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The Maplin Magazine

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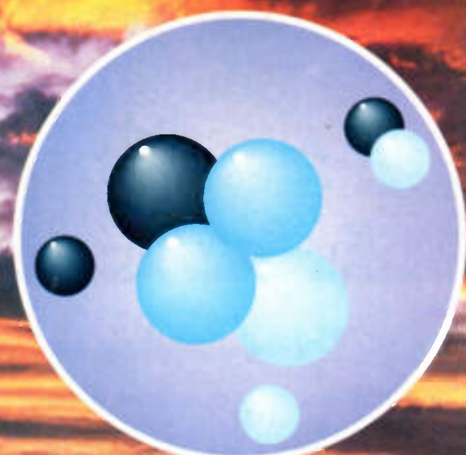
Cold Fusion
Fact or Fantasy?



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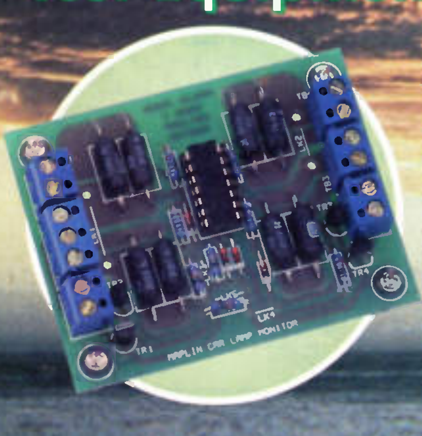

Ingenious Car Lamp Monitor Project plus Versatile Switched Capacitor Elliptic Filter Project for You to Build... and more!

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AUGUST 1994
VOL 13. No. 80

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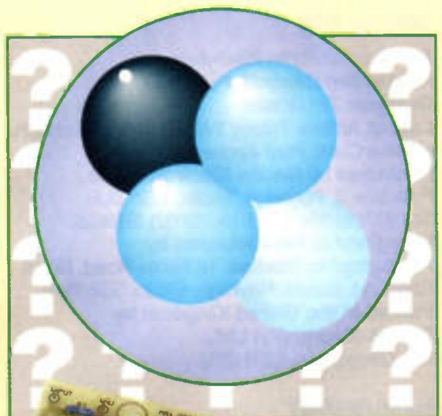

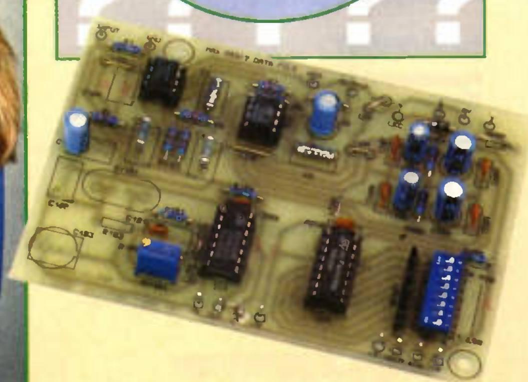

ABOUT THIS ISSUE . . .

Hello and welcome to this month's issue! As well as the usual fine collection of projects and features, this month sees the start of two new mini-series: 'Audio Power Amp ICs', and 'Test Equipment' which I'm sure will be of great interest to all of our readers, especially the more 'novice' constructors out there.

Fight Back

With burglaries on the increase, the 'Anti-Theft Device' should prove very useful. This ingenious little device can be used to protect almost any domestic appliance, and will remain silent until the item is 'moved' (read 'stolen').

Bright Idea

Have you ever noticed how many people regularly drive cars which do not have all of the lights working? – only one functioning brake light being a common example. The 'Car Lamp Monitor' project has been designed to remedy this problem; it will immediately alert the driver if one or more of the vehicle's lights fail. Hopefully, in the future all vehicles will be fitted with a similar device, making driving less hazardous for all.

Lesser Degrees

Unless you have been on a desert island for the past few years, you cannot have failed to notice that Britain's engineering industry is in trouble! Research grants for universities are being cut, and student grants are about to be cut by 10%; it is no wonder that fewer and fewer people are going on to read for an engineering degree when they could qualify as highly-paid accountants and financial brokers (in fact, many engineering students enter these professions immediately after graduating!). Surely, simply increasing the undergraduate grant for engineering courses would act as a sufficient enough incentive for many sixth formers to find out more about engineering careers. Some might then go on to read for an engineering degree, and (dare I say it?) of those, one or two might even enter the profession.

Partial Recall

It is exam time again (probably results time when you read this), and I would like to wish good luck to any of our readers who are currently taking exams!

Light Bite

On a lighter note, I would like to recount a story that I recently heard at a dinner party. It concerns a method of distinguishing between mathematicians, physicists and engineers: you simply ask them what 1 + 2 equals. The mathematician will answer '3', the physicist will answer 'somewhere between 2·5 and 3·4', and the engineer will say '3, but we'll call it 10 to be on the safe side'. If you have a good accountant, he will answer 'whatever you want it to be!' (no offence intended).

And Finally

Well, until next time, I hope that you enjoy reading this issue as much as we've enjoyed putting it together.
Happy reading!

R Ball

ABC CONSUMER PRESS

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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.

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'Get You Working' Service

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

Kit Retail Price	Standard Servicing Cost
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£80 to £99.99	£50
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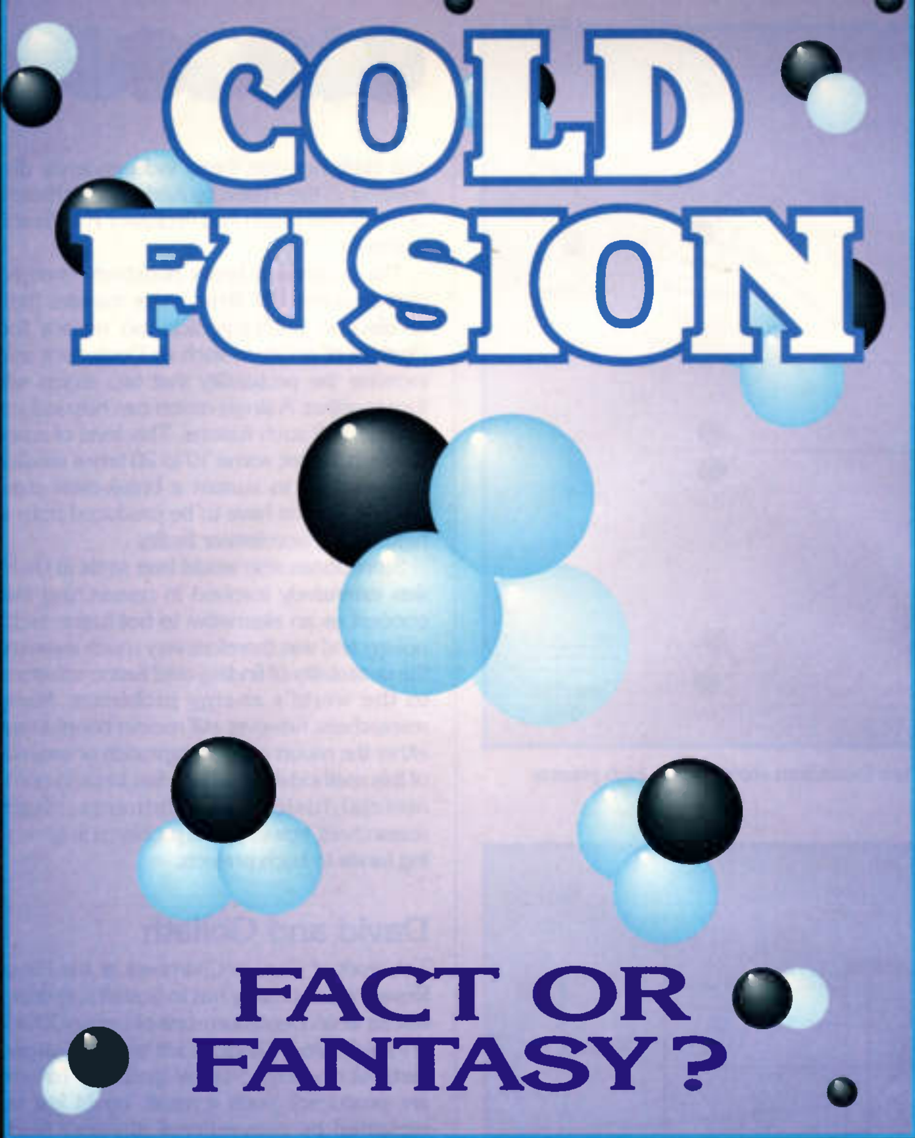
Over £150	£60 minimum

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.

