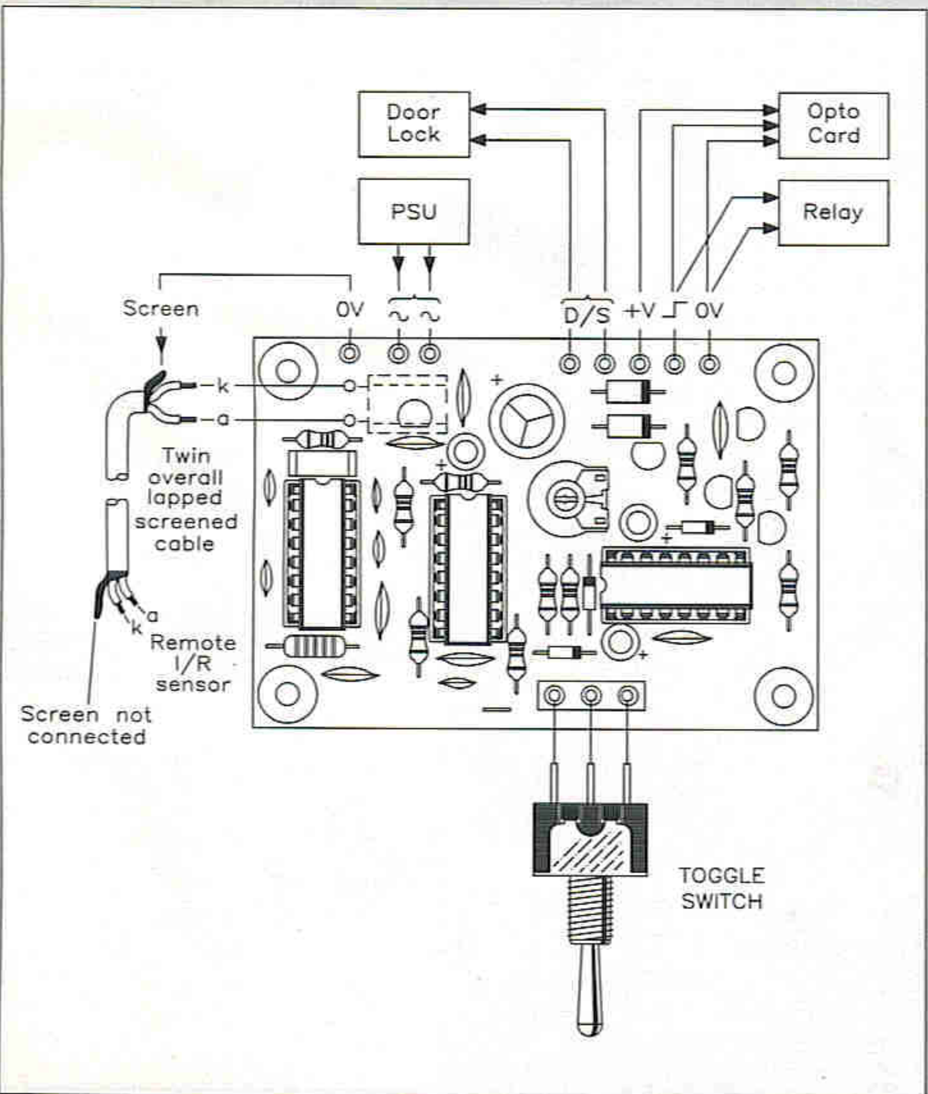


Figure 12. Receiver wiring.

The Receiver Module

There are at least two ways of installing the receiver, one of which is looked at in detail here. For flexibility, the IR sensor can be mounted on or off-board; as a result, the sensor can be mounted remotely if required. The wiring diagram in Figure 12 is common to all configurations, however.

The Receiver PCB could be housed within a double pattress fitted into (or onto) a wall, and the IR receiver diode (IR1) located remotely – in a window, perhaps. Depending on your requirements, a surface-mounting or a flush-mounting pattress could be used – each has its advantages. A double pattress provides sufficient room for the receiver module and the power supply transformer. If the Mains Opto Switch is to be used to switch a porch light, for example, this could be mounted, together with the mains transformer, in the double pattress – the receiver module could then be mounted in a single pattress. This has the safety advantage of keeping the high-voltage mains supply isolated from the low-voltage electronics. ***Please note that if the any items working at mains voltages (i.e. mains transformer, Mains Opto Switch) are installed in a metal case (e.g., flush-mounting pattress), the case MUST be earthed!***

If desired, the unit could be mounted in a box (ABS box MB2 is ideal), with the controls on the front and the receiver diode on the rear – in this case IR1 is mounted directly on the PCB. The box can then be placed on a window sill, with IR1 facing towards the glass and the world outside. If this option is to be followed, the power supply transformer should be mounted in a separate enclosure (for example, that shown in Figure 13).

Another option is to house the receiver in a single pattress, and the power supply transformer built into a separate enclosure. This latter option is featured here.

Constructing the Receiver PCB

Construction is fairly straightforward, and inexperienced readers are directed to the Constructors' Guide supplied with the kit. The PCB legend and track layouts are reproduced for your convenience, in Figure 14. First, fit the resistors and inductor – after soldering the components in position, trim off the excess leads; these can now be used for the link. Fit the diodes; D1 and D5 are 1N4001 power diodes, while D2, D2 and D3 are 1N4148 signal diodes, which are smaller. In each case, polarity is important, and the band on the diode should be lined up with that shown on the PCB legend. It is also important to align the three IC sockets correctly – these are all 16-pin types. In each case, the notch should be aligned with the corresponding one on the PCB legend.

We can now proceed with the capacitors. C1, C4, C15 and C16 are all electrolytic types – it is essential to insert these the correct way round. The negative symbol embossed on each capacitor must face away from the '+' symbol on the PCB legend. The other capacitors are non-polarised and can be fitted either way round. The transistors (TR1 to 3), thyristor (TI1) and regulator (RG1) can now be fitted; their

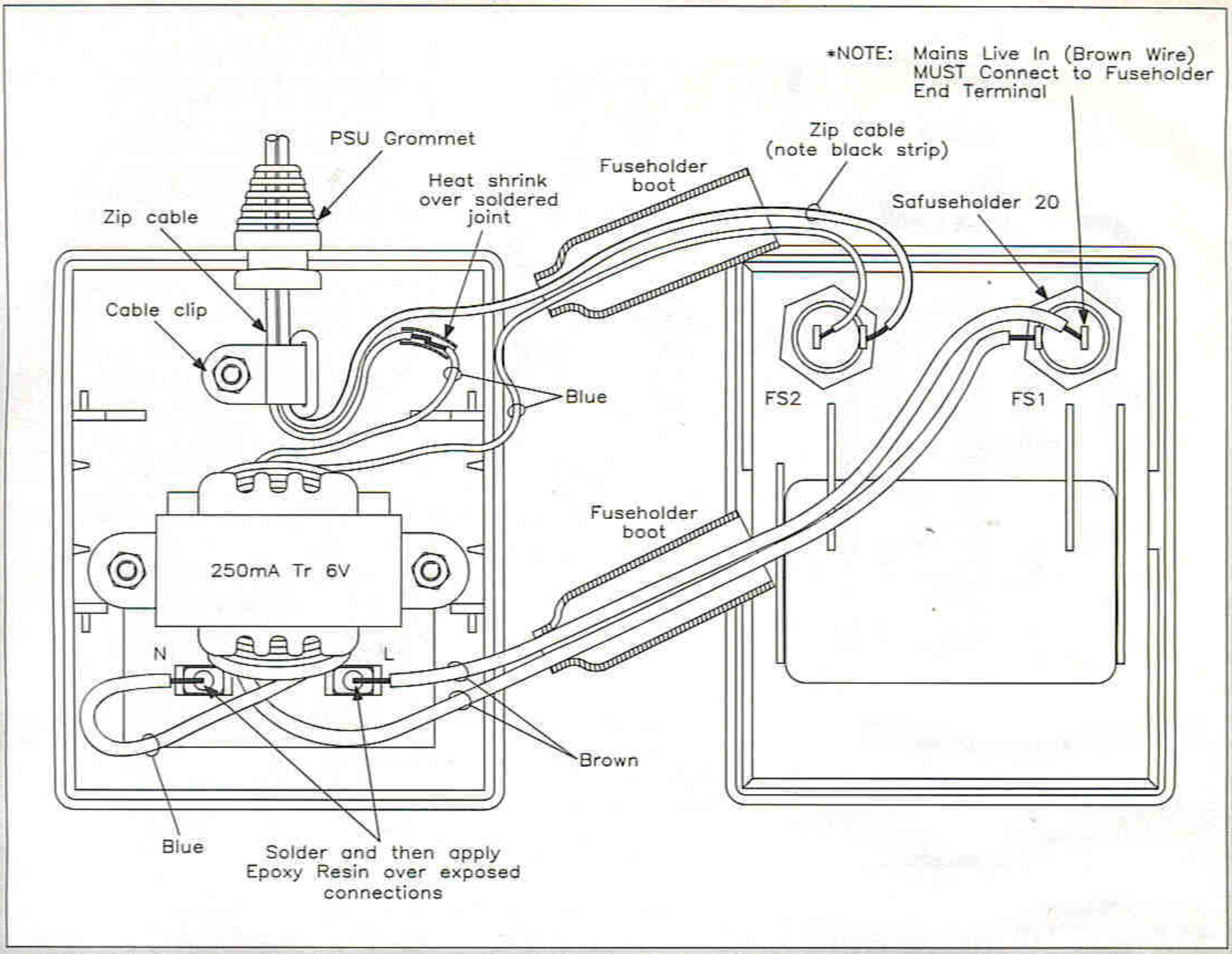


Figure 13. PSU wiring.

outlines should correspond with those on the PCB legend – it is important to fit these devices the correct way round.

The next step depends on how you wish to use the Infra-red Door Lock. If the IR diode (IR1) is to be fitted remotely, two PCB pins should be soldered in the 'a' (anode) and 'k' (cathode) positions, to take the interconnecting wires; note that they should be inserted from the *track* side. However, if IR1 is to be mounted on the PCB itself, it should be fitted on the *track* side of the board. Once the IR diode arrangements have been taken care of, the other PCB pins can be fitted (from the *track* side).

Referring to Figure 15, the code may now be set; it should, of course, correspond to the code to which the transmitter has already been set! Finally, thoroughly inspect your work and, when you are finally happy, insert the three ICs into the sockets. The module is now ready to be installed into the appropriate enclosure.

Final Construction and Installation

Decide where you are going to install the receiver pattress, and prepare the mounting surface (e.g., drill and install wall plugs). Obviously, it is advisable to choose somewhere near a power socket, the door and an appropriate window. Mount the receiver into a single pattress, using epoxy glue to hold it in place, as shown in Figure 16.

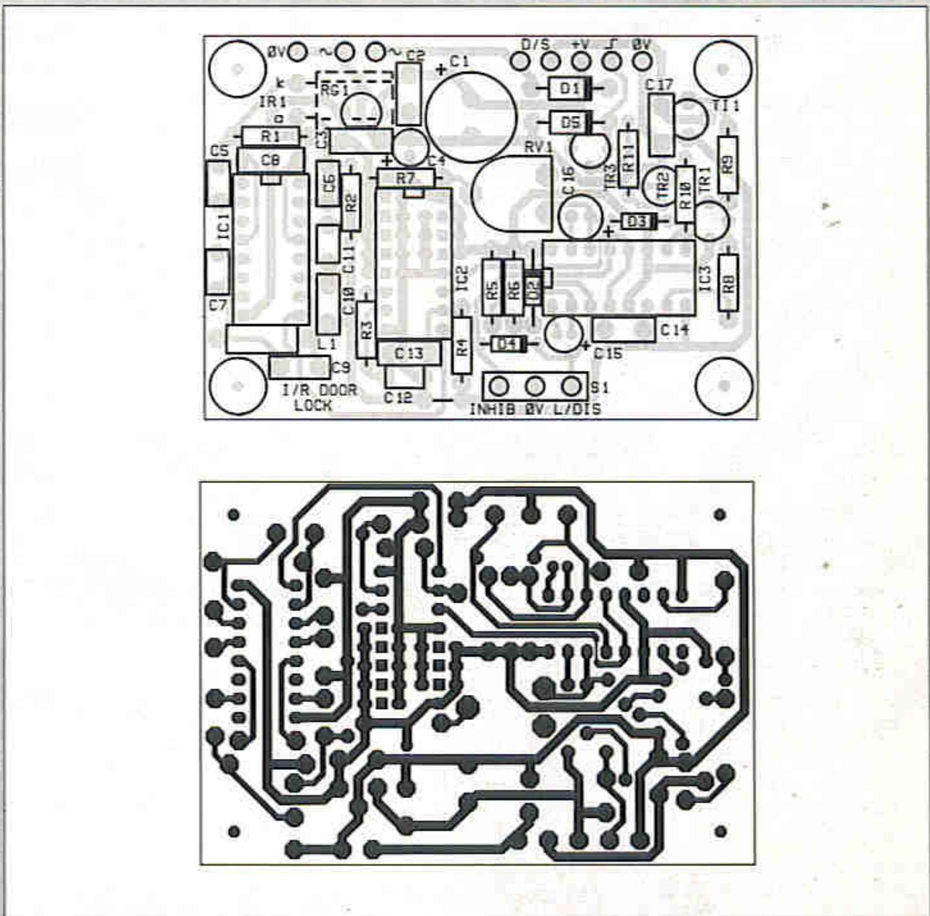


Figure 14. Receiver PCB legend and track.

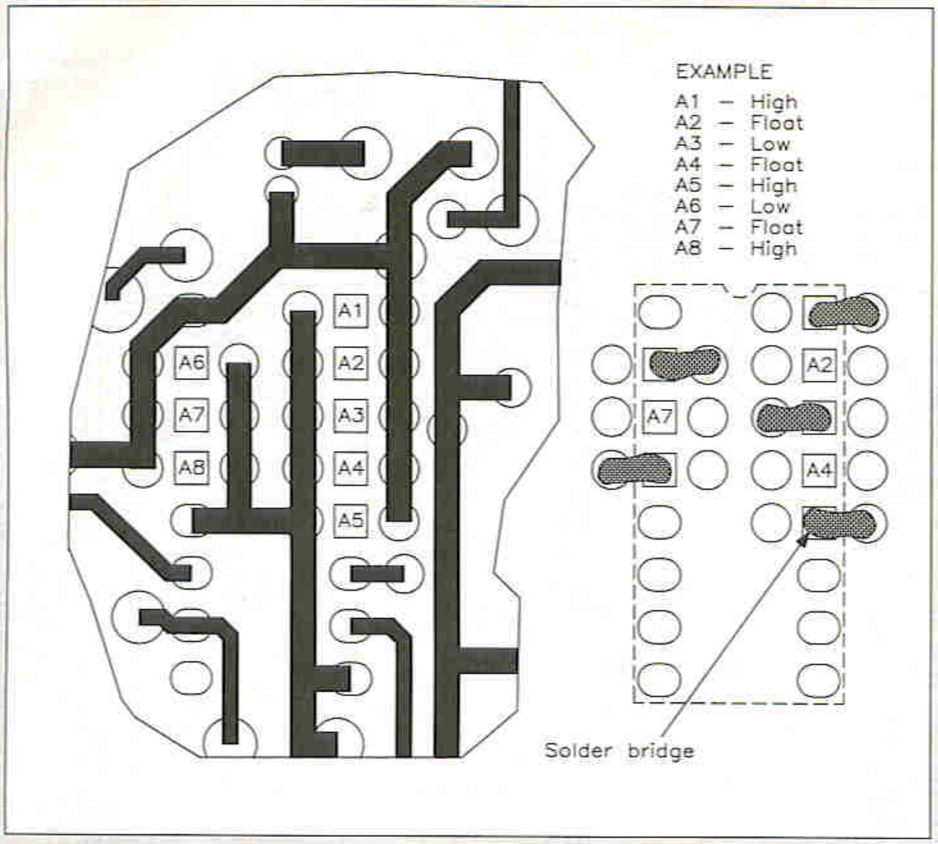


Figure 15. Three ways of fitting receiver links LK1 – LK8.

important – and insulate with heat shrink sleeving; the screen of the cable is trimmed short. After passing the power supply's output lead through the pattress hole, solder each wire to one of the two '~' (AC) terminals – polarity is not important here. The final connection is the one from the door solenoid. Pass the lead through the cable inlet hole, and solder each wire to one of the 'D/S' pins. Again, polarity is not critical.

Install the pattress in the previously-prepared position, and fit the IR diode so that it faces out of the appropriate window; alternatively, fit a 'spy hole', and mount the IR diode in it.

Drill a 7mm hole in the pattress blanking plate, which will accept the toggle switch. Before you drill the hole, it must be noted that the switch must be located in a position such that it does not foul the PCB. Wire the switch (mounted on the blank pattress) to the 'INHIB', '0V' (centre/common) and 'L/DIS' pins of the module.

Testing the System

Fit the pattress blanking plate, and set the toggle switch to the centre position. Apply power to the system. Step outside with the IR transmitter (and your door keys, just in case it doesn't work first time!). Point the transmitter at the receiver diode, and press the button – the door lock should release for

Note that a surface-mounted pattress is used for ease of construction; if a metal flush-mounted type is used, then the board needs to be mounted on spacers to avoid the possibility of short-circuits.

Next, we move onto the receiver power supply, which is shown in Figure 17. Fit the mains transformer into a large PSU box with the fuses, as shown in Figure 13. Drilling details are given in Figure 18. Don't forget to fit the fuseholder insulation boots! The transformer secondary centre tap, which is not used, should be cut short and insulated with heat shrink sleeving. Fit the cable exit grommet to the output lead (note that XR39N 'zip wire' is used for this purpose), connect to the transformer secondary and insulate with heat shrink sleeving. Before cutting off any excess lead, ensure that there is enough wire to reach from the nearest mains socket to the pattress. Secure the zip wire with a 'P' clip. Reassemble the case; a multimeter set to its AC range and connected across the output wires should read 13V or so, when the unit is plugged in.

Remove the cover plate from the door catch release mechanism and wire a 100nF capacitor across the solenoid's two screw terminals, as shown in Figure 19. At this stage, the lead-in wires can also be connected; again, 'zip' wire is used. After the cover plate has been replaced, the mechanism can be fitted to your chosen door. Safely route the lead to where the receiver will be located, and cut off any excess.

Break through one of the cable inlets of the pattress – this will accept the power, solenoid and IR diode wires. Connect a length of twin overall lapped screen cable (XR20W) to the points 'a', 'k' and '0V' (screen to '0V') as shown in Figure 12, and feed it through the cable inlet hole in the pattress. Solder the IR diode to the cable's other end – remember that polarity is

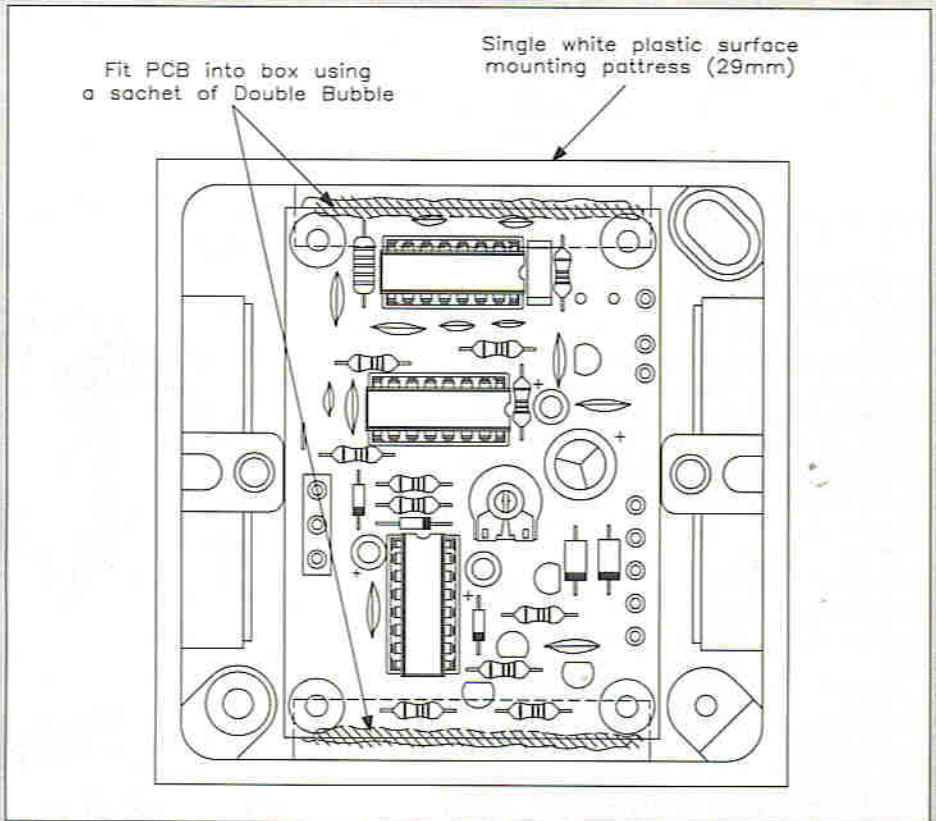


Figure 16. Fitting the receiver PCB to a surface-mounting single pattress.

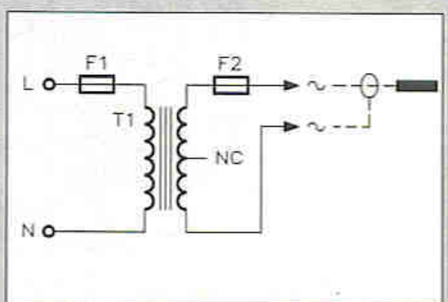


Figure 17. PSU circuit diagram.

approximately 3 seconds. Close the front door, press the transmitter button again and push the door when you hear the buzzing sound of the door lock – the door should open. Please note that any pressure exerted on the lock will prevent it from releasing. Repeat the test with the toggle switch in the other two positions, one of which should inhibit the lock. The other position will inhibit the external switching circuit (i.e. the relay or Mains Opto Switch). With the switch in the centre position, the system operates normally (door and external switch outputs active).

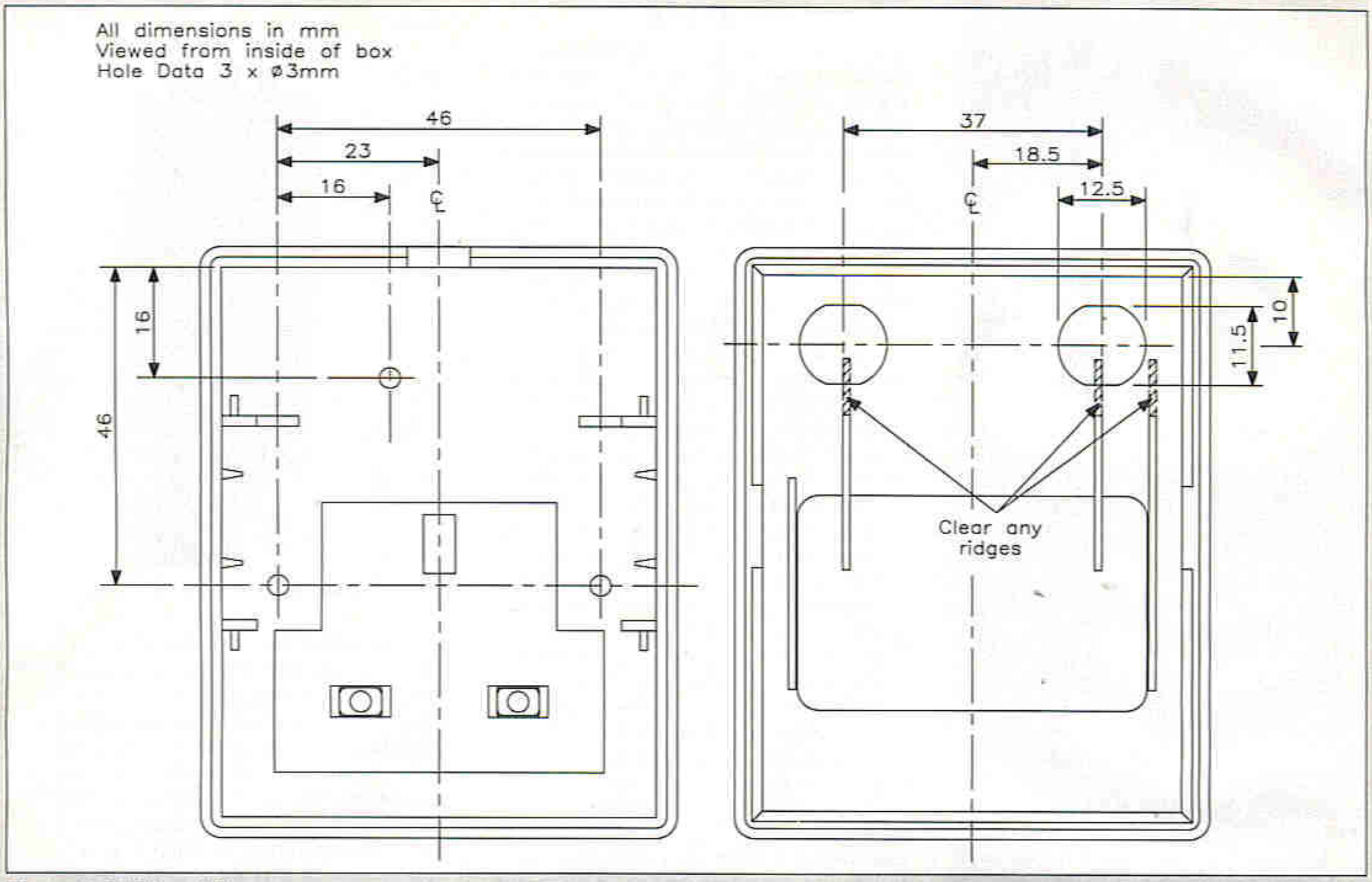


Figure 18. PSU box drilling.

Switching an External Device

Please note that all work must be carried out with the mains power removed!

Using the optional Mains Opto Switch kit (LP55K) with the Infra-red Door Lock enables a resistive mains load of 250W (max.) to be switched at the same time as the door solenoid. A porch or hall light would be ideal for use with such a system. The actual 'on' period is, thankfully, a great deal longer than that of the door solenoid – it can be varied between 1 and 2 minutes using RV1. The actual details for the Mains Opto Switch can be found in 'Electronics' Issue 41 (December 1990/ January 1991); by a twist of fate, the infra-red transmitter appears in the same issue, but in its original guise as part of the 'Compuguard' system!

If you are building a system from 'scratch', it is recommended that you build the system into two pattresses – a double one for the transformer and Mains Opto Switch, and a single one for the receiver. Remember that if metal pattresses are used, the PCBs must be mounted on pillars, and that the pattresses must be earthed. Since the power supply is permanently installed, there is no need for a fuse on the transformer's secondary winding (in the PSU unit in the 'standard' version, this is present to protect the transformer from a short-circuit trailing lead). If you are expanding the system already described, you can fit the Opto Switch in another single pattress located next to the existing one in which the receiver module is located.

Continued on p26

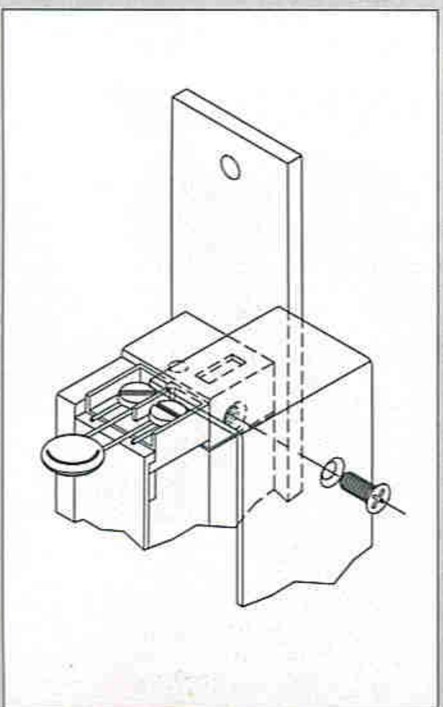


Figure 19. Door solenoid wiring.

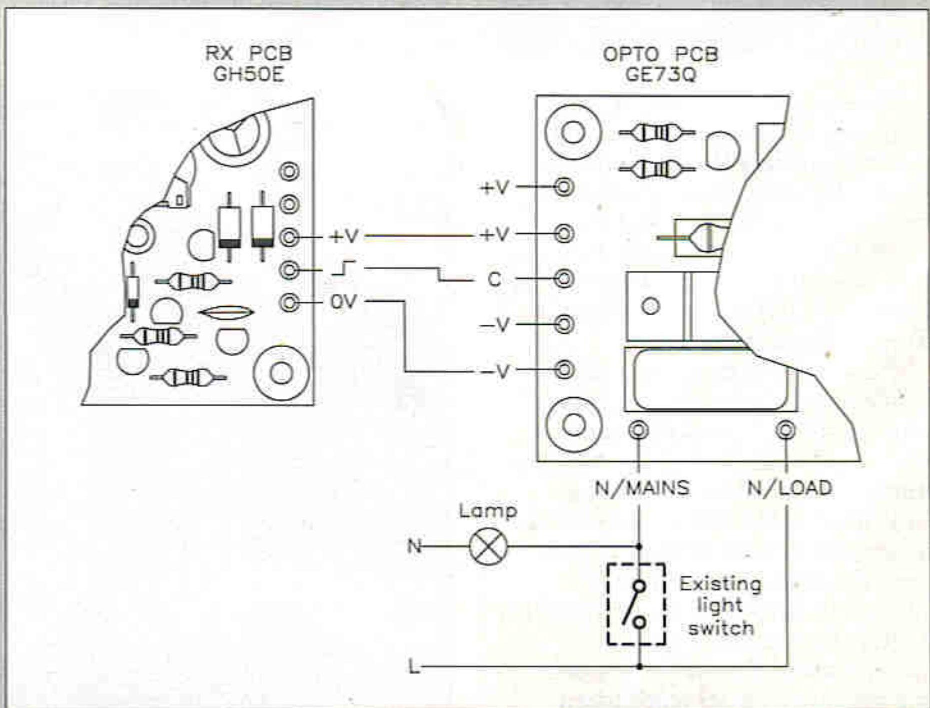


Figure 20. Using the Mains Opto Switch to control a porch light or similar load.

WHATEVER HAPPENED TO CB CITIZENS'BAND RADIO?

by Ian Poole
and Martin Pipe

In the heyday of British CB, at the beginning of the 1980s, everybody was talking about it. When it was legalised, phenomenal numbers of transceivers were sold, and the bands became overcrowded. Now, a little over 10 years later, very little is heard about CB via the mass media. What has happened to it?

The answer is that CB is still widely used. There are still a large number of die-hard enthusiasts who use the bands, and a growing number of casual users – people using hand-held transceivers ('walkie-talkies') for talking to their friends down the road, people in cars wanting to keep in touch with each other, fishermen on a riverbank chatting about the size of 'the one that got away', or schoolchildren doing their homework together.

How it Started

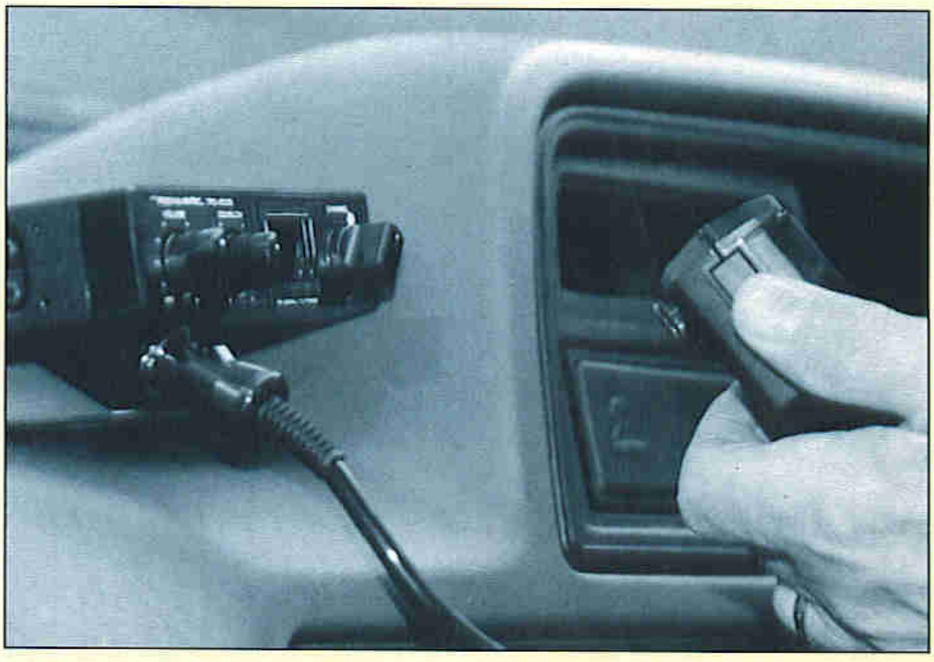
CB started in the States in the early Fifties. It grew out of the idea that any citizen should be able to use the radio spectrum. Unlike the long established amateur radio licences, no examinations or tests were required. Because of this, several restrictions were imposed. All equipment had to be approved, and the RF output power from the transmitter itself was limited to just 5W. Twenty-three AM channels were originally allocated in the 27MHz region.

The idea was very successful, and soon the bands were full. A wide variety of people used CB, but the most notable were probably the truck-drivers ('truckers'), who used it on long journeys. The CB set soon became a companion in the cab, enabling them to talk to other truckers about anything and everything – even obtaining traffic reports from further along the highway. This became particularly important when, after the 1973 oil crisis, the US Government imposed a blanket 55mph speed limit – truckers were used to travelling considerably faster than this to get their jobs done quicker, and so CB found a prominent role in warning drivers about impending police speed traps.

As CB became more popular, it became apparent that 23 channels were not enough to cope with the increased number of operators and so, in 1978, the number of channels was increased to 40 by the FCC (Federal Communications Commission). Mobile users apart, a growing number of 'home-base' sets were being installed in people's homes – CB was now proving to be a godsend to the handicapped and lonely, amongst others.

A colourful set of jargon was built up alongside this spectacular growth in the use of CB. The '10' code is probably the best known, but in addition to this a great variety of other expressions were also used. These became embedded in late-1970s popular culture, in the UK and around the world, as a result of

Left: A German (DNT) rig that operates on the original (CB 27/81) UK 27MHz FM frequency allocation.
Above: The Jesan CB-950 hand-held CB transceiver. Despite the unit's small size, it provides all of the features (and power output) expected from mobile and homebase rigs.
Right: Another (DNT) rig; this one works on the CEPT frequencies.
Below: A Realistic (Tandy) CB transceiver in use 'on the road'. Commercial vehicles notably accepted, mobile CB radio is becoming popular again – having shaken off the 'boy racer' image. Traffic congestion is the primary factor behind the 'CB renaissance'.



Right: The compact Maxon RD-3 rig, which is ideal for temporary installations. Note the car cigarette lighter plug. Below: Home-base CB operation is also popular.

films like 'Convoy', 'Citizens' Band' and 'Smokey and the Bandit', and of course the TV series 'The Dukes of Hazzard' (the latter is, out of interest, being repeated on satellite channel Sky One at the time of writing!).

With CB firmly established in the USA, the idea soon spread around the globe. To give a measure of its success, most of the Eastern European countries in the old Communist Bloc had introduced it by the end of the 1970s. However, even at this time there was no legal allocation in the UK.

Not surprisingly, American CB transceivers ('rigs') started to find their way into Britain. In the late 1970s and early 1980s, the amount of illegal CB activity rose dramatically. As the imported rigs used the same frequencies that were allocated to radio control systems, model makers were forced to stop using this band, and were allocated another band slightly higher in frequency. Those early UK 'breakers' had to concentrate as much on the likelihood of being 'busted' by the authorities, as they did speaking to their fellow enthusiasts. At the time, the authorities were known collectively as 'Buzby'; the Post Office held the responsibility of dealing with invaders on the electromagnetic spectrum! Illegal CB'ers, when caught, had their equipment confiscated and were duly summonsed to appear in court.

The British CB system was finally legalised in November 1981. However, unlike the USA and many other countries where SSB and AM were allowed, only FM could be used. The reason was that this mode was less likely to cause interference to other legitimate users, audio equipment and television sets. Power was also kept quite low, 4W being the maximum. Restrictions on aerial design were also placed. On the positive side, two bands were allocated; the first was in the popular 27MHz portion of the spectrum, whilst the second was at 934MHz.

Today

When CB was first introduced legally into the UK, activity 'over the air' was very high and the forty 27MHz channels were jam-packed. The media reported extensively on the CB craze, and the influence of CB could be seen in many British television programmes of the period. Many shops opened for business to cater for the enormous demand for sets and equipment. Today, the initial surge of activity has long since died out, and the number of CB shops has dwindled. Despite what this may indicate, there is still a very healthy and steady interest. Many of the people on the band are true CB enthusiasts – people who have remained loyal to the cause since it was legalised (and in some cases, before), enduring the music-players, wallies and 'mike-keyers' (the latter are somewhat brain-dead individuals who press their push-to-talk buttons without saying anything, to purposefully block others from engaging in conversation on a channel!). Others are casual users who may want to have a convenient way of communicating over short distances. CB, however, is starting to become more popular again – particularly for mobile applications. With ever-increasing traffic congestion, people are once again relying on CB to help them avoid trouble spots. Despite the constant criticisms levelled at CB'ers by self-righteous radio amateurs, many of the 'serious' enthusiasts went on to become hams themselves, having 'cut their teeth' on CB.

Wallies have, thankfully, reduced in number since activity reached a peak. Misuse has not, however, disappeared. The Government's Radio Investigation Service has (at last) acknowledged that irresponsible users do exist with the introduction of C-BOS – the CB Observation Service. Responsible breakers are encouraged to note down the time, date, physical area and channel over which the abuse occurred, and to then pass this information on to the C-BOS co-ordinator so that patterns of CB misuse can be detected, and the appropriate action taken.

Operation

Operation on CB is fairly informal. Apart from giving yourself a 'handle' (an individual and original call-sign, for example 'Red Arrow', 'Charlie Chaplin', 'The Phantom', 'Live Wire', 'Champers', 'Skyman'), there is comparatively little jargon used now (the short-term appeal of those 'Americanisms' (meaningless jargon, mid-Atlantic accents, etc.) has, thankfully, long since worn off), and it does not take long to get used to the way in which contacts are made. In fact, there is very little in the way of procedure. It is most important, however, to let the other person know when you are handing transmission over. If this is not done, then it is very easy for the contact to become confused, with both stations transmitting at the same time!

In addition to this, it is worth noting that some channels are allocated for special purposes. The famous Channel 14 is kept as a calling channel – stations use it for the purpose of making initial calls to the desired breaker, using their handle (alternatively, '1-4 for a copy' is the well-known invitation to make contact with anyone who may be monitoring). Having made contact, the two breakers can move to a vacant channel. Using Channel 14, stations who are monitoring the band for calls only have to listen to one channel. There is also another channel designated as a calling channel – Channel 19. Reserved for mobile users, it has displaced Channel 14 in some areas – to the chagrin of British truckers!

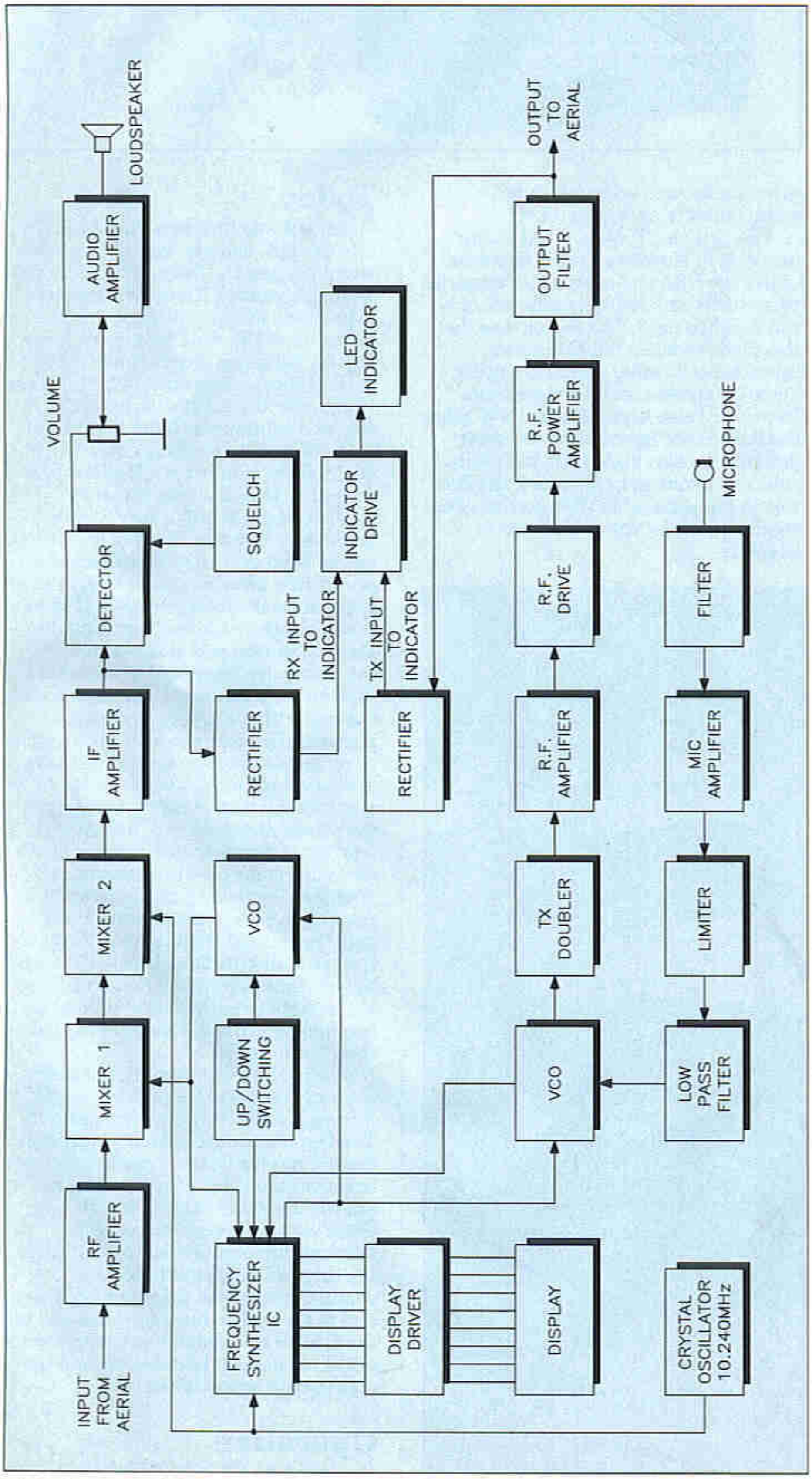
Finally, Channel 9 is used as an emergency channel, and this should be kept free unless it is really needed. Voluntary organisations, such as REACT, monitor this channel for emergency calls. There are irresponsible individuals who will insist in using this channel as they would the rest – but perhaps they don't realise that, at some time, *their* lives could depend upon it!