Write to: The Editor, Electronics – The Maplin Magazine, P.O. Box 3, Rayleigh, Essex,



In writing on the topic of cold fusion, there is the danger of the ignorant conveying the bias of the scientific establishment to the gullible public. In the case of cold fusion there is the immediate problem about defining what is observed. If one group of scientists claims to find a positive finding with cold fusion, then it is typical to find another group who bemoan that they have repeated the experiment and failed to find any effect. In terms of the theory, therefore, there are no 'respectable' theories to explain effects which themselves are not generally accepted as being real by the broad scientific community.

by Douglas Clarkson

THE puzzle and confusion which exists within the scientific community at present relates quite probably to a range of separate phenomena which experimental skills have not yet managed to identify. Indeed while initially cold fusion research was uniquely identified with Fleischmann-Pons electrochemical cells, this is now not one but four or five 'types' of cold fusion which claim to have been demonstrated.

In spite of indifference and official antagonism, there is no doubt in the mind of many scientists that work in cold fusion research is providing valid findings – not perhaps in the full gaze of national physics laboratories funded by taxpayers but in independent and commercial laboratories around the world. The effort is going into harnessing the technology. These thoughts were expressed in a recent Canadian Broadcasting Corporation television programme 'The Secret Life of Cold Fusion' of which the author has a copy.

Star Gazing

The stars are considered to fuel their nuclear fires by so called hot fusion mechanisms where energetic atoms at temperatures of millions of degrees collide and overcome their coulomb electrostatic repulsion and allow the strong nuclear forces to combine the nuclei to form other elements and release energy in the process.

Scientists are developing systems of so called hot fusion on earth to replicate the reactions of the solar furnace. The principal reaction being investigated is the collision of Deuterium atoms (isotopes of hydrogen) to fuse together and form three possible products as outlined in Figure 1. The Deuterium ions require, however, high levels of energy in order to overcome the repulsive Coulomb force of proton to proton interaction. Temperatures in excess of 100 million Kelvin (K) are required in a gas plasma environment.

Considerable research and development has been undertaken in developing hot fusion. Recently at the research facility at Daresbury, scientists witnessed the first exothermic reaction of hot fusion. Many billions of pounds will be required over the next 50 years or so before hot fusion becomes a viable commercial proposition.

The press conference announced on 23 March 1989 by Fleischmann and Pons basically claimed that fusion between Deuterium atoms, or some other, yet unknown nuclear reaction could be produced at room temperature in a specific Palladium electrode cell shown in Figure 2. As mentioned previously, this claim caused a problem for the scientific community. Not only was the experiment apparently difficult to replicate, almost every accepted theory of nuclear physics indicated that 'nothing nuclear' could be taking place. There simply was not enough energy available to enable Deuterium atoms to penetrate the mutually repulsive like charges (Coulomb barrier). Fleischmann and Pons pointed to as evidence of the nuclear effect the production of excess heat, neutrons and Tritium – a rare isotope of Hydrogen.

The trigger for the press conference of 23 March 1989 was in fact the impending announcement of Dr. Stephen Jones on the detection of neutrons from metal electrodes immersed in heavy water – i.e. water containing Deuterium. This work was essentially indicating that an 'effect' could be detected – but one which essentially had no prospect of any commercial exploitation. Jones and his colleagues worked with foils of Palladium in contrast to the wire rod electrodes of Fleischmann and Pons. This work, seen in perspective, however, would have received great attention from a wider 'fusion' community since the effects observed by Jones implied a review of orthodox theories of fusion of Deuterium were required.

In fact, elsewhere, chemists during 1989 had shown that if groups of heavy water molecules containing up to 1,300 molecules were accelerated to energies of 235eV then high energy Tritons and protons were observed. This process was described as 'cluster impact fusion' by the scientists at Brookhaven National Laboratory in the USA. The experiment was again a proof that something 'forbidden' was in fact taking place when Deuterium atoms were acting 'collectively'.

Clues from the Past

The earnest onlooker could be forgiven for thinking that 1989 marked year zero of cold fusion phenomenon. This is in fact not the case. In the 1920s two German scientists – Paneth and Peters claimed to have formed Helium from Hydrogen using a Palladium catalyst. This was in the days of considerable interest in Helium as a replacement for Hydrogen in Zeppelin airships. They were wrong in their claims, however, and retracted their discovery in 1927. The unique property of Palladium to absorb very large volumes of Hydrogen had been previously studied extensively by the Scottish physical chemist Thomas Graham (1805 to 1869). The work

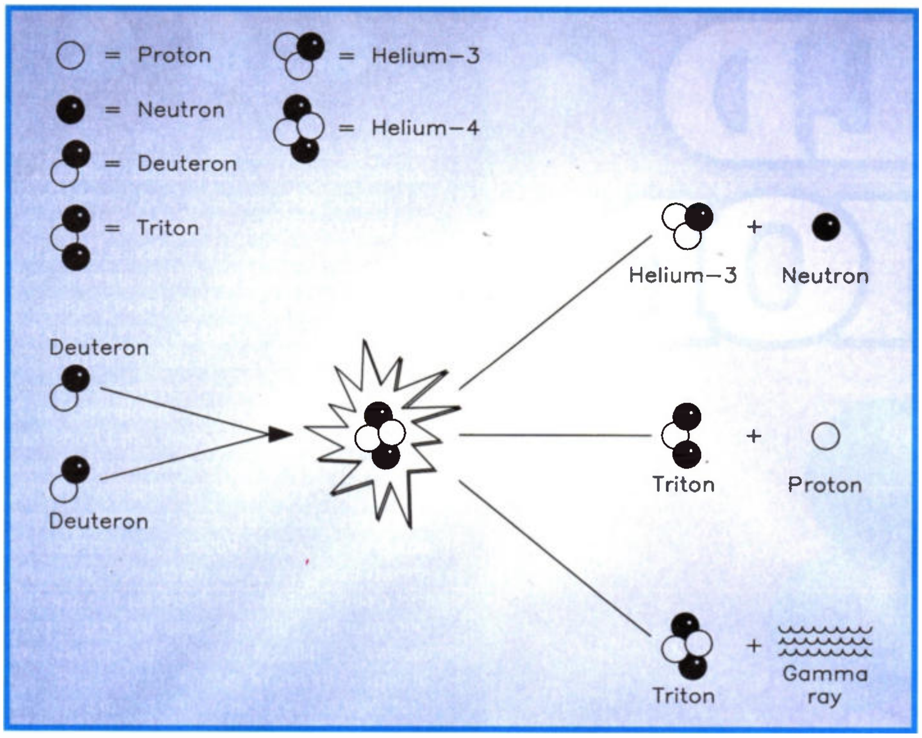


Figure 1. Mechanisms of 'conventional hot' fusion of two Deuterium atoms where high plasma temperatures are required to initiate reaction.

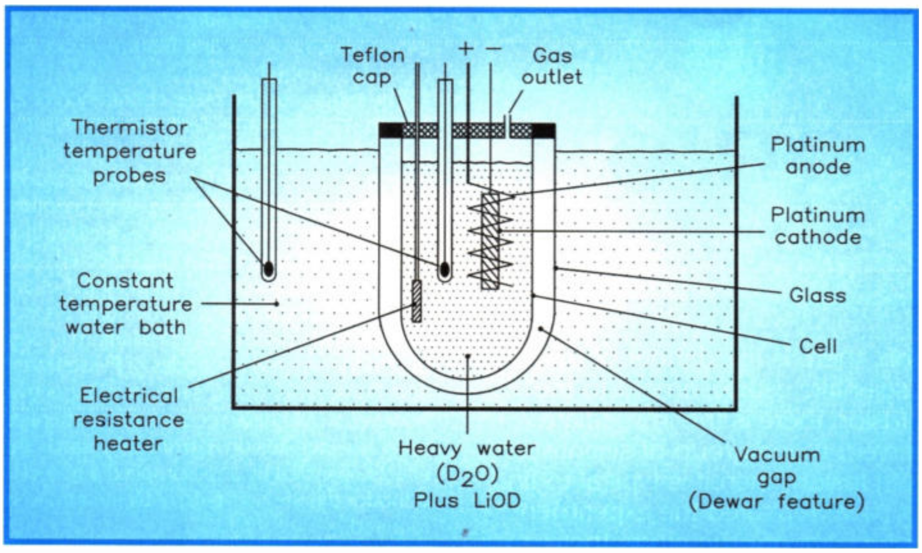


Figure 2. Schematic design of Fleischmann-Pons electrochemical cell used to demonstrate cold fusion.

of Paneth and Peters prompted the Swede John Tandberg to investigate the use of a Palladium electrode to try and fuse Hydrogen to make Helium. When the isotope of Hydrogen – Deuterium was discovered in 1932, Tandberg quickly decided to try to use this in his high voltage circuit to fuse Deuterium. Cold fusion was anticipated, therefore in the 1930s but never apparently demonstrated. Perhaps some 'unexplained' phenomena were observed but were never reported.

There is no doubt that from the 1970s onwards Fleischmann and Pons were intrigued by the properties of Deuterium loaded Palladium. It was anticipated that the associations of large numbers of Deuterium atoms in close proximity could cause 'coherence' in the interactions of Deuterium atoms. Rather than reactions depending on the independent coming together of two free atoms, as in hot fusion, groups of atoms could exchange energy with individual atoms and in so doing introduce effects not anticipated by standard quantum theory.

In tracing the evolution of cold fusion, there is also the phenomenon of muon induced fusion. This development came to prominence in 1956 when it was demonstrated at the University of California at Berkeley. The theoretical framework for such a phenomenon had, however, been independently discovered in the 1940s by Andrei D. Sakharov of the Soviet Union and Professor F. C. Frank of Britain.

Dr. R. J. Kucherov at the ENECO laboratory, Salt Lake City.

The muon is a heavy negatively charged particle some 207 times more massive than an electron. Such a particle can 'replace' the electron of an atom such as Deuterium and increase the probability that two atoms will fuse together. A single muon can help induce around 150 such fusions. This level of reaction is, however, some 10 to 20 times smaller that required to sustain a break-even state and the muons have to be produced from a high energy accelerator facility.

Steve Jones who would later settle at Utah, was extensively involved in researching this concept as an alternative to hot fusion technology and was therefore very much aware of the desirability of finding cold fusion solutions to the world's energy problems. Many researchers, however, still remain hopeful that either the muon catalyst approach or variants of this method will lead to a fast track to commercial fusion developments. Such researchers, however, find problems in attracting funds to such projects.

David and Goliath

The work of George Chambers at the Naval Research Laboratory has indicated surprising results when Deuterium ions of energy 350eV are fired onto a Titanium foil target. Charged particles of energy 5·9MeV (probably Tritium) are produced! Such a result 'could not be explained by conventional physics'. Such observations have subsequently been confirmed by other workers.

Glow Discharge Experiments

Considerable interest has been expressed in experiments in Russia by Y. R. Kucherov and colleagues in the field of glow discharge. In this experiment a discharge tube consisting of a cylinder some 20cm in diameter containing Deuterium gas is ionised with the discharge tube varying from 10 to 500mA as shown in Figure 3. The electrodes of the tube were Molybdenum with Palladium foil attached to the cathode (where positive Deuterium ions would migrate). Neutron detectors were located in the vicinity of the cathode. Initial experiments achieved an excess heat level of 100% at an input power of 1W. This equated to an excess energy of 1,000 Joules over a period of 1,000 seconds. Neutron bursts of variable size were detected – ranging from a few to 1,000 pulses in a burst.

Subsequent work has produced neutron fluxes as high as 1 million per second and with an excess heat of 300%. One theory of Dr. Kucherov is that fission of Palladium may be involved – the splitting of Palladium to much smaller atoms.

Such experiments would appear to indicate some very significant gaps in present day quantum theory and that the phenomenon of cold fusion is probably much wider than was first thought. Reports are circulating that this experiment has been confirmed by Shell Corporation scientists in France.

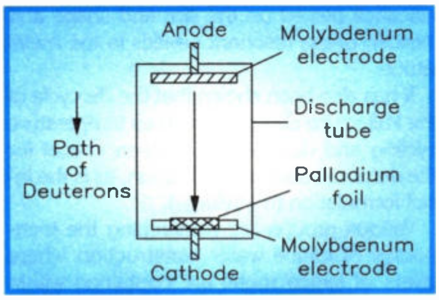


Figure 3. Glow discharge system of cold fusion. Excess powers of at least 300% have reported using this technique.

Molten Salt Cells

Considerable interest was initiated in reports of work undertaken at the University of Hawaii by the team of Professor Bruce Liebert and Bor Yann Liaw. Working at temperatures of between 350°C to 500°C excess power at levels of factors of 15 – i.e. 1,500% were observed. In one unit an input electrical power of 1·68W is claimed to yield 25·4W of excess thermal output. While in the initial stages of cold fusion, researchers were struggling to attain levels of 10% excess heat such high levels cannot be the result of observational errors. The group at Hawaii used a molten Lithium Chloride, Potassium Chloride mixture which was saturated with Lithium Deuteride. The cell used is shown in Figure 4. Details of typical cell input/output power results are shown in Figure 5. Levels of excess power generation of 600W per cubic centimetre have been attained. This is comparable or better than present day technology fission reactors.

The irony of the situation is that there is still no accepted explanation of how such cells work. This is perhaps a major stumbling block in the development of the technology – for some. It is probably not a problem for the Japanese or a corporation wishing to develop a range of 'clean' energy sources.

Writing the New Rules

Even as cold fusion was beginning to fight to exist in the eyes of the scientific community various theorists were advancing theories to explain the strange phenomena. It was well understood that if two positively charged Deuterium nuclei were to approach sufficiently close to overcome the coulomb electrostatic attraction so that strong nuclear forces came into play and fusion of nuclei takes place then an initial energy of 600,000eV was required. Even a cool plasma at 12,000K would only give a Deuterium atom an energy of 1eV. Theories to explain cold fusion would have to come up with ways in which the Coulomb forces could be overcome or 'got around'

The great problem which cold fusion had run up against was that any observations of neutrons, gamma rays and levels of Tritium and Helium were being assessed as if hot fusion reactions were taking place. For Palladium cells which were producing say 5W of excess heat, then there was a vast deficiency in the numbers of neutrons which were observed to be generated. Present observations are being interpreted on the basis of radically different mechanisms being involved in the fusion process.

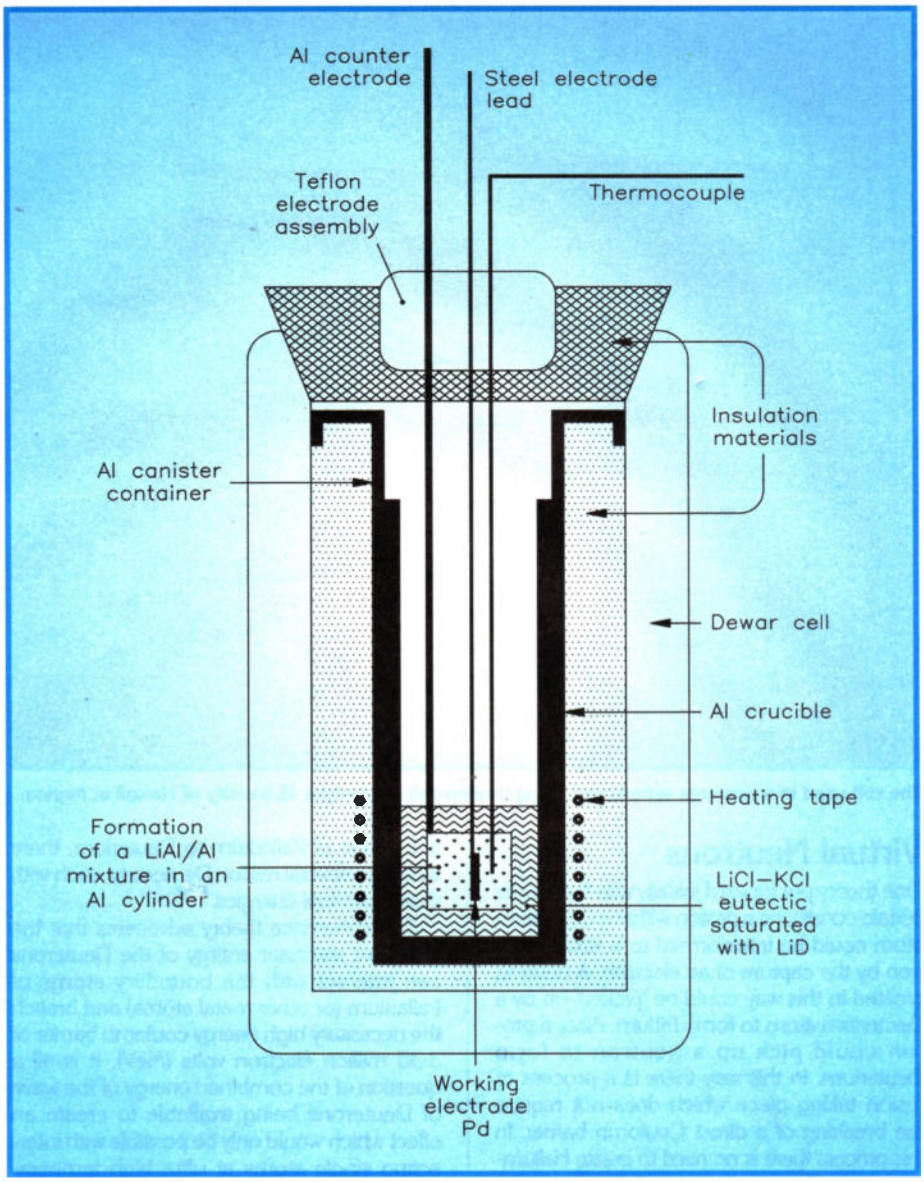


Figure 4. Molten salt 'cold fusion' cell developed by the University of Hawaii. The unit operates at temperatures between 350°C and 500°C.