Licences

To operate a CB rig legally, it is necessary to have a licence. Unlike an amateur radio licence, though, no exams have to be passed – after all, it is not called *Citizen's* Band for nothing! Many CB'ers, however, believe that a licence is no longer required! This perhaps explains why, out of 200,000 or so CB users, only around 70,000 are licenced. Unlicensed CB'ers should be aware that, if caught, they are likely to receive a fine – and that CB licence fees are used to help fund the Radio Investigation Service (RIS) – the body that deals with interference to protected services, radio spectrum misusers, pirate stations and the like. The licences used to be available from main Post Offices – recently, however, this changed. It is now necessary to obtain an application form from the Radiocommunications Agency (RA), which is part of the DTI. This can be done very simply by calling them on (071) 215 2217. This is a direct line that gets through to the correct office straight away. Alternatively to write to them at: Radiocommunications Agency, Room 712, Waterloo Bridge House, Waterloo Road, London, SE1 8UA.

Once the application form has been received, it should be completed and sent with the fee of £15 (correct at the time of writing) to: The Radio Licensing Centre, Subscription Services Ltd., P.O. Box 884, Bristol, BS99 5LF. The telephone number for enquiries is (0272) 258333. However, they do say that 21 days should be allowed for the licence to arrive.

Once the licence has been received, and the equipment is available, there are very few real restrictions. The main one is that only approved equipment can be used – this can be identified by its type-approval marks. In addition to this, aerials ('twigs') must conform to the license requirements, not exceeding 1·65m in length or 55mm in diameter on the 27MHz band. Finally, no 'burners' (additional amplifiers that boost the RF power) are permitted, as they will increase the power beyond the legal limit. Increase your power and, law-breaking aside, you're more likely to cause interference to fellow breakers and your neighbour's television set. In addition, 'tweaking', which became popular during the mid-1980s, is not such a good idea – the technical ignorance of some self-styled 'CB



Block diagram of the Jesan CB-950. This circuit topology is common to most, if not all, UK CB transceivers.

engineers' led them to believe that turning up the mic gain would help them 'get out better' (in reality, it caused over-deviation, and consequently any breakers located in the user's vicinity would suffer from adjacent channel interference, or 'bleedover'). Fiddling around with the pot cores in the transmitter section's final RF stage whilst monitoring the output level on the rig's signal strength/output power meter often gave these people the impression that they were tweaking up their output power – in reality, they tended to tune the output filters so sharply that any slight improvement on the tweaked channel was offset against considerably reduced performance on the rest!

Bands and Frequencies

The forty 10kHz-wide FM channels on the original UK 27MHz band were different to those used elsewhere, the centre frequencies varying from 27·60125MHz (channel 1) to 27·99125MHz (channel 40). Accordingly, equipment had to be specially designed for the UK market; this can be identified by the characters 'CB 27/81' embossed on the front panel of the transceiver – this denotes that the design was type-approved, having been proved to conform to the required specification. Out of interest, it was once proved to the co-author (to his disbelief) that a somewhat battered CB transceiver was more 'on spec' than a new (and considerably more expensive) 2m FM amateur radio set!

With the growing moves to integrate the UK with the rest of the EC a second, similar (26·965 to 27·405MHz, again with a channel bandwidth of 10kHz), set of 40 channels has been introduced over the last few years. These frequencies are the same as those used across the rest of Europe and the USA. FM, though, remains the only mode to be used.

The new 'CEPT' frequencies are available in addition to the old ones. New transceivers, for some reason or other, can use either set of frequencies, but not both. We are sure, however, that people have modified the frequency synthesisers of existing sets, so that the new channels are available at the 'flick of a switch'. This practice was rife in the 1980s, so that users of high-performance imported (but illegal!) rigs like the Cobra 148 could operate on all of the CB 27/81 channels! Interestingly, such sets need no modification to work on the CEPT channels.

In addition to the standard 27MHz channels, there are CB frequencies in a band at 934MHz. Equipment for this band (which can be identified by the 'CB 934/81' type-approval markings on the set's front panel) is more expensive (in 1981, a 934MHz mobile set up cost £350 as opposed to around £100 for a 27MHz one) and as a result it is less widely used – this is not helped by the fact that the present Government has, for some reason, stopped the import and manufacture of 934MHz rigs. This is highly irritating bearing in mind that, thanks to mass-market cellular telephones and satellite television, the cost of producing rigs that operate at these high frequencies could be much lower. The 20 allocated channels could therefore become much more popular if inexpensive equipment was to be made available; the 934MHz equipment offers good performance, and the aerials are small and unobtrusive, due to the small wavelengths involved. Out of interest, small businesses are the major users of 934MHz – despite the terms in the licence that state that CB should not be used for business purposes! Other users include radio amateurs (934MHz rigs appear quite regularly at the 'bring and buy' stalls of radio rallies) and serious CB'ers who were fed up with the irresponsible breed of '10-1 turkeys' that appeared to dominate 27MHz in its heyday.

What Equipment do I Need?

CB equipment, UK 27/81 at least, is still easy to obtain. Six or so years ago, you could buy these 27MHz rigs for peanuts – the co-author bought a well-made (West German) DNT rig for a fiver in 1986 – this represented CB's low-point; the slump following the boom. The CB airwaves became a lot quieter (the wallies moved onto playing video games, or whatever), and so the equipment had to go somewhere. Consequently the market was flooded, and this contributed to the demise of many a dealer. Since then, second-hand prices may have gone up somewhat, thanks to the increasing popularity of CB, but it's still a lot cheaper than buying a new rig. Try your nearest flea market, Exchange and Mart, or classifieds in your local paper. But what if you do want to buy a new rig? We say, think again! Contrary to just about any other consumer electronic item, a significant proportion of the rigs (CEPT sets notably excepted!) on sale now are exactly the same designs that were available 12 years ago! The same circuitry (even the same elderly frequency synthesiser IC), the same facilities (imagine what they could do with a microprocessor or three!) – even the same very-dated early-Eighties styling! This apparent lack of inertia on the part of the manufacturers indicates one thing – they believe that the UK CB market is dying. Wrong! Nevertheless, if you're convinced you do need a new rig, you may find them difficult to find in the High Street, but Maplin sell a range of items. These include a base station, a mobile set for use in the car and a hand-held – alas, no CEPT rigs (is anybody in the UK actually using them?) In addition to this, the catalogue details various ancillary items such as the essential aerials (home-base and mobile), power supplies (required if you want to run a mobile rig from the mains), VSWR (voltage standing-wave ratio) bridges (used when setting up the impedance of the aerial system, so that all power is transferred to it), dummy loads, and so on. Anyone using CB will undoubtedly find these items useful.

To demonstrate how CB can be used, two of the hand-held Jesan CB-950 rigs sold by Maplin were put into use. These sets are 40 channel transceivers conforming to the original CB 27/81 specification, and are capable of giving a full 4W output to the telescopic aerial. There is a simple push-button switch which can reduce the power to 0·4W for short-range operation. In a hand-held set, this is useful in helping conserve the batteries. This power-reduction facility is, in fact, required by law – under the terms of the licence you have to cut your power by 10dB if your aerial is a certain height

Feelings over the legalisation of CB ran high, as this photo demonstrates.

UK CB Frequency Allocations

27MHz Band MPT1320 (CB 27/81)

Channel	Frequency
1	27·60125
2	27·61125
3	27·62125
4	27·63125
5	27·64125
6	27·65125
7	27·66125
8	27·67125
9	27·68125
10	27·69125
11	27·70125
12	27·71125
13	27·72125
14	27·73125
15	27·74125
16	27·75125
17	27·76125
18	27·77125
19	27·78125
20	27·79125
21	27·80125
22	27·81125
23	27·82125
24	27·83125
25	27·84125
26	27·85125
27	27·86125
28	27·87125
29	27·88125
30	27·89125
31	27·90125
32	27·91125
33	27·92125
34	27·93125
35	27·94125
36	27·95125
37	27·96125
38	27·97125
39	27·98125
40	27·99125

27MHz Band MPT 1333 (PR 27/GB) CEPT

Channel	Frequency
1	26·965
2	26·975
3	26·985
4	27·005
5	27·015
6	27·025
7	27·035
8	27·055
9	27·065
10	27·075
11	27·085
12	27·105
13	27·115
14	27·125
15	27·135
16	27·155
17	27·165
18	27·175
19	27·185
20	27·205
21	27·215
22	27·225
23	27·255
24	27·235
25	27·245
26	27·265
27	27·275
28	27·285
29	27·295
30	27·305
31	27·315
32	27·325
33	27·335
34	27·345
35	27·355
36	27·365
37	27·375
38	27·385
39	27·395
40	27·405

934 MHz Band MPT1321 (CB 934/81)

Channel	Frequency
1	934·025
2	934·075
3	934·125
4	934·175
5	934·225
6	934·275
7	934·325
8	934·375
9	934·425
10	934·475
11	934·525
12	934·575
13	934·625
14	934·675
15	934·725
16	934·775
17	934·825
18	934·875
19	934·925
20	934·975

A well-stocked CB emporium – not all of them disappeared in the lean years following the boom.

above the ground. Whether anybody actually does is anybody's guess!

The receiver is a sensitive dual conversion design. Like most CB rigs, the first IF is at a frequency of 10·7MHz, while the second one is at 455kHz. By adopting this approach the high first IF enables good rejection of image signals to be achieved. The low second IF, meanwhile, enables good selectivity to be obtained with a ceramic filter. In fact the response is 60dB down at ±10kHz. As a result, the receiver has a high level of immunity from interference from adjacent channels – known in CB slang as 'bleedover'. In existing rigs, a popular remedy for 'bleedover' is to replace the ceramic filters with crystal ones that have a sharper response.

The transceiver uses a frequency synthesizer in the local oscillator to give simple, yet accurate tuning. To further improve its receive performance under weak-signal conditions, there is an audio noise limiter.

Operation

The rigs are very simple to use. All that is needed is for the aerial to be fully extended before the set can be turned on using the switch on the volume control. A squelch control is also provided so that the receiver audio can be turned off when no signal is present. This prevents large amounts of irritating noise coming out of the speaker during these periods.

Tuning is accomplished using 'up' and 'down' keys on the front of the set – this makes a change from the 40-position switch that has been a feature of most rigs since 1978! When the rig is turned on, it powers up on channel 9. Using the two keys the required channel can then be selected. Another key is provided that returns the set to channel 9 when pressed.

The sets each run from eight type AA cells. If Ni-Cd cells are used then ten are required. This is because Ni-Cd cells only give 1·2V, compared with the 1·5V from the average zinc-chloride or alkaline cell. There are positions for ten cells, but when normal dry cells are used, two short-circuiting links ('dummy batteries') must be placed in two of the positions (these are provided).

As previously mentioned, it is also possible to power the transceivers from an external 12V source; to facilitate this, an adaptor lead is supplied so that a cigarette lighter socket can be used.

The external power socket is located on the side of the unit, together with a headphone socket. There is also a connector for an external aerial, which could prove extremely useful if it is to be used in a car, as a proper mobile aerial would be very valuable. But this is where we encounter a problem – no external microphone socket. Having to lift the thing, complete with trailing leads, from the passenger seat whenever you want to talk to somebody (which you shouldn't do when your vehicle is moving, by the way!) gets to be a real pain – a smaller, lighter hand microphone (as used with conventional sets) would certainly improve matters if there was provision to fit one. But there isn't, and so you can't. Perhaps it's yet another case of 'horses for courses' – if you anticipate using the rig in your car a lot, a proper fitted mobile rig is by far the best option. These same comments apply to home-base operation, although it will do the job at a pinch. A proper

continued on page 42.

Stray Signals

by Point Contact

Many readers must be wondering, like Point Contact, when HDTV will eventually arrive – if indeed it ever does, this century. Also, when it does, whether it will be an analogue system after the style of MAC or whether it will be an all digital system. A majority of European industry ministers favour the former, but others including the UK feel that would saddle Europe with a passé inferior system. If we go the digital route, presumably a compression algorithm such as that proposed by MPEG (Motion Picture Experts Group) or the like will be used, together with a very bandwidth efficient modulation method, to pack all the data into a normal bandwidth TV channel. Recently, the BBC Engineering Department with Thomson-CSF successfully demonstrated such a system which requires only 8MHz of bandwidth, making it compatible with standard terrestrial TV channelling practice. Many progamme makers view the prospect of HDTV with some trepidation, since the increased definition will mean that they will no longer be able to get away with the crude scenery, props and wigs that now suffice with the current standards. It seems that less and less will be left to the imagination of the viewer.

In the days of B&W TV, one had to imagine for oneself the rosy cheeks of the heroine, and in the days before television, the imagination had to work even harder. In the inter-war period this did not deter the BBC from tackling programmes which one would have thought cried out for an accompanying vision channel, something which did not

"POY" Broadcasting a drawing lesson from a studio at Olympia.

The chorus of "Radio Radiance", one of the first revues. The chorus actually danced in the studio on a special platform, the sound of their feet being broadcast. In later revues the sound was imitated.

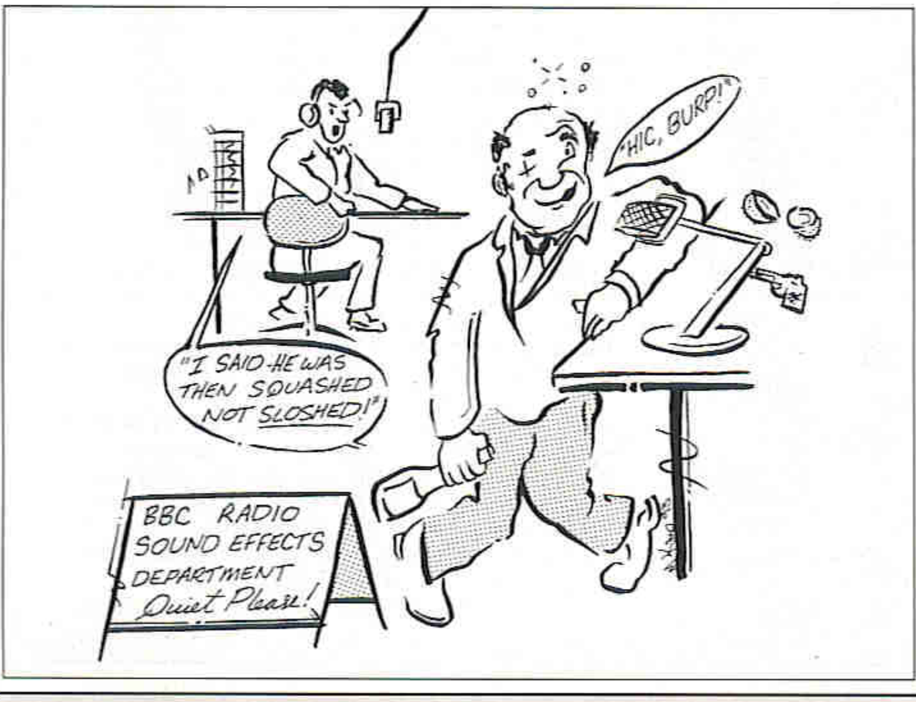
materialise until 1936. My illustration this month is reproduced from the BBC Year Book for 1930, and shows a specially staged revue being broadcast. It does not say when the programme went out, but as the caption makes clear, the use of live dancers was subsequently discontinued – whether it offended Lord Reith's sense of propriety or merely his Scottish canniness (why pay for dancers no-one can see?) is not known. Evidently it was thought that the listeners' imaginations were vivid enough to fill in the appropriate scene in the studio. Amongst the many other photographs included in the Year Book is one of a drawing lesson being broadcast from a studio at Olympia: it must have required some imagination on the part of the listeners to follow that! The Year Book contains a wealth of other fascinating information including dates of many broadcasting firsts; November 1924, first wireless relay of American station KDKA; May 1925, first broadcast from an aeroplane – Alan Cobham teaches Miss Heather Thatcher to fly; July 1926, first broadcast from under the Thames, by a diver, etc., etc. Readers of the Year Book were evidently expected to take a lively interest also in technical matters, not surprising in an age where if one could afford a wireless set at all, it would probably have to be home-built. More details in a later Stray Signals, perhaps.

Electronic engineers have always been famous (infamous?) for a puckish sense of humour. This is illustrated by the time-honoured tradition of various electronics magazines of publishing a spoof article in the April issue, often a vaguely plausible description of a supposed new component or development, that gets more and more fantastic line by line. An old friend of Point Contact submitted such an article to the readers' ideas section of one magazine, accompanied by a covering letter making it quite clear that the piece was suitable for the *April* issue. Clearly the staff dealing with that section of the magazine were not very technically minded, and evidently mislaid the covering letter. My friend received a call from them some time later, asking for the publisher and date of publication of a book mentioned in one of the references at the end of the piece, and was surprised to learn in the course of the conversation that they had scheduled it for the May issue! So he was able to point out gently that it was not suitable to publish, and the piece was duly returned to him. (It was published in the April issue of a magazine which was made well aware of its true nature, the following year.) So what was this advanced bit of electronic engineering wizardry? It was a simple CAD program written in BASIC, to automate the design of All-stop Filters!

In addition to HDTV (perhaps) by the end of the decade, we are also promised a global hand-held telephone service, Inmarsat-P, by the same deadline. Inmarsat has already developed a brief-case version called Inmarsat-M. Commercialisation of the ventures awaits a decision on suitable satellite configurations to service them. The wrist-watch style universal communicator operating throughout the solar system and beyond is a little further off yet.

Yours sincerely,

Point Contact



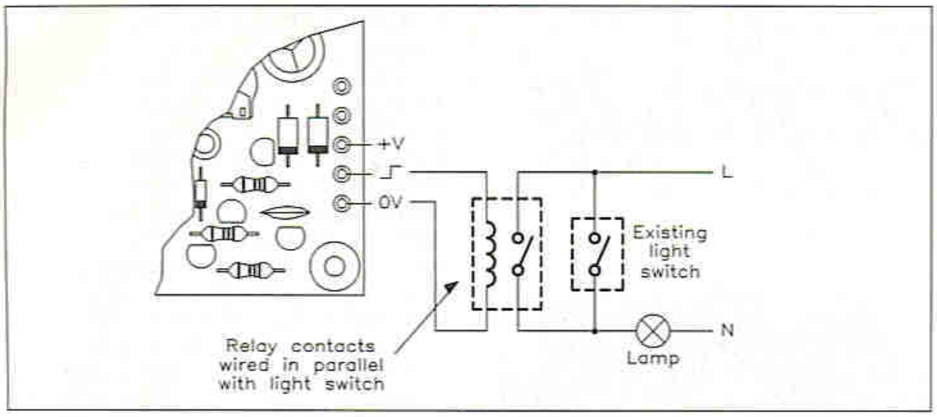


Figure 21. Using a relay to control a porch light or similar load.

Once you have decided where the Mains Opto Switch is to go, complete the wiring as shown in Figure 20. The switch across the 'N/LOAD' and 'N/MAINS' terminals of the Mains Opto Switch is a bypass switch, so that the porch light may be switched on irrespective of the state of the door lock. Of course, all connections at mains potential must be treated with the appropriate care and attention.

As an alternative to the Mains Opto Switch, a relay may be used to switch an ex-ternal load. This option should be used if the load to be switched exceeds 250W (a 500W halogen lamp, for example), but note that a relay with suitably-rated contacts is used.

WARNING:

It is imperative that every possible precaution is taken to prevent electric shock. 240V AC mains CAN KILL. Any modifications to fixed premises wiring must be carried out in accordance with BS7671 Requirements for Electrical Installations – IEE Wiring Regulations 16th Editions. If in doubt as to the correct way to proceed, seek advice of a suitably qualified person before continuing.

I/R DOOR LOCK PARTS LIST

RESISTORS: All 1% Metal Film (Unless specified)			
R1,2,5	1M	2	(M1M)
R3,10	47k	2	(M47K)
R4	220k	1	(M220K)
R6	10M	1	(M10M)
R7	4M7	1	(M4M7)
R8,11	4k7	2	(M4K7)
R9	470Ω	1	(M470R)
RV1	4M7 Hor. Enclosed Preset	1	(UH11M)
CAPACITORS			
C1	470µF 35V PC Electrolytic	1	(FF16S)
C2,3,13, 15,17,18	100nF 50V Disc	6	(BX03D)
C4	10µF 50V PC Electrolytic	1	(FF04E)
C5,6,7	10nF Ceramic	3	(WX77J)
C8	47nF Poly Layer	1	(WW37S)
C9,10	4n7F Ceramic	2	(WX76H)
C11,12	22nF Ceramic	2	(WX78K)
C15	1µF 100V PC Electrolytic	1	(FF01B)
C16	100µF 10V PC Electrolytic	1	(FF10L)
SEMICONDUCTORS			
IC1	TDA3047	1	(UL25C)
IC2	M145028	1	(UJ51F)
IC3	4098BE	1	(QX29G)
TR1	BC558	1	(QQ17T)
TR2	BC548	1	(QB73Q)
TR3	BC327	1	(QB66W)
D1,5	1N4001	2	(QL73Q)
D2,3,4	1N4148	3	(QL80B)
RG1	µA78L05AWC	1	(QL26D)
TI1	CP206D	1	(UR25C)
IR1	Infra-red Photodiode	1	(YH71N)
MISCELLANEOUS			
L1	4·7mH Choke	1	(UK80B)
	Electric Door Lock	1	(YU89W)
	Pin 2145	1 Pkt	(FL24B)
	DIL Socket 16-Pin	3	(BL19V)
	PCB	1	(GH50E)
	Instruction Leaflet	1	(XU24B)
	Constructors' Guide	1	(XH79L)
	PSU Box Large	1	(YU31J)
	PSU Grommet	1	(JM16S)
T1	250mA Transformer 6V	1	(YN14Q)
F1	Fuse 20mm 50mA	1	(WR93B)
F2	Fuse A/S 315mA	1	(RA07H)
	Safuseholder 20	2	(RX96E)
	Fuseholder Boot	2	(FT35Q)
	Filter Red	1	(FR34M)
	Standard Power Plug 2·5mm	1	(HH62S)
	Panel Mount Power Skt 2·5mm	1	(JK10L)
	Cable P Clip 3/16in.	1	(LR44X)
	Steel Screw M3 x 10mm	1 Pkt	(JY22Y)
	Steel Nut M3	1 Pkt	(JD61R)
	Steel Washer M3	1 Pkt	(JD76H)
	Isoshake M3	1 Pkt	(BF44X)
	Zip Wire	1 Pkt	(XR39N)
	Lapped Pair	1m	(XR20W)
	Twin Mains DS Black	1m	(XR47B)
	Double Surface Pattress 47mm	1	(YB17T)
	Double Blank Plate	1	(ZB49D)
	Mains Opto Switch	1	(LP55K)
	5A Mains Relay	1	(YX98G)
	Insulated Spacer M3 x 10mm	1 Pkt	(FS36P)
	SR Grommet F31	1	(LR47B)
	Sub-Min Toggle B	1	(FH01B)
	Wire 3202 Brown	1m	(XR34M)
	Spade 3·2mm	1 Pkt	(JH64U)
	Heat Shrink CP 32	1m	(BF88V)
	Double Bubble Sachet	1	(FL45Y)
OPTIONAL (Not in Kit)			
	ABS Box MB2	1	(LH21X)

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 LT32K (I/R Door Lock Kit) Price £24.95

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

The following new item (which is included in the kit) is also available separately, but is not shown in the 1993 Maplin Catalogue.

(I/R Door Lock PCB) **Order As GH50E Price £2.45**

CLASSIFIED

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2 PROJECT RATING

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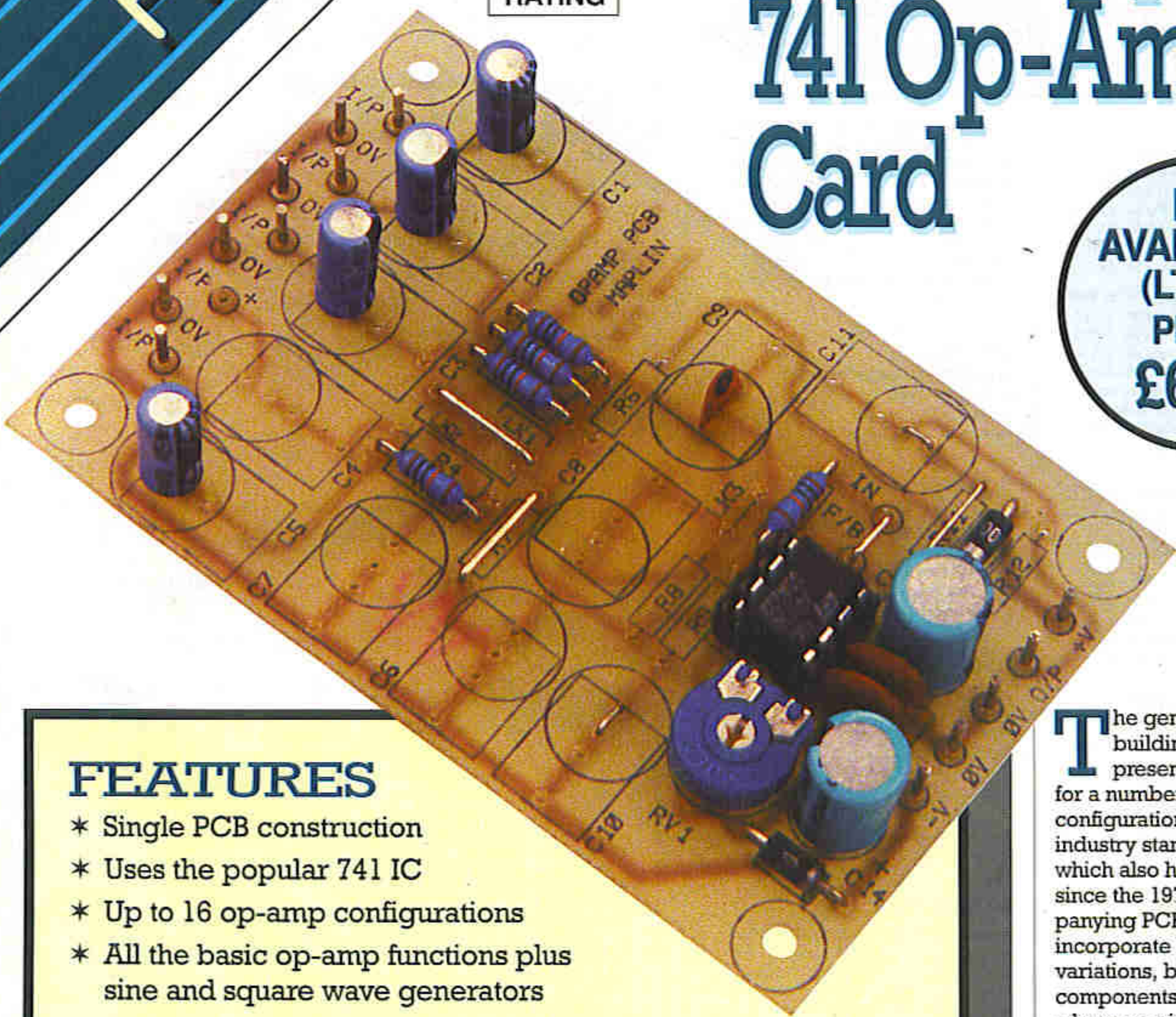


FEATURES

* Single PCB construction
* Uses the popular 741 IC
* Up to 16 op-amp configurations
* All the basic op-amp functions plus sine and square wave generators

APPLICATIONS

* Any AC or DC analogue processing * Audio applications
* Control signal processing * Signal generation
* Adding, summing, integration, etc.

The venerable op-amp has a multitude of possibilities, and has seen service for one application or another for the past twenty years or so. Originally developed for what were called 'analogue computers', which have long since disappeared, the op-amp is essentially a 'perfect amplifier block'. The summing or differentiation of various analogue signals is easily achieved through the use of simple resistor arrays, including control over gain or attenuation.

The general-purpose building block project presented here allows for a number of such different configurations, and uses the industry standard 741 device which also has been in use since the 1970s. The accompanying PCB is designed to incorporate all these possible variations, by simply fitting components or wire links where required for a particular configuration. Figure 1 shows the basic circuit diagram, from which all the options are derived. Not all of those components shown will share the PCB at the same time (it would be a very strange circuit indeed!), and for the same reason the values of many are not shown either, since these change depending on the application. This will become clearer later on.

Power Supply

Figure 2 shows two basic unregulated power supplies that can be used with the op-amp PCB. The capacitors shown are actually those mounted on the op-amp PCB, C12 to C15). The single rail version, Figure 2a, is known as an 'asymmetrical supply', and the split rail

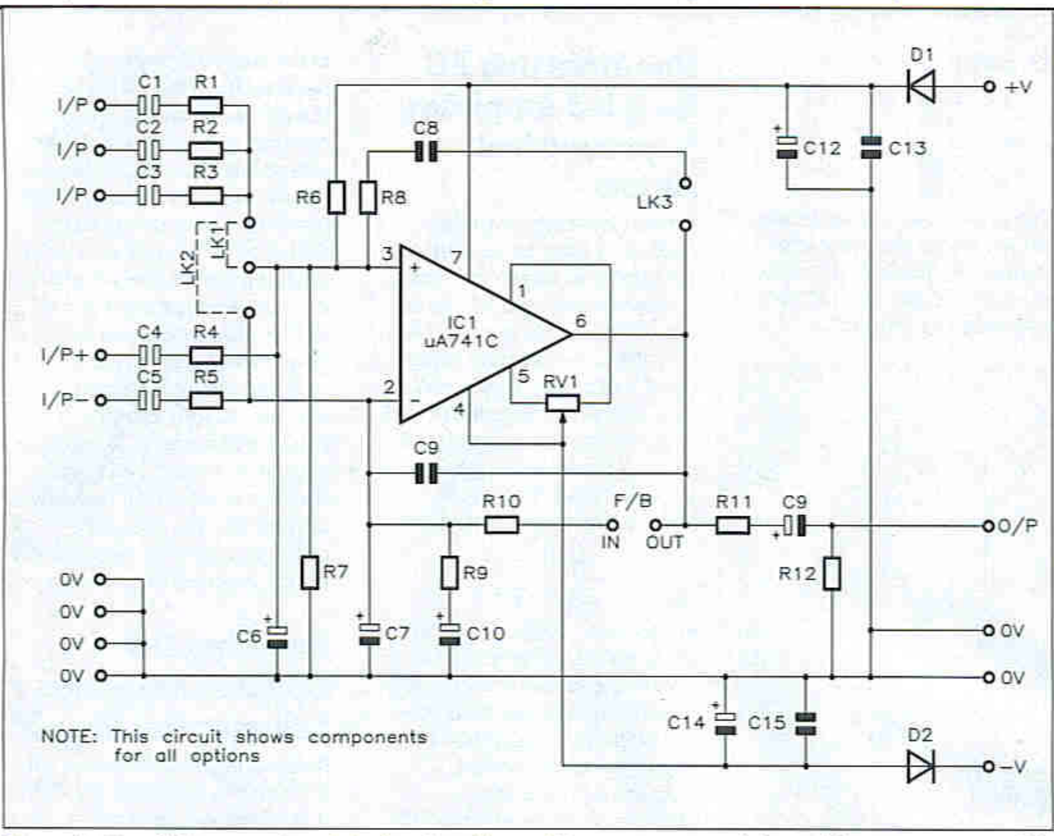


Figure 1. Circuit diagram of module showing all possible component variations. All components would not normally be used in the same circuit – see text.

version (Figure 2b) is known as a 'symmetrical supply'.

The PCB can be fitted with diodes D1 and D2 in series with each of the supply rails to prevent damage from accidental, reversed polarity connections. Where the asymmetrical supply is used, C14, C15 and D2 are omitted and the –V line is linked directly to 0V, and R6 is used to derive the half supply bias level for the op-amp itself. Otherwise the op-amp's DC bias is via R7 only and 0V is at the centre of two +V and –V supply rails. The supply should be in the range of ±5V to ±15V for symmetrical operation, and 10V to 30V for single-ended operation. The maximum supply level(s) must not exceed ±18V, or 36V in asymmetrical mode.

The various configurations which can be achieved with this module are outlined as follows.

Buffer, Symmetrical Supply

A non-inverting buffer is shown in Figure 3, which is probably the simplest configuration. Its most typical application is to provide a low impedance output from some high impedance source.

Half Supply Generator, Asymmetrical Supply

A variation of the buffer is the 'half supply generator' shown in Figure 4, which is a very useful circuit for providing a ground reference for circuits requiring a symmetrical supply, but operating from an asymmetrical supply.

The voltage at the output of the op-amp is equal to the voltage at the non-inverting input (+), and it will only be as accurate as the resistor tolerance. Capacitor C6 in parallel with R7 stabilises the voltage.

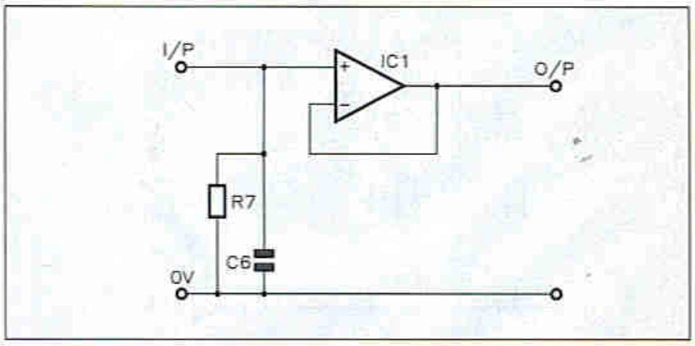


Figure 3. Non-inverting buffer.

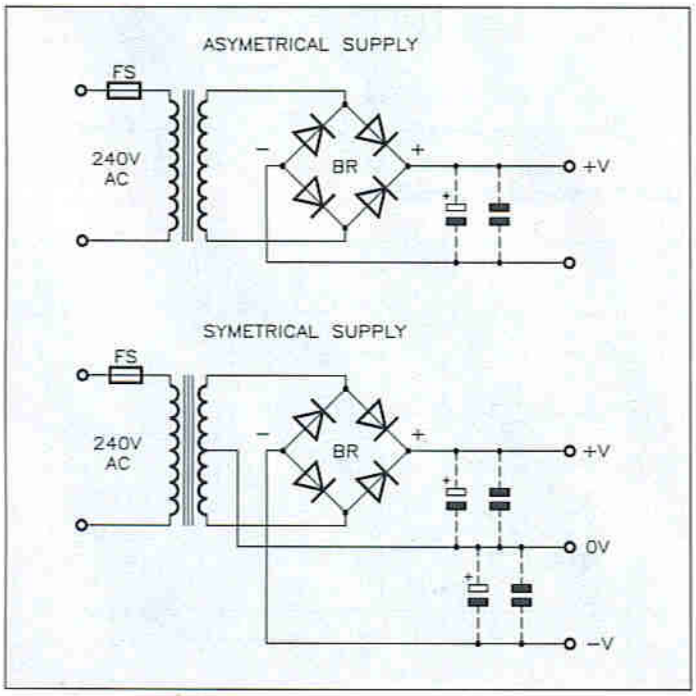


Figure 2. Circuits for symmetrical and asymmetrical power supplies.

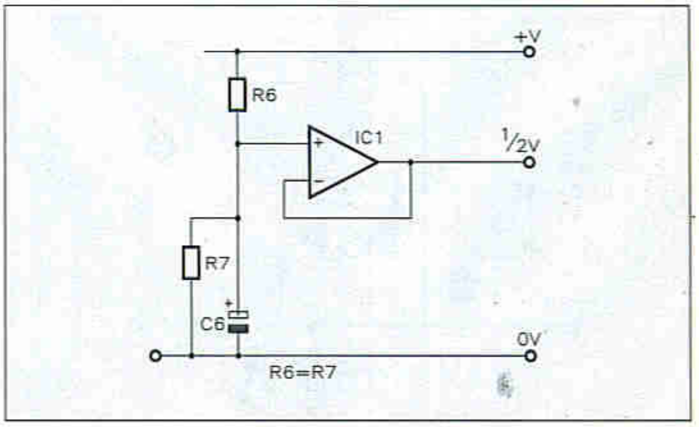


Figure 4. Half-supply generator.

Non-Inverting DC Coupled Amplifier, Symmetrical Supply

Adding two more resistors to the buffer circuit, as shown in Figure 5, will turn it into a voltage amplifier. The gain is determined by dividing the value of R10 by the value of R9, plus 1:

$$A_v = \frac{R10}{R9} + 1$$

or:

$$A_v = \frac{100k}{10k} + 1 = 11$$

Using the component values shown under the option for Figure 5 in Table 1, the circuit will have an AC *and* DC voltage gain of 11 times.

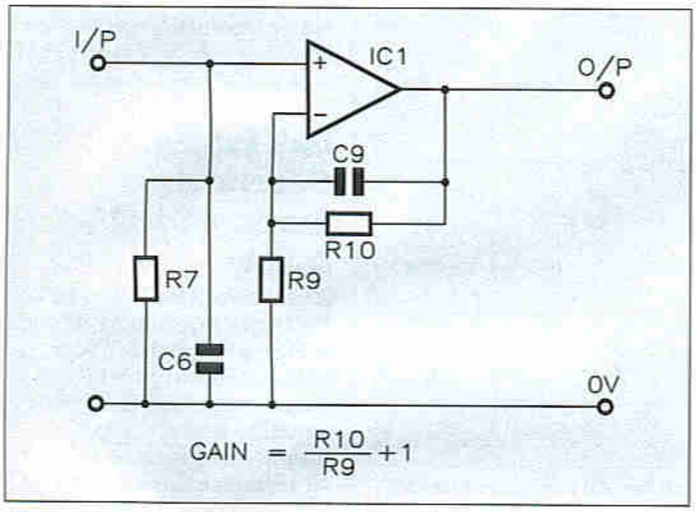


Figure 5. Non-inverting DC voltage amplifier.

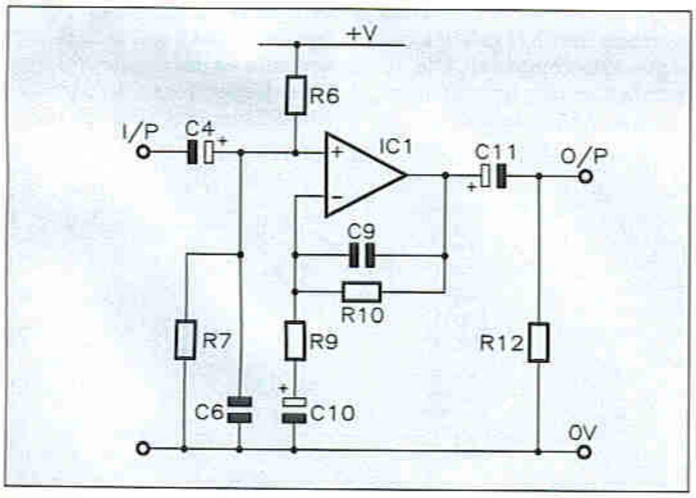


Figure 6. Non-inverting AC amplifier.

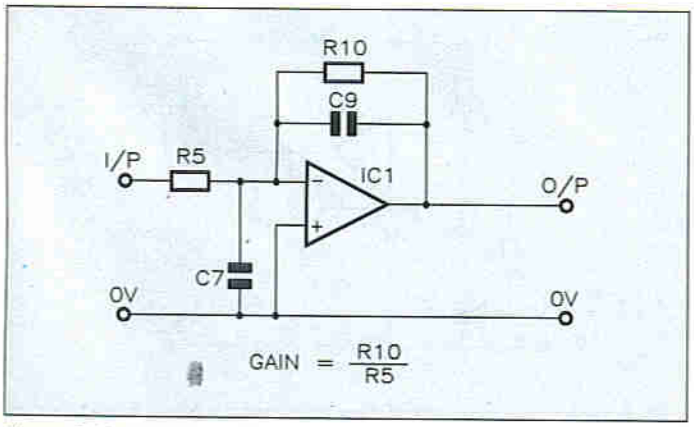


Figure 7. Inverting DC amplifier.

Non-Inverting AC Coupled Amplifier, Asymmetrical Supply

A non-inverting amplifier operating from an asymmetrical supply is shown in Figure 6. Resistors R6 and R7 are of equal value, and are used to bias the non-inverting input up to half of the supply voltage, allowing the positive and negative halves of the signal an equal amplitude, peak voltage swing. The input impedance is determined by

$$R_{in} = \frac{1}{\frac{1}{R6} + \frac{1}{R7}}$$

in this case, 10kΩ. Capacitors C4 and C11 are required to isolate the signal from the DC present at the input and output of the op-amp, since the supply is single-ended. Capacitor C10 is also required to decouple the DC at the inverting input of the op-amp from the 0V rail for the same reason; as far as the op-amp is concerned, 0V is effectively the –V rail. Resistor R12 is required to ensure that the output side of capacitor C11 is at 0V potential prior to anything being connected to it, thus avoiding nasty pops and thumps when a following stage is switched on-line.

Using the component values specified in Table 1, the circuit will have an AC voltage gain of 10 times (20dB). HF stability is provided by both C6 and C9, the values of which will have no detrimental effects at audio frequencies.

Inverting DC Coupled Amplifier, Symmetrical Supply

An inverting amplifier is shown in Figure 7, and here the gain is determined by dividing the

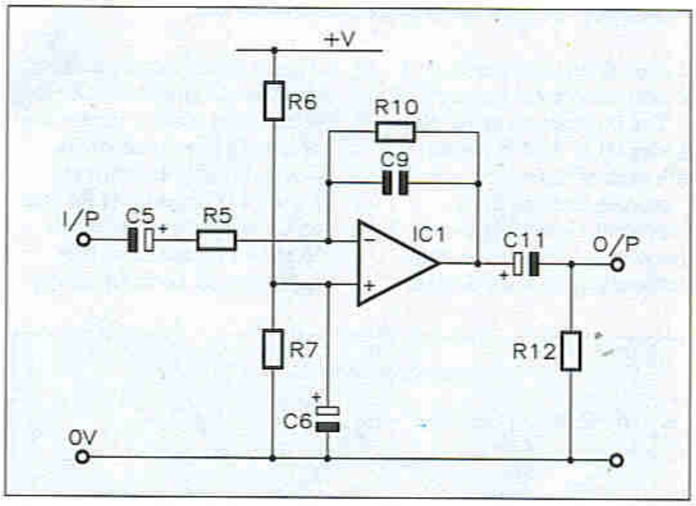


Figure 8. Inverting AC amplifier.

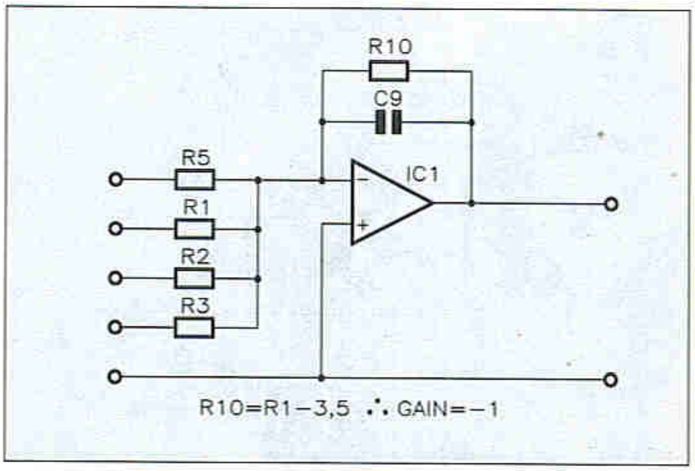


Figure 9. Inverting summing amplifier.

value of R10 by the value of R5. In practice the gain may not be exactly as calculated, and this is due to the impedance of the previous stage being *added* to the value of R5; if the impedance of the previous stage varies with frequency, then the gain of the amplifier will also vary with frequency.

The important distinction to be made with this configuration, compared with the foregoing non-inverting amplifiers, is that the non-inverting input of the op-amp is directly connected to 0V and the op-amp receives the input signal as a current flow via R5, but which is balanced by an equal and opposite current in R10. This is a direct result of the op-amp altering its output voltage to compensate for its two inputs attempting to move to different voltage levels, but in fact stay the same. The configuration can then be described as a 'virtual earth input' amplifier, since the '–' input stays at earth (0V) potential for all practical purposes. The input impedance, then, is exactly as R5.

Using the component values in Table 1, the circuit will have a gain of 10 times.

Inverting AC Coupled Amplifier, Asymmetrical Supply

An asymmetrical supply version of the inverting amplifier is shown in Figure 8. Using the component values in Table 1, the circuit will also

Inverting Summing Amplifier, Symmetrical Supply

Taking the inverting amplifier further, several resistors can be added in parallel to R5 to mix together several signals. In operational amplifier parlance, this is called 'summing'. An inverting summing amplifier, more commonly known as a virtual earth mixer, because the inverting input ('–') is almost at the same potential as the non-inverting input ('+'), can easily be made from an inverting amplifier by simply adding extra input resistors as shown in Figure 9. By keeping all the resistors (R1–3, 5, 10) the same value, the gain will be –1. This type of circuit is commonly used for simple audio mixers, although the summed output

Using the component values in the table, the circuit will have unity gain (times 1), and will be DC coupled. Capacitors C1 to C5 and C11 can be fitted for AC coupling.

Non-Inverting Summing Amplifier, Symmetrical Supply

The non-inverting mixer, Figure 10, is not as effective as the inverting type, but it can still be useful. The reason for this is that the virtual earth action has been lost by using the '+' input instead of the '–' input. Attenuation at the input is minimised by using a high value for R7, which can be omitted altogether if the inputs are DC coupled.

Using the component values in Table 1, the circuit

	Fig. 3	Fig. 4	Fig. 5	Fig. 6	Fig. 7	Fig. 8	Fig. 9	Fig. 10	Fig. 11	Fig. 12	Fig. 13	Fig. 14	Fig. 15	Fig. 16
D1	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001
D2	1N4001	–	1N4001	–	1N4001	–	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001	1N4001
R1	–	–	–	–	–	–	100k	100k	–	–	–	–	–	–
R2	–	–	–	–	–	–	100k	100k	–	–	–	–	–	–
R3	–	–	–	–	–	–	100k	100k	–	–	–	–	–	–
R4	Link	–	Link	Link	–	–	–	100k	4k7	–	–	–	–	–
R5	–	–	–	–	10k	10k	100k	–	4k7	1M	27_	–	Link	–
R6	–	4k7	–	20k	–	20k	–	–	–	–	–	–	–	–
R7	100k	4k7	10k	20k	Link	20k	Link	1M**	4k7	1M	10k	1k6	4k7	4k7
R8	–	–	–	–	–	–	–	–	–	–	–	1k6	4k7	4k7
R9	–	–	10k	10k	–	–	–	10k	–	–	–	LP	–	–
R10	–	–	100k	100k	100k	100k	100k	100k	4k7	470Ω	10k	39Ω	–	4k7
R11	Link	Link	Link	Link	Link	Link	Link	Link	Link	Link	Link	Link	Link	Link
R12	–	–	–	100k	–	100k	–	–	–	–	–	–	–	–
Rv1	–	–	10k*	–	10k*	–	10k*	10k*	10k*	10k*	10k*	–	–	–
C1	–	–	–	–	–	–	10μF*	10μF*	–	–	–	–	–	–
C2	–	–	–	–	–	–	10μF*	10μF*	–	–	–	–	–	–
C3	–	–	–	–	–	–	10μF*	10μF*	–	–	–	–	–	–
C4	Link	–	Link	10μF	–	–	–	10μF*	Link	–	–	–	–	–
C5	–	–	–	–	Link	10μF	10μF*	–	Link	Link	100nF	–	Link	–
C6	12pF	47μF	120pF	56pF	–	47μF	–	–	–	–	–	100nF	–	–
C7	–	–	–	–	120pF	–	–	–	–	–	–	–	–	100nF
C8	–	–	–	–	–	–	–	–	–	–	–	100nF	Link	Link
C9	Link	Link	12pF	12pF	12pF	12pF	12pF	12pF	–	1μF	270pF	–	–	–
C10	–	–	Link	47μF	–	–	–	Link	–	–	–	Link	–	–
C11	Link	Link	Link	100μF	Link	100μF	Link	Link	Link	Link	Link	Link	Link	Link
C12	100μF	100μF	100μF	100μF	100μF	100μF	100μF	100μF	100μF	100μF	100μF	100μF	100μF	100μF
C13	100nF	100nF	100nF	100nF	100nF	100nF	100nF	100nF	100nF	100nF	100nF	100nF	100nF	100nF
C14	100μF	Link	100μF	Link	100μF	Link	100μF	100μF	100μF	100μF	100μF	100μF	100μF	100μF
C15	100nF	–	100nF	–	100nF	–	100nF	100nF	100nF	100nF	100nF	100nF	100nF	100nF
IC1	741	741	741	741	741	741	741	741	741	741	741	741	741	741
LK1	–	–	–	–	–	–	–	Link	–	–	–	–	–	–
LK2	–	–	–	–	–	–	Link	–	–	–	–	–	–	–
LK3	–	–	–	–	–	–	–	–	–	–	–	Link	Link	Link
FB	–	–	Link	Link	Link	Link	Link	Link	Link	SW1	Link	Link	–	Link

* Optional
** Only required if input is AC coupled

Table 1. Component references for configurations 'A' to 'N'.

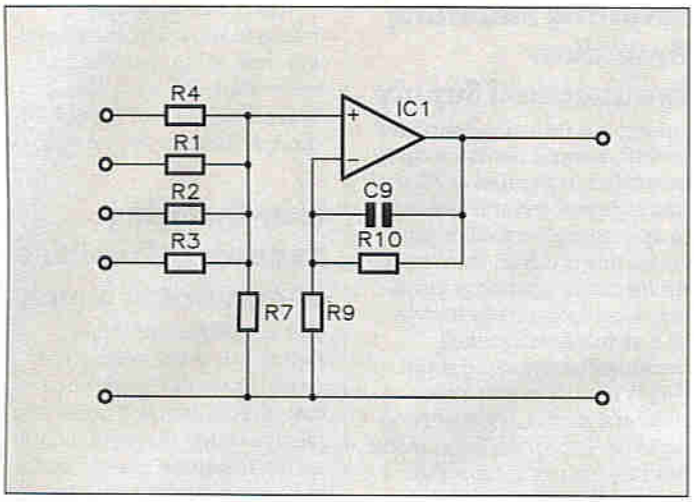


Figure 10. Non-inverting summing amplifier.

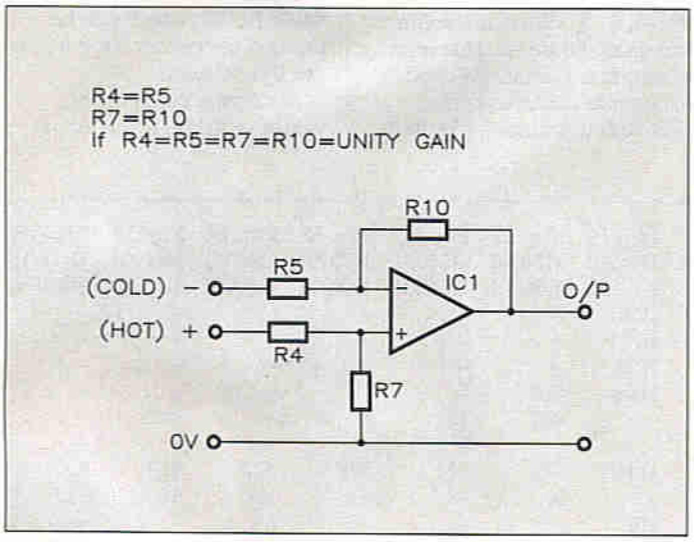


Figure 11. Differential amplifier.

Differential Amplifier Symmetrical Supply

Differential amplifiers are very useful circuits for removing common mode noise, and are often used in instrumentation circuits, balanced line receivers and audio input stages, i.e. for microphones.

The in-phase and out-of-phase signals (sometimes referred to as 'hot' and 'cold') are applied to the differential amplifier inputs. Any noise common to both inputs will be cancelled; the net result is a noise free signal. The circuit is shown in Figure 11.

Basically if all resistors are of equal value, then the opposed phase 'hot' and 'cold' signal will be passed on at the output. Any signal on R4 will be halved at the junction with R7 and the '+' input of the op-amp, but recovered to unity gain at the output by the opposite phase signal path in R5 and R10. However, the same signal in the same phase on both inputs will result in the output being reduced to zero.

Using the component values from Table 1, the circuit will have unity gain on each input but the output signal will be the sum of the signals on the inverting and non-inverting inputs.

Basic Integrator

A basic integrator circuit is shown in Figure 12, and this type of circuit was often used in analogue computers for calculus computation of continually varying signals. It is also used as servo correction in feedback circuits. The formula for calculating the gain is:

$$V_{out} = \frac{1}{R5 \times C9} \int V_{in} \delta_t$$

where δ_t = time taken for change.

Basic Differentiator

The differentiator (see Figure 13) was also used in analogue computers for calculus computation of velocity (the rate of change); differentiator circuits are not widely used as they are prone to noise, and the gain varies with frequency.

$$V_{out} = -R10 \times C5 \times \frac{\delta V_{in}}{\delta_t}$$

where δV_{in} = change in input voltage.
A circuit is shown in Figure 12, and component values for this are listed in Table 1.

Sine Wave Wien-bridge Oscillator

To form an oscillator, two things are required – firstly, the circuit must have a gain of more than unity (>1), and secondly, a phase shift of 360° from output to input. Both these requirements can easily be met for a square wave oscillator (a square wave because the amplifier will run into saturation). But, for a low distortion sine wave oscillator, two types of feedback are required, positive feedback (regenerative) for oscillation, which should be of unity gain (or very slightly greater to overcome losses), and negative feedback (degenerative) to prevent saturation and reduce distortion.

A Wien-bridge oscillator is shown in Figure 14. The Wien bridge part of the circuit is R7, R8, C6 and C8, which form the regenerative feedback network. Keeping the values for R7 and R8 the same, C6 and C8 will simplify the formula for frequency which would then be:

$$f_o = \frac{1}{2\pi \times R \times C}$$

The regenerative feedback network components are R10 and LP (in the position of R9), and operate similarly to the non-inverting amplifier, by controlling the gain of the oscillator. This being equal to R10/LP, where LP = lamp filament resistance, the gain should never be so high as to cause flat topping of the sinewave.

The (apparently strange) use of a lamp in the gain setting network stabilises the output amplitude; if the output amplitude increases, the voltage across the lamp will *also* increase and heat up the filament. Therefore the filament resistance will also increase, which in turn will decrease the gain. For a Wien null network, where the phase shifting components C8, R8, R7 and C6 also attenuate by a factor of three, the lamp filament's task is to maintain the regenerative gain of the amplifier also at three. The final effective gain is, then, unity. The advantage of this method is that the lamp will maintain the necessary gain for all combinations of the negative feedback chain for all frequencies.

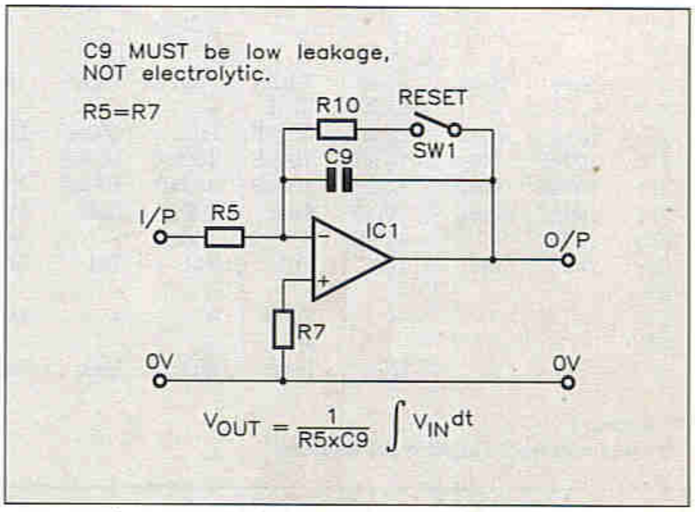


Figure 12. Basic integrator.

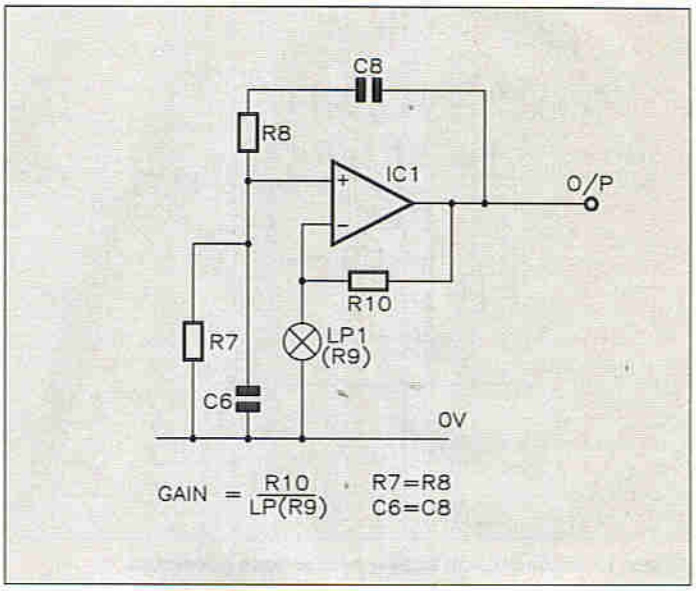


Figure 14. Basic Wien-bridge oscillator.

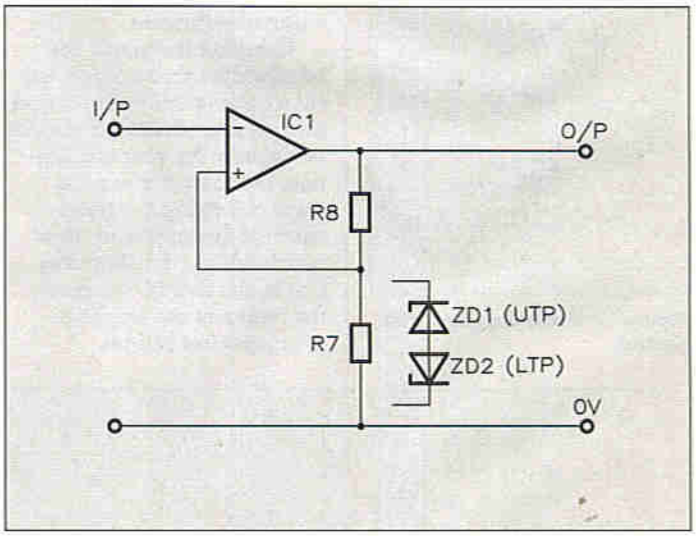


Figure 15. Basic Schmitt trigger.

Using the values shown in Table 1, the output frequency will be approximately 1kHz.

Basic Schmitt Trigger

A basic Schmitt trigger is shown in Figure 15, and this type of circuit is very useful for interfacing varying analogue signals to digital circuits. A Schmitt trigger is designed to have 'hysteresis' – the upper and lower input trip points which are set to affect a change at the output. In the circuit of Figure 15 the hysteresis that a varying analogue input must overcome to trip over the output is simply determined by the voltage level at the junction of R7 and R8. The formula for the upper trip point (UTP) measured at the non-inverting input is

$$V_{UTP} = -V \times \frac{R9}{R10 + R9}$$

the lower trip point formula is

$$V_{UTP} = +V \times \frac{R9}{R10 + R9}$$

Note the change in sign. Because the circuit operates from a symmetrical supply, the hysteresis is centred around 0V; the total hysteresis is LTP + UTP.

An alternative method of setting the trip points directly is to use two back to back Zener diodes in place of R9, also shown in Figure 15. This method will only allow an LTP below 0V and an UTP above 0V.

Using the values shown in Table 1, the UTP will be 50% of the +V supply and the LTP will be 50% of the –V supply.

Square Wave Schmitt Trigger Oscillator

A square-wave oscillator can easily be constructed with an op-amp, as shown in Figure 16. Resistors R7 and R8 set the UTP and LTP, and altering either value will change the trip points and hence the mark space ratio at the output. With equal values for R7 and R8, the output mark space ratio will be 1:1. The amplitude of the square wave will be almost equal to the supply rail voltages. Components R10 and C7 set the frequency of oscillation. Keeping the values for R7 and R8 equal will simplify the formula to

$$f_o = \frac{1}{2{\cdot}2 \times R10 \times C9}$$

A triangular waveform is also available at the non-inverting input, but if you want to use this signal this connection will require buffering to prevent loading the R8/R7 network and upsetting the behaviour of the oscillator. The amplitude at this point will be approximately 75% of the +V and –V supply rails.

If a high frequency oscillator is required, then a high slew rate amplifier should be used instead of the 741, which includes internal frequency compensation which limits its upper frequency response.

Using the values shown in Table 1, the output frequency will be approximately 1kHz.

The following notes apply to many of the above circuit configurations, where applicable:

Using Offset Trim, for Symmetrical Supplies Only

Like many other op-amps the 741 provides an offset trim facility, which enables the output offset error voltage, which is usually in the order of millivolts, to be reduced to zero by the inclusion of RV1 (see Figure 17). Generally this is only required where minute DC signals from the output are to be amplified further. If AC coupling is used, offset null trimming is unnecessary. Basically RV1 is rotated for an output of 0V DC while the output is monitored with a DC millivoltmeter (or multimeter with a very sensitive DC volts range).

CAUTION: shorting the trim terminals of the 741 IC to either the +V or 0V rails will destroy the 741 op-amp!

Adding Bandwidth Limiting to a Non-Inverting Amplifier

Referring to Figure 18, which shows the Gain BandWidth product (GBW or GB) of the 741 op-amp, it can be seen that the open loop response (0% feedback) of the op-amp has very little bandwidth before the gain begins to roll off; this area is known as the 'full power bandwidth'. At the other extreme, with the op-

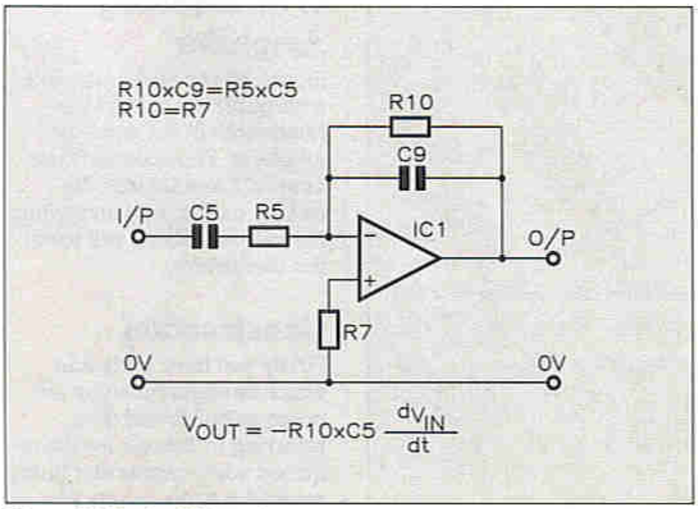


Figure 13. Basic differentiator.

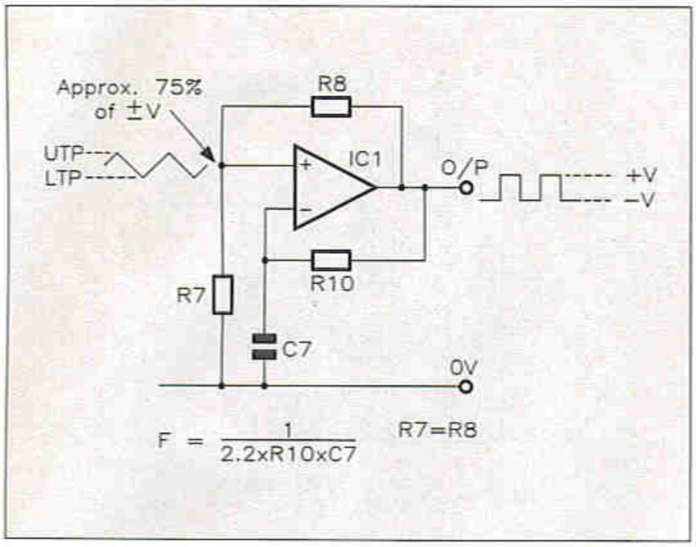


Figure 16. Basic Schmitt trigger square wave generator.

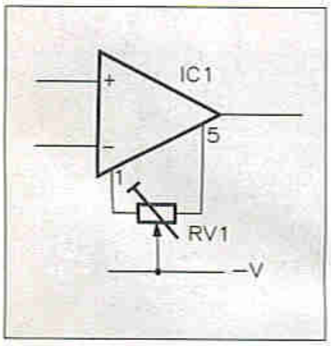


Figure 17. Using the offset null control.

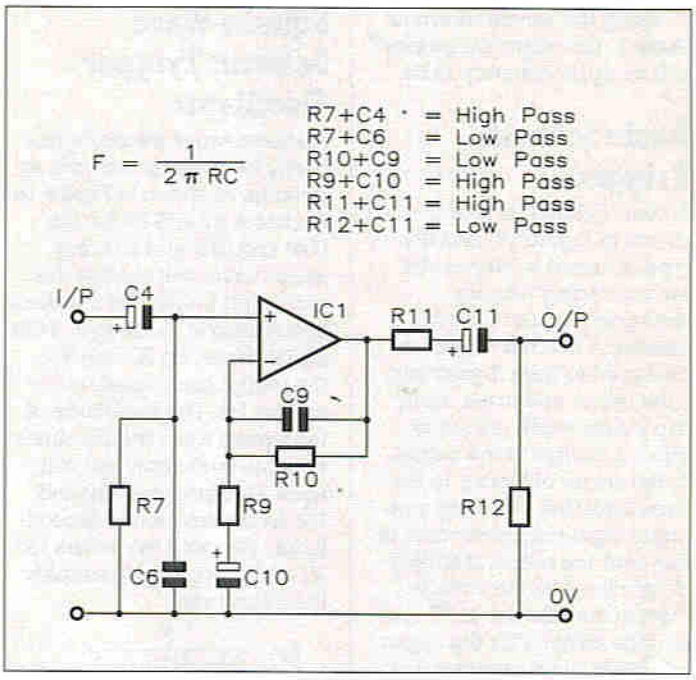


Figure 19. Adding bandwidth limiting to a non-inverting amplifier.

amp running at unity gain (100% feedback), the bandwidth is very wide.

Using such a graph, the bandwidth can be predicted for a given gain; you may find that at low gain the bandwidth is too wide for your application, but there are several ways of limiting the bandwidth of the amplifier. All of which reduce the slew rate, that is, the rate of change at the output of the amplifier over a period of time, expressed as V per µs.

Figure 19 shows some of the possible filter configurations, and simple high-pass, low-pass, bandpass and notch filter functions can be easily realised.

Each component pair shown in the list accompanying Figure 19, e.g. R7 and C4, or R12 and C11, etc. is known as a 'pole'. A single-pole filter is also known as a 'first order filter' or –6dB per octave filter.

Higher order filters (–12dB, –18dB, etc.) can be made by cascading circuits of the same frequency, e.g., a first order high-pass filter circuit feeding into a second order high-pass filter circuit will give a third order response, i.e. –18dB per decade.

The formula for the –3dB point of a first order filter frequency is:

$$f_{-3dB} = \frac{1}{2\pi \times R \times C}$$

Bandwidth Limiting of an Inverting Amplifier

Figure 20 shows the possible configurations to limit the bandwidth of the inverting amplifier. The action of capacitors C7 and C9 was discussed earlier, and increasing the values of these will lower the bandwidth.

Construction

Firstly you have to decide which configuration you are going to build, and then, referring to Table 1 for the required components and links, select the components you need. The values shown in

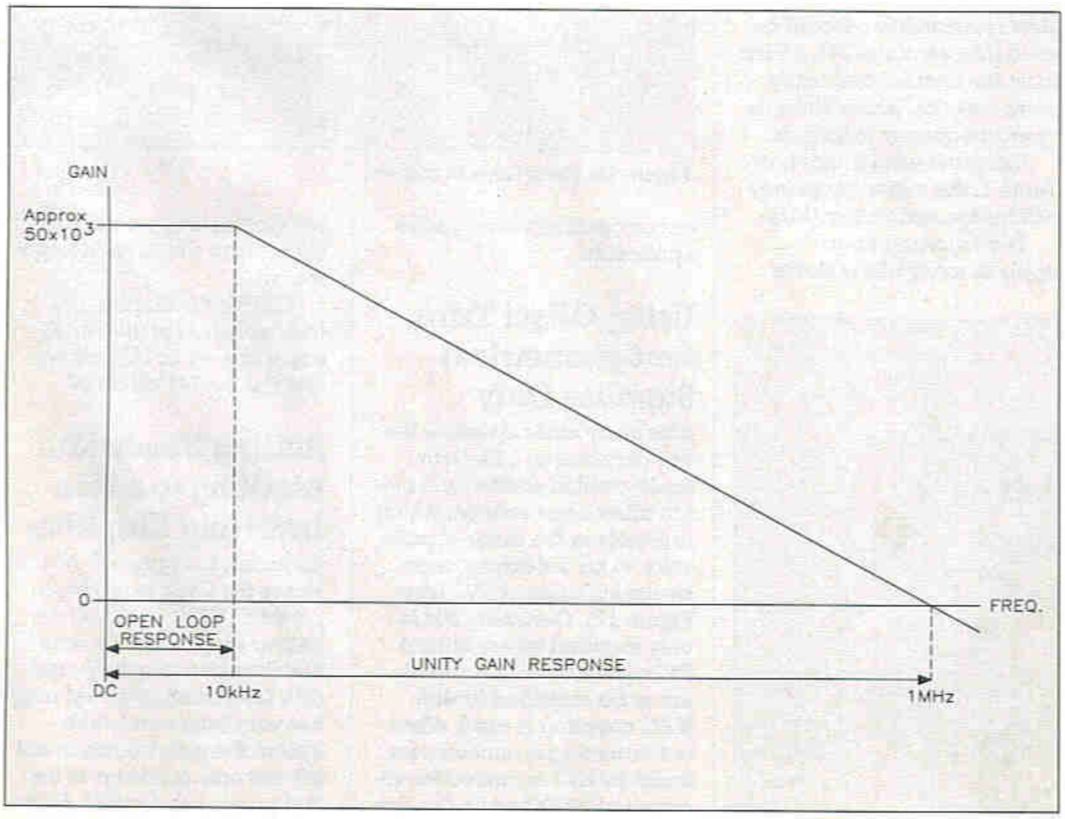


Figure 18. Graph of gain bandwidth of a 741 op amp.

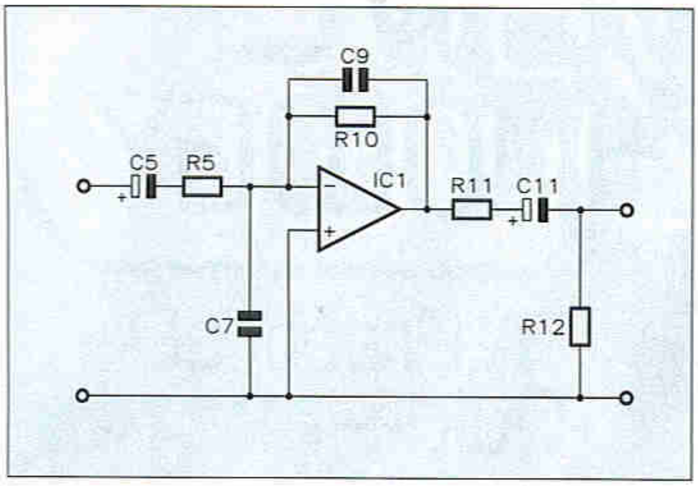


Figure 20. Adding bandwidth limiting to an inverting amplifier.

the table are only suggestions and need not be adhered to, but in many instances may be a good starting point.

While referring to the PCB legend, Figure 21, fit the resistors required in the positions on the PCB according to the selected option from Table 1. Similarly fit the links. Fit the diodes, followed by the PCB pins. Install the IC socket making sure that the orientation marker at one end aligns with the marker on the legend.

Fit the capacitors required. The polarity of the input electrolytic capacitors (if used) are not marked on the legend; their orientation will depend upon what type of power supply is to be used (symmetrical or asymmetrical).

As a guide, if a symmetrical supply is used, then the capacitor(s) positive ('+') lead should be orientated *towards* the input pin; if an asymmetrical supply is used, the *negative* ('–') lead should be connected to the input pin.

Finally, upon fitting the IC into the socket, the module is ready for use.

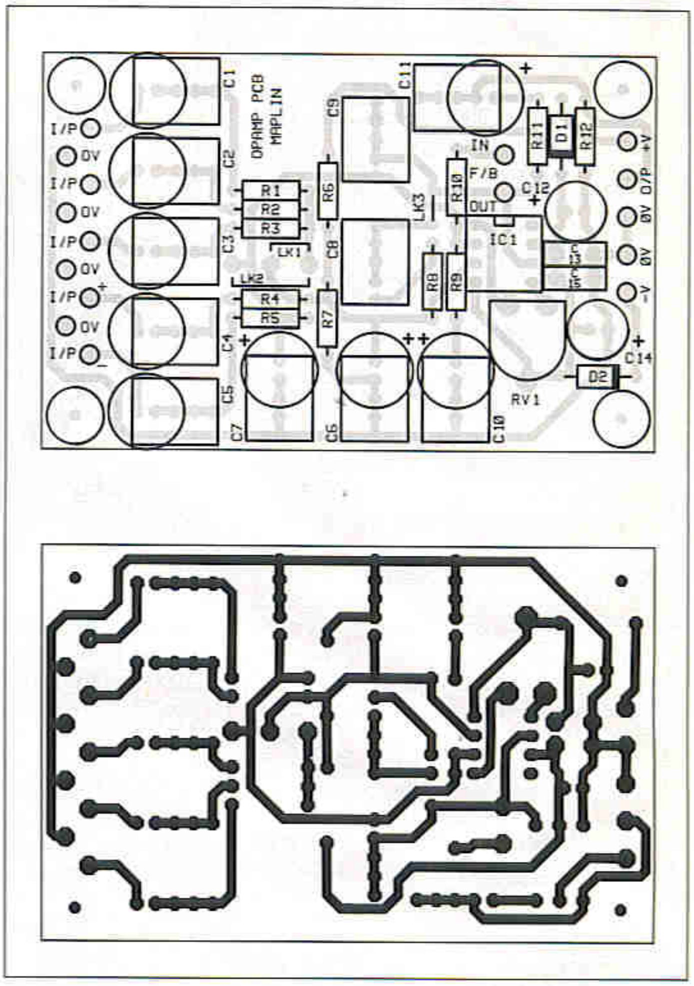


Figure 21. PCB legend and track.

741 OP AMP PROTOTYPE CARD PARTS LIST

Note: For component references see Table 1.

RESISTORS: All 1% Metal Film (Unless specified)

27Ω	1	(M27R)
39Ω	1	(M39R)
470Ω	1	(M470R)
1k6	2	(M1K6)
4k7	4	(M4K7)
10k	2	(M10K)
20k	2	(M20K)
100k	5	(M100K)
1M	2	(M1M)
10k Hor. Enclosed Preset	1	(UH03D)

CAPACITORS

12pF Ceramic	1	(WX45Y)
56pF Ceramic	1	(WX53H)
120pF Ceramic	1	(WX57M)
270pF Ceramic	1	(WX61R)
100nF Disc	2	(BX03D)
100nF Poly Layer	2	(WW41U)
1μF Poly Layer	1	(WW53H)
10μF 50V PC Electrolytic	4	(FF04E)
47μF 50V PC Electrolytic	1	(JL16S)
100μF 35V PC Electrolytic	2	(JL19V)

SEMICONDUCTORS

1N4001	2	(QL73Q)
μA741C	1	(QL22Y)

MISCELLANEOUS

Push Switch	1	(FH59P)
DIL Socket 8-Pin	1	(BL17T)
Pin 2145	1 Pkt	(FL24B)
PCB	1	(GH51F)
Instruction Leaflet	1	(XU22Y)
Constructors' Guide	1	(XH79L)

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

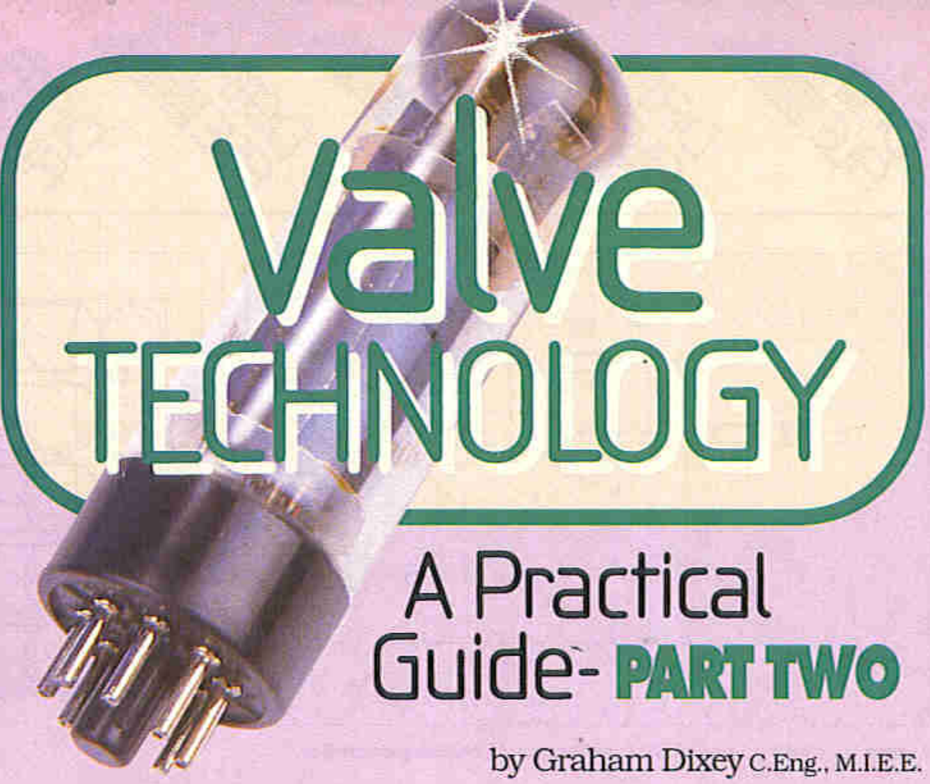
The above items are available as a kit, which offers a saving over buying the parts separately.

Order As LT33L (Op Amp Proto Card Kit) Price £6.95

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

The following new item (which is included in the kit) is also available separately, but is not shown in the 1993 Maplin Catalogue.

(Op Amp Prototype PCB) **Order As GH51F Price £2.75**



Valve Technology
A Practical Guide - PART TWO

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

Introducing the Triode Amplifier

In general, amplifiers can be classified according to their characteristics and properties. One such classification is according to the frequency range over which they are supposed to operate, and which falls into four broad divisions: (1) direct-coupled amplifiers; (2) audio-frequency amplifiers; (3) radio-frequency amplifiers and (4) video-frequency amplifiers.

Another possible classification may be used to determine whether the amplifier is 'aperiodic' (untuned) or tuned. For example, audio-frequency amplifiers are aperiodic, because they are intended to handle all frequencies in the audio-frequency spectrum equally. Radio-frequency amplifiers, on the other hand, whether in transmitters or receivers, are tuned amplifiers, since they are intended to concentrate on a narrow band of only frequencies centred around a single radio-frequency, often the 'carrier', to the exclusion of all others.

Amplifiers can also be classified as either voltage or power amplifiers, according to whether the primary aim is to raise the voltage level or the power level of a signal. This is true whether the amplification is at audio or radio-frequencies.

Finally, amplifiers can be classified according to their operating conditions, e.g., class A, class B, class AB or class C.

But for the moment at least we shall consider the use of the triode valve as a voltage amplifier at audio-frequencies.

The Triode as an AF Voltage Amplifier

To understand how amplification is possible with a triode valve, we need to remind ourselves about the mutual characteristics of a triode (the graph of anode current I_a against grid voltage V_g), and of the need for a grid bias voltage and how the latter is obtained. In Part One of this series we discussed this characteristic, in particular how it showed that the standing value of anode current through the valve depends upon the negative voltage applied to the grid; if this negative voltage is made sufficiently large, the anode current becomes cut off altogether. We also discussed how the negative bias voltage for the control grid could be obtained by making the cathode *positive* with respect to the grid, this then being termed cathode bias.

With the above in mind, now look at Figures 1(a) and 1(b). Figure 1(a) shows the triode valve with cathode bias components R_k and C_k, and the grid leak resistor R_g. An alternating input signal (a sinewave) is applied to the grid; the latter is known as v_g (small 'v') as opposed to V_g which is the DC bias voltage. This situation is shown graphically in Figure 1(b). The construction shows that, for this particular valve, the value of the bias voltage V_g is −1·0V, which produces a standing value of anode current I_a equal to 4mA. This is obtained by projecting upwards from the value of $-V_g$ until we intercept the static curve for $V_a = 150V$ and then projecting across to the vertical axis where we read off the value of I_a, namely the 4mA referred to. This discussion has only dealt with the DC conditions which are valid in the absence of a signal.

However, the above amplifier has an alternating signal voltage applied to the grid and Figure 1(b) shows that this has a peak value of 0·5V. Thus, as can be seen from this figure, the grid voltage swings between the limits of −0·5V and −1·5V, this occurring equally on either side of the bias voltage value of −1·0V. From this we would expect that the anode current would also alternate in a similar manner, increasing on the 'positive going' half-cycles and reducing on the 'negative going' half-cycles. Notice the reference to the 'positive *going*' half-cycle rather than simply saying *positive* half-cycle. This is, of course, because the grid never actually becomes positive (with respect to 0V) but only 'less negative'. The peaks of the alternating grid signal voltage have been projected upwards to intercept the static curve referred to earlier and then projected across to the I_a axis. This gives the limits of the corresponding variation of anode current.

When the grid voltage swings to −1·5V the anode current falls to 2·7mA, and when the grid voltage swings up to −0·5V, the anode current then increases to 5·3mA. This represents a Pk-to-Pk anode current variation of 2·6mA, centred about the steady anode current (no signal) value of 4mA.

So far we have used a voltage variation on the grid to produce a corres-

Underside view of experimental valve chassis, showing tagstrip for components and screw terminal block connector.

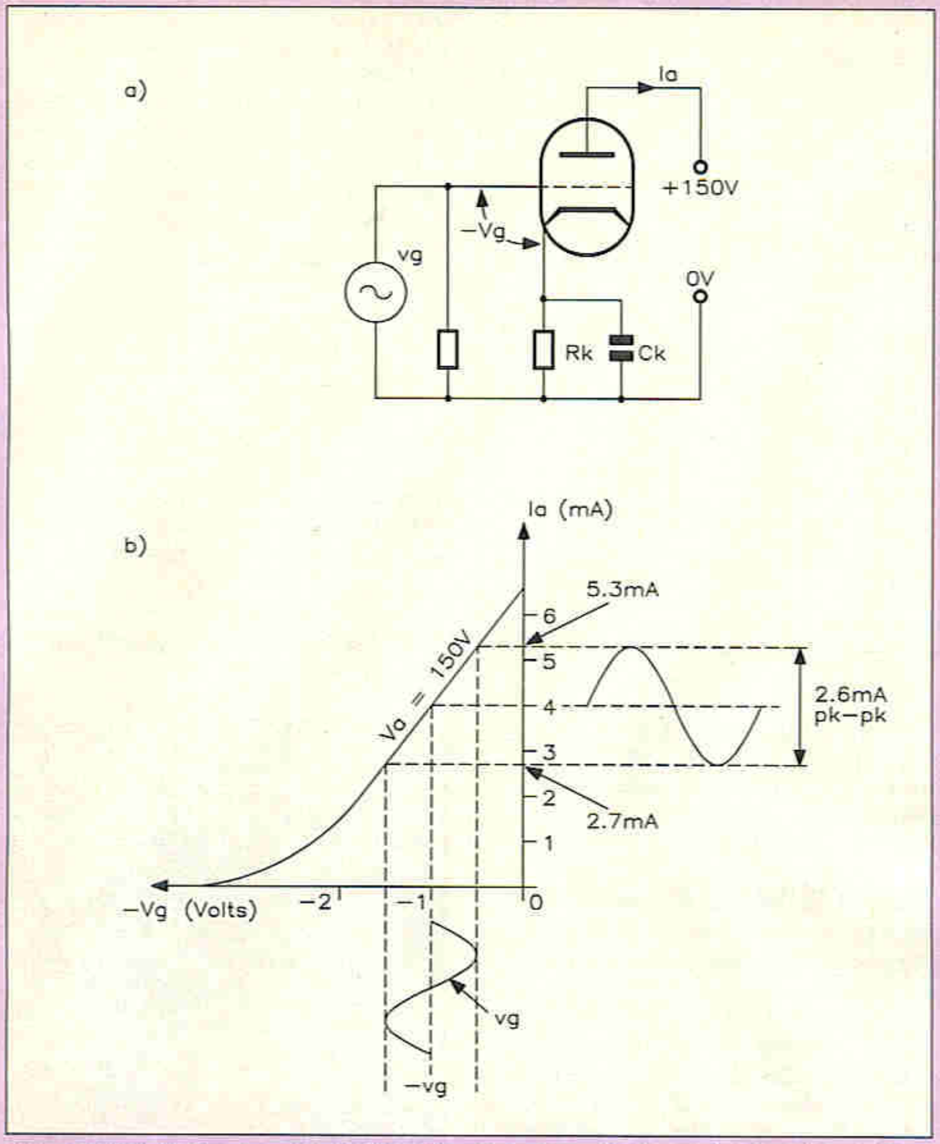


Figure 1. (a) A triode valve with grid bias Vg and an alternating input signal vg; (b) standing and alternating voltages and currents for the valve of (a).

ponding variation in the anode current. That is to say, we have a voltage input and a current output. What we need for voltage amplification is to have a voltage output for a voltage input.