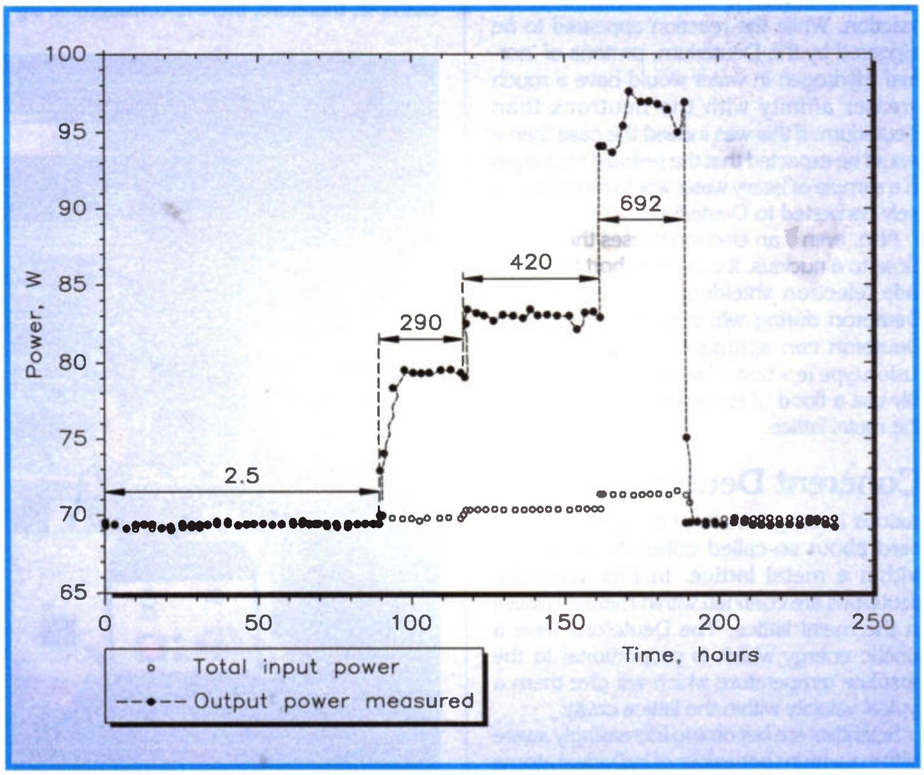
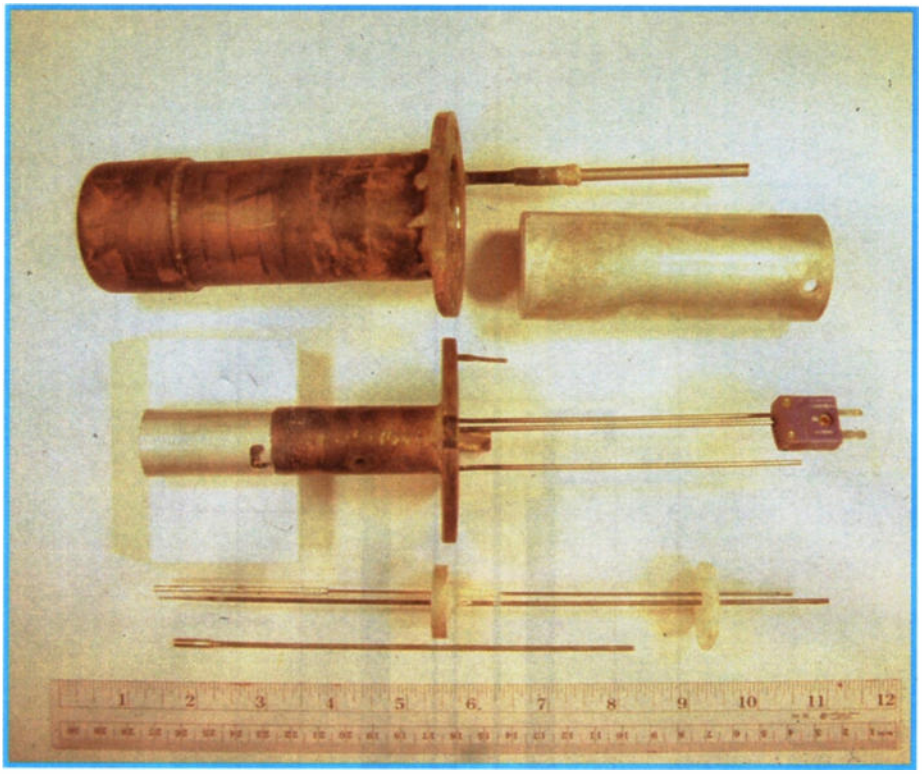


Figure 5. Variation with time of output/input power of a molten salt electrochemical cell. Numbers in the figure are the current densities in mA/cm² at which Deuterium was charged into the Palladium electrode.



The cell used in a previous experiment using molten salt electrolyte. University of Hawaii at Manoa.

Virtual Neutrons

One theory put forward initially was that under certain conditions a proton within a Deuterium atom could be transformed to a virtual neutron by the capture of an electron. A neutron created in this way could be 'picked' up by a Deuterium atom to form Tritium. Also, a proton could pick up a neutron to form Deuterium. In this way there is a process of fusion taking place which does not require the breaking of a direct Coulomb barrier. In this process there is no need to create Helium-4 and this mechanism would explain why Helium-4 is not observed in most experimental work. The Palladium metal in this scenario is considered to act as a catalyst of the reaction. While the reaction appeared to be triggered by the Deuterium, protons of 'normal' Hydrogen in water would have a much greater affinity with the neutrons than Deuterium. If this was indeed the case then it would be expected that the residual Hydrogen in a sample of heavy water would be progressively converted to Deuterium.

Also, even if an electron passes through or close to a nucleus, it can for a short time provide 'electron shielding' to the proton or Deuteron during which another proton or Deuteron can approach and interact in a fusion type reaction. Cold fusion devices usually use a flood of electrons pouring through the metal lattice.

Coherent Deuterons

Various investigators have thought long and hard about so-called coherent Deuterons within a metal lattice. In this scenario, deuterons are confined within minute cavities in the metal lattice. The Deuterons have a kinetic energy which is proportional to the absolute temperature which will give them a typical velocity within the lattice cavity.

Scientists are becoming increasingly aware of the quantum behaviour of individual atoms – how they have characteristics of both particles and waves. Within a typical cavity of width 10 microns and which had been loaded with a 1:1 ratio of Palladium to Deuterium, there would be several million Deuterons, each with their individual energies.

The coherence theory advocates that the collective resonant energy of the Deuterons can interact with the boundary atoms of Palladium (or other metal atoms) and breach the necessary high energy coulomb barrier of 3·38 million electron volts (MeV). It is all a question of the combined energy of the wave of Deuterons being available to create an effect which would only be possible with interacting single atoms at ultra high temperatures. This introduces therefore, a different framework of free high temperature plasmas, compared to lattice bound Deuterium. In this example, therefore, there is considerable significance placed on the size and shape and 'history' of the resonant cavities in the metal lattice.

It has also been shown that the life cycle of the Palladium electrode such as temperature cycling and degassing has been critical for the demonstration of cold fusion, as is the initial formulation (metallurgy).

Various groups are researching the technology of lattice wafer construction where layers of lattice metal are contained within thin layers of high neutron absorbing elements such as Boron, Indium, Cadmium or Gadolinium. It is clear, however, that it is the status and conditioning of the host metal lattice electrode which has the critical effect on cell performance.

This starting reaction for 'Deuteron wave' interaction is considered thus to be:

$$d + {}^{108}Pd \rightarrow {}^{109}Pd + p\ (3{\cdot}9MeV) \qquad (1)$$

where the reaction involves a ^{108}Pd atom. With this reaction there is a net release of energy of 3·9 – 3·38 = 0·52MeV.