The Anode Load Resistor

Of course, all we need to do to turn a current into a voltage is to pass it through some passive component, which is capable of developing a potential difference. Obviously such a device should be linear if we wish to prevent unnecessary distortion occurring. The choice, naturally, is a resistor. This resistor is inserted in series with the anode supply voltage (Figure 2) so that the anode current flows through it on its way to the positive supply terminal. There will, therefore, be a potential difference across it, which can be seen to have two components, as follows.

i) A steady voltage equal to the product of the standing current (I_a = 4mA) and the value of the anode load resistor (in this case, 10kΩ). This product equals 40V.

ii) An alternating voltage whose peak value equals the product of the peak value of the alternating anode current (1·3mA) and the value of the anode load resistor (10kΩ). This product equals 13V.

Thus, by inserting a load resistor in series with the alternating anode current, we have effectively converted the latter into an alternating output voltage of a Pk-to-Pk value of 26V.

This is clearly much greater than the value of the input signal voltage. By comparing these two values, input and output, we can obtain a figure for the voltage amplification factor (VAF) of the stage.

$$VAF = \frac{\text{alternating output voltage}}{\text{alternating input voltage.}}$$

Obviously we must compare the two voltages specified in the same way, that is, both peak, both Pk-to-Pk or both RMS. We don't know the latter but could calculate it; we know both of the former and one is as good as another for our purposes. Let us use Pk-to-Pk values thus:

$$VAF = \frac{26V}{1{\cdot}0V} = 26,$$

in other words the voltage gain is 26 times.

General Expression for Voltage Gain

There is a simple expression which can be used to find the voltage gain of a stage such as that shown in Figure 2. It involves just two factors: the mutual conductance, g_m, of the valve, and the 'effective' load in the anode circuit. In the case of this example, the anode load is simply the 10kΩ resistor. In practice, this stage might well feed another, following, one, in which case the anode load resistance of the first stage would be shunted by the input impedance of the second. To take account of such shunt resistances, the effective load is termed the 'equivalent load resistance', denoted by R_{eq}. The general expression for voltage gain is then given by:

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

We ought to be able to use the above expression to confirm the voltage gain value obtained graphically in the previous example. The value of R_{eq} is clearly just 10kΩ, since there is no following stage attached. Okay. The next question is, then, what is the value of g_m? If we knew the valve type, we could simply

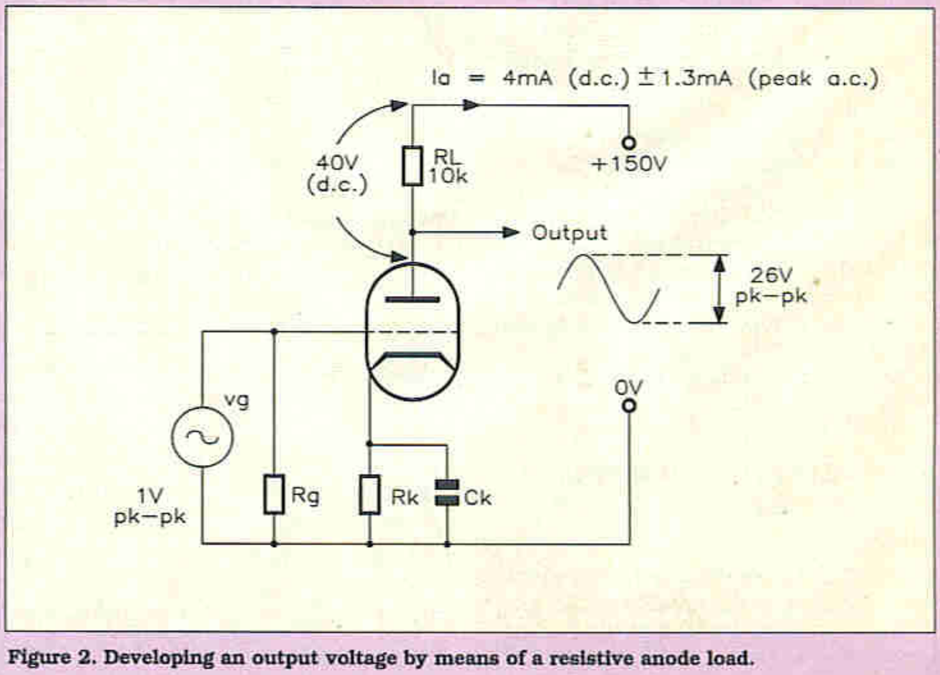


Figure 2. Developing an output voltage by means of a resistive anode load.

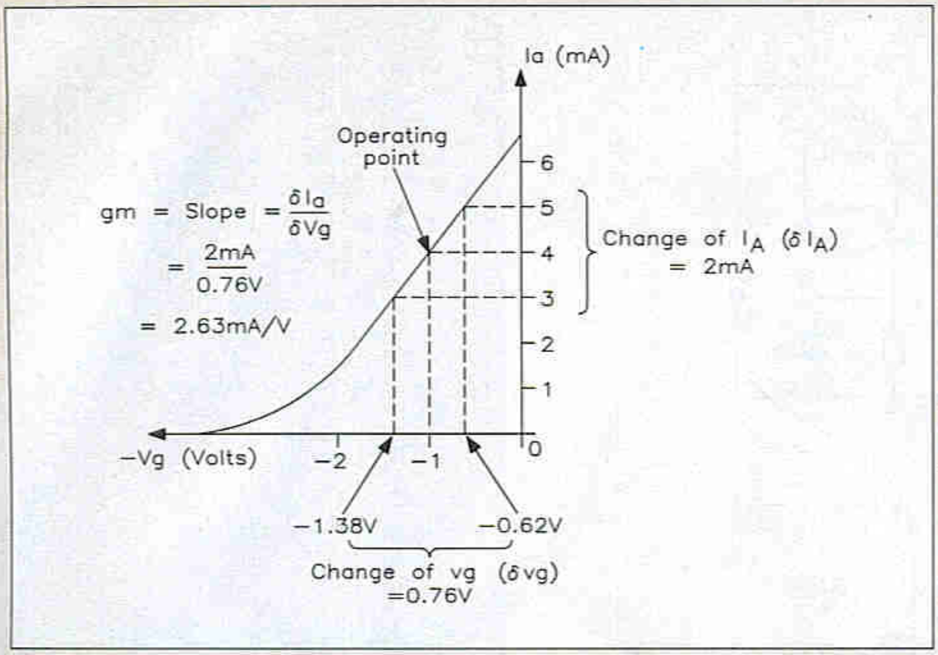


Figure 3. Determining the gm of a triode valve.

look up the typical value of g_m in a valve data book. However, we will instead obtain it in a way that will make use of the theory given in Part One – a much more useful if more lengthy procedure!

The g_m of a valve can be obtained by measuring the *slope* of the mutual characteristic. This measurement should be *made at the operating point*, that is, the portion of the characteristic at which the valve is seen to be DC biased, in this case, defined by $V_g = -1{\cdot}0V$; $I_a = 4mA$. The mutual characteristic of Figure 1(b) is now repeated in Figure 3, with the appropriate construction added, as follows.

A graph has been drawn with convenient increments of anode current, I_a, in the vertical Y axis; in this case the increments of I_a are 1mA on either side of the standing quiescent value of 4mA, i.e. a total change of I_a (δI_a) of 2mA. Note the use of Greek letter δ, *delta*, also often Δ, used to describe the triangular shape outlined by the dotted lines in Figure 3, thus identifying that these are not the static DC biased values we are dealing with. All we need do now to find the value of g_m is to project this variation δI_a downwards onto the horizontal V_g axis to find the corresponding change in V_g (δV_g). Dividing the change in I_a (δI_a) by the corresponding change in V_g (δV_g) yields the mutual conductance g_m.

Since the increment in V_g is from −0·62V to −1·38V, then the total change in V_g is 0·76V, giving a value for g_m of 2mA/0·76V, which equals 2·63mA/V, a perfectly reasonable value for a triode. We are now in a position to calculate the voltage gain of the stage.

As stated previously, $VAF = g_m \times R_{eq}$,

where $g_m = \dfrac{\delta I_a}{\delta V_g}$

VAF = 2·63 (mA/V) x 10 (kilohms),

= 0·00263 (A/V) x 10,000 Ω,

= 26·3.

This is the figure obtained previously, thus pointing to the validity of the formula used. Note that the product of g_m in mA/V and load resistance specified in kilohms will give the correct numerical value, a useful fact which avoids the use of the appropriate powers of 10 (since these are implicit as in the method of the second line above).

The Triode Parameters

We have now met two of the three triode parameters, namely the anode slope resistance r_a, and the mutual conductance g_m. The third of the parameters is μ (mu) and is known as the 'amplification factor'. This is NOT the same thing as the Voltage Amplification Factor (VAF) referred to above. Mu is a parameter of the valve itself, and has no relation to the value of anode load used. VAF is the voltage gain of an actual stage and *is dependent* upon the value of anode load used. It is not surprising that the value of VAF will always be somewhat less than the value of μ, since there will always be some signal loss due to the fact that the valve amplifier has some internal resistance (r_a in fact). What μ does give us is a clue to the ability of any given valve to act as a voltage amplifier – a starting point for a design, if you like. There is a simple relationship between the three valve parameters, by which any one can be calculated if the other two are known. This relation is:

$\mu = r_a \times g_m$.

Taking a real example, the entry in Table 1 for the ECC81 shows that r_a = 13·5k Ω and g_m = 4mA/V. These two figures can be multiplied together directly to give the amplification factor μ.

Thus, μ = 13·5 x 4, = 54.

This is the value given in Table 1. There are, of course, no units for μ, since it is a ratio of output voltage over input voltage (signal values). This can be seen from a simple multiplication, as follows:

$$r_a = \frac{\text{change of } V_a}{\text{change of } I_a;}$$

$$g_m = \frac{\text{change of } I_a}{\text{change of } V_g;}$$

or, less verbose:

$$r_a = \frac{\delta V_a}{\delta I_a} \qquad g_m = \frac{\delta I_a}{\delta V_g}$$

If we multiply these two expressions together, to get an expression for μ, we shall end up with the expression,

$$\mu = \frac{\delta V_a}{\delta V_g}$$

since the 'δI_a' term will cancel out in both expressions.

Completed chassis with valves in place.

Frequency Response of Triode Amplifier

The bandwidth of an amplifier is conventionally defined as being the range of frequencies lying between the two points, where the response has fallen by 3dB from the mid-band value. At high frequencies the response is limited by shunt capacities, such as the interelectrode capacity between grid and cathode (known as C_{gk}). This latter is an obvious 'stray' capacity in parallel with the signal path. What is not so obvious is that this value of input capacitance is enhanced by a further shunt capacity which is 'reflected back' to appear in *parallel* with C_{gk}. This additional capa-

Type	Heater		Anode		Negative	r_a (kΩ)	g_m (mA/V)	μ
	Volts	Amps	Volts	Amps	Grid Volts			
ECC81	6·3	0·3	100	3·7	1·0	13·5	4	54
	12·6	0·15	180	11·0	1·0	9·4	6·6	62
ECC82	6·3	0·3	100	11·8	0	6·2	3·1	19
	12·6	0·15	250	10·5	8·5	7·7	2·2	17
ECC83	6·3	0·3	100	0·5	1·0	80	1·25	100
	12·6	0·15	250	1·2	2·0	62·5	1·6	100

Table 1. Principle parameters of ECC81, ECC82 and ECC83 double-triode valves.

city has a value equal to C_{ag} (the capacitance between anode and grid) multiplied by (approximately) the voltage gain of the stage; this is termed the 'Miller effect'. Thus, the input capacitance can actually be quite high, and this sets a limit on the high-frequency performance of triodes, unless special measures are taken to improve this aspect of performance.

The response at the low-frequency end of the spectrum is largely determined by external factors, namely the high-pass filter formed by the series coupling capacitor and the input resistance of the valve. The latter is apparently infinite, because the input circuit of the valve itself is a physical gap between the cathode and grid, with no current flowing in the grid circuit. However, the grid leak resistor appears in parallel with the grid-cathode path and, since this usually has a resistance of 1MΩ, this becomes the input resistance of the amplifier. The frequency response at low frequencies is then determined by the value of the series coupling capacitor.

With a simple RC filter of this type, the –3dB response point occurs when the reactance of the capacitor equals the value of the resistor. This makes it easy to calculate the value of capacitor required in order to obtain any given low-frequency response. Let us take an example.

Suppose that the grid leak does have a value of 1MΩ and that the lower –3dB response point is to be at 40Hz. This means that the reactance of the coupling capacitor must have a value of not more than 1MΩ at this frequency. Thus, since

$$X_c = 10^6\Omega \text{ and } X_c = \frac{1}{2\pi \times f \times C}$$

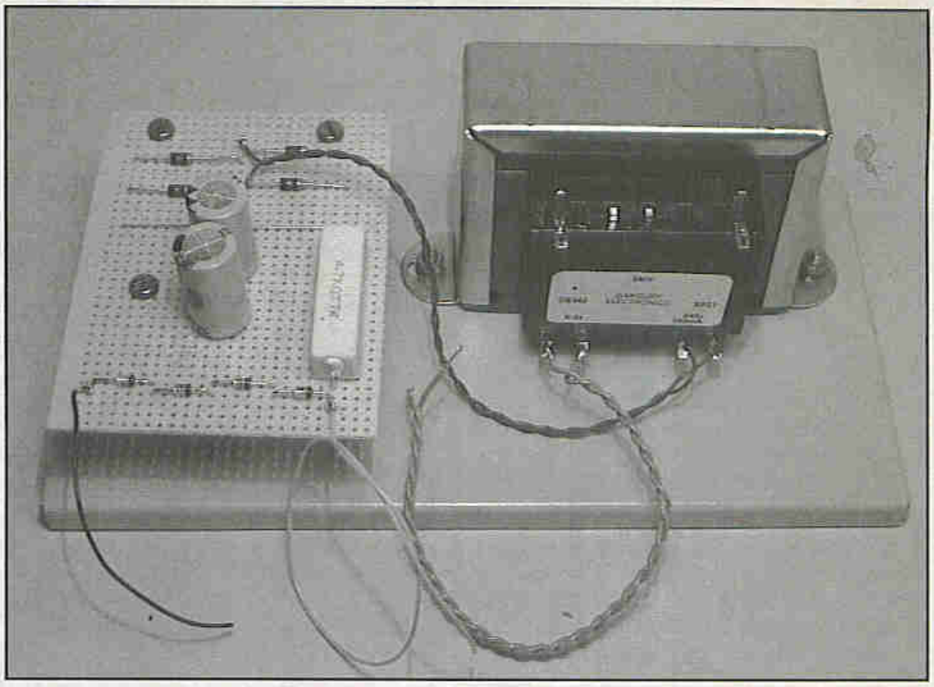
Then:

$$C = \frac{1}{2\pi \times 40}\ \mu F$$

$$= 0{\cdot}004\,\mu F$$

$$= 4nF$$

This illustrates how the high input impedance of valves allows small values of coupling capacitors to be used. In a solid state amplifier using BJTs (Bipolar Junction Transistors), coupling capacitors are more likely to have values of the order of 10µF or so (since the input impedance of a common emitter amplifier is of the order of only 2 to 3kΩ). In practice, valve audio-frequency amplifiers in the past commonly used coupling capacitors having values of, say, 0·1µF (100nF), which is plenty enough.



The valve power supply, with transformer and circuit board mounted on sub-chassis.

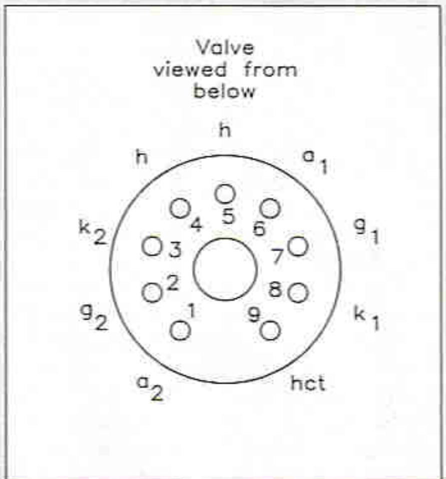


Figure 4. Base connections (underside view) for the ECC81, ECC82 and ECC83 double-triodes.

Currently Available Triode Valves

Not surprisingly, the availability of valves of any sort is extremely limited these days, since there are so few applications for them (and for those that are available, the quality can be a bit suspect). Forgetting about the high-power applications such as radio transmission and industrial eddy current heating sets, for which they are ideally suited, the audio field offers the major application area now, especially for power amplifiers. In this case the first stage is likely to be a pentode, as will be the power output stage also (operating in push-pull).

Triodes are used for the intermediate amplification, and the most usual (and useful) configuration is the double-triode, that is two triodes of the same type in the same envelope (glass tube). There have always been three firm favourites in these stakes, and these are the ones still readily available today. They are the ECC81, ECC82 and ECC83, also

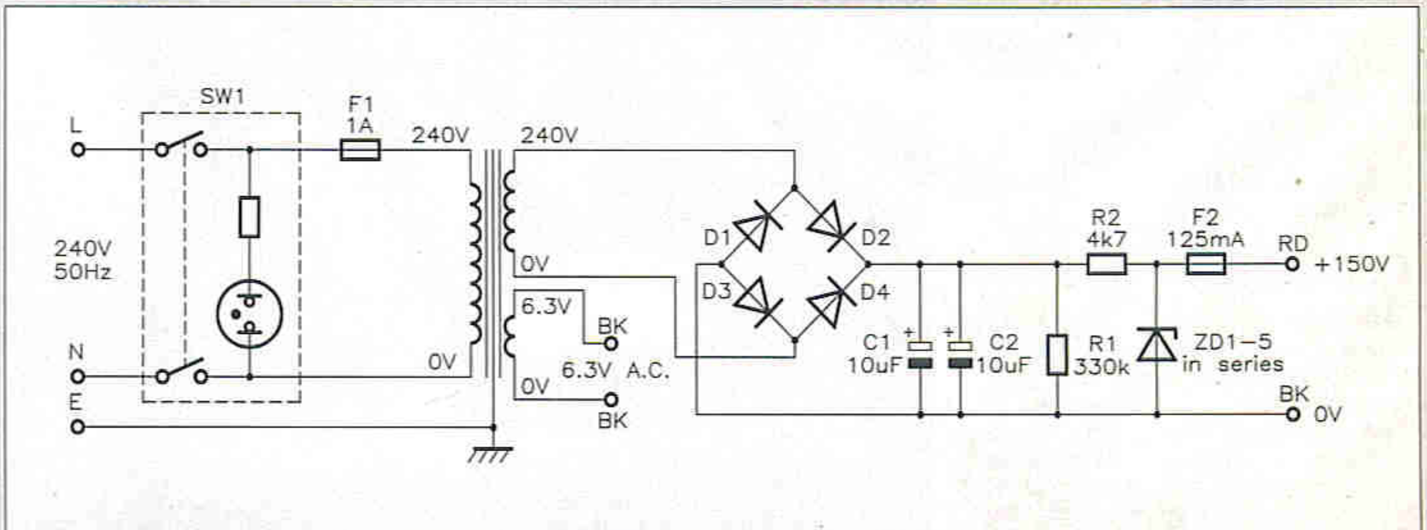


Figure 5. Circuit diagram for a simple stabilised valve power supply.

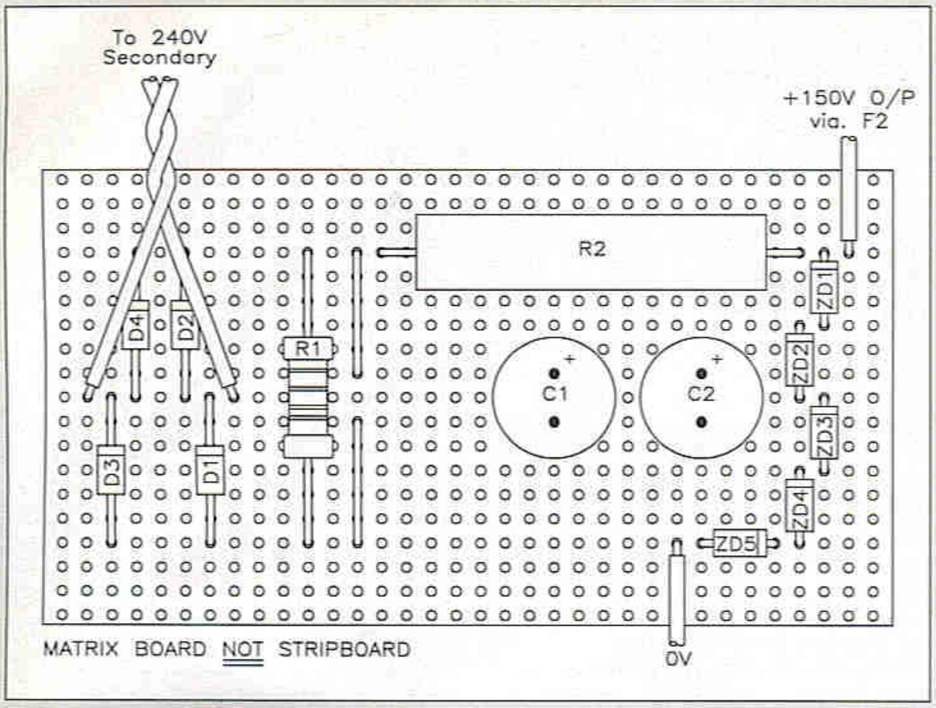


Figure 6. Layout diagram for the power supply circuit board. Component leads are hard wired on the underside of the matrix board.

known alternatively as the 12AT7, 12AU7 and 12AX7 respectively.

In the latter nomenclature the first part, the number 12, indicates the heater voltage (actually 12·6V AC at 0·15A), and this implies that a 12V supply is required to power the heaters. In fact this is not so since the heater is actually centre-tapped, so making it possible to parallel the two halves and energise them from a 6·3V AC supply at twice the current, namely 0·3A. (If powered in series the higher voltage option is actually 12·6V.) The pin connections for all these three types are the same and are shown in Figure 4. This makes it easy to swap the different types around in the same valve holder while experimenting with them.

Table 1 shows the principal data for the three types for comparison. This data includes typical anode and grid voltages, and a corresponding anode current value. The values of the three triode parameters, μ, r_a and g_m, are also given. This table indicates that the ECC81 is a medium gain valve with moderate values of r_a and quite high values of g_m; the ECC82 is a low gain valve, with low values for both of these parameters, but the ECC83 is a high gain valve, due to its having a very much higher value of r_a even though its g_m value is very low.

An Experimental Chassis

While it is possible to build valve circuits on PCBs, it is more convenient (and more interesting) to use a more traditional aluminium chassis with round cut-outs in the top for chassis mounted valve bases. A tag strip can be mounted inside (or a tag board on pillars) to allow circuits to be hooked up and modified without too much aggravation. A suitable chassis exists (XB56L) and the photographs show how this has been used for the purpose described. It is worth buying a ready made chassis like this as it saves the chore of bending raw sheet into shape, which is not easy to do neatly without specialised bending tools. The B9A bases (Order Code CR31J) used for the valves require a 22·5mm (⅞ in.) diameter hole to be cut in the chassis, which is easily done using a 'Q-Max' hole punch (Order Code BA68Y). This also requires an 8mm Allen key to turn it, but if this is lacking it is possible to use a suitably sized box spanner and tommy bar.

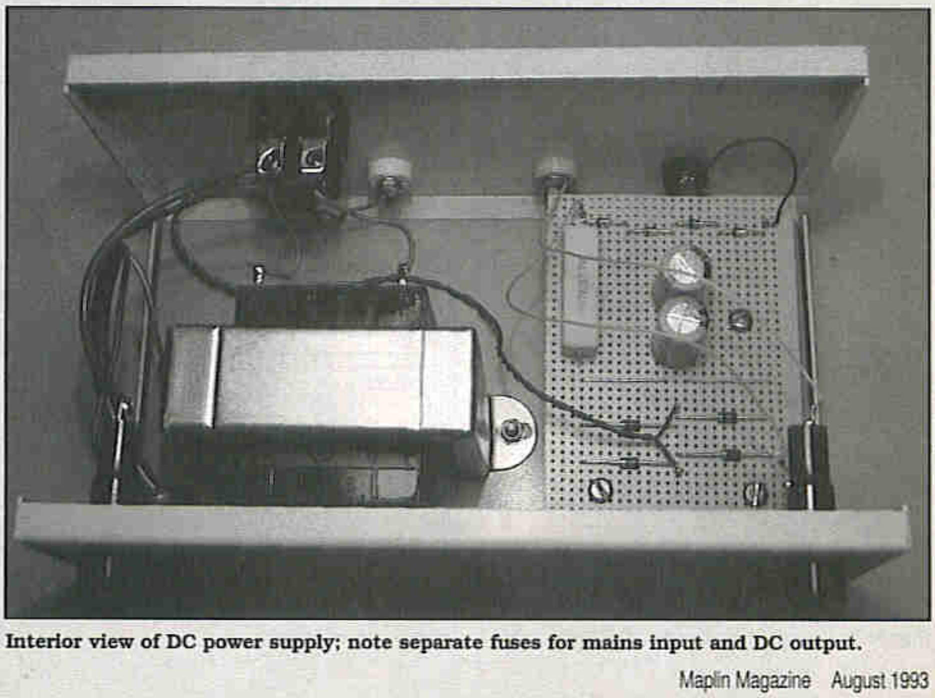
A tag strip on the inside of one long side allows for the mounting of components and as a 'jumping off point' for components or connections to the valve bases themselves. To take the power, both HT and LT, into the experimental chassis, a 'chocolate block' (screw terminal block) can be mounted at one end and the wiring run through to the interior of the chassis through a small hole, using a grommet for safety. The use of this chassis will be dealt with in more detail next month, but its introduction now will allow time for those interested to prepare one in advance.

A Valve Power Supply

Compared with solid state devices, valves need much higher voltages although at very much smaller currents. This reference is to the HT voltage, of course (HT = High Tension, as it was known). The heater supply will be 6·3V at, often, several amperes. This requires a specialised transformer, which must have both a low voltage, high current winding for the heater supply, as well as a high voltage secondary winding for the HT. Such a specialised transformer has been made available and can be found in the Maplin Catalogue (see Parts List for details). This has a 240V 100mA secondary and a 6·3V 1·5A secondary. Thus it is capable of supplying the heaters of five valves if each is rated at 6·3V 0·3A, as are the double-triodes described earlier.

The circuit diagram of the complete power supply is shown in Figure 5.

There are some fundamental problems in the design of valve-based equipment these days, due to the fact that much of the supporting hardware is simply no longer available. In the days when valve designs were current, appropriately rated capacitors were available in a wide range of values. For example, the reservoir capacitor for a valve power supply would have a value of about 16μF with a voltage rating of 350V DC or 450V DC. Moreover, such a component would be quite large physically. Today, in the Maplin Catalogue, there is only one component that gets anywhere near matching this specification and that is a 10μF 450V DC item. However, on the plus side (pardon the pun), it shows that technology has apparently advanced such that this current item is a fraction of the size of its forebears (which used to be tall, alu-



Interior view of DC power supply; note separate fuses for mains input and DC output.

The standard format of the Mullard type number as printed on *Mullard* and equivalent valves comprises two or more letters followed by a group of up to three figures, for example:

E CC 8 3

The type number is organised as follows:

E C C 8 3

- **3** — Second and subsequent digits refer to a particular design or development.
- **8** — First digit indicates type of plug base:
  - 2 B10B (10-pin)
  - 3 Octal (bonded-on 8-pin plastic base)
  - 4 B8A base
  - 5 B9D (magnoval, wire-ended, etc.)
  - 8 B9A (noval, 9-pin integral with glass envelope)
  - 9 B7G miniature 7-pin, glass
- **C** (second) — Class of second valve sharing envelope, if any (as below)
- **C** (first) — Class of primary valve:
  - A single diode
  - B double diode
  - C triode
  - D power output triode
  - E tetrode
  - F pentode
  - L power output tetrode or pentode
  - H hexode or heptode (hexode type)
  - K octode or heptode (octode type)
  - M tuning indicator ('magic eye')
  - Y half-wave rectifier
  - Z full-wave rectifier
- **E** — Heater or filament voltage or current:
  - A 4·0V
  - C 200mA
  - D 0·5 to 1·5V filament
  - E 6·3V heater
  - G 5·0V heater
  - K 2·0V
  - P 300mA heater
  - U 100mA heater

Therefore the ECC83 is a double triode with 6·3V heater and a B9A base, and the design is taken to 'version 3'. Other types can be deduced in this way, e.g., EC90, a single triode with B7G base and 6·3V heater; PCF806, a triode pentode with B9A base and a heater designed for a 300mA series heater chain, and was designed for use in mains powered TVs.

Table 2. Mullard Valve Device Types Nomenclature.

minium cans mounted vertically on top of the chassis with the aid of capacitor clips, their tags made accessible beneath via a round cut-out); it is also very cheap. Thus the design uses two of these in parallel in order to get a total capacitance of 20μF. The ripple rating of these capacitors is 280mA, which is more than adequate for this modest design.

The rectifier needs to have a voltage rating to match the 340V peak secondary voltage available and, for this purpose, a bridge has been constructed from four discrete 1N4004 rectifier diodes, which are conservatively rated for this purpose. So far, the design yields an unregulated DC voltage of 340V DC across the reservoir capacitor. It was thought that this was far too high for the experimental purpose for which it was intended, and so it was decided to add a simple shunt regulator using series-connected Zener diodes to perform two useful functions – dispose of the excess DC voltage and obtain a stabilised supply with a nominal output of 150V. It was decided to use four 36V Zener diodes, giving 144V at the full-load output current of 30mA. Although higher voltage Zeners are available, this would limit the possible output current further since all diodes in the available range have a power rating of only 1·3W. The design of the shunt regulator means using a series resistor capable of dropping some 200V at 36mA (the extra 6mA keeps the Zener diodes in conduction when full load current (30mA) is being drawn. The calculated power rating is about 7W and an appropriate wirewound resistor is used.

A case was chosen from the Maplin range, which had its own separate chassis. This is conveniently sized and allows the transformer and a small piece of matrix board (no copper strips) to be mounted in it and wired, prior to installing it in the case and connecting it up to the case-mounted components. Figure 6 shows the layout of the circuit on matrix board, and the photographs show the layout used for the front panel and rear panel components, the latter being separate fuses for the mains input (1A) and HT output (125mA). A neon double-pole rocker switch is used for power on/off, and 'touch proof' 4mm sockets are used for the LT and HT outputs. Use red and black sockets for the HT output and two black sockets for the LT output. The prototype used 4mm terminal posts, but it is strongly recommended that 4mm 'touch proof' sockets suggested are used for reasons of safety. It is also recommended that a high voltage warning label is applied to the unit. It is important that the case and transformer are properly earthed, this can be achieved by using a solder tag; secure it to one of the transformer mounting lugs by means of a nut, bolt and shakeproof washers. It is important that any varnish is removed from the mounting lug so that a sound electrical connection is made. The incoming mains cable earth wire should be soldered to the tag. All connections within the PSU should be suitably insulated. The HT output is floating but the 0V side of the regulated DC output can be earthed if required by strapping it to this terminal. Alternatively, a further front panel 4mm terminal post could be added (connected to the solder tag) to allow earthing of the HT supply at will. To illuminate the neon in the rocker switch, the mains wiring should be made as shown in Figure 7.

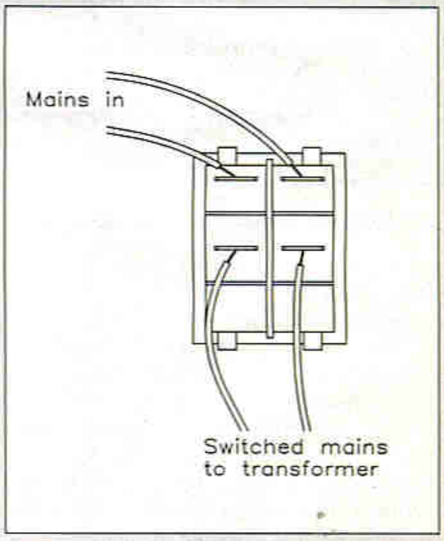


Figure 7. Wiring of the double-pole rocker switch. Connections should be insulated.

Output Ripple Voltage

The unit was tested when built, and loaded to full capacity on the HT side by drawing the full-load current of 30mA. The output voltage was measured as 144V and the ripple at this loading was less than 0·2V Pk-to-Pk. For the output voltage quoted this is less than 0·14%, so is not of any significance.

Note: The power supply is not designed for continuous use with the output unloaded.

In Part Three we shall use this power supply while designing, building and testing some triode amplifier circuits.

WARNING

It is imperative that every possible precaution is taken to prevent electric shock. High voltages on both primary and secondary ports of the PSU **can kill.** Do not operate the PSU with the case disassembled. High voltage is present on the HT output sockets. The capacitors in the PSU will hold a substantial charge for a period of time after switch off; this charge will also be present on the HT output sockets. Full construction details have not been given, therefore safe construction and use depends on the expertise of the constructor. If in doubt as to the correct way to proceed, seek advice of a suitably qualified person before continuing. Tests for earth continuity and insulation resistance should be made before powering up the unit.

The completed power supply unit (note prototype shows 4mm terminal posts, it is strongly recommended that 4mm 'touch proof' sockets are used instead for reasons of safety).

PARTS LIST FOR THE POWER SUPPLY UNIT

RESISTORS			
R1	330kΩ 1W Carbon Film	1	(C330K)
R2	4k7 10W Wirewound	1	(H4K7)
CAPACITORS			
C1, C2	10µF 450V PC Electrolytic	2	(JL11M)
SEMICONDUCTORS			
D1-D4	1N4004	4	(QL76H)
D5-D9	Zener Diode BZ61C30V 1·3W	4	(QF64V)
MISCELLANEOUS			
T1	Tr. 240V/100mA, 6·3V/1·5A	1	(XP27E)
	Fuseholder 20mm	2	(RX96E)
F1	Fuse 20mm 1A	1	(WR03D)
F2	Fuse 20mm 125mA	1	(UJ75S)
S1	Dual Rocker Switch Red Neon	1	(YR70M)
	Shrouded Socket Red	1	(CK66W)
	Shrouded Socket Black	3	(KC49D)
	Blue Case 226	2	(XY46A)
	Matrix Board 0·1in. 39 x 29 holes	1	(JP54J)
	Nuts, bolts etc.	As Req.	

Miscellaneous hardware items to finish:
grommet, pillars, screws, cable clamp, solder terminals.
The Maplin 'Get-You-Working' Service
is not available for this project.
The above items are not available as a kit.

CB Radio continued from page 24.

wall or roof-mounted CB aerial would give much improved results over the telescopic aerial fitted to the set.

When the set is to be used from its own internal batteries, rather than a cigarette lighter socket or home-base power unit, there are a number of very useful battery-saving features. Apart from reducing the power to 400mW (this reduces current consumption from 1·2A to 700mA), it is possible to turn the display off. This is useful because LED displays are power-hungry, and in the case of this CB transceiver, it is not really needed once the rig is set to the correct channel.

The rigs come complete with a protective case and, of course, an instruction manual. The manual gives all the operational details that are needed, and it even includes a circuit diagram for those who want to know a little more about the technicalities.

In Use

The sets performed well. They were very easy to use and even people in the family who were unfamiliar with radio equipment were able to use them without any trouble. This, of course, does reflect the nature of CB – transceivers can become a very useful form of communication for the family.

The distances which can be reached were found to be very respectable. With one transceiver located in the home (bear in mind the screening effect of the wiring, pipes and other metal objects), and the other just outside the car, distances of about three miles could be achieved quite comfortably. In fact, this test demonstrated one practical use of CB – the mobile set was used in a supermarket car park to check that the shopping list was correct!

Battery life was not found to be a major problem. In most cases the set was used in the 'low-power' position. Only over the longer distances did it need to be increased to full power. The channel indicator was turned off when not required. It is difficult to give an assessment of battery life because it depends very much on the way in which the set is used – whether any of the battery-saving features are used, and the time spent transmitting. However, a fully-charged set of Ni-Cd batteries should last for an hour or more, even when transmitting for much of the time. In the car, the cigarette lighter adaptor lead ensured that copies could still be made when the rechargeable batteries ran out.

CB-950 Summary

The sets performed well and, priced at £69.95⊞ each, the CB-950 (CM30H) provides a very convenient and cost-effective way for the casual user to use Citizens' Band. For the already-converted enthusiast, it is an ideal hand-held for those occasions when operation away from the base-station is envisaged.

CB – What Next?

It has been impossible to describe everything about CB in a short article. The best thing to do, if you're interested in its many benefits, is to find somebody who has a set (almost everybody knows someone who has had a set up at some time) and try it out for yourself, or to contact your friendly local CB retailer. In the meantime, '10-10' for now!

National CB Association

Due to the public's lack of awareness about CB, the National CB Association has recently been formed, embracing individual breakers, user groups, the Radiocommunications Agency, CB press and trade alike. Apart from introducing the public to the many benefits of CB, the NCBA sets out to represent the views of existing breakers, and to campaign on issues as diverse as licencing arrangements, deregulation, abuse and transmission modes. For further details, please write to the NCBA at the following address:

National CB Association,
P.O. Box 35,
Huntingdon,
Cambridgeshire PE17 3UQ.

Acknowledgments

The authors would like to thank Tony Hetherington, editor of 'Citizens' Band' magazine, for supplying photographs and information on NCBA.

NEW BOOKS

The Setmakers

by Keith Geddes in collaboration with Gordon Bussey

Of all the major developments this century, few have been as important as the tremendous expansion of radio and television throughout the world. What started as a 'cottage industry' has grown into an enormous worldwide industry, with tremendous opportunities, that exploits modern technology to the limits.

This very enjoyable book tells the British involvement of the development of radio and television, the colourful characters involved, who lead to the enormous growth in radio in the 30s and television in the 50s. This rapid growth was soon followed by an equally rapid fall, with the subsequent loss of famous household known manufacturing names. This change in fortunes left many in its wake and witnessed some hugely expensive casualties.

The book discusses the interdependence of setmakers and broadcasting, and in particular the very close liaison between the setmakers and the BBC. This liaison led to major technological developments in Britain, not least of all, television, which by 1937, Britain was showing to the world. The book is very much up to date, as it goes on to tell the story of the chaos surrounding the introduction of satellite TV in the UK.

The setmakers have now created a giant, profitable, industry that is now setting very high standards, but almost entirely owned by multinational companies, most of which are Japanese.

This profusely illustrated hardback book is highly recommended to anyone, young or old, who has an interest in radio or television, as it provides a detailed history of setmaking in the UK.
1991. 464 pages. 250 x 180mm, illustrated.

Order As WZ96E
(The Setmakers) **£14.95 NV**

Circuit Source Book 1

R. A. Penfold

This book has been written to help the reader create and experiment with their own electronic designs by combining, and using, the various standard building block circuits described in the book. To widen the possible use of some circuits, advice is given on how to alter the circuit parameters. Many simple projects can be built up from standard circuit blocks, and this book will be invaluable to those who are embarking on electronic project design. To the more experienced circuit designer, it will be a very useful reference source, for all the circuits are tried and tested, and are not just theoretical circuits. Example values are given, together with advice on how to alter the values of components so as to alter the circuit parameters e.g., to vary the value of a filter frequency, or amplifier gain etc. Explanation of circuit block functions and what they do, is not given in great detail, for the book is only intended for those who have some knowledge of electronics. However, no advanced mathematics is required in order to make use of this book.

The book is divided into three chapters with the first chapter covering filter circuits such as active filters, bandpass filters, tone controls, notch filters, state variable etc. Chapter two covers amplifiers, while chapter three covers miscellaneous circuits such as mixers, audio gates, rectifiers bargraphs and many more. Virtually all the circuits, and there are over 150, are concerned with some form of signal processing.

A very useful and handy book for all professionals, students and hobbyists to have in their book collection.
1992. 182 pages. 179 x 111mm, illustrated.

Order As WZ92A
(Circuit Source Book1) **£4.95 NV**

Guidance Notes to the 16th Edition Wiring Regulations

IEE

A series of guidance notes that have been issued by the Wiring Regulations Committee of the Institute of Electrical Engineers (IEE). These booklets are designed to enlarge upon and amplify some of the requirements in the 16th Edition of the IEE Wiring Regulations (WZ90X). The principle section numbers that each guide relates to, are shown in the left hand margin, with the relevant Regulations and Appendices noted in the right hand margin. The Notes may also include material that was included in earlier editions, but may not be in the 16th Edition. Additionally, the Guidance Notes contain references to other relevant information. A very useful range of booklets that all electricians in the electrical installation and maintenance industries should find extremely useful.

On Site Guide

This Guide is concerned with limited application of the Regulations in accordance with '1.1 Scope'. The booklet is split into 11 sections which includes: introduction, the service position, protection, bonding and earthing, isolation and switching, labelling, conventional final circuits, special locations giving rise to increased risk of electric shock, inspection and testing, guidance notes on initial testing of installations, operation of residual current operated devices. The appendices covers a variety of related topics, including; cable capacities of conduit and trunking, resistance of copper and aluminium conductors under fault conditions, current-carrying capacities and voltage drop for copper conductors etc.
1992. 115 pages. 216 x 155mm, illustrated.