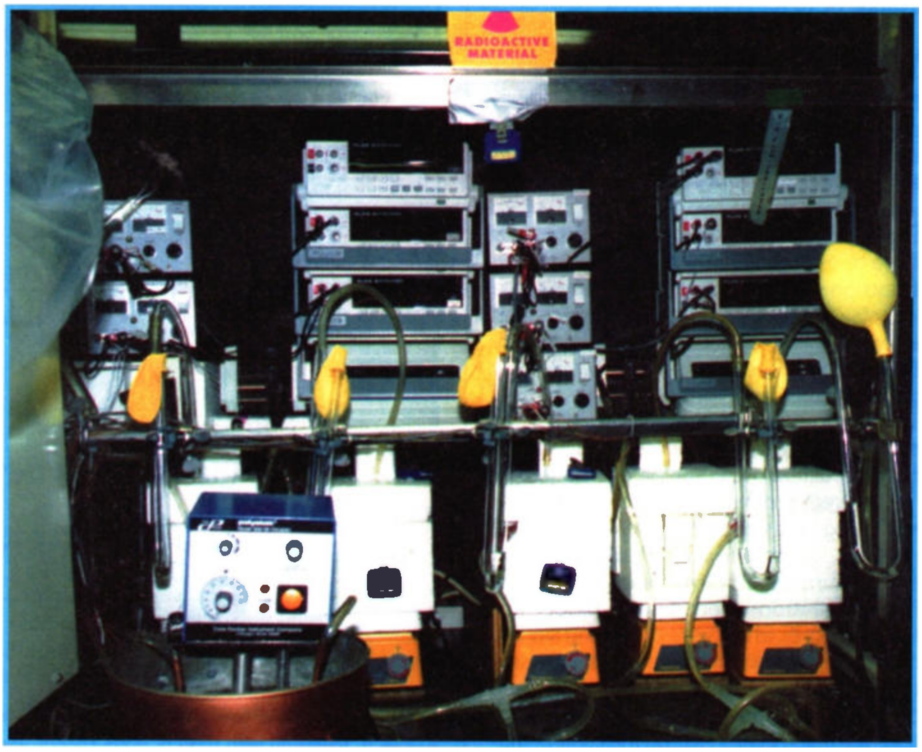
Tritium Production

One of the great controversies of cold fusion has been the variability of detection of Tritium, the isotope of hydrogen with one proton and two neutrons. Most experiments in cold fusion which have detected Tritium have observed it without excess heat and this has presented problems for the theorists.

One possible mechanism is that the released proton in equation 1 reacts with a Deuteron to create a Tritium atom and a positron thus:

$$p(3{\cdot}9MeV) + d \rightarrow T(3{\cdot}3MeV) + B^{+}\ (5{\cdot}47MeV)$$

In this example, the proton has sufficient energy to react not with the coherent wave of deuterons but with a single deuteron. It is



Bush and Eagleton's laboratory; electrolytic cells utilising Palladium on Silver substrate in Lithium Deuteride.

likely, however, that the positron will decay while still inside the electron shells of the Tritium and the energy of the emergent gamma ray will be reduced.

Helium may also be produced by the reaction:

$D + D \rightarrow {}^{4}He + 23{\cdot}8MeV$

also,

$D + {}^{6}Li \rightarrow {}^{8}Be^{*} \rightarrow 2\,{}^{4}He$

* Highly unstable, does not last even for $1\mu s$.

Neutrons

In most observations, neutron production is at a low level – although there have been occasions where neutron bursts have been observed. Models have been developed in which an energetic proton reacts with a Deuterium atom to form two protons and a neutron with an average energy of 0·57MeV. These models predict that detected neutron fluxes of about 1 per second could be expected. The neutron production pathway, however, is not a major feature of cold fusion for conventional Fleischmann-Pons cells.

Ultrasonic Triggers

Dr. David Deak of Deak Sonoteck in the USA is investigating the use of sonic and ultrasonic waves to trigger cold fusion via the process of cavitation where small micro cavities opened up in a liquid by the 'negative' pressure wave collapse violently during the 'positive' pressure wave cycle. This process of cavitation has been exploited previously for other effects, such as cleaning and surface processing of materials. It is understood that very high temperatures and pressures are generated at the time when the cavity is collapsed. The 'SONACTOR' cold fusion reactor being developed by Dr. Deak primarily utilises the effects of cavitation taking place on the surface of cell electrodes to trigger cold fusion processes.

Eagleton (left), Bush (right). Borax is used for nutron shielding during one series of experiments at Dr Robert Eagleton's laboratory, Pomona, California.

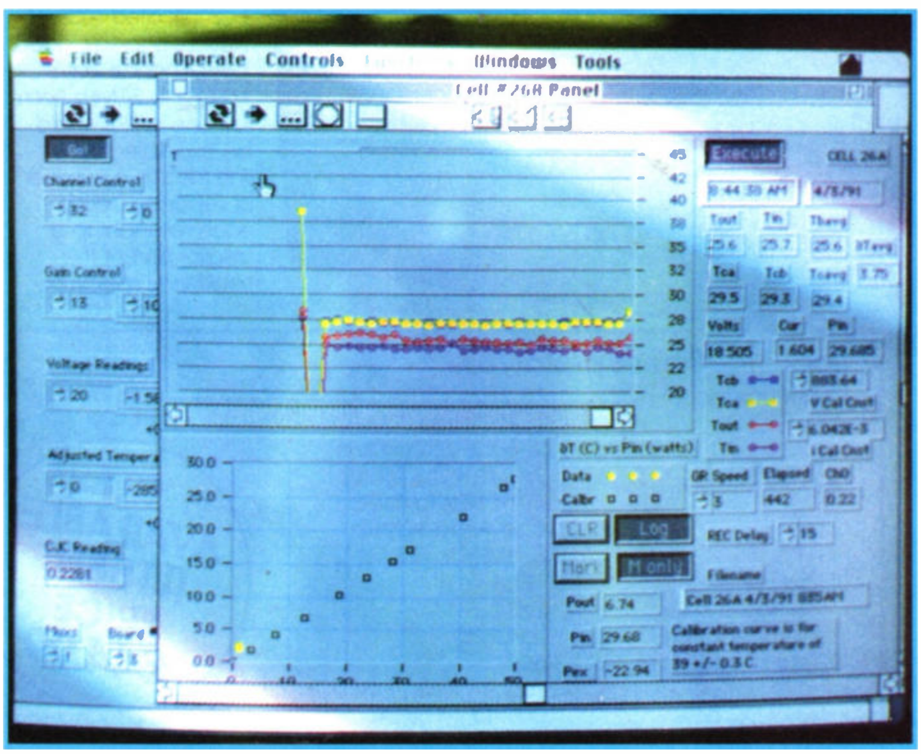
Temperature Effects

From a practical point of view, also, more useful heat can be abstracted from a heat source at a higher temperature. This must be a subtle requirement for future commercial development of cold fusion as an energy source. Cells could therefore be of more commercial value if a molten salt type or pressurised heavy water cells were used.

Light Water Cells

In the general uncertainty of phenomena where excess energy is demonstrated, there may also be effects which do not involve mechanisms of cold fusion. In the so called 'Mills Cell', significant heat production of around 500% (the Bush-Eagleton cells have achieved 30 to 300% excess heat) is claimed to be achieved without evidence of neutrons, gamma rays or Tritium. Moreover, the effect takes place with normal 'light' water. The principle of the Mills Cell according to its developer is to facilitate the relaxation of the normal ground state Hydrogen atom to a lower state corresponding to a fractional quantum level. The electrolyte used in the cell is typically Potassium Carbonate. The technology is being developed by Hydro Catholysis Power Corporation (Tel: +1 717 291 6673).

Even within the cold fusion community, however, the Mills Cell is a contentious issue. Workers at the Cathalysis Research Centre, Hokkaido University, Japan, are trying to explain the phenomena on a cold fusion effect of protons fusing with Potassium to form Calcium.



A close up of computer monitor showing the virtual instrument stored in computer memory and used for cell data acquisition and cell monitoring.

Conclusion

As more and more effort goes into 'big science' the thought that the next generation of scientific discoveries will come exclusively from this arena is uppermost in the minds of the general scientific community. Phenomena such as cold fusion appears to contradict this viewpoint and highlight that some of the fundamental theoretical assumptions driving 'big science' may in fact be flawed or at best incomplete. Breakthroughs do *not* normally come from big government or corporation laboratories, but from the small laboratories. It is more than ever a time for the best endeavours of the scientific community to take cold fusion phenomena more seriously and for national science research funding to give backing for such work. On the surface it appears that certain elements of the scientific community have been behaving in a most unscientific way.

Further Reading

Fire from Ice, Eugene F. Mallove, John Wiley and Sons, 1991.

Calorimetry of the Pd-D2O System: From Simplicity via Complications to Simplicity, Martin Fleischmann and Stanley Pons, Physics Letters A, 176, (1993) 118-129.

Fusion Facts: December 1992, Volume 4, Number 6.

Fusion Facts: May 1993, Volume 4, Number 11 q12.