Order As WZ97F
(IEE On Site Guide) **£9.00 NV**

Number 1 – Selection and Erection

Number One in the series is concerned with Part 5 – Selection and Erection. The eight sections cover the topics: selection and erection of equipment; protection against electric shock; external influences; installation of cables; the sizing of cables; other influences; installation of equipment. A comprehensive appendices covers related topics.
1992. 122 pages. 297 x 210mm, illustrated.

Order As WZ98G
(Selection & Erection) **£11.00 NV**

Number 2 – Isolation and Switching

Number Two in the series is concerned with Chapter 46 – Isolation and Switching. The six sections in this booklet cover: statutory requirements; the regulations for electrical installations, definitions and principles; the regulations for electrical installation; detailed requirements – isolation; the regulations for electrical installation, detailed requirements – switching off for mechanical maintenance; the regulations for electrical installation, detailed requirements – emergency switching and emergency stopping; the regulations for electrical installation, detailed requirements – fireman's switches.
1992. 30 pages. 297 x 210mm, illustrated.

Order As WZ99H
(Isolation & Switch) **£8.00 NV**

Number 3 – Inspection and Testing

Number Three in the series deals with Part 7 – Inspection and Testing. The booklet is divided into three parts: part one covers initial inspection, testing and verification; part two covers periodic inspection and testing; part three covers reference tests for initial and periodic testing, and includes polarity tests, earthing and residual current operated devices.
1992. 92 pages. 297 x 210mm, illustrated.

Order As AA00A
(Inspection & Testing) **£11.00 NV**

Number 4 – Protection Against Fire

Number Four in the series deals with Chapter 42 – Protection against thermal effects. The five sections cover the statutory requirements; wiring regulations; thermal effects; use of the installation and alterations and additions; and finally other related topics (safety services, fire alarms, emergency lighting, smoke detectors, lightning etc.).
1992. 23 pages. 297 x 210mm, illustrated.

Order As AA01B
(Protection Against Fire) **£8.00 NV**

Number 5 – Protection Against Electric Shock

Number Five in the series covers Chapter 41 – Protection against electric shock. The eight sections deal with wiring regulations, protection against direct contact; protection against indirect contact; protection by means of extra-low voltage; earthing; circuit protective conductors; bonding and special installations or locations.
1992. 85 pages. 297 x 210mm, illustrated.

Order As AA02C
(Protection Against Shck) **£11.00 NV**

Number 6 – Protection Against Overcurrent

Number Six in the series is concerned with Part 4 – Protection for Safety. The eight sections in this booklet deal with the regulations concerning protection against overcurrent; protection against overload; protection against fault current; determination of fault current; equations for the calculation of short-circuit currents; equations for the calculation of earth-fault current; selection of conductor size and finally a note on 'fault current withstand of flexible cords.'
1992. 87 pages. 297 x 210mm, illustrated.

Order As AA03D
(Protection Again O\Crrt) **£11.00 NV**

GENERAL-PURPOSE STROBOSCOPE MODULE

Text by
Nigel Skeels and
Mike Holmes

Note: Use of this unit in a place of public entertainment will require a local authority license.

KIT AVAILABLE (VE52G) PRICE £14.95

3 PROJECT RATING

FEATURES

- ★ Single PCB module
- ★ Simple construction
- ★ Uses high-speed flash tube

APPLICATIONS

- ★ Discotheque style lighting effects
- ★ Photographic special effects
- ★ The study of fast moving objects
- ★ Lightning effects for theatrical productions

Specification

Power supply:	220 to 250V AC
Average current consumption:	60mA @ 20Hz, 370mA peak
Flash frequency:	2 to 20Hz

Been to any 'raves' lately? If you have, the chances are that you would have seen a 'strobe light'. These are the rapidly flashing lights that make it look as though you can *actually* dance!

This Stroboscope has an adjustable flash rate from 2 to 20Hz, which ranges from a couple of flashes per second to a constant pulse of the kind most sought after by 'groovers' large and small.

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

WARNING: Flash rates in the range 4Hz to 17Hz may, in some circumstances, cause epileptic seizure in people who suffer from photo sensitive epilepsy.

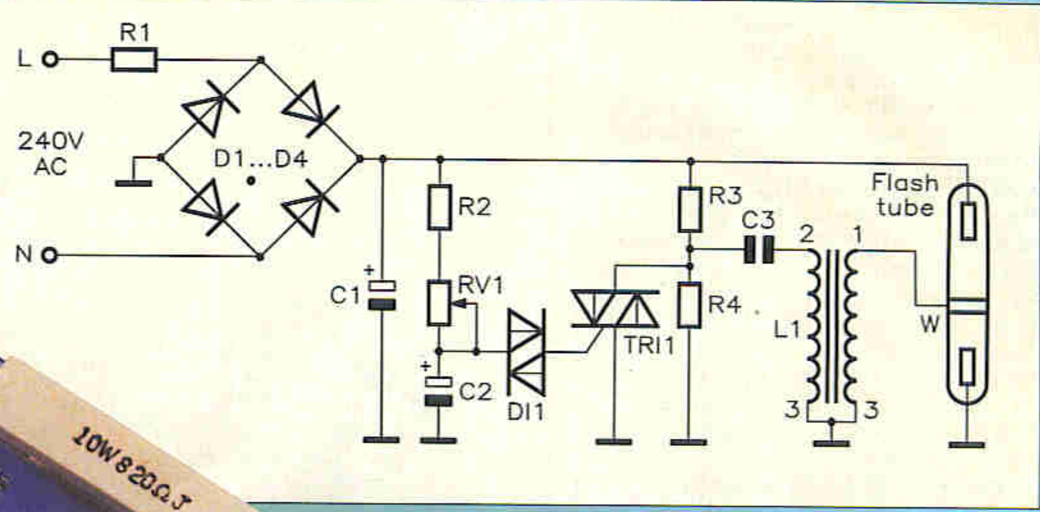
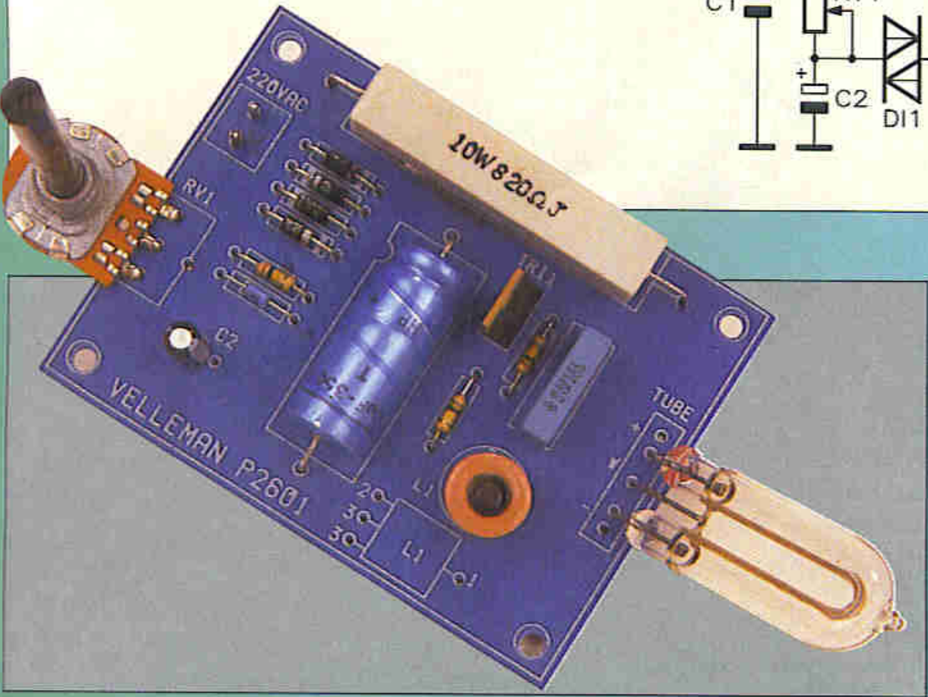


Figure 1. Circuit diagram.



The assembled strobe PCB.

But before we get carried away with images of flashing lights, loud music and incomprehensible conversation, we must remember that the humble strobe light has other uses. For example, how many of you have seen the actual shape of a falling drop of water? It usually travels too fast to be seen by the naked eye, but, with the aid of a strobe light, a falling drop of water becomes 'visible'. This is because it appears to be stationary every time the strobe flashes.

The strobe can also be used to imitate the bright flashes of lightning, which would be useful for theatrical productions. More practical applications include the observation of the angular positions of revolving machine parts, the commonest known being the process of determining the crankshaft position of an engine for adjusting ignition timing. (It is possible that this module might be pressed into service for such a function if powered from a suitable HT inverter and provided with the necessary input triggering.)

Circuit Description

The circuit is shown in Figure 1 and is, as it stands, very simple in operation. Power is derived from the 240V AC mains supply, and R1 is used to limit the current into the circuit, while D1 to D4 rectify the mains supply into DC, after which it is stored by smoothing capacitor C1. In its basic form the module has an on-board triggering system variable with time, where R1 and RV1 provide the varying time constant to charge C2.

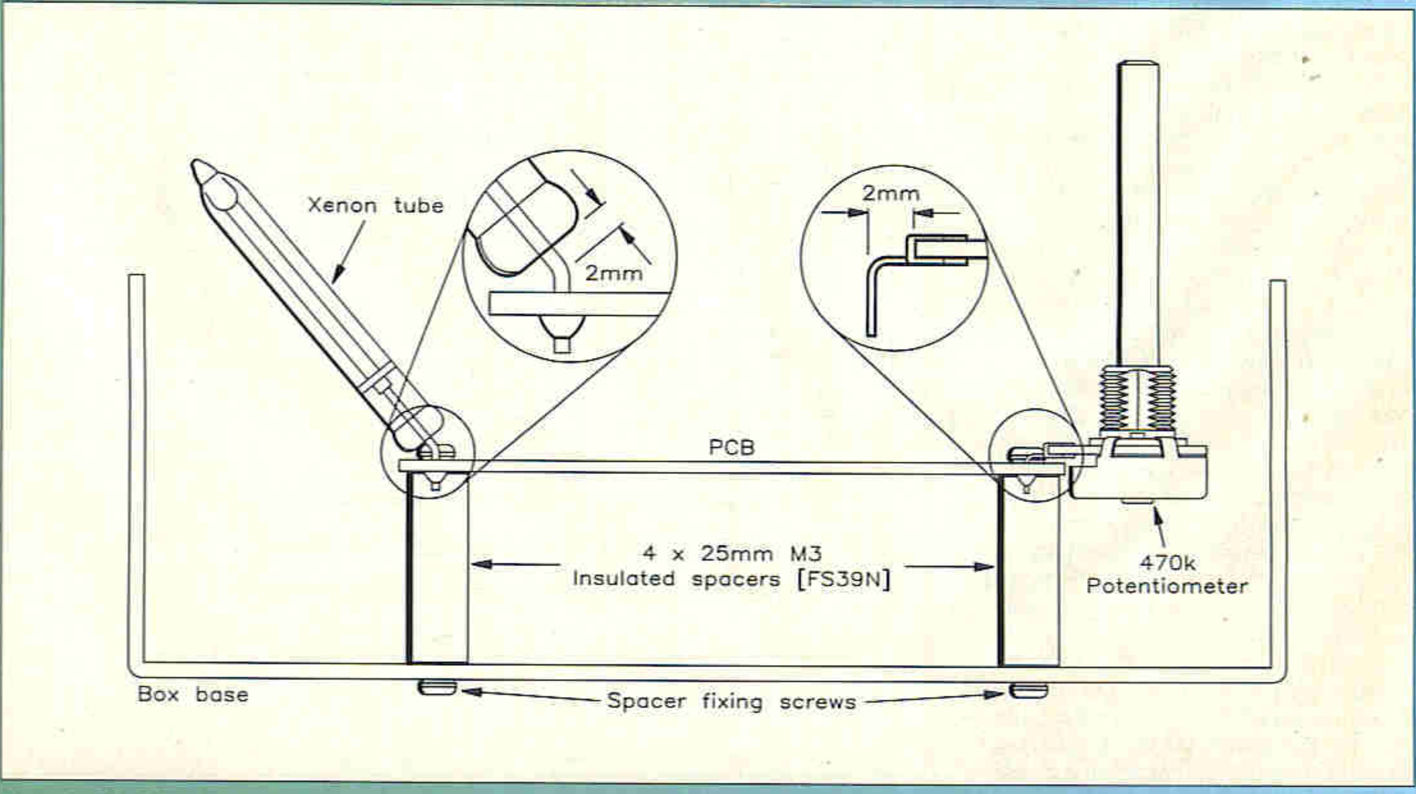


Figure 2. Orientating the strobe tube and VR1, and mounting in the box.

TRI1 is a 'triac', an AC form of an SCR (Silicon Controlled Rectifier). DI1 is a 'diac', a sort of dual-polarity Zener diode which has equal threshold voltage levels in either direction. When C2 has charged to a voltage level sufficiently high enough to exceed the threshold of DI1, DI1 conducts quickly, discharging C2 into the triggering gate of TRI1 and firing it, which in turn short circuits R4. This causes the charge on C3, originally derived via R3 and the primary of L1, to appear as a pulse across L1 primary (this is a capacitive discharge technique), which is then transformed up to a very high voltage at the secondary of L2. This is necessary in order to ionise the gas inside the flash tube locally at 'W'.

The ionised gas then becomes conductive allowing current from the charge stored in C1 to flow from the anode to the cathode of the tube at a much lower voltage. The gas gives out a bright, white light. C1 then becomes discharged with the collapsing of the supply level, until the light output from the flash tube extinguishes and TRI1 turns off. The circuit will then be restored to its original state, and, once the supply has recharged, is ready to begin another cycle.

The maximum rate at which the strobe can be triggered is mainly determined by the time taken for the supply to regenerate the necessary voltage level across C1. Since the power supply input is full-wave rectified, then for a frequency of 50Hz, giving 100Hz peaks, the theoretical maximum flash rate will be unable to exceed 100Hz, or less. The purpose of R1 is to allow C1 to discharge while the input remains at 240V AC.

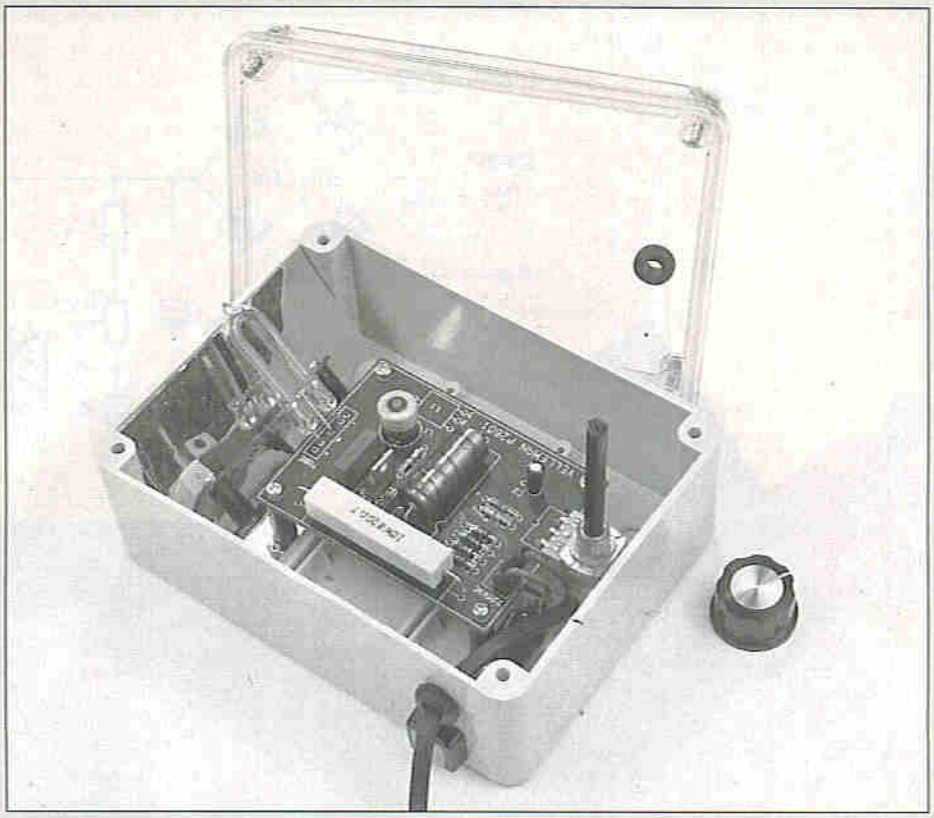
Construction

Construction is quite straightforward since all components are mounted on one PCB. However, since the module is initially intended to be mains powered it is necessary to install it in a suitable insulated enclosure.

To begin with, however, mount all the smaller components onto the PCB by fitting R2, R3, and R4, followed by diodes D1 to D4. Do make sure to orientate these correctly where the silver band at one end of the body of each aligns with the equivalent stripe on the PCB legend. Also fit two PCB pins at the mains input marked '220V AC' (see Optional Parts List).

Fit and solder the diac DI1; it can be installed either way round. After this some of the larger components can be installed, namely C2, C3 and C1, followed by L1. Note that the design of this item may vary, and depending on its pin displacement may fit the three-way layout in the round legend marked 'L1', or the four-way layout identified by the rectangular legend. Only one trigger transformer needs to be fitted; the other space remains empty.

Fit the long, ceramic encapsulated resistor R1, supported by its wire leads 3 to 4mm above the top surface of the PCB. This is to ensure that heat from this element does not damage the surface of the board when in use.



Final assembly of the strobe.

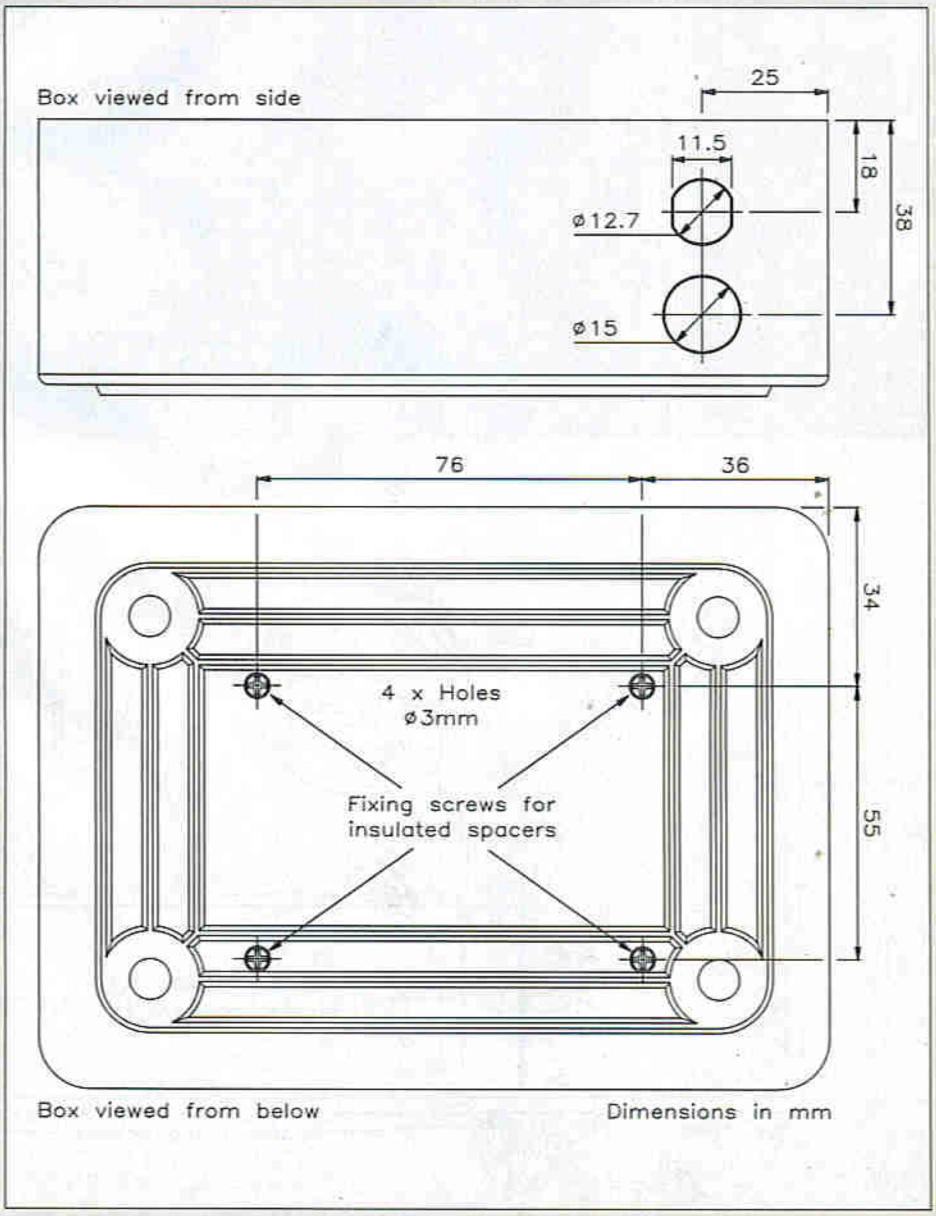


Figure 3. Box drilling details.

Fit TRI1, which has a three-pin plastic package with heatsink tab. The device is mounted vertically with the heatsink tab facing the side of the legend identified by double white lines. Lead length above the PCB should be approximately 5mm. The device does not require a heatsink to be fitted.

Next the flash tube can be fitted into the PCB, but first *carefully* bend its three leads to approximately 45° prior to insertion. The red spot at one side of the tube must be inserted into the hole marked '+' ('+' and '-' holes are duplicated, whichever ones can be used depends on the dimensions of the strobe tube supplied). The tube should lean out over the edge of the board to an angle of 45°, as shown in Figure 2.

Also shown in Figure 2 are the modifications to the leads of RV1, which should be bent to an angle of 90° as shown, and the whole component fitted into the PCB at the end opposite the strobe tube.

This completes assembly of the PCB, which should then be cleaned with a suitable cleaning solvent, and examined for bad solder joints, solder bridges, etc. which should be rectified.

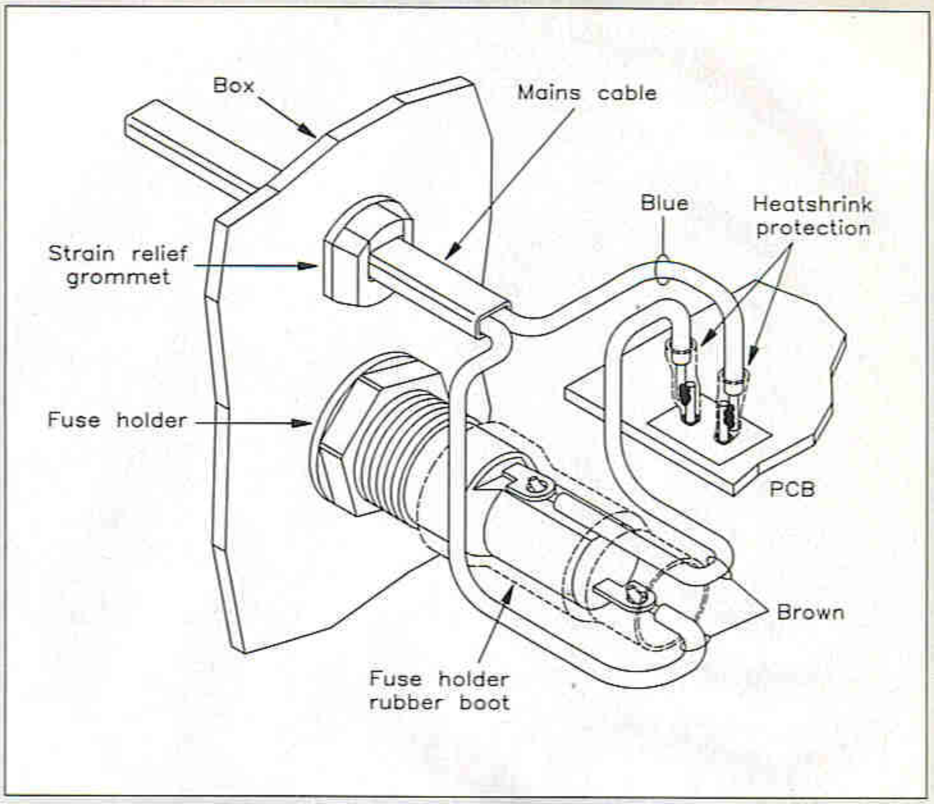


Figure 5. Mounting the fuseholder and strain relief grommet.

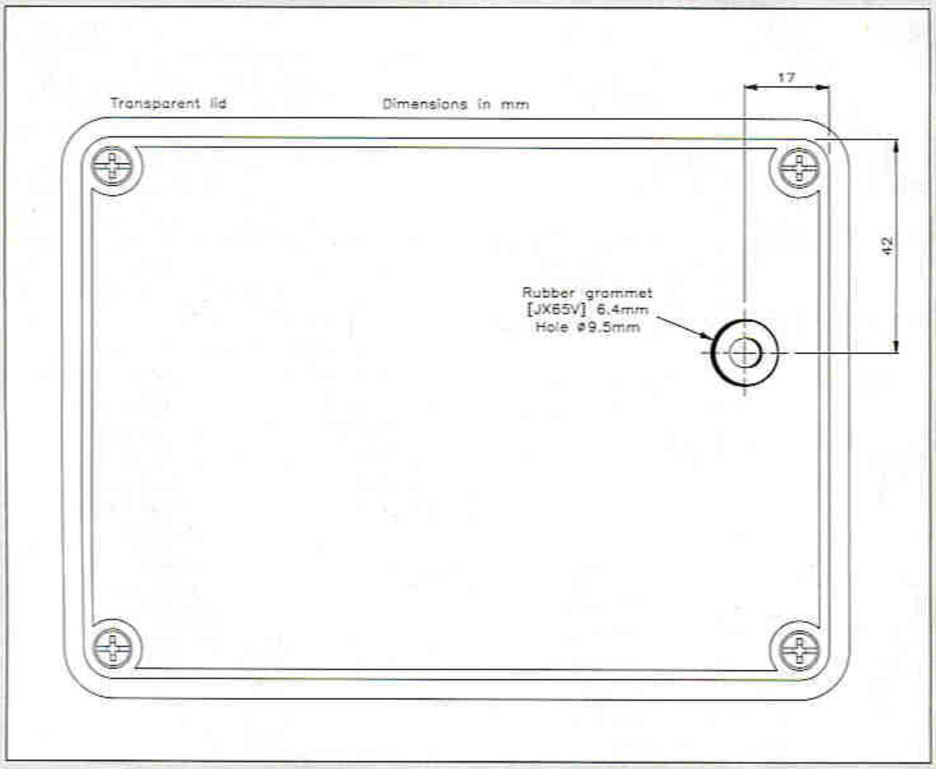
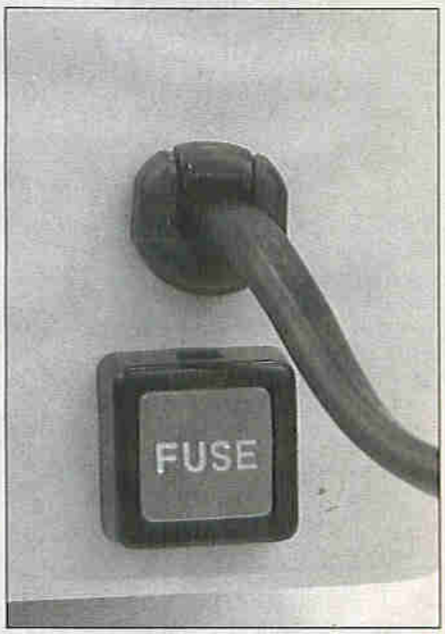


Figure 4. Drilling the lid for the grommet.



Strain relief grommet and fuse.

Encasing the Module

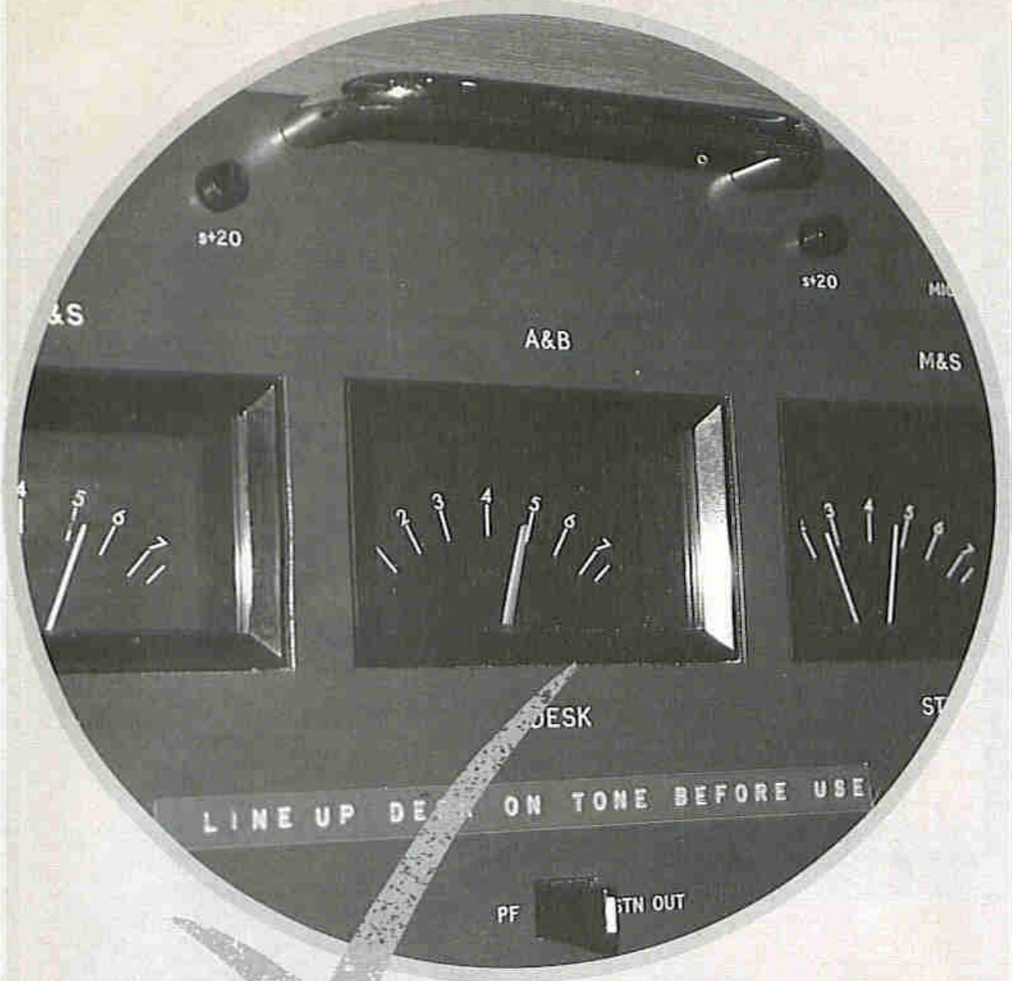
Due to the fact that mains voltages are involved, the whole assembly *must be fitted into a suitable enclosure.* A water--proof plastic box with transparent lid (Order Code YM93B) is ideal and drilling details are shown in Figure 3. The lid is drilled for a rubber grommet as in Figure 4, through which the spindle of VR1 can protrude.

It is also *very important* to protect the device with a suitable fuse. For this purpose a panel mounting click catch style fuseholder (Order Code FA39N) is ideal and easily accommodated in the box, and this should be used with a 1¼in., 100mA quickblow fuse (Order Code WR08J), and should be insulated with a PVC fuseholder boot (Order Code FT35Q). A metre or two of 2-core 3A mains cable (Order Code XR47B) is ideal for supplying power, the entry of this is secured with a strain relief grommet F31 (Order Code LR47B), fitted along with the fuseholder as Figure 5. The PCB pins should be insulated with CP32 heat shrink sleeving (Order Code BF88V), and the PCB sprayed with acrylic conformal coating (Order Code YT50E) to prevent electrical discharges (arcing) occuring across the surface of the PCB..

Using the Module

Beware high voltages! When using the strobe it is important to remember that *mains voltage* is present on the PCB, and also that the trigger pin of the strobe tube can have pulses (abeit of very short duration) of up to 3kV. We therefore strongly advise mounting the device on M3 x 25mm insulated spacers (Order Code FS39N), see Figure 2,
in the optional box described above, which is made from a tough thermo-plastic. The transparent polycarbonate lid allows the whole assembly including the xenon flash tube to be mounted inside, thus protecting it from physical impact and electrically isolating it from the outside world, yet allowing normal light output.

Continued on page 52.



A GUIDE TO PROFESSIONAL AUDIO PART FIVE

by T. A. Wilkinson

Stereo Techniques

Conventional 'XY' stereo recording is based around the common practice of using two closely matched microphones of the same type. The mics usually have a cardioid response, and are mounted as close together as possible, as a 'coincident', or 'incident', pair on a 'stereo bar', or T bar', that is attached to a microphone stand, as shown in Photo 3.

Ideally, the stand will be raised 2m to 3m above floor level and placed a similar distance from the sound source. The microphone capsules are inclined towards each other at an angle of between 60° and 130°, and one should be set slightly higher than the other in order that neither mic shadows the sound from the other. The angle of incidence is dependent upon the width of the sound source, and as a rule of thumb, it could be said that the wider the sound source the larger the angle of incident, and vice versa.

In this set up, the two AKG C451 condenser units are placed very close together, so the audio signal from the sound source reaches both microphones at almost the same time. As a result, there will be no appreciable phase difference problems.

The output of the two microphones may be processed by a mixing desk, or routed direct to a tape recorder. If using a mixing desk, the microphones would obviously occupy two channels, and it is usual to 'pan' one of the channels hard left and the other hard right. However, there is nothing wrong with experimenting with the pan-pot controls a little. Whilst this will not alter the image width, it will have some effect on the subjective or perceived image. Of course, if both channels were panned centrally, a composite mono type (L+R) image would occur.

If you were using a stereo pair to cover a very wide image, such as a large choir, the angle of incidence would need to be large, and probably around 120°. It is possible that this may give the effect of a very wide stereo image, or spread, with little or no information (effectively a 'hole') in the centre. To overcome this problem a third microphone could be added, which should be placed facing the centre of the image, and somewhat lower than the stereo pair. Its output would be panned centrally on the mixing desk, and balanced so as to reinforce the central image without being overpowering. It is largely a matter of adjustment and re-adjustment to obtain a satisfactory result.

In addition to using two totally separate microphones for stereo work, there are available special stereo microphones from various manufacturers. The concept is to house two closely matched, independent, transducers in a single body, with either an adjustable angle of incidence, or fixed, normally at 90°. The adjustment, if available, is usually achieved by rotating one or more sections of the microphone body that contain the capsules, thus allowing the angle of incidence to be adjusted over a wide range.

To facilitate the setting up of the capsules, some manufacturers include a small LED in the rotating sections (powered by the phantom supply) which gives an instant visual indication of the angle of incidence and is particularly useful in darkened auditoriums.

Other goodies available on serious stereo units include 'MS' matrices (more on this later), 'LF' filters, gain attenuators (pads) and switchable polar responses.

Often the adjustment of polar response can be done remotely (by varying the relative polarising voltages on the condenser capsule elements) using a dedicated microphone control unit, such as that supplied with the AKG C422 stereo microphone as shown in Photo 4.

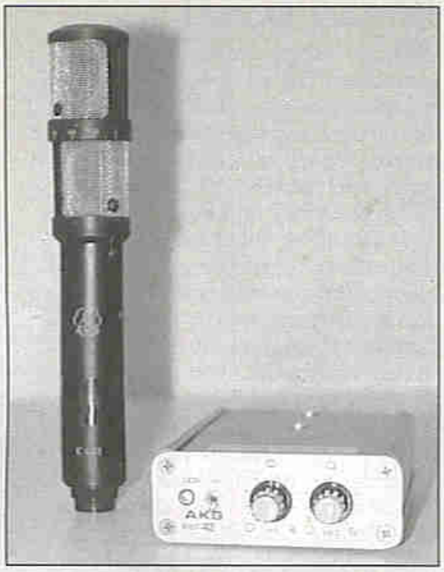
This particular unit (although now superseded) included options on the remote control unit for selecting cardioid, omni and figure of eight responses. The two upper sections of the body can rotate independently of each other to set the required angle of incidence. This is a superb unit capable of very accurate results, but at a cost, cheap at twice the price!

MS Stereo

Although conventional 'XY' stereo techniques produce good results, there is an alternative method of using two microphones, which can produce very flexible and quite astounding stereo images.

'MS' (Middle and Side or Sum and Difference) techniques have a long history in the audio industry, but recent years have seen a return to a higher level of interest in this less well-known stereo technique.

'MS' techniques have several advantages over conventional 'XY' methods. The most user obvious is the fact that the microphone signals can be manipulated in such a way as to allow



AKG C422 Stereo microphone and control unit.

Comparison of XY and MS Stereo Methods

XY Stereo Advantages

Simple and well documented.

The left and right outputs of the stereo pair are directly available. Reasonable results are possible with the most basic of microphones.

Disadvantages

True mono signals are not possible because neither mic points directly forward to the sound source, and both suffer off-axis frequency response coloration to direct sound source.

Angle of recording (physical positioning), and thus image width must be set at the time of recording.

MS Stereo Advantages

True mono signals are possible, as with no S signal added to the mix, only the M mic, which points forward to the sound source, produces an output.

Stereo image width can be adjusted after the recording by simply varying the amount of S signal added to the mix.

Because the stereo image is made up of two separate elements (M and S), it is possible to feed these down a pair of long wires such as telephone lines, without encountering serious phase related problems as may be the case with 'XY' signals sent down the same wires.

Disadvantages

Direct left and right signals are not available without some means of correctly combing M and S signals.

Even the most basic of 'figure of eight' mics are not cheap.

user control of the spread or width of stereo image. This minimises the time spent mechanically setting and adjusting microphone angles. A comparison of advantages, and disadvantages, of 'XY' and 'MS' methods is shown above right.

The term MS is used to describe the way in which the signals from the two microphones are combined, and how the resulting stereo image is derived by manipulating the 'sum' and the 'difference' of the two microphone signals.

Unlike conventional 'XY' stereo methods, 'MS' does not require the use of two closely matched microphones of the same type. Instead two microphones are employed with dissimilar polar response characteristics. Indeed, two units from different manufacturers can be used. The usual practice is to use one microphone, with a cardioid response (but any other polar type can be used), to produce the M (Sum or mono) signal and a microphone with a 'figure of eight' response to produce the S (Difference or stereo information) signal.

These two units would be mounted one above the other, with the cardioid facing forward to the sound source, and the figure of eight sideways on and with its 90° 'null' point facing forward to the sound source. It should be firmly understood that the outputs of the two microphones cannot be used directly to produce a useful stereo image. Indeed, if our two signals were recorded onto the left and right tracks of a tape recorder, and subsequently replayed directly from the tape recorders outputs, they would produce a rather strange and useless form of stereo. Thus it is necessary to use some method of combining the signals, by adding and subtracting, to produce useful stereo information. This adding and subtracting process is often referred to as 'MS matrixing' or 'MS coding/decoding'. The basic concept of 'MS' technique is illustrated in Figure 5. Here the output of the cardioid mic producing the 'M' signal is added in phase to the 'S' output of the figure of eight mic, this addition of 'M+S' produces the left part of the stereo signal.

Additionally, the 'M' signal is added to the 180° phase shifted 'S' signal and the resulting 'M-S' produces the right part of the stereo output. The combination, or matrixing, of the microphone signals can be done in various ways, and at many stages of the recording and reproduction process. For example, it is not uncommon to find stereo microphones which include a built-in matrix system, thus providing direct 'MS' outputs in addition to matrixed 'XY' (left/right) outputs. Using this type of microphone means no other hardware is required to use 'MS' techniques and it is a very simple operation to switch between 'XY' and 'MS' output modes.

The 'MS' outputs of the microphone can be fed directly to the left and right inputs of a tape recorder for recombination and returned to stereo, by a mixer or decoder unit, at a later date. This

AKG C451s used as a stereo coincident pair.

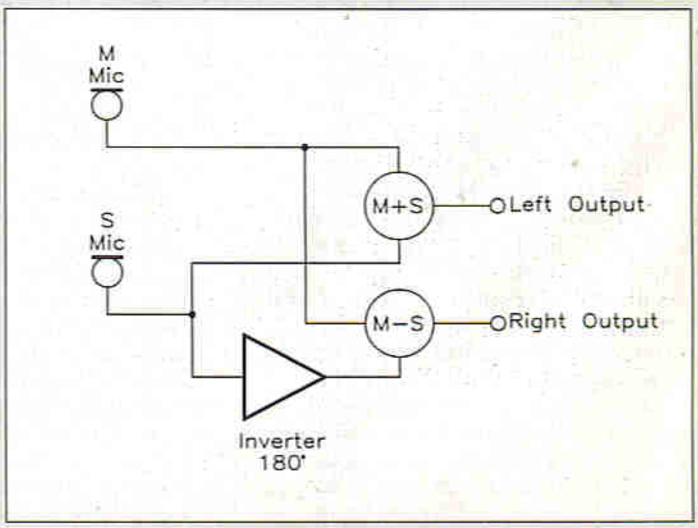


Figure 5. 'MS' concept diagram.