Fusion Facts, P.O. Box 58639, University of Utah Research Park, Salt Lake City, UT 84158, USA.

Design by Chris Barlow G8LVK Text by Chris Barlow and Robin Hall G4DVJ

AERIAL ACTIVATOR

The Aerial Activator is designed as an add-on device for your LW/MW/SW receiver. It is designed to increase the strength of the radio signals received over a wide range of frequencies. For LW/MW broadcasts and shortwave listeners using a general coverage receiver, this unit offers improved reception even when used in conjunction with a small aerial system.

3
PROJECT RATING

IF this project sounds vaguely familiar it is because something very similar was published in the June/July 1986 issue of *Electronics*. At that time the project appeared as two separate projects, the Active Aerial (LM05F) and the Aerial Tuning Unit (LM06G). The best features from both were combined into one project, the result is the brand new and improved Aerial Activator presented here; it completely supersedes the previous two projects, is much easier to build and cheaper!

Aerials

Aerial theory is a very complicated subject. Needless to say, good performance from 150kHz to 30MHz from just one aerial would be expecting a lot. The ideal is a number of separate aerials each resonant to a smaller part of the frequency spectrum.

FEATURES

* Gain of over 15dB
* Six wavebands
* Usable with a wide range of radio receivers
* Low power consumption
* On-board voltage regulator
* Signal input protection
* Power input polarity protection
* Internal battery or external power supply

APPLICATIONS

* Improve radio reception
* Indoor active aerial
* Active aerial tuner

Specification of prototype

Frequency range:	150kHz to 30MHz (six wavebands)
	1. 150kHz to 300kHz
	2. 300kHz to 600kHz
	3. 600kHz to 1·5MHz
	4. 1·5MHz to 4MHz
	5. 4MHz to 10MHz
	6. 8MHz to 30MHz
RF gain:	15dB
Noise figure:	2dB
Input impedance:	Variable
Output impedance:	50Ω
Internal power:	Four AA cells (+6V DC)
External DC power:	+10 to +16V DC
Supply current:	20mA (internal batteries)
	28mA (external +12V DC)

KIT AVAILABLE (LT58N) PRICE £44.99

However, not everyone has the space or budget available for so many aerials, and so one aerial must suffice for the whole of the range.

One of the most common types of simple outdoor receiving aerials is the end-fed, long wire aerial; its length is governed by the amount of space available within the boundaries of your property. An average length of such an aerial is between 20 and 50m. Its height above the ground is not critical at LW/MW/SW frequencies, but it is far more convenient to get it up in the air out of the way, usually at around 5 to 10m. The main disadvantage of this system is that its impedance presented to the aerial input of a communications receiver varies in relation to frequency.

The range of impedance values may swing from a few ohms to several thousand ohms. When looking at the frequency/impedance characteristics of your aerial system you need to know its wavelength relationships.

The mathematical calculation is quite simple. The velocity of a radio wave, whilst travelling through free space, is constant at 186,000 miles per second or 300,000,000 metres per second. In the following formula, V= velocity, and F= frequency in Hertz (cycles). The result is the full wavelength in metres.

$$\lambda = \frac{V}{F} = \frac{300,000,000}{1,875,000\text{Hz}} = \frac{300}{1{\cdot}875\text{MHz}} = 160\text{m}$$

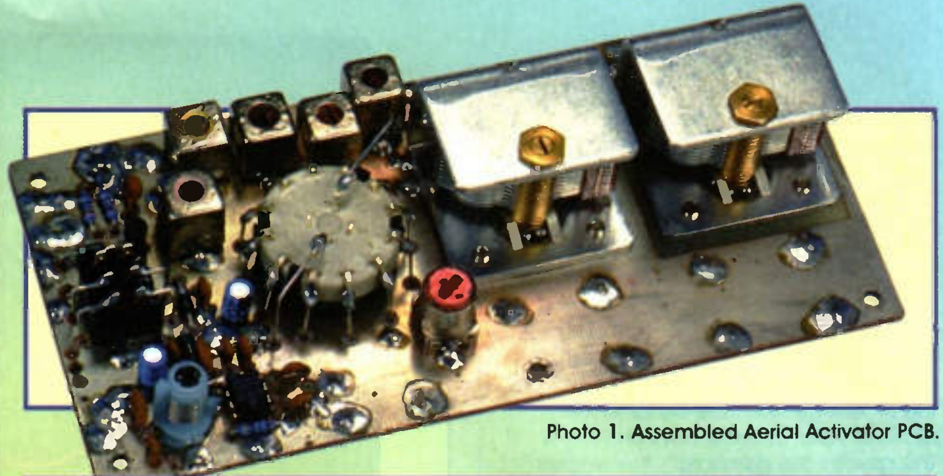


Photo 1. Assembled Aerial Activator PCB.

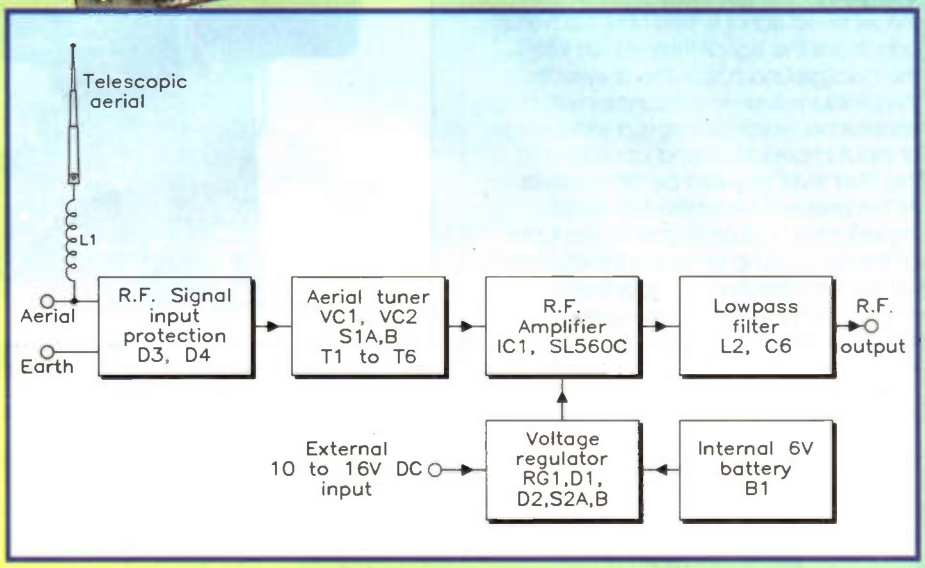


Figure 1. Block diagram of the Aerial Activator.