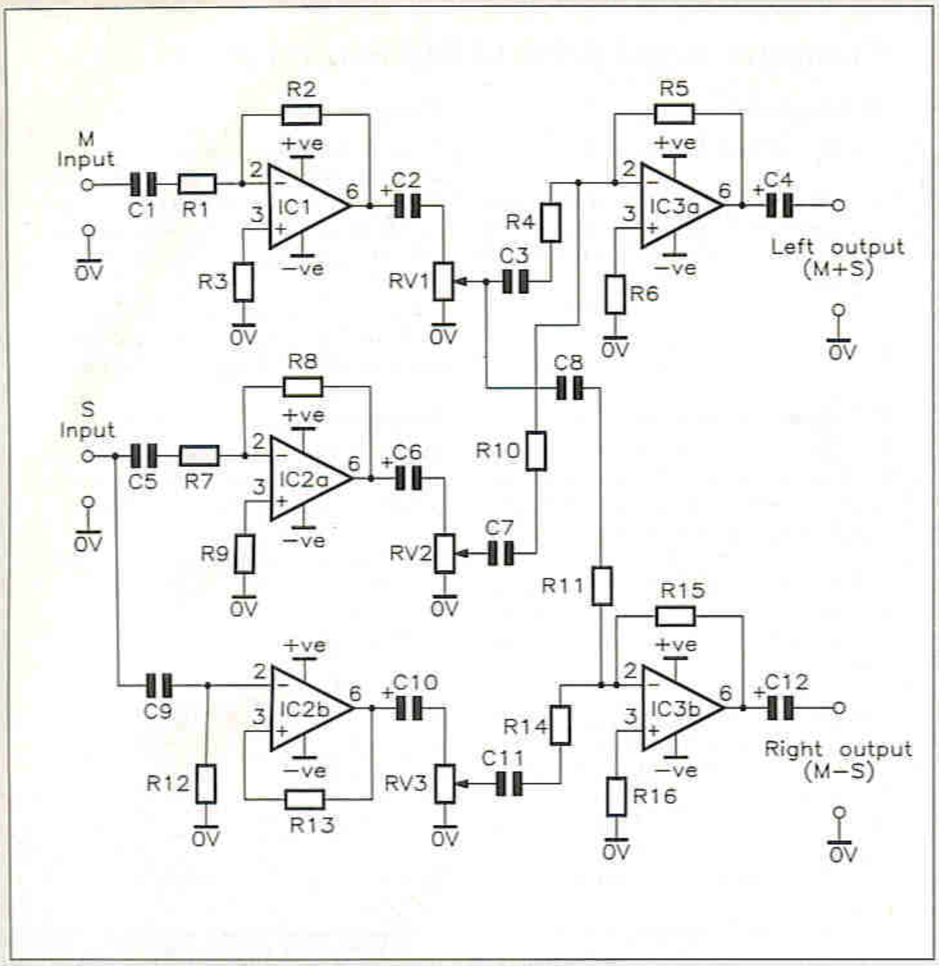


Figure 6. Circuit diagram of 'MS' decoder.

allows the stereo image to be adjusted after the event, and takes away some of the pressure in tricky recording situations. However, it may be necessary to monitor the microphone outputs to give some idea of how the end result will sound, and therefore some sort of 'MS' decoding unit needs to be used whilst the recording is in progress.

Figure 6 expands the basic concept to give a working circuit diagram of an 'MS' decoder arrangement. It is intended for decoding material that has previously been, or is being recorded, as 'MS' stereo. The decoder unit is intended for insertion between the left and right outputs of a tape recorder, and the inputs of a mixer, or amplifier, for re-mixing, or monitoring purposes.

The 'M' signal is fed to unity gain amplifier IC1 and then sent via level control RV1 to the mix bus of the left output amplifier. Also, a buffered feed of is sent, via R11, to the mix bus of the right output amplifier.

Now the 'S' microphone signal is split and fed to the inputs of IC2a and IC2b, the outputs of these ICs (which are opposite in phase) are fed, via dual pot RV2, to the mix buses of the left and right output amps respectively. The final output of IC3a is composed of 'M+S', and is therefore the left output, whilst the output of IC3b comprises of 'M-S' and is thus the right output.

Varying the level control of the 'M' amplifier, RV1, adjusts the overall level of the output signal. However, adjusting the 'S' level controls (which must be operated together to give exactly the same amount of gain, and is therefore a dual pot) actually alters the width, or spread, of the stereo image.

It should be obvious that with the 'S' gain controls at minimum, i.e. no 'S' signal, the output will be a pure true mono signal. Increasing the 'S' gain controls gives difference information, and thus produces a variable stereo output.

The circuit of Figure 6 is intended to operate with line level signals (nominally 0dbu), and is presented here to directly interface with unbalanced inputs, and outputs, normally found on semi-professional equipment. It is quite straightforward to balance the inputs, and outputs, of the circuit in order to interface with balanced equipment, and the methods described in Part One of this series should be implemented if required.

Circuit Detail

With the values shown in the component list, each signal input has an impedance of at least 20kΩ, and should not present any significant load to its source. All op amps must be low noise types, such as NE5534 for IC1 and NE5532 for IC2 and IC3.

It should be noted that some components have been given arbitrary values, and so some experimentation and adjustment may be required to achieve optimum results from the circuit, but that is what electronics is all about isn't it?

As shown, the circuit is intended for dual supply rail operation using two 9V batteries, as detailed in Figure 7. As the circuit draws less than 30mA, two alkaline cells would provide a considerable operating period. If a mains power supply is to be used, then it must be fully smoothed and regulated, with ample supply line decoupling in order to maintain the benefits of using decent low noise op amps.

The circuit could be modified, in the usual way, to run with a single supply rail, and if so required, then I would suggest a minimum supply voltage of +15V.

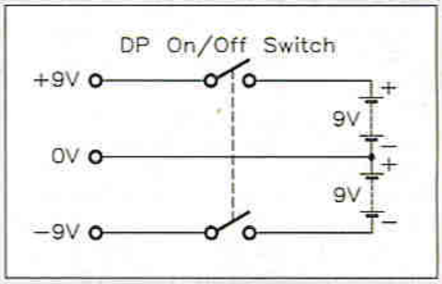


Figure 7. Dual rail battery supply using alkaline PP3 cells.

MS DECODER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film			
R1,2,3,7,8,9	22k	6	(M22K)
R4,5,10,11,14,15	100k	6	(M100K)
R6,12,13,16	47k	4	(M47K)
VR1	47k Pot Log	1	(FW24B)
VR2	47k Dual Log Pot	1	(FX11M)
CAPACITORS			
C1,5,9	1µF Polyester	3	(BX82D)
C2,4,6,10,12	10µF 35V Minelect	5	(JL05F)
C3,7,8,11	470nF Polyester	4	(BX80B)
SEMICONDUCTORS			
IC1	NE5534A	1	(YY68Y)
IC2,3	NE5532	2	(UH35Q)

MS and Mixing Desks

Using a mixing desk with balanced inputs, the two microphone signals can be routed, unchanged, in the normal way to their respective inputs. The necessary matrixing process, and subsequent mixing to stereo, being carried out in the mixer itself, prior to being fed to a tape recorder, or broadcasting link. The two microphone signals will occupy three channels on a mixer. The cardioid output being fed to one channel with its pan-pot control set centrally and the figure of eight output will be split, and fed in-phase to one of the remaining two channels and 180° out-of-phase to the third channel. The latter two channels would have their pan-pots shifted hard left and hard right respectively. In addition, the fader controls of these two channels should be 'ganged', (i.e. must be operated together) to give exactly the same amount of gain.

If the mixer has balanced inputs, it is quite easy to produce the required 180° of phase shift by reversing the relative phase at the microphone input connector. This can be done by taking a parallel feed of the 'S' mic cable, as shown in Figure 8. The necessary phase reversal is achieved by simply reversing the 'hot' and 'cold' legs (pins 2, 3) of the balanced pair at the input XLR connectors of channels 2 and 3.

If the mixer used does not have balanced inputs, it will be necessary to invert the input to channel 3 in some way – although some mixers have a phase invert button to do this for you.

Operation

With the phase reversal process complete, the manipulation of the audio signals is carried out using the mixer fader controls. The fader which carries the 'M' signal, from the cardioid, has control of the overall level of the final output, and so opening up this fader will give an overall increase in level, and vice versa.

The two other faders, when operated together, have the effect of actually changing the size or width of the stereo image. Increasing the gain, by opening up these faders, widens the stereo image, whilst doing the opposite reduces the width. In use, there are practical limits to this, and too much gain would give a very wide image and unnatural sounding stereo, conversely, too little gain would result in the greater level of the single cardioid giving a predominantly mono signal with little difference information.

Experience has shown that allowing the 'S' signal to be 4dB to 8dB below that of the 'M' signal gives a well detailed stereo image, but the problem here is that of how to monitor this accurately.

In Part One, we looked at PPM meters. One of the types discussed briefly was the twin pointer M+S meter, and it is this unit which can be used as an effective tool for the purpose of inspecting stereo images. The unit has inputs for the left (A) and right (B) elements of a stereo signal. Internal electronics take care of the summation and differentiation of the two signals and driving the meter movements, one pointer displays the sum (A+B) and the other pointer displays the difference (A-B) of the two inputs, thus due to the simple PPM scale, (one division = 4dB), it is very easy to establish and control a 4dB to 8dB level difference between the 'M and S' signals.

Like many other aspects of microphone technique, experimentation is the key, and practice makes (almost) perfect. If used with care, the 'M+S' technique can produce astounding results. The sheer opulence of having a fingertip control of the stereo image should persuade you that this system is worthy of anybody's time and investigation, facilities of course, permitting.

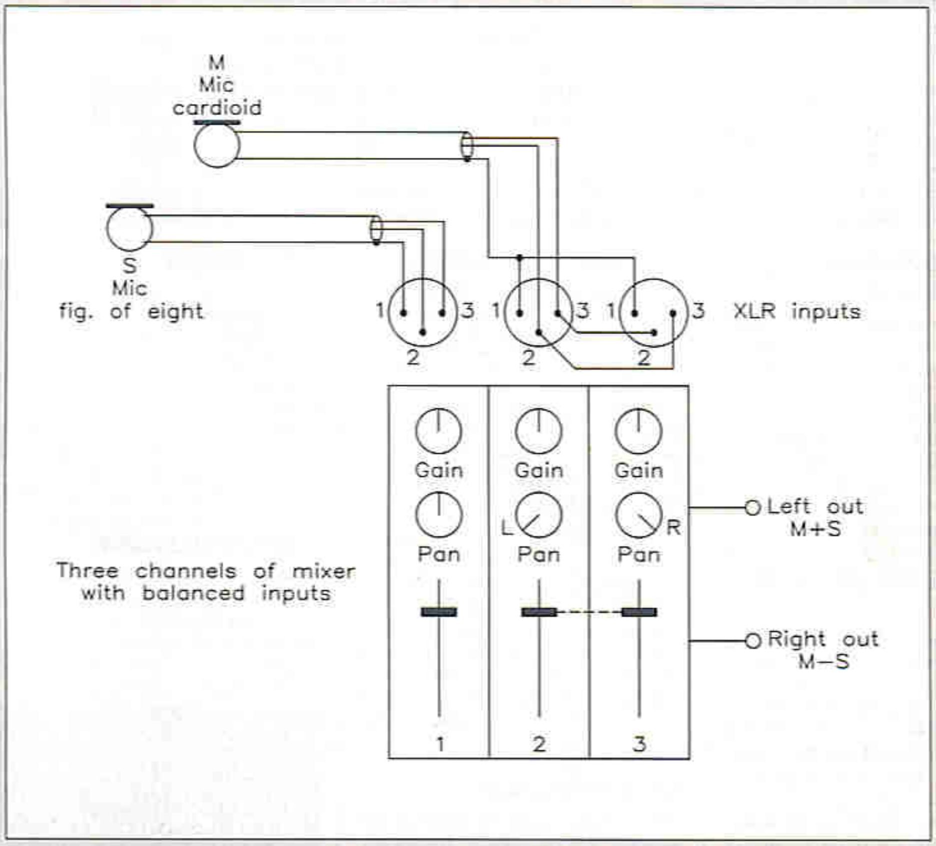


Figure 8. Using 'MS' with a mixer – the 'S' signal is split and fed to inputs 2 and 3, with phase reversal at the input to channel 3.

Multi-Microphone Set Ups

There are situations such as large scale recording and broadcasting work which demand the use of dozens of microphones to secure a satisfactory result. An orchestra would require maybe 30 to 40 microphones in order to mike-up each instrument – the drum kit alone would gobble up at least seven (kick drum, snare, 2 x toms, hi-hat, 2 x overhead)! Of course, this does not mean that a multitrack tape recorder is necessary to record them on, indeed some situations of this kind are often mixed down directly to stereo and recorded on only two channels of a tape recorder or transmitted as a live stereo broadcast.

Certainly what is required is a sufficient number of channels on a mixing desk to handle all the microphones separately, thus permitting a great deal of control and balance of the overall sound.

'Miking up' a drum kit.

The governing factor when choosing microphones in large set-ups is not so much based on ideals, but more often a case of what is available. If funds were unlimited, then there would be no problem, but this is usually not the case, and a sound balance engineer would have to choose what to use where, based on experience.

He may have at his disposal a range of units to suit particular instruments, and if so, it is likely that these would be deployed first and the remaining instruments miked-up with whatever is left over! What is desirable is to try and be consistent with specific groups of instruments, and use the same type of microphone for each of the strings, brass, woodwind etc.

Once the deployment of microphones has been finalised, the placing, wiring, checking and fine tuning of these can be very time consuming, and occasionally laborious, but is very necessary, and will save problems arising during the performance.

Fortunately, most musicians are more than used to the distractions of microphone adjustment during rehearsals, and turn a deaf ear to the often distorted, and unintelligible, instructions emanating from the loudspeaker of the on stage walkie-talkie!

Photo 5 shows a forest of microphones mounted on stands, waiting to be placed during the recording (for subsequent re-broadcast) of a 'big band', with a live audience in attendance. The venue was a very large sports hall at a leisure centre, this presented massive problems with serious natural echo and long reverberation times. It was necessary to mike-up each instrument, individually, and as closely as possible, in order to exclude much of the reflected sound in an effort to get a clean(ish) recording.

However, the fact that there was a live audience meant a PA system had to be used, mainly for the vocalists. Add to this, a foldback system for the band, and things get more difficult, and less controllable, and careful mic placement is vital. Standing two thirds of the way down the length of the sports hall, the sound was an awful mixture of direct, and many reflected sounds. But the end result was a quite acceptable recording, considering the restrictions imposed by the venue.

Handy Hints

With all microphones there is a good, and not so good, way of using them, while there may be some obvious do's and don'ts, it is largely a matter of experience as well as trial and error. A seasoned recording engineer will have a pretty good idea of where to place a particular microphone for use with a particular sound source. He, or she, may need to fiddle around only a little to optimise its performance.

The following guidelines may be of help when placing and using microphones.

1. Be familiar with a microphones 'theoretical' response patterns.
2. Do experiment with different microphones if options allow.
3. Do not believe everything you read (!) and let your ears be your guide.
4. Do not automatically reach for the equalisation controls on your mixer and try listening 'flat', you may be surprised at the results.
5. Do experiment with microphone positioning and don't just settle for the first position you try simply because you think it sounds reasonable.
6. Do make sure that microphones are supported securely on rigid stands using the correct mounting accessories.
7. When miking-up loud sound sources such as kick drum or PA cabinets, a dynamic moving coil mic will generally sound more punchy and may be less easily damaged than a condenser type.
8. Condenser mics can produce an accuracy and clarity not possible with many moving coils, and are well suited to delicate sounding instruments and vocals.

Stroboscope Module continued from P47.

STROBOSCOPE MODULE PARTS LIST

RESISTORS			
R2-4	100k ⅓W 5%	3	
R1	820Ω 10W	1	
RV1	470k Pot	1	
CAPACITORS			
C1	10µF 350V	1	
C2	10µF 40V	1	
C3	100nF 400V	1	
SEMICONDUCTORS			
D1-4	1N4007	4	
DI1	DA3 Diac	1	
TRI1	TIC226 Triac	1	
MISCELLANEOUS			
L1	Trigger Transformer	1	
TUBE	Xenon Strobe	1	
	PCB	1	
	Instruction Booklet	1	
	Insulated Spacer M3 x 25mm	1 Pkt	(FS39N)
	Knob K7B	1	(YX02C)
	Heat Shrink Sleeving CP32	1	(BF88V)
	Fuseholder 1¼in.	1	(FA39N)
	Fuse 100mA 1¼in.	1	(WR08J)
	Fuse Holder Insulation Boot	1	(FT35Q)
	Grommet F31	1	(LR47B)
	Twin Mains DS Cable	As Req	(XR47B)
	Conformal Coating	1	(YT50E)
	PCB Cleaner	1	(YJ45Y)
	Grommet 6·4mm	1	(JX65V)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	Pin 2145	1 Pkt	(FL24B)
	Clear Waterproof Box	1	(YM93B)

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

The above items (excluding Optional) are available in kit form only.

Order As VE52G (Strobe Module Kit) Price £14.95

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

NEXT issue

In next month's super issue of 'Electronics – The Maplin Magazine', there are some really great projects and features for you to get your teeth into! The September issue is on sale August 6th, available from Maplin's regional stores, and newsagents countrywide, and of course by subscription (see page 57 for details). To whet your appetite, here's just a taster of some of the goodies on offer:

15-CHANNEL INFRA-RED REMOTE CONTROL SYSTEM

This versatile device allows 15 channels to be independently controlled without leaving your chair – great for the disabled, or for those days when the work's been real heavy! Four switching options allow the unit to be used for a wide variety of applications, and there are even two 'memory' functions, used for storing often-used output combinations.

MULTI-PURPOSE 555 TIMER CARD

The 555 timer is an incredibly useful little device which crops up in many applications. The Multi-Purpose 555 Timer Card, a companion general-purpose educational project to the Op Amp Card featured in this issue, allows you to get to grips with many of these. Apart from the basic astable and monostable modes of operation, edge triggering, initiation by supply and pulse width modulation are all discussed.

GLOBAL CLIMATIC CHANGE

It is a universally-acknowledged fact that the Earth's climate is changing – and it is similarly recognised that it is important to understand these changes, and the mechanisms that drive them. Both are looked at in a special feature by Douglas Clarkson.

SSM2017 MICROPHONE PREAMPLIFIER

The SSM2017 IC, at the heart of this project, is a latest-generation audio preamplifier. It features very low noise and distortion, wide bandwidth and high slew rate. This project is suitable for use with both balanced and unbalanced microphones, although a decent-quality balanced microphone is likely to bring out the best in this preamplifier.

VALVE TECHNOLOGY

Graham Dixey's superb series on the wonders of thermionic technology continues with an in-depth look at the practical design of triode amplifiers.

E510 DATA FILE

The E510 IC is a versatile MIDI keyboard scanning IC, which can scan up to 128 keys, and is velocity sensitive. Possibly the best thing about it is that very few extra components are required! The article describes a 'building block' project designed around the E510, and explains how it can be used in many applications – including a MIDI master keyboard.

SATELLITE TELEVISION

Continuing with his two-part review of currently-available satellite receivers, Martin Pipe looks at the Echostar SR-50 and TechniSat ST-6002S receivers, which are primarily intended for the 'multi-satellite' market.

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

'ELECTRONICS – THE MAPLIN MAGAZINE'

BRITAIN'S BEST SELLING ELECTRONICS MAGAZINE

Text by Nigel Skeels and Mike Holmes

2
PROJECT RATING

Do you ever feel frustrated when you're late for work, it's Monday morning, you turn the key in the car ignition and what happens? The engine turns over but it refuses to start. Oh well, time to find that bus time table.

Perhaps it would have started if an electronic ignition had been fitted.

There are two main types of electronic ignition currently available, the first being that which completely replaces the 'electromechanical' ignition (contact breaker points, condenser, etc.). This operates by using optical or magnetic sensors to detect the position of the camshaft, and so ignite the correct cylinder at the correct time, and can even include alternative ignition advance devices. Such schemes are usually an integral part of the vehicle from new and have been developed and installed by the manufacturer.

The other type of electronic ignition system, however, retains the original contact breaker assembly in the original distributor body and can be fitted as an 'up-grade', producing what is commonly called 'transistor assisted ignition'. In this instance, the task of switching the coil current is shifted from the contact breaker to a 'transistor switch'. The usual effect, that is, of improved switching speed, results in an 'amplified' spark (for want of a better explanation).

This is mainly due to the condenser being made redundant, and removed

FEATURES

* Easy to fit, only four wires
* Transistor assisted ignition method
* Significantly reduces contact breaker wear
* Original connections can be easily restored at any time
* Improved coil performance returns easier starting and cleaner combustion

APPLICATIONS

* For any petrol burning motor vehicle
* Suitable for vehicles with engines of 2 to 8 cylinders

IGNITION AMPLIFIER

Main: The ignition amplifier fitted to the ignition system of a Mini. Inset: The assembled ignition amplifier PCB.

from the low-tension primary side of the ignition coil. Wherever a mechanical switch (the points) is used, the substantial back EMF from the coil primary has a habit of bridging the breaker gap (which is very small at the actual moment when the current flow is broken), *instead* of bridging the sparking plug gap on the HT side. This has *always* been a problem and is solved (by compromise) by adding a capacitor in parallel to the switch ('condenser' is just an old-fashioned name for a capacitor).

With this in place, when the switch opens the coil primary is not allowed to reach a voltage high enough to bridge the breaker contacts until it has charged the condenser, by which time the breaker gap is too wide to be bridged by such an arc. Unfortunately, this also 'softens' the pulse generated by the collapsing magnetic field in the coil, so the HT output is less than might otherwise be possible. It is also aggravated by badly mating contact surfaces which do not break cleanly. Some, albeit minimal, arcing still takes place and this damages the surfaces, requiring periodic replacement and readjustment.

'Transistor assisted ignition' still makes use of the 'conventional' mechanical timing switch (the contact breaker points), but this means that, as well as providing a faster switching speed and more energy to the spark, it places less wear on the points because the *arcing factor* is removed, and so keeps the engine in tune for longer periods. Remaining wear is purely mechanical and cannot be completely ignored, but the situation is considerably improved.

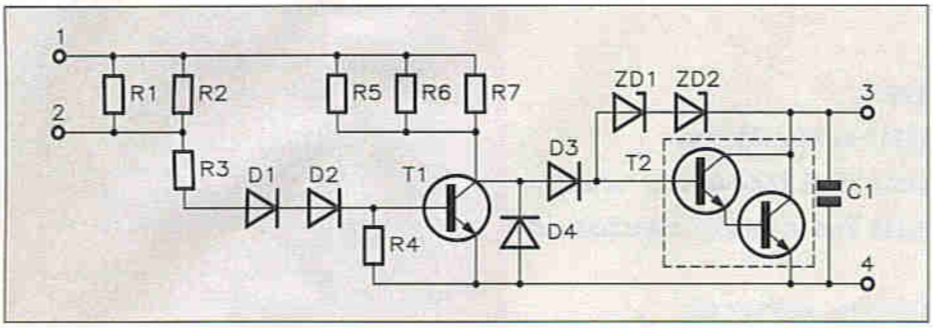
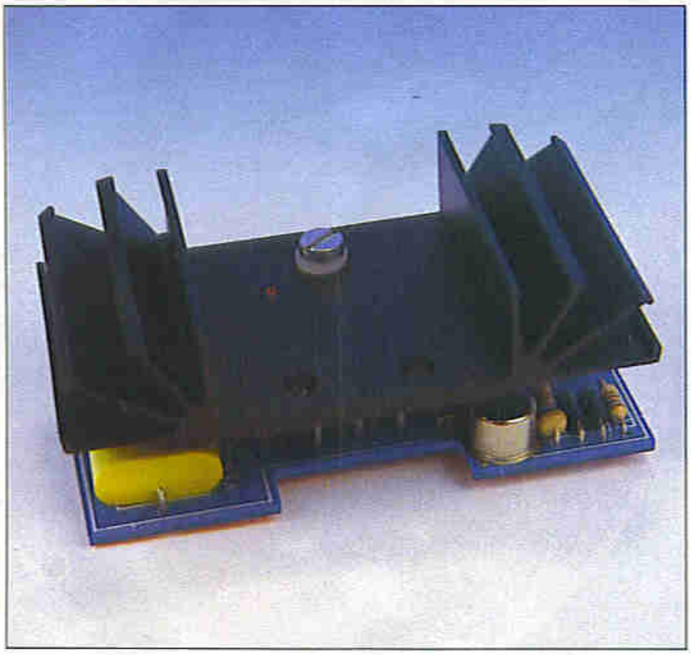


Figure 1. Circuit diagram.

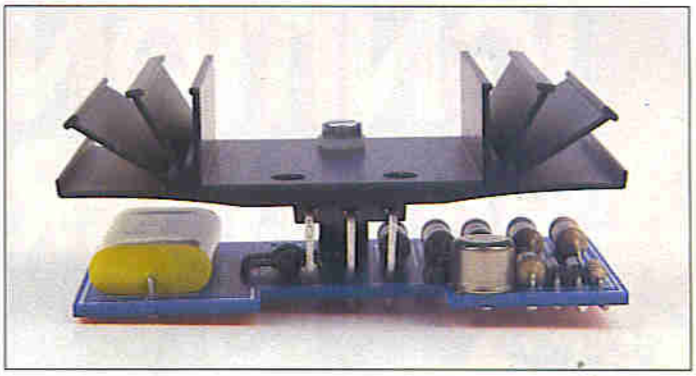
Circuit Description

The circuit is of very simple design and is specifically intended to be driven from a contact breaker source. A circuit diagram is shown in Figure 1. Here, the (vital) coil switching function is taken over by T2 from the breaker points.



Specifications

Switching speed:	1μs
Firing interval:	2ms minimum
Coil switching current:	4A nominal
Supply voltage:	12 to 14V DC
Polarity:	Negative earth only
Supply current drain:	320mA approx.



Side and top views of ignition amplifier, showing the power transistor and heatsink mounting.

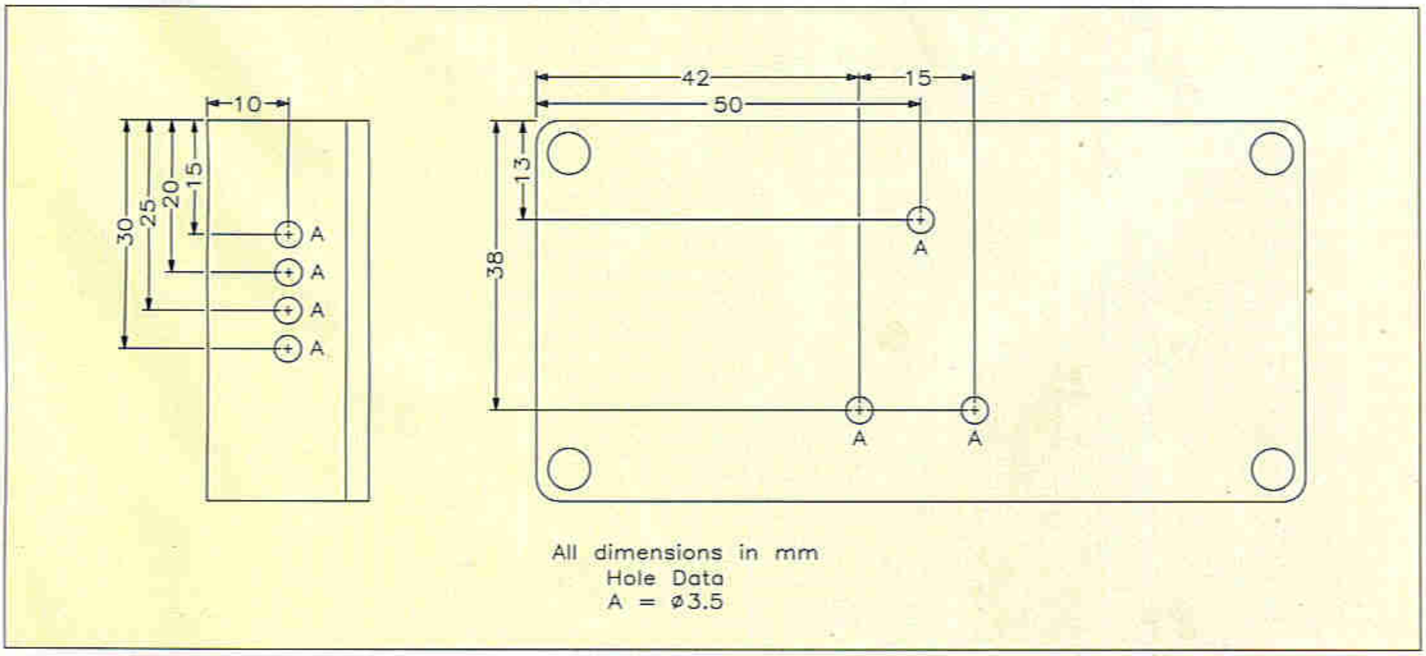


Figure 2. Box drilling details.

Although T2 is a high voltage device, which usually means that its current gain is not very great, it is also a Darlington configuration and so is biased on comparatively easily by paralleled bias resistors R5 to R7. The function of these is to keep T2 'on' with the minimum V_{CE} during the coil's required 'dwell time', bearing in mind that the current sink is typically 4A.

During this time T1 is 'off' since its bias path via R1, R2 and R3 is defeated by the input pin '2' being effectively grounded by the contact breaker. In this situation a current of some 90mA flows from R1 and R2 to give the contact breaker 'some work to do' and maintain electrical continuity through the contacts.

An input threshold of sorts is provided by the combined diode junctions of D1, D2 and the base/emitter of T1. When the contact breaker opens, the voltage at pin '2' must exceed 2V before T1 begins to conduct, which it then does sharply because of the logarithmic behaviour of the combined diode junctions as conduction is established. This helps to speed up the transition from 0V to +V from the contact breaker, if necessary. T1 then 'clamps' the bias for T2 to 0V, shutting off T2.

As already mentioned, there is an appreciable pulse generated by the coil primary at switch off, and is in reality a smaller scale image of what's happening at the HT side. This pulse, though of very short duration, is typically up to several hundred volts and will endeavour to destroy T2 if allowed (regardless of how high a V_{CE} it may have). ZD1 and ZD2 are provided to protect T2 from this over voltage, which also involves D3. The arrangement forces T2 itself to limit the maximum voltage drop across its own collector and emitter. Rated at 150V each, the two Zener diodes make T2 hold the initial coil pulse down to 300V (always positive polarity). D3 blocks the Zener current to prevent it being shorted to 0V via T1, and redirects it to T2 base. D4 protects T1 against any reversal communicated back via ZD1, ZD2 and D3 due to the coil 'ringing'.

Construction

More detailed construction is provided in the leaflet supplied with the kit, but the following notes will be helpful. It is probably best to mount the smallest components first, beginning with the diodes. Be careful to ensure correct polarity; the white stripe on the body must align with that on the PCB legend. Four of these diodes have black cylindrical bodies; the two Zener diodes may be 'bead shaped', in which case the *black* end must align with the stripe on the legend.

The two small resistors can be mounted next (R3 and R4), followed by the larger resistors. Transistor T1 can be fitted next, noting that the tab at the base of the metal case identifies the emitter lead, and must align with that shown on the legend outline. Capacitor C1 should be fitted flat against the PCB.

Transistor T2 must be mounted above the PCB, its metal heatsinking surface parallel to it and held with an insulating spacer, so that it can be affixed to a finned heatsink (provided), also parallel to the board. Details about bending the transistor leads to fit are explained in the leaflet. The device *must not* be soldered in position until the mechanical fixing is completed (at least temporarily to set the position). Heat transfer compound must be used, on *both* sides of the mica insulator. Be very careful with this transparent mica material, it is very brittle. If only the heatsink is to be fitted (see below), this can be completed now, with the nylon shoulder washer pushed through from the outside, together with the long fixing bolt. The bolt is then fixed with the nut on the track side of the PCB. The mica insulator *must not* move and expose the metal tab to come in contact with the heatsink during this operation. Only then can the transistor leads be soldered into the board, once its accurate position is established.

Case Preparation

Before installation commences, all of the solder joints should be checked and the device should be built into a suitable box with some connection leads. We recommend one of our small diecast boxes (LH70M). This box is big enough to house the PCB, but the heatsink must be mounted on the outside of the box.

Figure 2 shows the lid drilling details and where four holes can be drilled in one end of the case for the wires, which should be colour coded as follows: 1 Red (+V), 2 Black (Input), 3 Blue (Output), 4 Green (0V), where the numbers correspond to the numbered connections shown in Figure 1. These wires should be type 3202 (XR32K etc.) which are identical to typical automotive wiring gauge, and which will fit push-on Lucar style connectors.

Additional screws should be used to hold the heatsink in place on the lid (it is provided with two extra mounting holes), and the mica insulation should be placed in between transistor T2 and the inside surface of the box lid. Refer to Figure 3. Note that, because of the added thickness of the heatsink and the lid together, the shoulder insulating washer may not reach all the way through to the transistor mounting tab hole. In this event it may be a good idea to extend it with a very short piece of suitably sized plastic sleeving pushed on below it over the mounting bolt; this will improve electrical isolation between the transistor tab and the case. Achieving good insulation can be a problem with this kind of circuit where high voltage pulses are involved.

The spacer is still used as shown in the leaflet diagram to hold the transistor above the PCB, as described above, and this will actually support the PCB on the lid. Also apply silicone rubber sealant to the screw holes prior to fixing permanently (see below).

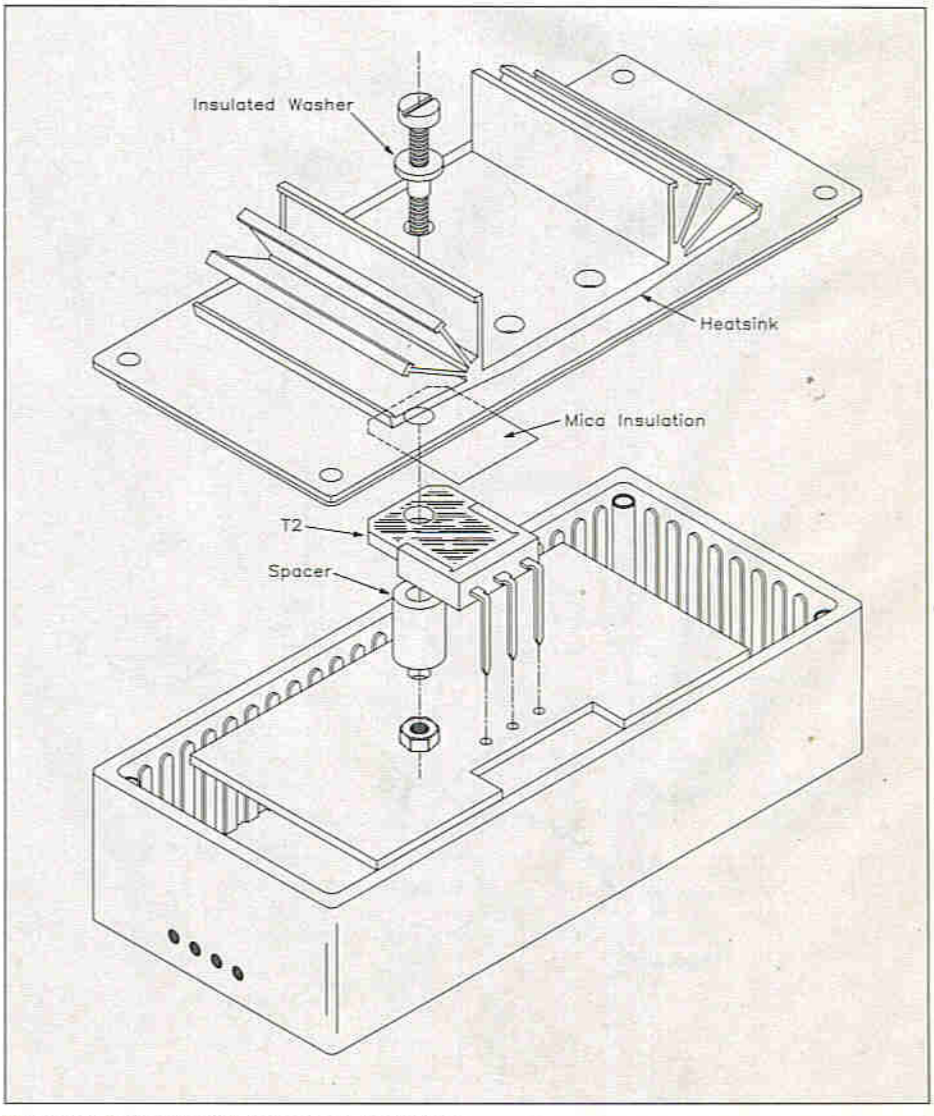


Figure 3. How to install the module in the box.

To decide how long the different leads need to be, you first have to establish where the amplifier will be fitted in the car in relation to the ignition coil and/or distributor body. Allow for generous lengths of wire which can be trimmed later. Strip and insert the four wires into the four PCB holes in the order '1' Red, '2' Black, '3' Blue, '4' Green. If the holes are not quite big enough drill them out to 1/16in. or use PCB pins. This done, thread the four wires through the four holes in the end of the case body, prior to attaching the lid.

At this point it may be a good idea to carry out some pre-final installation tests. If a 12V source and ohmmeter are to hand, power up the unit ('+' to Red wire, '–' to Green wire) and check for continuity on the lowest ohms setting between the Blue and Green wires (positive from the multimeter must be to the Blue wire; most often this is the *black* test lead). Initially the meter should show infinite resistance.

Upon temporarily connecting the Black wire (input) to 0V (battery '–') T2 should switch on, as seen by a low resistance reading on the meter.

The biggest problem with anything electronic when fitted to a motor vehicle is to do with the harsh environment, mainly damp and extremes of temperature. Hence, before fastening the lid it is a good idea to apply some silicone rubber sealant around the cable exits and around the lid's edge. (The lid is lipped to aid sealing.) This will inhibit the ingress of moisture. Also apply the sealant to the lid's screw holes. Other precautions can include spraying the board with PCB laquer or conformal coating prior to installing in the box.

Of course a box does not have to be used, the device could be solidly encapsulated in potting compound, but this has the disadvantage that it is virtually impossible to make any modifications or repairs after the resin has set, should these be required. Also we do not endorse the leaflet's further suggestion that the module could remain exposed to the open-air but be covered in two layers of sprayed-on lacquer, this is not in reality adequate protection.

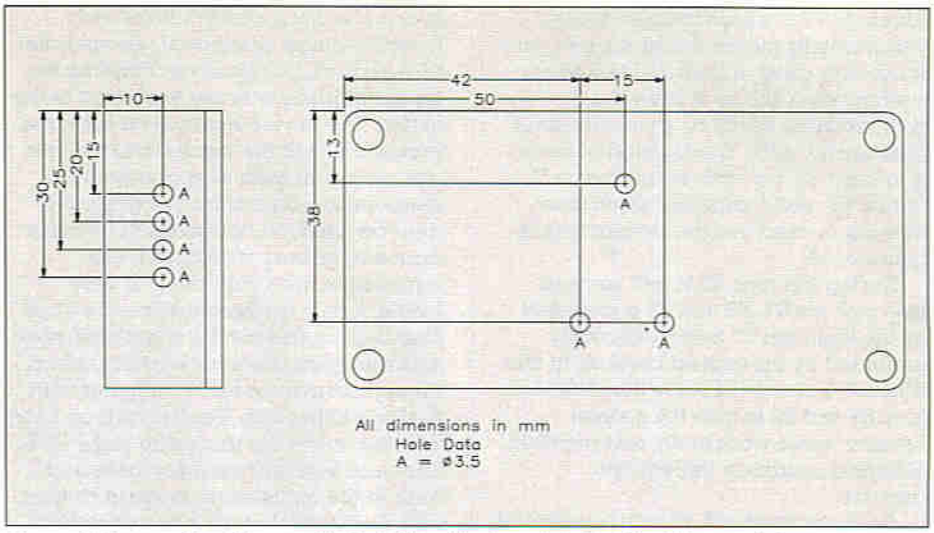


Figure 5. Connecting diagram for installing the transistorised ignition module.

Installing the Finished Unit

Now it's time to actually install the complete unit into the vehicle. Firstly a suitable position needs to be located. This should be either under the bonnet or under the dashboard, but it must be noted that the device may get warm so it must be in an open, well ventilated area. If installed under the bonnet then avoid placing it somewhere immediately adjacent to the exhaust manifold, for example.

On Nigel's Mini it was decided to mount the ignition 'piggy-back' on top of the coil, this was partly because of the lack of space, and because it was near to all of the places that the wires had to be run to. It was attached to the coil by means of two plastic tie wraps (the completed unit is very small and light).

Now to Connect the Wires!

Firstly you need to disconnect the 'condenser' and the lead joining the contact breaker 'live side' to the coil '–' terminal. The condenser is usually situated outside on the casing of the distributor (but may be inside under the distributor cap), and it is usually connected by means of a plug and socket or bolt arrangement which also shares the coil connection. Figure 4 shows this in a typical contact breaker ignition system.

Next, find a suitable connection to ground; this is usually any substantial bracket or piece of metal work. Pin '4' should be attached to this which we have colour coded with the Green wire (marked 'GROUND' in Figure 5). If connecting to a fixing bolt of some description then the wire needs a suitably sized crimped-on tag washer. Very important: remove all traces of rust and paint where the connection is to be made.

Connection '2' (Black wire) is to be taken to the distributor (to where the condenser *was* attached at the contact

Continued on page 59.

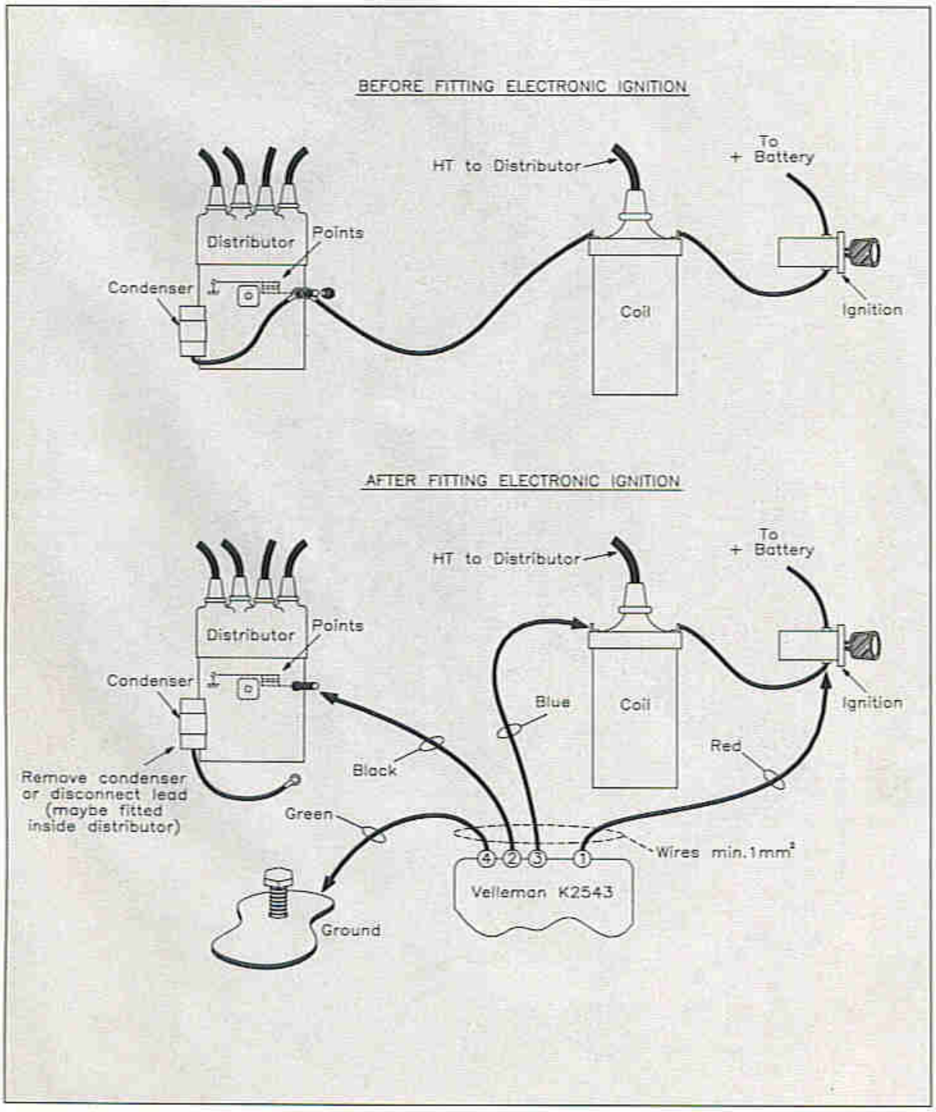


Figure 4. Connecting diagram of typical original contact breaker ignition.

Ignition Amplifier continued from page 56.

breaker connection), and connection '3' (Blue wire) must go to the low tension side of the coil ('–' terminal) that was previously connected directly to the distributor (a multimeter set to the continuity or low ohms range can be used to trace this through). The final connection '1' (Red wire) is to a convenient supply terminal which will be active when the ignition switch is turned on; the most convenient to use is the other low tension side of the ignition coil ('+' terminal), which is the positive supply to the device. In this instance a 'piggy-back' Lucar push-on connector will be useful for reconnecting the existing supply lead. The original interconnecting lead which connected the contact breaker to the coil '–' side may be entirely removed if separate (and kept in a safe place), or if part of the wiring loom of the car the free ends should be tied out of the way. All Lucar connectors should have insulating covers.

The Module in Use

Once all is finished and double-checked for correct connections, it should be possible to start and run the engine. Once the contact breaker adjustment and ignition timing is correctly set, the breakers themselves should keep to this setting for longer as the surfaces are no longer eroded by the arcing action. This just leaves mechanical wear, for which readjustment (and ultimate replacement) is required less often. Don't forget however, that the rest of the system must also be in a reasonable state of health as regards condition and setting of spark plugs, HT leads and distributor cap.

In use the device was found to have improved the cold starting of the car so that the choke is not used for as long as it was before. Also there seems to be an improvement in the way the car accelerates up hills and pulling away from stand still.

Most importantly there is a detectable increase in fuel economy and the engine responds quicker than it used to. If you don't believe all of these claims, fit one and see for yourself!

IGNITION AMPLIFIER PARTS LIST

RESISTORS			
R1,2	330Ω 1W 5%	2	
R3	150Ω ⅓W 5%	1	
R4	100Ω ½W 5%	1	
R5-7	150Ω 1W 5%	3	
CAPACITORS			
	220nF Polypropylene or Equiv.	1	
SEMICONDUCTORS			
D1-4	1N4004 (1N4005, 1N4006, 1N4007)	4	
ZD1-2	150V Zener	2	
T1	BSX45 (2N2219A)	1	
T2	TIP162	1	
MISCELLANEOUS			
	Vaned Heatsink	1	
	Spacer	1	
	Mica Insulator	1	
	Insulated Shoulder Washer	1	
	Bolt M3 x 20mm	1	
	Nut M3	1	
	Wire 3202 Red	2m	(XR36P)
	Wire 3202 Black	2m	(XR32K)
	Wire 3202 Blue	2m	(XR33L)
	Wire 3202 Green	2m	(XR35Q)
	Lucar Style Push-On Receptacle	1 Pkt	(HF10L)
	Lucar Style Push-On Blade	1 Pkt	(HF11M)
	Push-On Blade Covers	1 Pkt	(FE66W)
	Push-On Receptacle Covers	1 Pkt	(FE65V)
	Screw M3 x 40mm	1 Pkt	(JF28F)
	Tie Wrap 385	5	(FE00A)
	Heat Transfer Compound	1	(FL79L)
OPTIONAL (Not in Kit)			
	Box DCM5002	1	(LH70M)
	Flexible Rubber Sealant	1	(YJ91Y)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
The above items (excluding Optional) are available in kit form only.
Order As VE00A (Ignition Amplifier Kit) Price £12.95.
Please Note: Some parts, which are specific to this project (e.g., PCB, heatsink), are not available separately.

DISCOVERING SATELLITE TELEVISION

Part Six
IRDs – A Change for the Better?
by Martin Pipe

In Parts Four and Five of this series, we looked at how to uprate existing or obsolete satellite receivers. Before we move on to that most 'obvious' piece of domestic satellite reception hardware, i.e. the dish, it is probably worth looking at some of the various types of satellite receiver currently on sale – particularly valid if you want to 'start from scratch', want all the 'bells and whistles' that your existing receiver doesn't have, or simply want features that aren't covered by our modified equipment. We have decided to look at four receivers – two this month, two the next – all of which are different, and so fulfil a slightly different user need.

This month we will look at a pair of IRDs (Integrated Receiver-Decoders). The Pace MRD920 is a full-feature PAL/D2MAC receiver, complete with Eurocrypt decoding facilities and MAC teletext. Pace Micro Technology will be familiar to many 'Electronics' readers through their range of modems, which are produced at their Shipley plant, together with the satellite receivers that have been taking an ever-increasing share of the company's business since 1987. Mimtec, however, may not be quite so well-known – although the company carries out a lot of contract assembly work for none other than Big Blue – yes, IBM. This company have manufactured a well-received range of receivers since 1989, the Premiere 2 reviewed here being the latest, and one of the new breed of 'mass-market' satellite receivers capable of much more than Astra can throw at it. And yes, the Mimtec is also equipped with a decoder; instead of the Pace's Eurocrypt, however, the more familiar (in the UK at least) Videocrypt circuitry is provided. Interestingly, the Mimtec Premiere 2 features a 'unique patented interface' to improve the much-criticised (myself included!) Videocrypt picture quality. And did it? Read on and find out. The dishes used were an 80cm solid offset dish with 1·3dB voltage-switched LNB for the Astra channels (19·2°E), an ex-BSB 35cm compact dish for the French D2MAC DBS channels (19°W), and a motorised 1·2m offset dish with triple-band LNB for the rest.

Pace MRD920 (and MSP990 Positioner)

We start with a look at this comprehensively-equipped 99-channel receiver, since its superficial similiarity to the Trac/Ferguson (ex) BSB receiver gives us a suitable frame of reference. OK, so the Trac system costs are a fraction of that of the Pace, but that is more a positive side-effect of the collapse of BSB than anything else. Nevertheless, the Pace receiver offers significant advantages over the Trac system – as one would expect from the price difference. But there are also significant disadvantages, which we will discover later. The receiver is a fairly small box, some 58 x 360 x 200mm, into which is crammed some fairly advanced electronics. The use of a switch-mode power supply dispenses with the bulk and weight of a conventional mains transformer. In addition, surface-mount components are extensively employed, and the tuner/demodulator – the unit at the heart of the satellite receiver – is tiny compared to those hitherto experienced by the author. The main PCB, out of interest, is that of the SS9200 – an extremely well-regarded Astra IRD. Full marks to Pace for variety reduction, which helps to keep costs down. Instead of the Videocrypt decoder daughterboard, however, is the MAC decoder – based, like that of the Ferguson BSB receiver, on an ITT chipset. On the review sample an extra sub-PCB, available as an option, was present. This enables magnetic or electromechanical polarisers to be controlled; the skew can then be programmed per channel. Unless you want to use this system with just Astra (and possibly an old Squarial to provide the German or French DBS channels), the extra cost (a mere £30) is worth it for the added flexibility – this is par ticularly valid if you intend the use the receiver with its matching MSP990 positioner. Because the satellites are arranged in an arc in the sky, the absolute polarisation sense of each transponder will depend on its satellite's position on the arc. For example, a vertically-polarised transponder on Intelsat VI-F4 will differ significantly in

The Pace MRD920 (top), and the Mimtec Premiere 2 (bottom).

polarisation sense from a vertically-polarised transponder on, say, Astra. This is why variable polarisation – known as 'skew' – is essential for multi-satellite systems – a voltage-switched LNB, for example, can only be set up for one satellite, and satellites significantly further away on the geo-arc will be brought in with weaker signal strength, and there is a possibility of interference from channels of the opposite polarity. The fact that the skew (and hence the exact angle of polarisation) can be set per channel is extremely useful – particularly with magnetic polarisers, where the amount of current required depends not only on the satellite's position and the polarity of the received signal, but also on the transponder's frequency. For example, a horizontally-polarised Telecom-band transponder on Eutelsat II-F1 requires a slightly higher polariser current than one of its FSS-band counterparts. Many dedicated multi-satellite receivers still insist in allowing only two skew settings (i.e. vertical and horizontal 'compromises') to be programmed for each satellite, but the MRD920 is a great deal more flexible – and this is interesting when you consider that the MRD920 is not marketed as a multi-satellite receiver *per se*.

Another recommendation is to buy, if you're interested in this receiver, the version with two LNB inputs; this enables, for example, a main dish (motorised or Astra-only) to be connected to one input, and a second dish which could, for example, be aimed at Eutelsat II-F1, or a redundant BSB aerial for the high-powered DBS cluster at 19°W. Unfortunately, the IF tuning range is a limiting factor – many modern receivers will go as far as 2050MHz, but the MRD920 will stop at 1750MHz. As a result, there will be a 'hole' in the DBS band when this unit is matched with the triple-band type of LNB that is ideal for use with a receiver of this type. This is where the old BSB aerial comes in; the gap in coverage is most noticeable with those high-powered European DBS satellites at 19°W.

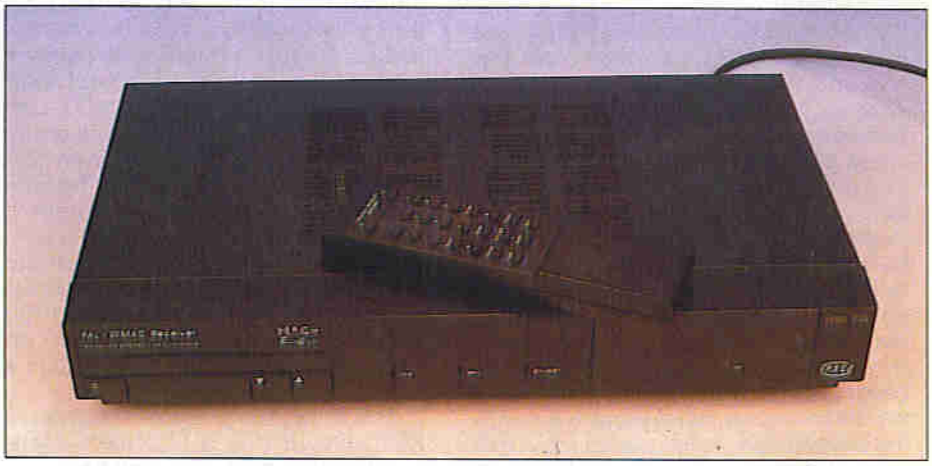
Triple-band LNBs split the FSS ('normal'), DBS and Telecom bands into two frequency ranges – the first covers the FSS and half of the DBS band; the other half, together with the Telecom band, is covered by the second range. The two ranges are switched using the LNB supply voltage (in the same way as the polarity of a Marconi-type LNB is controlled). Used with such an LNB, the MRD920 will tune up as far as 11·70GHz – the end of the FSS band. The lower portion of the DBS band, upon which (ironically) many MAC channels lie, is sadly out of reach. The AFC of the receiver will, however, 'pull in' MCM – the fabulous French pop music channel located at the beginning of the DBS band – with the dish aimed at the 19°W DBS cluster. Most receivers, out of interest, will do this with standard LNBs – multi-satellite system owners take note!

An additional LNB input and a polariser controller may be options, but (thankfully) standard is the provision of three SCART sockets (one for the TV, one for an external decoder and/or MSP990 positioner, and one for VCR). There is also a pair of phono sockets for the audio outputs, so that the MRD920 can feed a Hi-Fi system. Of course, there are the obligatory aerial, RF output (tunable over a wide range, from ch. 30 to ch. 45) and mains input socket. What is lacking, though, is a S-VHS output socket, more of which later.

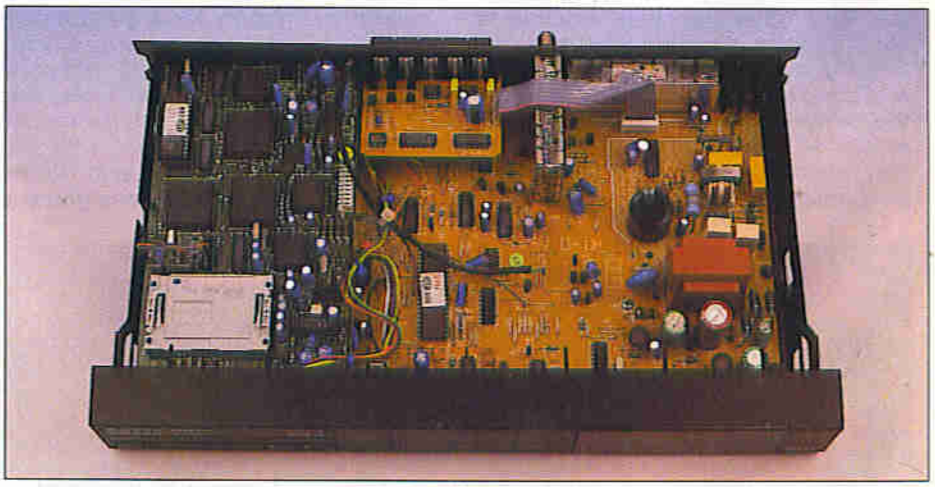
Ease of Use

Driven by a comprehensive on-screen menu/submenu system (similar to that of the Trac/Ferguson system), the MRD920 proved easy to use. All parameters, apart from standby and preset channel selection, are controlled in this way and via the remote control – without which you're lost! Video and audio frequency tuning aside, you can control the MAC picture (contrast, colour, brightness), MAC audio (volume, background/main sound balance), PAL contrast (i.e. video level), external decoder (e.g., Videocrypt) settings, polarity/skew and band switching. A frequency scan feature is provided, so you can align your dish until something registers. This, unfortunately, is so slow that it is, for all practical purposes, effectively useless! There is also a 'LNB offset' feature, which enables you to allow for any errors in the LNB's local oscillator alignment, so that the correct transponder frequency is displayed. Frequencies, by the way, can be entered directly, using the remote control like a calculator keypad.

Among the more unique features is a very comprehensive parental lock facility, in which a personal identification number (PIN) must be entered in order to gain access to a channel – valid in these days of soft-porn programmes, from an increasing number of 'adult' channels. Unfortunately, since today's technologically-literate generation of children can easily get round this problem by tuning in a spare or unlocked channel until the wanted broadcast is found, may we suggest that, after 'locking' channels, the remote control itself (and, come to think of it, the smart card as well) is locked away! Another



The Pace MRD920.



Inside the Pace MRD920 – this is the 'F' version, which has the polariser controller. The board on the left, populated with surface-mounted ICs, is the MAC decoder – the cardholder is clearly visible. Next to the MAC board, towards the top of the photo, is the polariser sub-PCB, next to this is the tiny Sharp tuner/demodulator. The main board is that from a SS9200 Astra IRD; note the switch-mode PSU on the right.

parental control function is provided by the Eurocrypt decoder, more of which later. In another useful 'user' feature, the MRD920 allows you to christen each of the first 20 channels with a 6-character identification. One can assume that this was not extended to the remaining 79 due to memory constraints. Nevertheless, the ability to name your own channels is a very user-friendly feature; for example, you can name those that you don't watch that often so that you can recognise them. One user convenience that is missing, however, is a VCR timer – surprising on a modern IRD, and in particular one with access to so many channels. An VCR timer changes to a particular channel at a preset time; most offer eight such events to occur. Coupled with a VCR fitted with a multi-event timer, this enables the desired programmes from several different satellite channels to be recorded when you're out.

The information shown on the front panel is, unfortunately, limited to three indicators: '16:9' (this indicates a transmission with a 'widescreen' 16:9 aspect ratio, and also blinks when the receiver is in programme set up (tuning, etc.) mode); 'MAC' (indicates D2MAC transmissions); and 'STANDBY'. Pace rely on using your TV set as a display terminal when you are operating the receiver – and this can be a real pain if, for example, you only want to access satellite radio stations at a particular time (for example, when the TV is being used for terrestrial pictures by other members of the family). I know that this practice saves money, but it would be good to see essential information (e.g., channel number, audio subcarrier frequency) shown on, for example, three or so 7-segment LED displays that show information. For radio fans in such domestic predicaments, Pace do, however, offer an 'audio' button, which cycles through the presettable audio modes – but this presupposes that the receiver is already tuned to the correct transponder. The 'on-screen only' method of controlling the receiver seems, unfortunately, to be becoming the norm. This aside, the MRD920 is very easy to use, the on-screen menus being sensibly organised. I did come across a problem related to the on-screen graphics generation – occasionally vertical sync would be lost. Although it could be cured by resetting the receiver (i.e. removing, and then re-applying power), it does demonstrate a problem, at least with the review sample.

Satellite Sounds

Apart from the recovering stereo audio from MAC transmissions, the MRD920 also offers comprehensive audio facilities for normal 'PAL' channels. True Wegener Panda-1 is fitted (the receiver's front panel proudly declares this fact), for genuine compatibilty with suitably-encoded subcarriers (most, if not all, of them!). To get round paying Wegener Communications an annual licence fee, many manufacturers (including, shamefully, those of expensive multi-satellite receivers!) use sound-alike circuits. Panda-1 is a companding subsystem, and so any system that does not expand the dynamic range of the audio system, in proportion to the way in which it was originally compressed, will not sound right – generally lacking in low-frequency energy, and seeming hissy and 'scratchy' at the top end. Soundalikes have included a low-pass filter with a 8kHz –3dB point (negligible hiss, but predictably 'dull' sounding), and National Semiconductor's LM1894 DNR system. Now DNR is a superb system – it retains the top end while removing the hiss without any intrusive sound effects – but is not, and I repeat NOT, compatible with Panda-1 encoded soundtracks. DNR, particularly when fitted with adjustable threshold, is however very good for cleaning up satellite sound – after it has been de-emphasised in the correct way. Interested readers are directed to 'Electronics', Issue 40 (October/November 1990), which featured a standalone DNR project. It works well with noisy tapes as well!

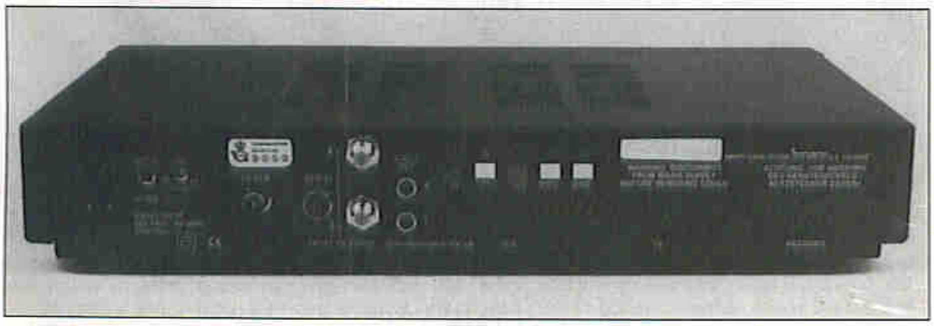
Back to the Panda-1 equipped MRD920. It has a total of 4 stereo 'modes' (presets), and nine mono presets. What's more, they can all be tuned; this makes for a great deal of flexibility. The tuning range is ample – 5MHz (This delves down into the upper reaches of the video signal in the case of PAL/SECAM, but not those transatlantic NTSC transmissions with their 4·2MHz bandwidth) right up to 10MHz; well done Pace! Many designers of new multi-satellite systems still refuse to believe there's anything above 8·5MHz, although Telecom satellite radio listeners will grudgingly disagree!

The four most common subcarrier pairs (7·02/7·20MHz, 7·38/7·56MHz, 7·74/7·92MHz, 8·10/8·28MHz) can be assigned to the stereo modes – as a result, it will cope with all the radio stations that Astra can throw at it. Unfortunately, the subcarriers are fixed 180kHz apart, since this receiver uses the audio tuning system discussed in Part Five (albeit with a frequency synthesiser in place of the fixed-frequency crystals). This system, while fine for subcarrier pairs that conform to the Wegener specification, is no good for accessing the stereo radio stations on Telecom, which use non-standard spacing; for example, Classique FM, where the subcarriers containing the left and right channels are spaced by 900kHz, and Europe 1, where the spacing is 350kHz.

The first mono audio mode, Mono 1, operates to the 50μs de-emphasis standard; even though narrow-bandwidth (150kHz) ceramic filters are used, reasonable results are obtained with the wideband primary subcarriers (e.g., 5·8MHz, 6·5MHz, 6·65MHz, 6·8MHz). Unfortunately, there is no J17 de-emphasis mode, which will mean that certain Eutelsat/Telecom-delivered European channels will be delivered with somewhat 'bright' sound. It can still be heard, though (and with better sound quality than Wegener-soundalikes trying their best on a Panda-1-encoded subcarrier!).

Panda-1 sound on the MRD920 is extremely good – lots of sparkle and detail, and with minimal distortion. This reflects Pace's considerable experience with Panda-1 – its first suitably-equipped stereo receiver was introduced in 1989. Good though it is, it pales into insignificance when compared with the superb sound quality available from the MAC channels. The D2MAC specification allows for 4 high-quality sound channels, each with 15kHz bandwidth (e.g., 4 mono, or 2 stereo). In the place of one high-quality channel will fit two 'medium' quality channels (7kHz bandwidth). The high quality channels sound superb – near-CD quality, better than FM radio, and generally limited by the broadcasters' source material. The low-bandwidth 'commentary' channels are not Hi-Fi quality, nor do they purport to be, being intended for speech only. MAC audio channels are selected via an on-screen menu – the actual names of the radio broadcasters, if any, are displayed as well!

In all cases, the various audio modes can be accessed by simply pressing the 'AUDIO' key on the remote control handset. This is a boon – particularly for the radio stations on Astra, once all the relevant subcarriers have been tuned in and assigned to audio presets. Now there's no excuse



Rear view of the MRD920F – everything but the S-VHS socket!

for failing to discover the delights of these generally undiscovered broadcasts, which to my mind are just as important as the television services. And they're free!

Eurocrypt

The MRD920, being intended primarily for Scandinavian countries (the instruction book also has Danish and Swedish sections), includes a Eurocrypt card reader for encrypted MAC channels – e.g., Filmnet/TV3/TV1000 on Astra. To the average UK viewer, this is likely to be of little interest – save for the rich elite who can afford to be ripped off by fly-by-night companies offering illegally imported Filmnet and TV3/TV1000 cards at grossly inflated prices! However, Canal Plus can be accessed, as mentioned earlier, by using nothing more than a Squarial aimed at TDF1 at 19°W. Canal Plus is frequently 'soft encrypted' in Eurocrypt, and so can be viewed without a smart card. Out of interest, the Trac/Ferguson BSB system offers a Eurocrypt 'softscram' feature. On most of the clear periods that I have seen, boxing seems to feature most often!

For the purpose of this review, a TV3/TV1000 card was obtained (no holds barred for 'Electronics' readers!), so that the various user features of the Eurocrypt system could be assessed, and indeed the system can be compared with our own Videocrypt. Out of interest, the Eurocrypt 'M' variant, which relies on parallel data transfer between card and decoder, is catered for by the MRD920. The rival Eurocrypt 'S', which relies upon a 9600 baud serial interface is, unfortunately, incompatible with the MRD920.

It will come as no surprise that the picture quality is far superior to that offered by Videocrypt/PAL – and that's viewing the picture after it has been converted from D2MAC to PAL. Lest we forget, the video signal is transcoded first from PAL, or whatever, into D2MAC, and at the receiver end, it's converted from MAC into RGB/sync. A dedicated Sony PAL coder chip is used to generate a PAL signal, so your favourite channel can be recorded, and/or displayed on a TV set without RGB input facilities. All this, and it still knocks Videocrypt into a cocked hat! It really does make me sad that Sky took this route, rather than D2MAC/ Eurocrypt, for its Astra channels. However, although I would have been prepared to pay the £100 or so difference for a vastly superior system (that retained PAL capabilities, of course!) it is unlikely that the average Joe Public would have done so, at a time when the concept of DTH (Direct-To-Home) satellite television was new – at least as far as mass-marketing goes!

While on the subject of the in-built PAL encoder, Pace have, unfortunately, forgotten to include a S-VHS output, which is a pity since those fortunate enough to own a suitable video recorder will be unable to make the most of the better picture quality available using such a connection, which maximises the wide bandwidth available by bypassing the chroma and luminance band-pass filters; these are not required, since in the S-VHS system the two components have independent paths (out of interest, they do in all VCRs that use the 'colour under' system or recording – which includes all domestic formats, even "grotty" standard VHS – Ed). It is particularly galling, bearing in mind the superb picture quality of MAC broadcasts, which is primarily due to the fact that the broadcasters in question actually bother to find source material of suitable technical merit, i.e. *proper* broadcast quality – yes, there is a dig there! Consider all those standards conversions that take place before a MAC signal is watched on your TV set – this puts the quality of the source material in perspective.

If you want the best results from the MRD920, though, use a direct RGB connection to your TV set, rather than the composite video one. After correctly setting up brightness, colour and contrast using the 'MAC Vision Menu', the results were little short of breathtaking – particularly with live (studio) material from France 2, and quite frankly showed up the UK terrestrial channels, the technical standards of which have dropped considerably in recent years. If you want to see the technical quality that BSB viewers came to take for granted (when PAL material wasn't being broadcast!), then this is the closest you'll get! Lots of fine detail and bold, natural colour abound (without cross-colour and cross-luminance problems, which produce the notorious colour fringing and banding).

Operationally speaking, Videocrypt and Eurocrypt are superficially similar. Viewing, or more to the point *trying* to view, a hard-Eurocrypted MAC channel without the required smart card displays the 'Please Insert Card' prompt familiar to UK IRD-owners without the cash or inclination to subscribe to Sky's channels. Blanket subscription services apart, Eurocrypt offers a 'pay per view' (PPV) system – so does Videocrypt, but nobody has made any use out of it yet! Whether the Videocrypt version is anything as comprehensive as Eurocrypt's remains to be seen – pre-booked and impulse PPV are both part of the Eurocrypt specification. Credit (and 'overdraft'!) PPV ratings are displayed, as are the times for which pre-booked PPV has been registered. For blanket subscription services, you can even obtain an on-screen history of payments.

The Eurocrypt system also offers an excellent parental control system (in addition to the MRD920's own parental lock system) – which is probably mandatory given the Swedish broadcasters' somewhat liberal attitudes to pornographic films! Akin to the late and lamented BSB system, you can define the age group deemed suitable for a particular transmission (12 and over, 15 and over, or 18 and over), or the type of film (universal – U, or parental guidance – PG)

Teletext Too!

One significant feature (for UK viewers, at least!) that the MRD920 offers over the Trac/Ferguson system is an in-built teletext decoder, that allows pages of information to be retrieved from the MAC channels in the same way that a teletext-equipped TV allows you to gain access to Ceefax and UK Teletext in Britain. I would like to say that the MRD920 upgrades a normal TV into a teletext one, enabling Sky's teletext service to be recovered, for example, but alas no. With conventional frequency-division multiplexing (FDM) systems (PAL, SECAM, NTSC), the teletext information is broadcast in the vertical blanking interval. The time-division multiplex (TDM) MAC system broadcasts its teletext data in the data packet; the systems are thus fundamentally incompatible, and this is why a specific MAC teletext decoder is required in the MRD920. Unfortunately, at the time of compiling this review only one of the MAC channels was found to be providing teletext – France 2, the French public service broadcaster – and even then, the MAC service was fairly intermittent; a quick swing of the dish to the France 2 SECAM service on Telecom 2B proved that the service was alive and kicking there. Why aren't MAC broadcasters making more use out of this excellent information provider? One area, however, in which the teletext decoder is being somewhat better utilised is that of subtitles. My period with the TV3/TV1000 card revealed that TV1000 offers Danish, Norwegian and Swedish subtitles – all of which can be selected via an on-screen menu. For the hard of hearing, these subtitles can be recorded.

But that's not the only on-screen information feature. A 'programme information' option (similar to one on the Trac/Ferguson system) displays the name of the service, the orbital position of the satellite, and the satellite transponder number. It also tells you where the service originates from. This can be revealing in itself – TV3 is, in fact, uplinked from the UK!

What About DMAC?

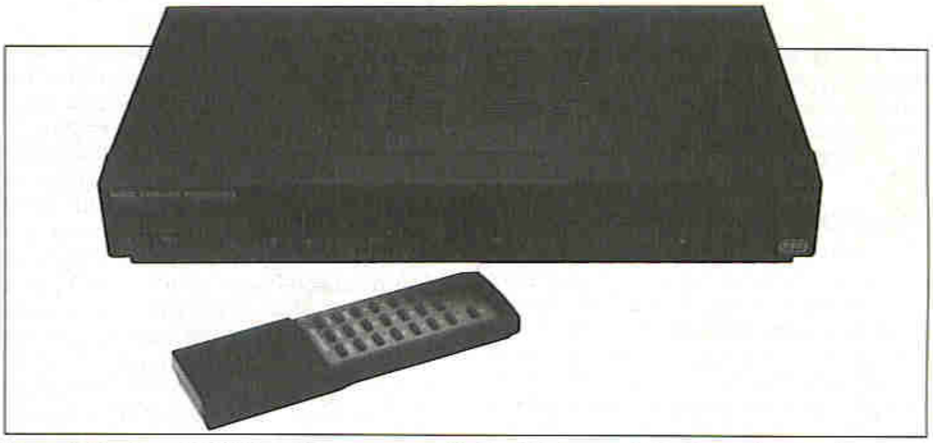
For all its advanced user facilities, the MRD920 is lacking in one crucial area – and one particularly relevant, bearing in mind the receiver's main (Scandinavian) market. The unit provides great pictures on all D2MAC channels, but try to get it to work with a DMAC channel such as Norway's NRK! That's right, they forgot to include DMAC decoding capability, which cuts out not only NRK, but two Swedish broadcasters (TV2 and Kanal 1) on Intelsat VA-F12 (1°W), as well as CNN on the Thor bird at 0·8°W. I doubt very much that the MAC chipset used in the MRD920 differs drastically from that used in the Trac/Ferguson setup (considerably cheaper than the Pace!), and as a result D2MAC/DMAC control is probably done with software. Alienating themselves from customers for the sake of a few lines of program code? Now that's a crime! To make matters worse, the MRD920 user guide lists 'NRK DMAC' as channel 35 in its 'programme line-up'! Someone, somewhere, has er . . . cocked up quite badly! Pace do seem to be listening to their customers, though; the MRD920's eventual replacement, the 199-channel MRD 950, will include DMAC as well. Unfortunately, they are not listening hard enough, since they assure me that a S-VHS output will not feature on the new model either. Whoops! The good news for MRD920 owners is that, according to Pace engineers, a software upgrade giving DMAC capability will shortly be available.

Widescreen Capability

One feature that the MRD920 does have is, as hinted earlier, compatibility with 16:9 broadcasts, when used with a suitable (and highly expensive!) widescreen TV set. However, no current UK-licensed broadcaster provides such a service at the time of writing. That said, who knows what the future will bring? Sky were rumoured to be looking into such a service in the recent past. An experimental Belgian 16:9 film channel, TV Plus, can be found on Eutelsat II-F3 (16°E), but it is hard-encrypted in Eurocrypt and subscriptions, if at all available, cannot be purchased in the UK for copyright reasons – lest we forget, Sky has the monopoly on satellite-delivered films for UK viewers. Clear D2MAC widescreens test transmissions can occasionally be found though, particularly from France 2.

Matching Positioner

Pace have thoughtfully made available the microprocessor-controlled MSP990 positioner, which cosmetically matches the MRD920, and the 9200 series Videocrypt IRDs. Unfortunately, the review sample came with its toroidal mains transformer floating around in its innards. Should power have been applied in this state, severe damage could have been caused to the unit and/or reviewer! Clearly, the transformer securing bolt had not been sufficiently tightened prior to packing, and had loosened in transit. Perhaps Pace should do something about this apparent lapse in quality control.

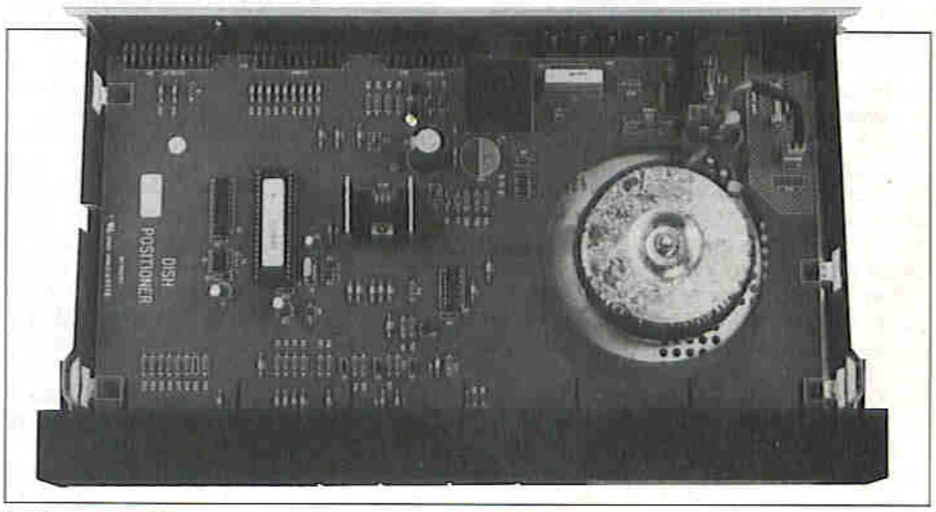


The matching Pace MSP990 positioner – an excellent unit in its own right. Just make sure that nothing rattles before you plug it in!

This niggle aside, the MSP990 can store a maximum of 60 satellite positions, and is therefore well suited to anything the Clarke Belt is likely to serve up for some time yet. The unit is supplied with a remote control, and as such can be used to upgrade any receiver into a multi-satellite set up, when used with a suitable motorised dish. If used with a Pace receiver such as the MRD920 or the SS9200, however, various MSP990 features come into their own. If the two units are linked together, the receiver's remote control will also work the positioner, thus obviating the need for yet another remote control. The decoder port on the rear panel of the receiver is connected, via a SCART to SCART lead (why isn't this supplied with the unit?) to the 'REC I/F (interface)' socket of the positioner. And, just in case you still want your Videocrypt (in the case of the MRD920) or Red Hot Dutch decoder wired into your satellite system, you will be pleased to know that the decoder port (or two of them, to be precise) are duplicated on the back of the positioner.

Using the receiver and positioner together as a system really works well. For example, a satellite position can now be assigned to each channel number – this is extremely versatile (remember that skew settings are also programmed per channel). In addition the positioner's 3-digit LED display, which normally displays the dish position, can be switched to display the channel to which the receiver is currently tuned – this overcomes, to a great extent, the 'on-screen graphics only' limitation covered earlier.

The unit itself is extremely easy to set up and use, and works very accurately, with no noticeable overshoot when moving from one stored position to another. Assuming that the dish has been aligned to track the geo-arc correctly, it is a case of setting the dish limits (the most easterly and westerly satellites that can be reliably received without putting any strain on the dish), and then programming in the positions of the required satellites. The 3-LED display shows the number of feedback pulses counted with reference to the east dish limit – yes, the MSP990 is designed to work with an actuator (dish motor) that provides positional feedback in the form of pulses; these can be derived by means of a reed switch, or a shaft-encoder (the latter is the more reliable option, but for some reason the least common). Earlier actu-



Inside the MSP990.

ators that use a potentiometer for feedback cannot be used; in any case, these were really designed only for 'C' band, where the accuracy requirements are not as stringent as those for Ku-band systems. The actuator motor must be a 36VDC type, and must not draw more than 1A continuous (3A peak).

Quirks and Omissions – But a Pleasure to Behold!

In all, the MRD920/MSP990 combination was a pleasure to use – offering a great deal of power within a limited space. It also performed well; MAC channels (including the encrypted ones) came though superbly. The Sharp tuner/demodulator module used is a good one, having a low threshold (6·5dB dynamic); as a result, pictures, even from the weaker satellites such as Intelsat VA-F12, stood up well despite the great English weather! The IF bandwidth is fixed at 27MHz (presumably for compatability with Astra channels) but good pictures were obtained with PAL channels of higher transmitted bandwidth (e.g., Superchannel on Eutelsat II-F1, which has a 36MHz transponder bandwidth). A slight amount of streaking was noticeable on peak-whites (in this case, the Superchannel logo, and the occasional caption), but this is to be expected, and in any case it is hardly obtrusive. The only real niggle with PAL pictures was a slight amount of residual 'dispersal' signal, which manifests itself as low-frequency 'flicker' (the dispersal signal, as we found out in an earlier instalment of 'Discovering Satellite Television', is a 25Hz sawtooth wave that is superimposed on the programme during uplink, to reduce any interference effects on terrestrial microwave links).

The excellent sound quality, both MAC and Wegener, cannot be faulted. If you can tolerate the DMAC omission (something that irritates me more, every time I think of it) and the lack of wide-band tuner, S-VHS output and VCR timer, the MRD920 can be warmly recommended – most MAC transcoders cost more than the MRD920's asking price. The hole in coverage, when a motorised dish and triple-band LNB are used, can be mostly filled by putting a redundant BSB Squarial to work at 19°W, but don't forget to get the version of the MRD920 that has two LNB inputs. Or, for that matter, the one with the polariser driver!

The MSP990 positioner is also an excellent unit. Even if you don't need the receiver, and want to upgrade your existng set-up into a multi-satellite one, this unit will accurately control your new motorised dish at an economical price. Don't forget to make sure that nothing rattles around inside, first! If your receiver does not offer polariser driver facilities, tunable audio and at least 48 channels, my advice would be to buy a new receiver and/or receiver/positioner – or get round the problem with a bit of electronics DIY – refer back to Part 4. Upmarket Astra receivers like the excellent Salora 5902/ITT Nokia SAT1100 are, however, ideal contenders for the multi-satellite treatment, without such modification.

Readers might also like to know that a matching Pace stand-alone Videocrypt decoder – the VC 100 – is available. This does exactly the same job as the old Thomson one (now discontinued), but is built into a much prettier case. Multi-satellite enthusiasts should note that this unit is the only stand-alone Videocrypt decoder now available. If you already have a multi-satellite set up, you may be interested in the D100 D2MAC/Eurocrypt transcoder, which offers all of the MRD920's D2MAC, Teletext and Eurocrypt functions covered in this review.

Mimtec Premiere 2 IRD

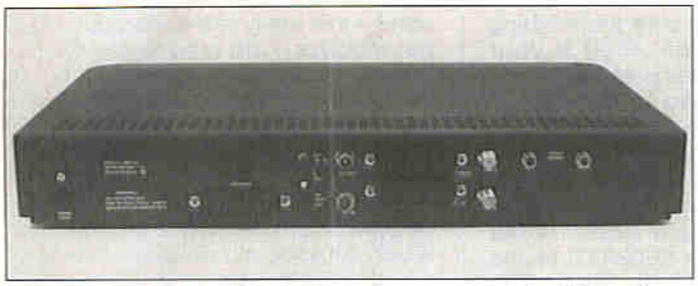
This is, by a long shot, the best-built receiver out of the four in the review group, which is no mean feat as it's one of the cheapest. In fact, the fairly large case (435 x 65 x 280mm) is basically the same as that used for the receiver's more expensive big brother, the Spirit S2. The only thing that really gives it away is the different logo on the front, and the reduced amount of socketry (no polariser output, etc.) on the rear.

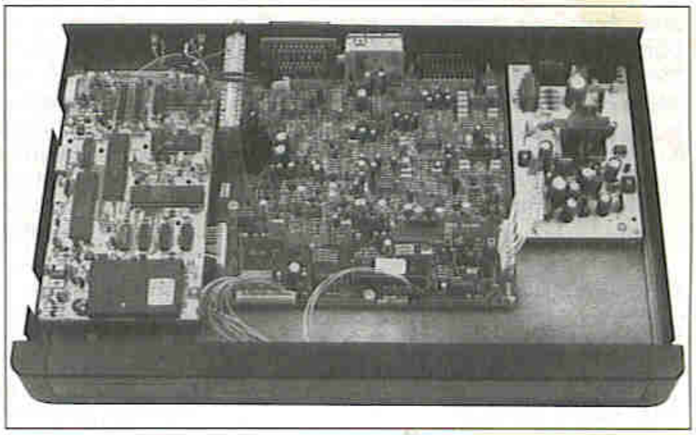
The Premiere 2 is billed as an 'Astra receiver plus'; there are two IF inputs suitable for use with LNBs equipped with voltage-switched polarity selection, 99 fully-programmable channels, and a wide variety of audio tuning modes. To put the Pace to shame, a full-band (950 to 2050MHz) tuner is used – this really is excellent for a budget receiver. I am glad to see Mimtec putting money where it counts, but no RF lead is supplied (although one is shown in the instruction manual), which is fairly irritating. This was confirmed by Mimtec.

Astra apart, the Premiere 2 is designed for use with a second dish, which could be aimed at another satellite of interest – for example, Eutelsat II-F1 (Euronews, Superchannel, Red Hot Dutch), Intelsat VI-F4 (Discovery, Parliamentary Channel, Country Music Television), or Telecom 2B (M6, Arte, TF1, France 2). Alas, there is no provision for controlling a polariser; with this receiver, multi-satellite capability stops at the two fixed dishes (although a circuit, such as that described in Part Four, could be used to drive a magnetic polariser).