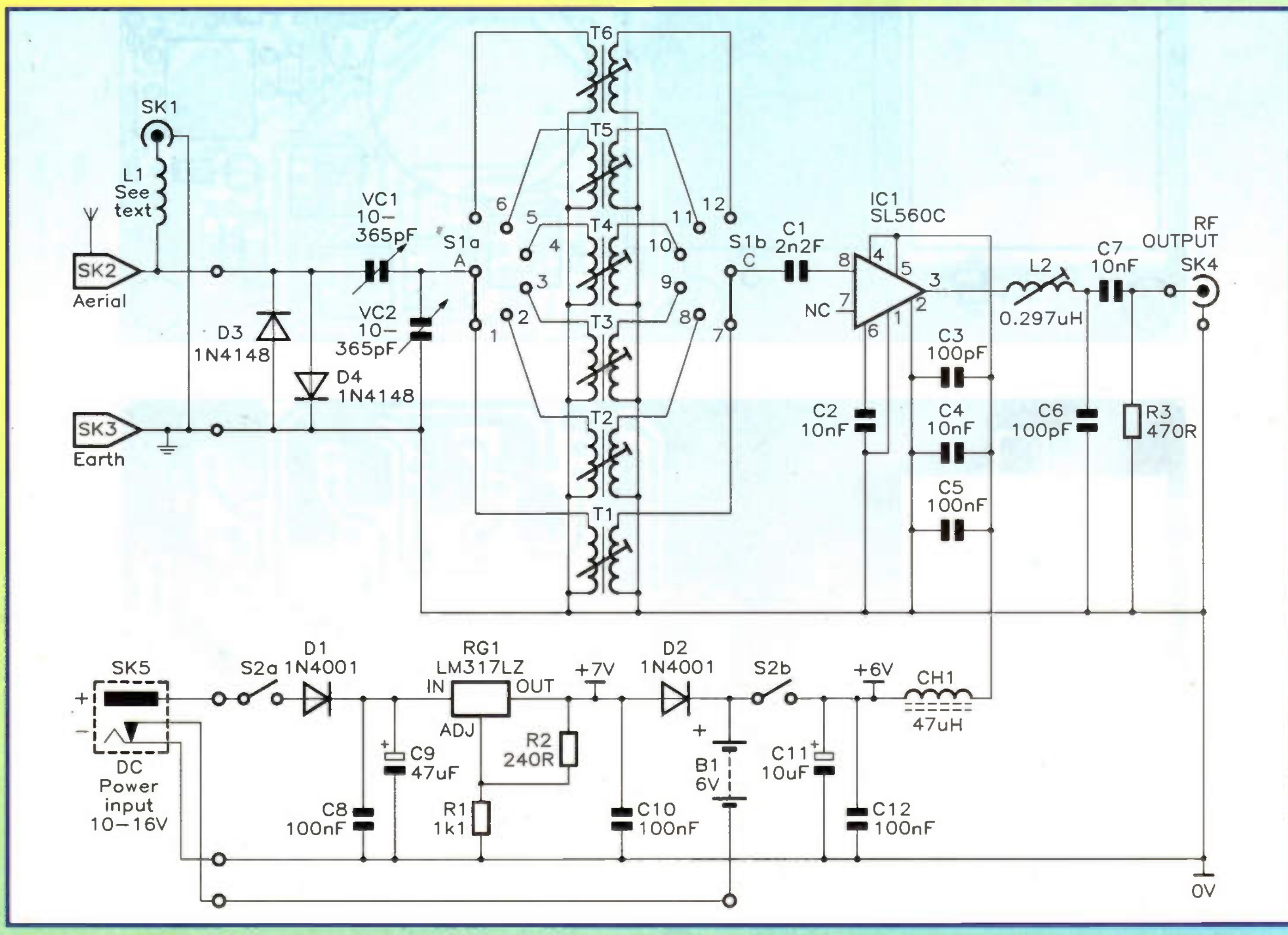


Figure 2. Circuit diagram of the Aerial Activator.

The relationship between the impedance and the wavelength of the aerial varies; at a full or half wavelength it appears to the receiver as a relatively high impedance. At quarter-wave, or at odd multiples of quarter-wave, it is considerably lower.

The aerial input impedance of most communications receivers is 50Ω. Unless the impedance of the aerial matches that of the input of your receiver, all the RF energy from the aerial to the receiver input circuit is not transferred. The greater the mismatch, the weaker the received signal is, and under adverse conditions the signal may vanish into the background noise. The answer to this problem is an impedance matching transformer which accepts a wide range of input impedance and converts it to the 50Ω level required by the receiver. At the frequencies where the aerial impedance is close to that of the input of the receiver no amount of matching will improve the signal. Under these conditions more gain in the aerial system is necessary to boost radio reception.

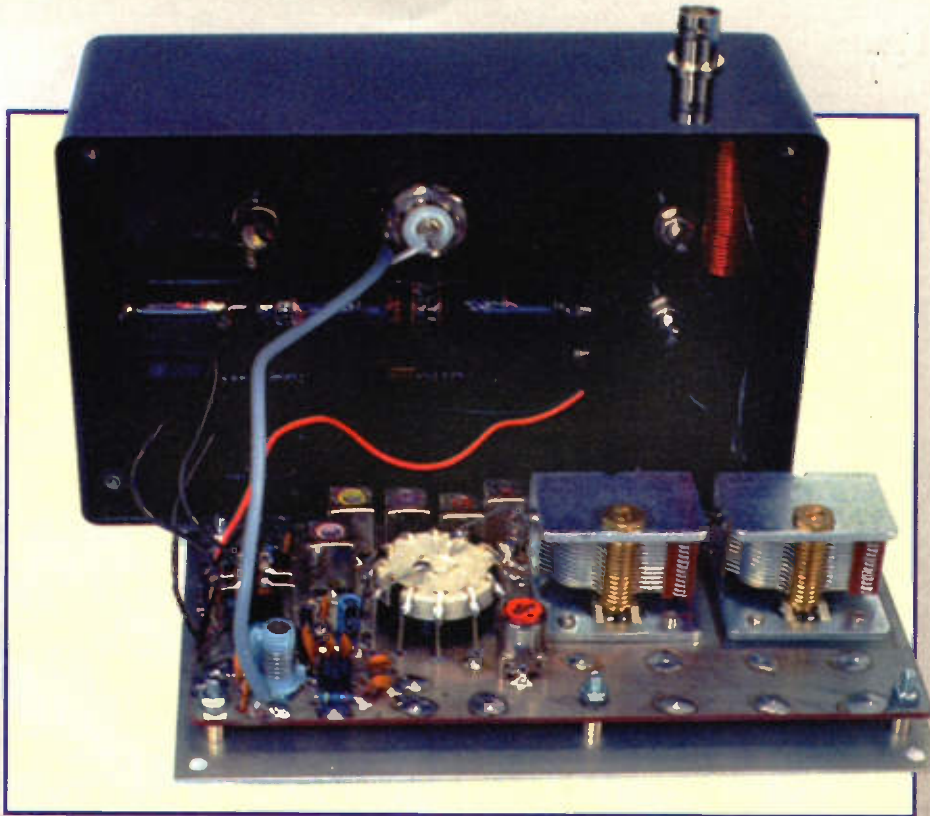


Photo 2. Internal view of the completed unit.

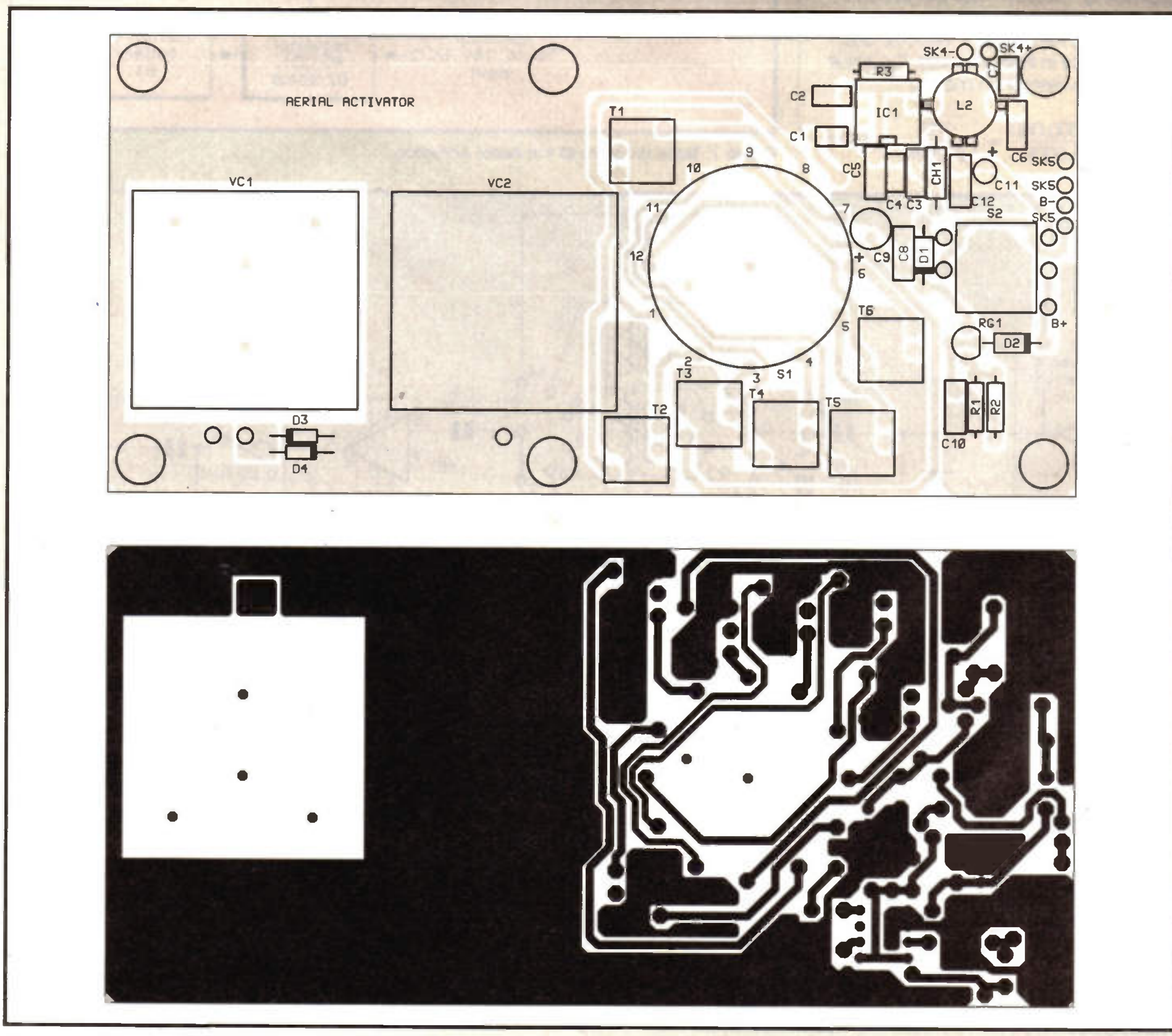


Figure 3. PCB legend and track (please note that this design employs a double-sided PCB with component side ground plane,.