The attractively-finished but robust black steel case contains the electronics, mounted on four PCBs. A Videocrypt decoder is built-in; a hinged flap on the very solidly-made plastic front panel conceals the card slot, which can be closed with a card inserted, thus protecting it. Simple, and excellent design. Also on the front panel are three buttons; channel up, channel down and standby. In addition to the LNB, aerial and mains lead connections, there are (as with the MRD920) audio phono sockets and three SCART sockets, again for external decoder (MAC, Filmnet, RHD, etc), VCR and TV. Not bad for a budget receiver! Where the budget categorisation does show is the lack of on-screen graphics – but I am glad that Mimtec have saved money here, rather than in such areas as build quality, or in such areas as tunable audio. The RF modulator tuning range, if the rear panel is to believed, is fairly limited (ch. 30 to ch. 39). Fortunately, the modulator in the test unit could be tuned from ch. 24 to ch. 42. This should prevent problems if you have got other home entertainment devices, such as VCRs and videogames, that modulate their outputs onto a UHF carrier. But, then,

The Mimtec Premiere 2.





Above: The rear panel of the Premiere 2, with a surprisingly high number of connectors, including 2 LNB inputs and 3 SCART sockets. No output for a polariser, though.
Right: Inside the Premiere 2. To the left, the Videocrypt decoder; in the middle, the main receiver board; on the right, the SMPSU that caused all the hassle! The patented Mimtec interface lurks under the Videocrypt board.

you should all be using video connections wherever possible, anyway! Out of interest, the manual states that the modulator is tunable between channels 22 and 40.

The Premiere 2 is exceptionally well-built inside as well; by far the best receiver out of the four. The main PCB and Videocrypt decoder PCBs are double-sided PTH fibreglass boards. So is a third board, which hides under the Videocrypt decoder. This is the much-heralded 'patented Videocrypt interface', more of which later. Like the MRD920, a switch-mode PSU is used, and its circuitry is mounted on a PCB that nestles on the opposite side as the decoder. In fact, there are many similarities between the Pace and Mimtec receivers, as we shall discover.

Setting Up

The Premiere 2 is simple to set up and use, despite the lack of on-screen graphics. All information, such as frequency, channel number, external decoder mode, LNB input and polarity selection is displayed via the front panel's quadruple 7-segment green LED display. Like the MRD920, all programming is done via the remote control (after all, the number of front panel controls is minimal). Incidentally, although the remote control was as well-made as the receiver, I was not impressed with its layout. For example, the numeric keypad is laid out in two rows of five keys (1 to 5, and 6 to 0), rather than the standard '3 rows of 3 + 1' that is standard everywhere else. Like the case, the remote control is the same as that supplied with the Spirit S2; I wonder if any Mimtec customers have received the wrong receiver?

Mimtec have devised an ingenious system to prevent channel information from being accidentally 'wiped' out; the Menu key on the remote control has to be pressed, followed by a user-defined PIN number, before any parameters can be change. The receiver offers a similar parental lock facility to that of the Pace, but the Mimtec system is far superior – since the cleverer minors cannot even re-tune the receiver (to watch what they shouldn't!) from an unlocked channel without knowing the PIN number. And with 9999 possible combinations to choose from, they could be trying for a long time (just don't forget the PIN number yourself!).

Like the Pace, transponder frequency entry can be direct, or via the channel 'up' and 'down' keys. Since the display only has four digits, the four least significant digits of the desired frequency are entered (e.g., 0950 for a transponder frequency of 10·950GHz. The frequency entered, out of interest, is the first IF frequency, i.e. that sent down the coax from the LNB. Like the Pace, an 'LNB offset' facility is included, to compensate for those off-frequency LNBs.

Timer

Reflecting the increased choice available from satellite television today, the Premiere 2 – unlike the Pace – offers a VCR timer, which allows 4 events to occur over 4 weeks. This is another useful feature, as we have discussed earlier, since it means that VCR owners have the option of time-shifting programmes from more than one satellite channel. And, unlike most modern VCRs (why can't these go back to sensible designs, like the 2 week/8 event one used on Thorn/JVC machines of the mid-80s?), it's easy to use. It even switches on one minute before its preset time, which is more than enough time for your VCR to lace up – and that's assuming that they both come on at the same time. Of course, this timer facility depends on an internal 24-hour clock, which must be set with the correct time and day of the week. To save the clock setting from accidental missetting, your PIN has to be entered first. Once entered, the time is available by pressing the 'time' button on the remote keypad – handy to set your watch by. Unfortunately, Mimtec have committed the cardinal sin of failing to include battery back-up – a momentary glitch on the mains, and you lose your clock and timer settings. Satellite fans in rural areas watch out!

Audio Provisions

Like Pace, Mimtec are licensed to use the Wegener Panda-1 system for the narrow-bandwidth sound subcarriers, this fact being emblazoned on the front panel (as for the MRD920) with a 'Panda' logo. The Premiere 2 offers a wide range of audio modes, each of which can be selected using the 'Audio' button on the remote control; there are four fixed stereo modes (7·02/7·20MHz, 7·38/7·56MHz, 7·74/7·92MHz and 8·10/8·28MHz), and one fully tunable. Unfortunately, like the Pace the subcarriers are fixed 180kHz apart, so if you want stereo radio with non-standard subcarrier spacing, forget it!

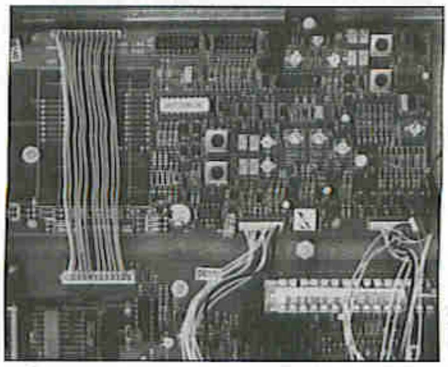
There are also eight fixed mono modes (frequencies as above), and one tunable. Unlike the fixed modes, which use Panda-1, the tunable one has 50μs de-emphasis, and is thus suited for use with the primary subcarriers of other satellites – this means that the Premiere 2 can cope with virtually everything that's thrown at it sonically (except, of course, those stereo radio stations on Telecom!). Admittedly, there's no J17 de-emphasis, but the Premiere is only a budget receiver. In any case, you can still hear the sound – which is more than you can with earlier budget receivers with their fixed subcarriers. As with the Pace, the sound IF bandwidth is fixed, in this case at 180kHz; this limitation did not, however, present any problem with the wideband primary subcarriers. In both stereo and mono tuning modes, the subcarrier tuning range is fairly limited (5·5MHz to 8·5MHz), but unless you specifically want to gain access to Telecom's weird and wonderful French radio stations, it is perfectly adequate. Not one for knocking a gift horse in the mouth I welcome, with open arms, the provision of fully tunable audio on a receiver in this price range.

The sound quality was very good – certainly among the best of the genre, and certainly better than the Wegener soundalikes employed by other manufacturers. It was, perhaps, a little limited in 'top end' and bite when compared to the MRD920, but its performance at the lower end of the frequency range was much better. All in all, the Premiere 2 gave a far better account of itself, in the audio department, than any of the budget Astra-type receivers of only a couple of years back – and, come to think of it, many multi-satellite systems as well. Like the Pace, all audio features are easy to use, and so there is no excuse for seeking out those elusive satellite radio stations. One point, omitted from the manual, is how to store the desired audio mode for a particular channel. Locate (or tune) the desired subcarriers; *as soon as you find them,* press both 'store' buttons on the handset simultaneously. Whenever you change channels, you will now find that the audio modes follow suit; radio stations can now have their own dedicated channel numbers (great for timer-taping your favourite satellite radio programme when you're out!). I find this omission in the manual particularly interesting, since Mimtec receivers have always sold on their audio capabilities alone!

Don't Forget the Video!

As mentioned, the Mimtec features a built-in Videocrypt decoder for reception of Sky's subscription channels, and all of the others that are now attempt*ing to extract our hard-earned cash* from us (out of interest, the retail price of the Premiere 2 is considerably less than an annual subscription to Sky's pay-TV channels. Monopolies are helpful things . . .) Unfortunately, the picture quality of the Videocrypt system is notoriously bad; this, out of interest, is compounded by the extremely poor technical quality of some of the material shown by satellite broadcasters. When you consider that Videocrypt dices each picture line into several segments, before reassembling them in a different order prior to transmission (the 'cut and rotate' system), and that each line has to be reconstructed at the other end, it's amazing that the system works at all. Videocrypt, incidentally, was one of the systems discussed in Part Three of this series. One can expect some degradation of the picture quality, which tends to be noticeable as 'streaking', but bearing in mind the high cost of pay TV, a significant number of people (author included) are not happy with it. Many Astra veterans will remember the staggering drop in picture quality when Sky Television started scrambling its 'Sky Movies' channel in 1990, after a grace period of a year. This situation is set to repeat itself now that the broadcaster is planning to encrypt its Sky News and Sky One. Others are waiting in the wings to do so, although 'Videocrypting' is a mainly British phenomenon, and thus pan-European broadcasters, such as MTV, will choose something acceptable to all of the main countries within the Astra footprint. For example, the Premiere and Teleclub channels are now firmly established using Syster; it is unlikely that the German public will spend over a hundred pounds (or whatever that is in Deutsche Marks these days!) for a box that will only provide MTV or whatever – and an annual subscription on top of that. If Eurosport, now merged with Screensport, decides to scramble, it will probably be in Videocrypt whatever happens. Only time will tell for sure, though.

Because of the explosion in the number of Videocrypted channels, and the level of dissatisfaction with the poor picture quality, Mimtec engineers have developed (and patented) a special interface circuit that sits between the decoder and receiver. Apart from purporting to improve the picture quality, the circuit is said to overcome another criticism of Videocrypt, quickening access times to scrambled channels. Normally, there is a lengthy wait for the decoder to 'figure out' just what is going on, and to select either the 'straight through' signal, or the output from the Videocrypt circuitry – this comment applies, most noticeably, when changing from a clear channel to a Videocrypted channel, and vice versa.



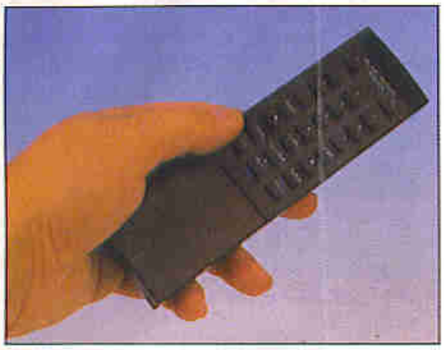
Close-up view of the Mimtec Videocrypt interface PCB – the subject of much controversy.

A quick look at the circuit board allows us to guess as to how the interface works. Most noticeable are several multi-pole LC filters. The first filter is on the decoder input, and is likely to be an anti-aliasing low-pass filter to remove any signals (spuriae, etc.) out of the bandwidth of the Videocrypt decoder's ADC. Of course, the filter must have an extremely sharp response, so that the higher frequencies – which relate to the fine detail – of the picture information are preserved. After the digitised picture information has been manipulated into the correct order by the cut and rotate algorithms, it is converted back into the analogue video signal by a DAC. And this is where the other filter is, removing unwanted high-frequency conversion products ('hash') from the output of the DAC. Again, the frequency response of the filter has to be sufficient such that the fine detail is retained. Other circuitry on the board includes video amplifiers (complex filters such as those used have significant insertion loss) and the fast switching system. This appears to be based around an application-specific IC – probably a custom logic gate-array of some description.

But how did it perform? On clear Astra channels – particularly the German ones with their superior picture quality – crisp, clear pictures were obtained that could put many more expensive systems to shame. The baseband demodulator threshold is clearly low – reasonable pictures were produced from channels on the 'weaker' satellites (e.g., TVN on Intelsat VA-F12 at 1°W), using the large dish.

Unfortunately, the results with Videocrypt channels were disappointing. There was severe patterning, and the notorious Videocrypt streaking was more evident than on other set ups – ironically systems without the benefit of Mimtec's interface (in particular, the original Thomson Videocrypt decoder, used with the MRD920 and the Technisat ST-6002S – reviewed next month). You might be thinking, at this stage, that I was sent a rogue sample – and you would be right! A second Premiere 2 was duly sent – apparently the power supplies used in a recent batch had problems; Mimtec assure me that such gripes have since been ironed out. The replacement receiver exhibited none of the patterning – but the streaking was still there. Another call to Mimtec (their service department, by the way, is very helpful) resulted in another power supply winging its way to yours truly. A cable harness links the PSU to the main PCB; the power supplies were physically incompatible, requiring slightly different cases – and cable harnesses! Luckily, my suspicions were aroused, and just as well – had I connected up the new supply indiscriminately, the receiver would have died a nasty death – the connections were also incompatible! Mimtec faxed down power supply circuit diagrams, and the cable harness was re-made accordingly. However, no improvement in the Videocrypt picture was yielded. It should be noted, at this point, that the test channel was UK Gold (my current favourite!), since at the time of writing this is available to everyone with a Videocrypt IRD, regardless of whether or not they subscribe to Sky. Mimtec recommended

Close-up view of the Premiere 2's well-designed card slot.



Pace MRD920 remote control handset.

that the test should proceed using Sky's hard-encrypted movie channels – and what do you know, much better results all-round – in fact, a slight improvement on the other two systems mentioned earlier. Perhaps somebody could explain this! However, I expect improvements on *all* channels. Perhaps Mimtec engineers don't watch UK Gold (they only give Sky's subscription number in the manual), but participants in a recent *What Satellite TV* readership survey, UK Gold was voted the most popular channel – and you can't argue with the public! Picture quality aside, the interface really did improve switching times – so no problems there!

Mimtec's Videocrypt interface would appear to work, then, but I feel that it needs further refinement. Full marks to Mimtec, though, for actually trying to limit the shortcomings of Videocrypt. Perhaps the Premiere 2 could be made, as an option, for £20 or so less *without* the interface board. The receiver would then wipe the floor with the competition – in all other respects it is an excellent receiver, and certainly the best-made budget receiver I have come across! It would be nice to see a polariser interface (at least as an option, a la Pace), but we start invading the territory occupied by Mimtec's other contender, the Spirit S2.

So here we have two very different IRDs, each with their own quirks and shortcomings, but both capable of excellent performance and supplied with features not even dreamt of three years ago! In next month's issue, we will look at two receivers for the satellite enthusiast – the Echostar SR50, fitted with Eurosat's Threshold Assistance Device, and the new Technisat ST-6002S.

Mimtec Premiere 2 remote control handset.

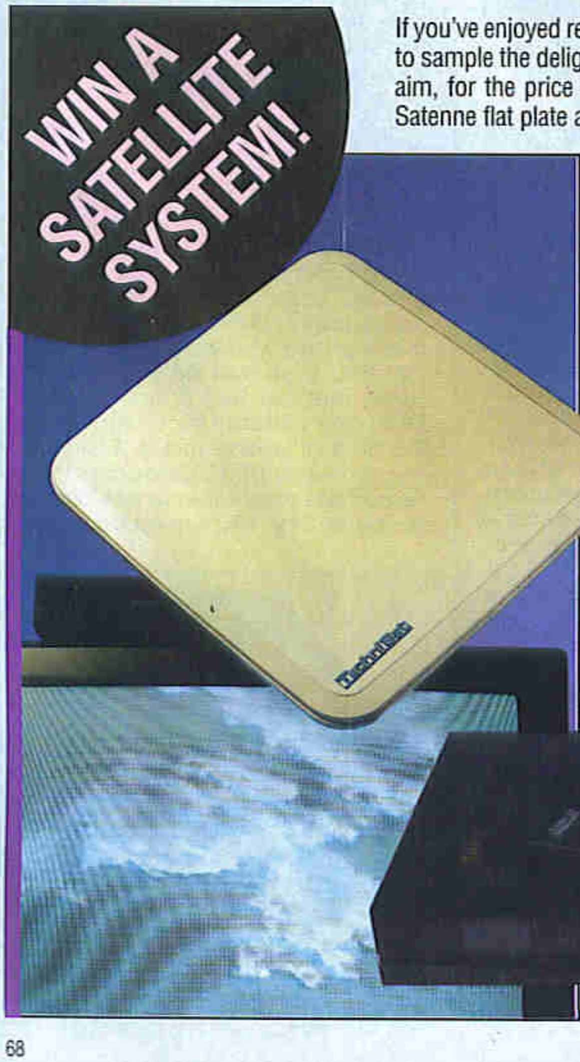
Retail Prices

Pace MRD920, no polariser driver, single LNB input: No longer available
Pace MRD920, with dual LNB inputs: £299
Pace MRD920, with dual LNB inputs and polariser drive capabilities: £329
Pace VC100 Videocrypt decoder: £119
Pace D100 D2MAC/Eurocrypt transcoder: £229
Mimtec Premiere 2: £199

Contact Addresses

Pace Micro Technology,
Victoria Road,
Saltaire,
Shipley BD18 3LF.
Tel: (0274) 532000.

Mimtec Limited,
2 Hutton Square,
Brucefield Industrial Estate,
Livingston EH54 5DD.
Tel: (0506) 416262.



If you've enjoyed reading the 'Discovering Satellite Television' series, you will (no doubt!) be wanting to sample the delights of satellite television at first-hand. To enable one lucky reader to achieve this aim, for the price of the postage stamp, we've got a TechniSat ST 2002S satellite receiver, and Satenne flat plate aerial, to give away.

This superb system is primarily intended for use with the Astra cluster of satellites. The receiver features 99 channels, a 2GHz tuner, a versatile decoder loop, fully tunable audio with stereo sound and infra-red remote control. Used with suitable ancillary equipment, this receiver could form the basis of an excellent multi-satellite system. The TechniSat 'Satenne' antenna is a development of the old BSB 'Squarial', and it is intended for use instead of a small dish for high-powered satellites like Astra. Measuring a mere 47cm across each side, it is fitted with a low-noise LNB and it is, we're sure you'll agree, a good deal more unobtrusive than a dish!

For each of the four runners-up, we also have a great prize lined up. A copy of the extremely readable Newnes' Guide to Satellite Television, which looks at everything from first principles, to dish installations, could be yours!

To enter the contest, all you have to do is answer four extremely simple questions. Write your answers on a postcard or sealed-down envelope (don't forget to include your name, address and daytime telephone number!) and send it to: 'TechniSat Satellite System Contest', The Editor, 'Electronics – The Maplin Magazine', P. O. Box 3, Rayleigh, Essex, SS6 8LR. Employees of TechniSat (UK) Ltd., or Maplin Electronics PLC, and family members of same, are not eligible to enter. Also, please note that multiple entries from one and the same family group will be disqualified.

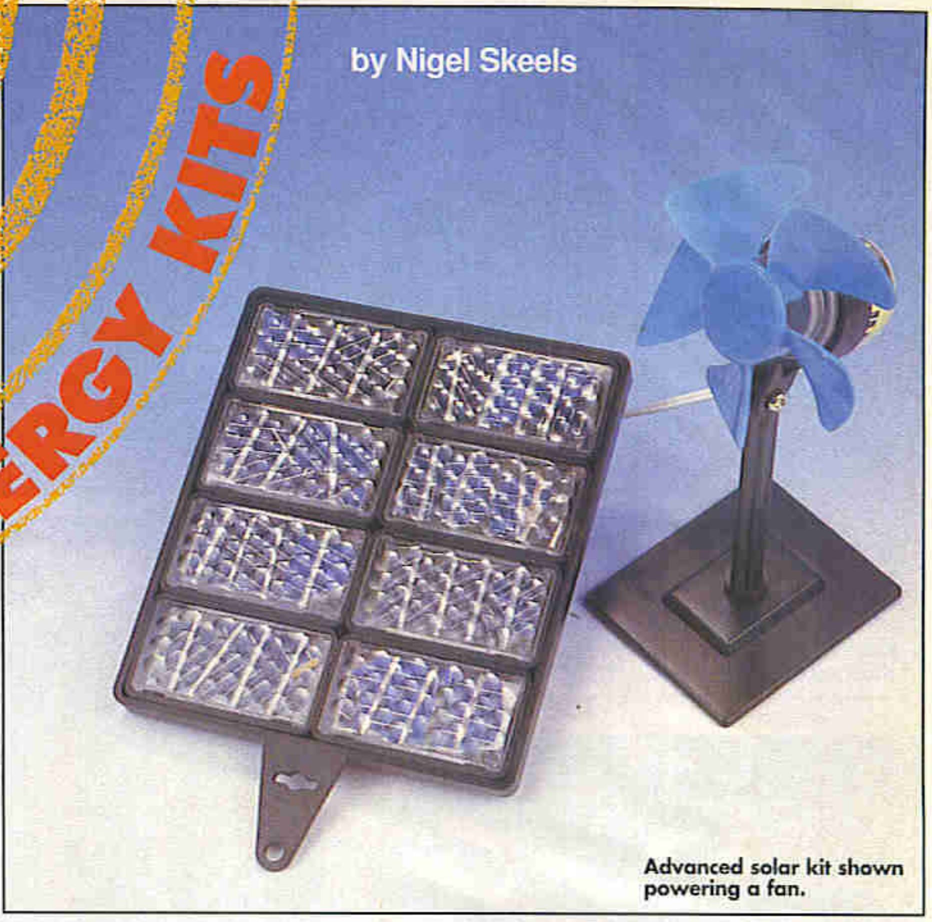
Closing date for entries: 31st August 1993.

So, move into the space age now!

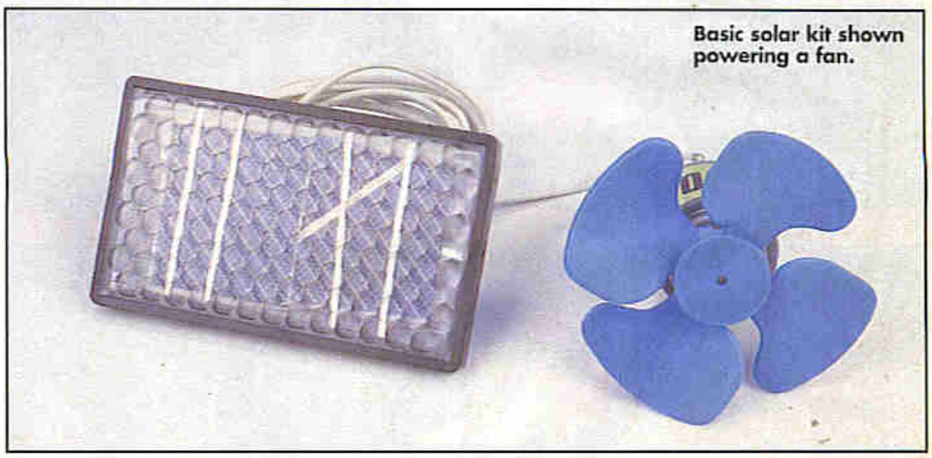
1. On which satellite can you find Sky Movies Plus?
   a) Discovery.
   b) Telstar.
   c) Astra.
   d) Telecom 1C.
2. Which of the following is not a type of domestic satellite receiving aerial?
   a) The parabolic dish.
   b) The Editor's hat.
   c) The 'Squarial'.
   d) The Cambridge 'Squish'.
3. What is UK Gold's encryption system?
   a) Videocrypt.
   b) It hasn't got one.
   c) Crypt-o-matic.
   d) Enigma.
4. How many parts of the 'Discovering Satellite Television' series have been published in 'Electronics' so far (including this part!)?
   a) Four.
   b) Five.
   c) Six.
   d) Seven.

EDUCATIONAL SOLAR ENERGY KITS

by Nigel Skeels



Advanced solar kit shown powering a fan.



Basic solar kit shown powering a fan.

Is it sunny outside? If it is then you could be in for a treat. Imagine if your favourite electronic toy could work without having to be plugged into the mains or use expensive batteries that keep going flat. Well, if you had the correct size solar panel and some sunshine, then it is possible that you would never need to use another power supply again!

How a Solar Panel Works

A solar cell is made from a thin disc of almost pure silicon crystal. When the silicon crystal is being formed, a small amount of Boron is added. This Boron gives the crystal a unique characteristic, which is that it has a positive electric charge. This part of the cell is called 'p-type' silicon ('p' for positive).

The second part of the cell is called 'n-type' silicon. unlike the p-type, this contains a small amount of Phosphorous instead of Boron. This Phosphorous gives the material a negative charge ('n' for negative). The p-type and n-type layers are combined to produce a neutral cell.

When radiation (photons of light) penetrates into the junction of the n-type and p-type silicon, it creates a flow of electrons (negatively charged particles) throughout the crystal structure by 'knocking off' electrons from the outer electron shell of the atom, leaving a 'hole'.

The crystalline structure of the silicon contains empty areas ('holes') which will accept electrons. As one electron moves to fill a hole, it creates another hole. It is this flow of electrons which produces electricity. The electrons are not 'lost' as they leave the negative terminal of the solar panel, because they are replaced with the electrons flowing into the positive terminal of the solar panel.

Applications of Solar Energy

You will have most probably seen solar cells being used in everyday applications such as solar powered calculators and watches. For low powered applications solar cells are ideal, but anything that requires more power will need larger panels and more sunlight.

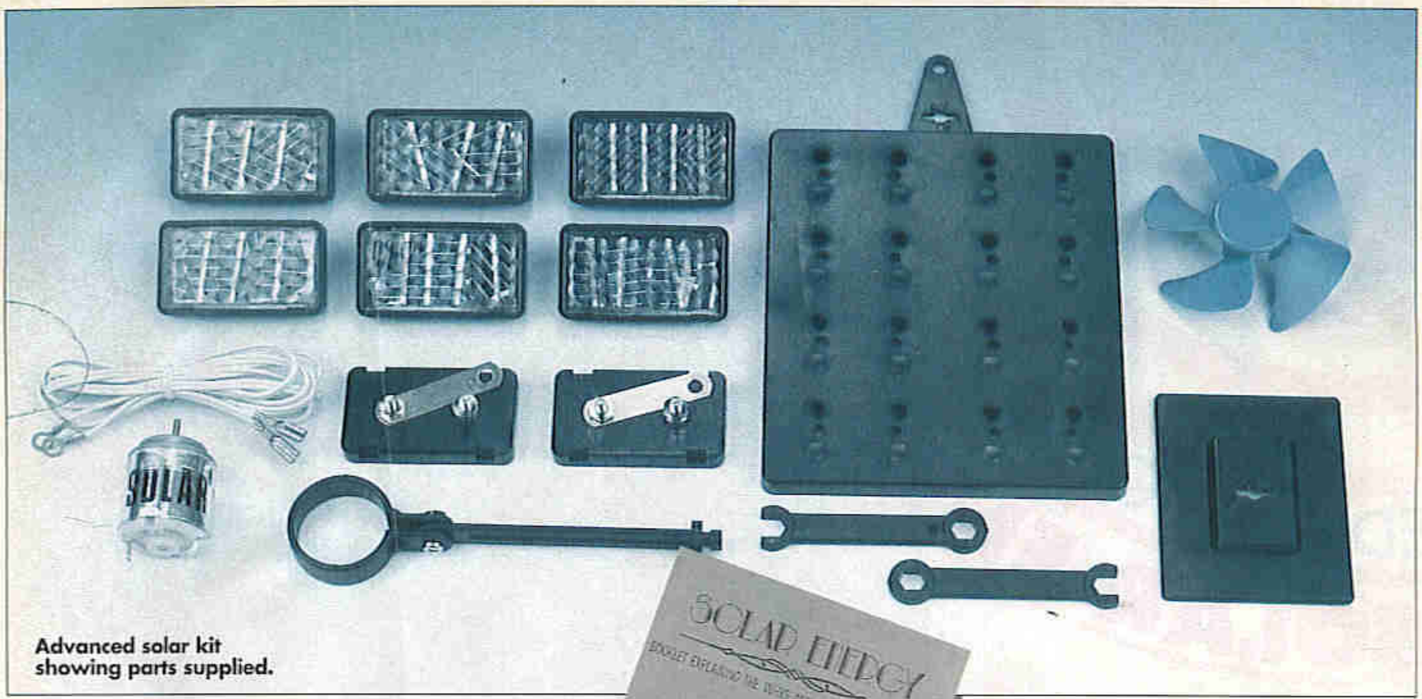
As a power source, solar energy is best suited to providing electricity for remote places where large arrays of panels can be set up without damaging the aesthetics of the surrounding area. A good example of this is in space, where solar panels are used to power satellites. Here solar power is extremely important, as it would be impractical to pop down to the local shop for a fresh set of batteries! Another important factor is that an array of panels is lighter than the equivalent battery, therefore the fuel cost of initially launching a satellite into space is considerably reduced.

In fact most of the developments in solar power have been helped by the space industry. If you look closely at some cheaper panels you will see that they appear to be made up of broken pieces, this is because they are made from the offcuts of panels that are not efficient enough for commercial purposes.

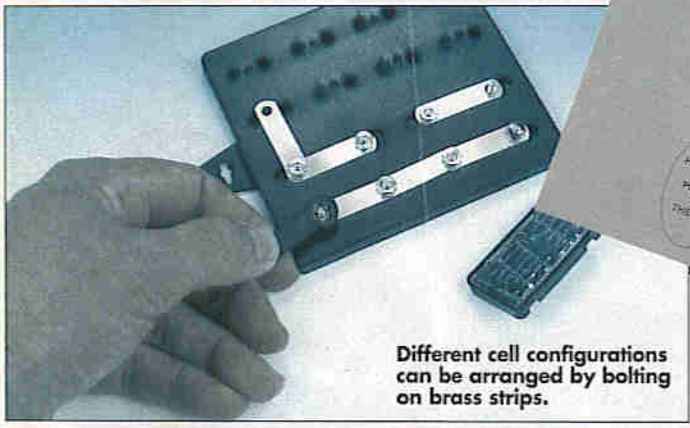
Experiment Yourself!

If you are interested in experimenting with solar energy, you might be interested to know that various educational kits and separate panels are available. The basic kit (Order Code BZ48C) contains one 0.9V 400mA panel, a small DC motor, connecting wire, a plastic fan, turntables, and coloured spinner discs and pictures. The basic kit is ideal for children to learn while they play, and should whet their appetite for finding out more.

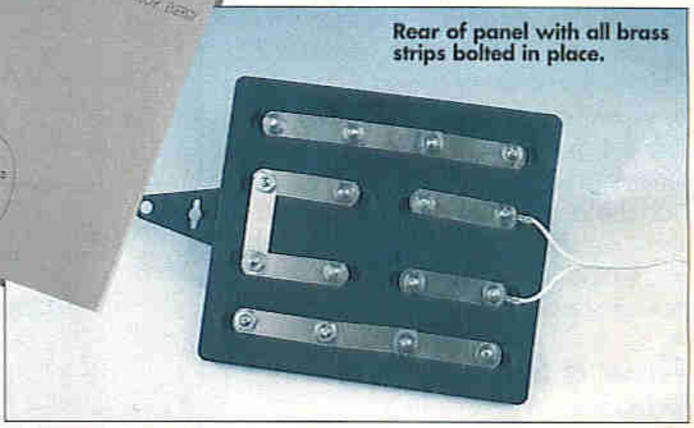
The advanced kit (Order Code BZ52G) takes the theory of solar power a stage further. The kit contains eight 0·4V 100mA cells, which enable the user to learn about different configurations and experiment with varying outputs of voltage and current (ranging from 0·8V at 400mA to 3·2V at 100mA), which is useful for powering other devices such as radios, calculators and other low powered items. The kit also contains a small DC motor as well as two plastic spinners, plastic fan blades, a stand for the fan, a tray for the cells, and a detailed book-



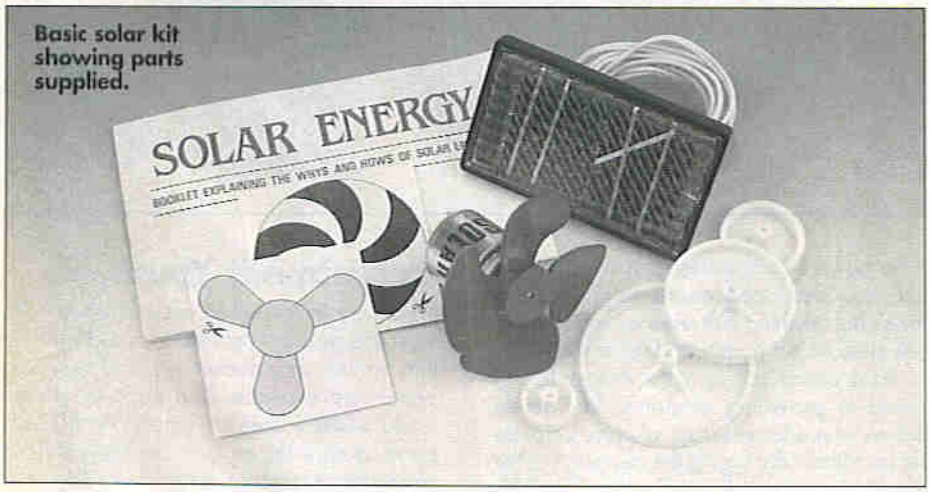
Advanced solar kit showing parts supplied.



Different cell configurations can be arranged by bolting on brass strips.



Rear of panel with all brass strips bolted in place.



Basic solar kit showing parts supplied.

Solar Cells mA	V DC	Size mm	Order Code	Price
200mA	0·45V	55 x 35 x 12	BZ43W	£1·48
400mA	0·45V	75 x 45 x 12	BZ44X	£1·98
700mA	0·45V	95 x 65 x 12	BZ45Y	£3·95
400mA	0·9V	95 x 65 x 12	BZ46A	£3·95
400mA (with motor)	0·9V	95 x 65 x 12	BZ47B	£4·95

Solar Panels mA	V DC	Size mm	Order Code	Price
50mA	9V	146 x 105 x 13	RK23A	£9·95
30mA	12V	146 x 105 x 13	RK24B	£11·95
250mA	12 to 16V	292 x 239 x 17	BZ50E	£39·95 A
500mA	12 to 16V	254 x 283 x 17	BZ51F	£59·95 B

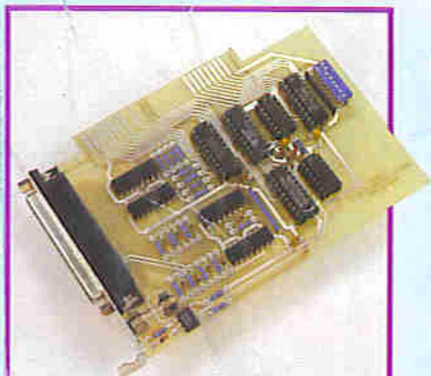
let explaining everything from how it works to how to configure the cells to provide different outputs.

Other solar cells and panels are also available, ranging from the 0·45V, 200mA cell to the higher capacity 12V, 500mA solar panel, which is capable of charging sealed lead acid batteries. A useful application for the 500mA 12V panel is as a car battery trickle charger, for example, where the panel may be laid on a car's rear window parcel shelf. Both 12V solar panels include reverse blocking safety diodes for battery charging applications. A summary of these items is presented below.

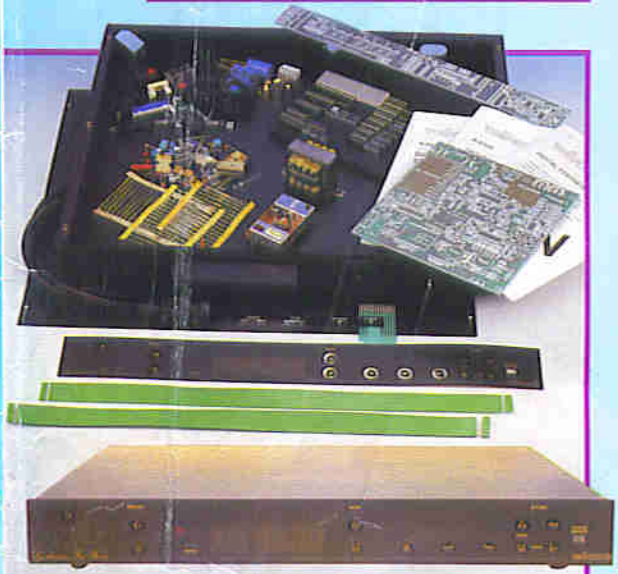
For those of you with 'green fingers', a 'Solar Powered Plant Turner' (Order Code BZ49D) makes use of the sun's energy to rotate a turntable (with the aid of a motor and reduction gear train) so that your plants will grow evenly, in other words not lopsidedly as a result of reaching towards the light! Other possible uses for this item could include those for display purposes in shop windows or to create an eye-catching display in glass-fronted display cabinets. The 'Plant Turner' can also be driven from suitable artificial light, especially bright incandescent light.

Type	Order Code	Price
Basic Solar kit	BZ48C	£5·95
Advanced Solar kit	BZ52G	£6·95
Solar Plant Turner	BZ49D	£9·95

Analogue and Digital Development Unit

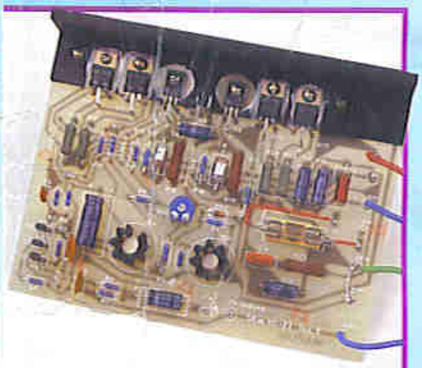


IBM PC Opto-Isolator Card

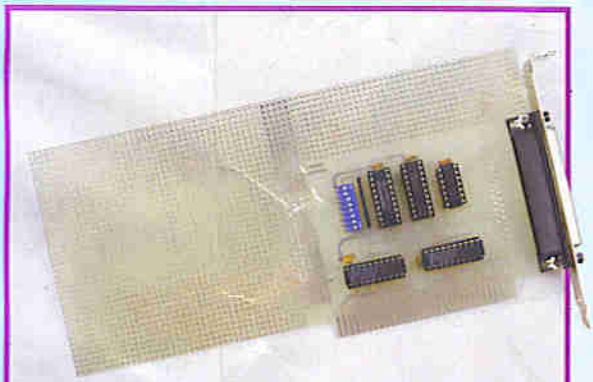


Synthesised Digital VHF/FM Tuner

DID YOU MISS THESE PROJECT KITS?



50W Hi-Fi Power Amplifier



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Details of the various modules that form the 6/12 Channel Modular Mixer can be found in 'Electronics' Nos. 59 (XA59P), 60 (XA60Q), 61 (XA61R), 62 (XA62S), 63 (XA63T), 64 (XA64U), 65 (XA65V) and 66 (XA66W).

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This card has a matrix of DIL IC spaced solder pads and power rails and has on-board buffering, address decoding and selectable base address.
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50W HI-FI POWER AMPLIFIER

A high quality 50W amplifier with very low distortion (<0·05% at 1kHz, 4Ω load) ideal for Hi-Fi systems or as a subwoofer amplifier.
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Carriage Codes – Add; [A]: £1.40, [B]: £2.00, [C]: £2.55, [D]: £3.05, [E]: £3.60, [F]: £4.10, [G]: £4.95, [H]: £5.50.

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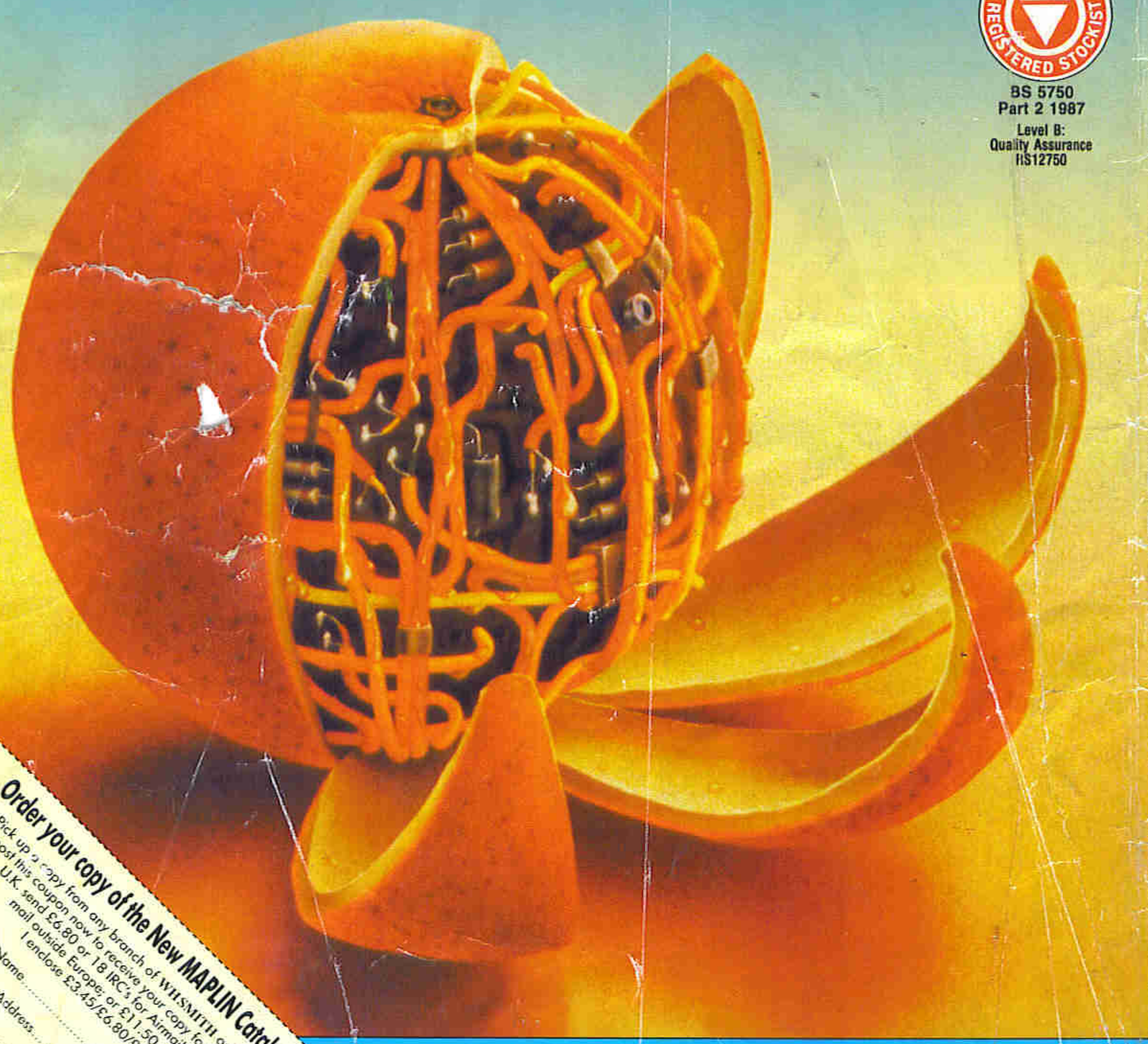

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