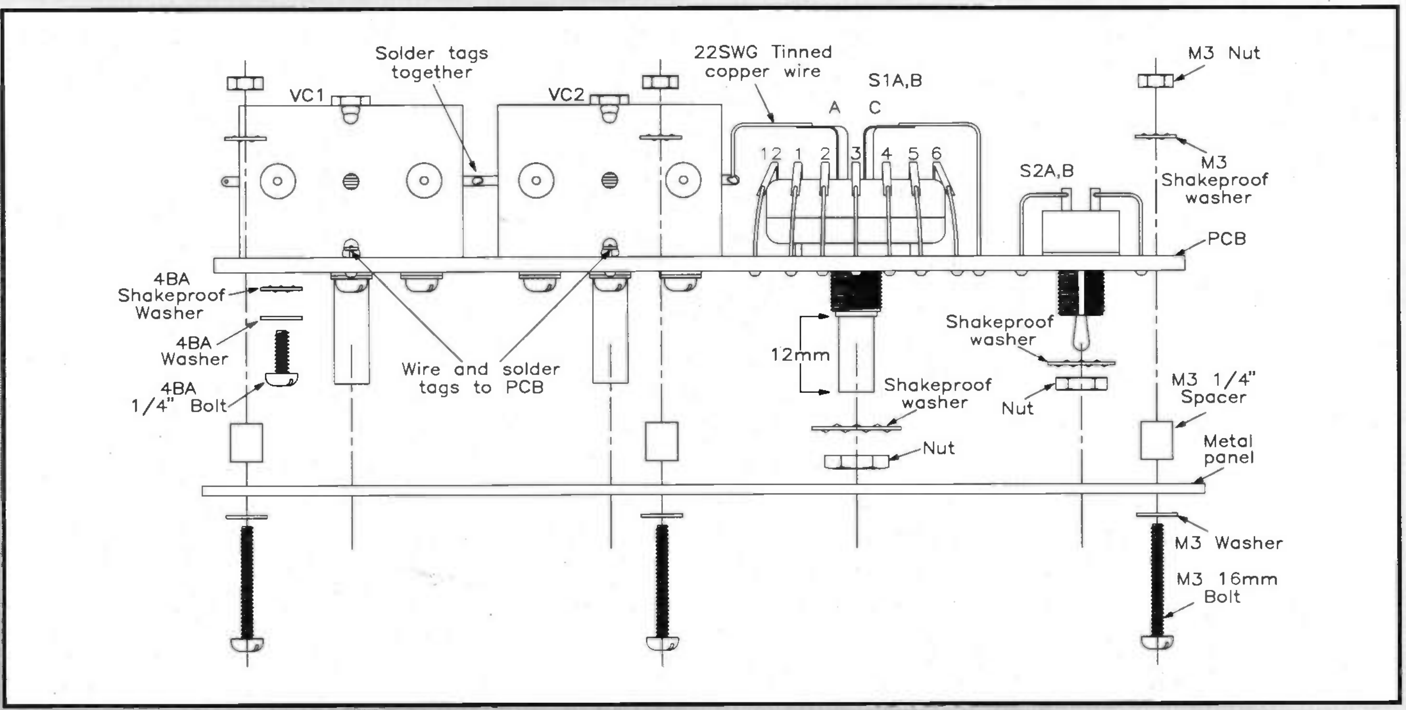


Figure 4. Variable capacitors and switches – mounting and wiring.

In some cases, it is not possible to have an outdoor aerial, and yards of wire trailing about the house are definitely not desirable – especially for the wife! So instead, a small telescopic aerial can be used, but at LW and MW frequencies, even with an aerial tuning unit, it will have a very poor performance over the entire range of frequencies.

The solution to these problems is to use an active tuned aerial amplifier; when used with an indoor or outdoor aerial system this will offer improved reception over the entire frequency range. The tuning of the amplifier is very similar to that of a radio, with bandswitch and tuning-controls. To obtain the best results, simply match the aerial impedance and tune the amplifier to the same frequency as the radio, for a peak in signal strength.

The RF amplifier used in this design is based upon the SL560C data file first seen in the February 1994 issue of *Electronics*. The SL560C is a monolithic Integrated Circuit (IC) which contains three very high performance transistors and associated biasing components held in an eight-pin package. In this application it is configured as a 50Ω line driver circuit, with a gain of approximately 15dB.

Circuit Description

In addition to the block diagram shown in Figure 1, a circuit diagram is detailed in Figure 2. This should assist you in following the circuit description or fault finding in the completed unit.

The Aerial Activator has two aerial inputs. The first is for connecting a wire aerial for outdoor, or indoor installations and this connection is made using a small terminal post, SKT2. The other aerial input is intended for use with telescopic aerials which have BNC plug terminations. This type of aerial has become fairly commonplace as it is used on the majority of hand-held transceivers and scanners. The RF coil L1 is used as a base loading coil for the telescopic aerial and can peak up the performance over a wide range of frequencies as the length of the telescopic aerial is effectively altered. The precise physical dimensions of L1 depends upon two factors; the maximum length of the telescopic aerial and the frequency range it is to work over – some experimentation is therefore required to achieve optimum results.

However, as a starting point the following dimensions should be of use: Using 20SWG enamelled copper wire (BL26D) wind 40 turns on a 10mm former, remove the former to make an air-cored coil.

This coil can be omitted from the design if a flatter response is desired. If this option is chosen, then simply replace L1 with a short piece of hook-up wire (BL00A) from SKT1 to the main aerial input socket SKT2. The earth element of any aerial system is important and this

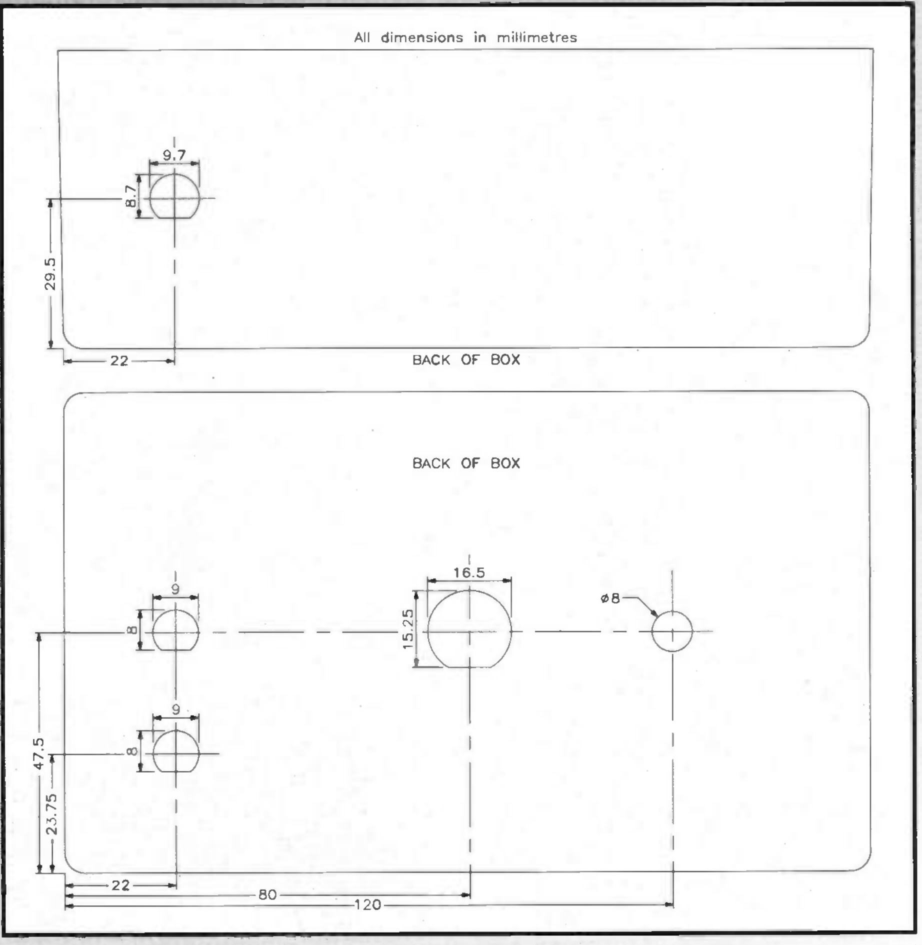


Figure 5a. Case drilling.

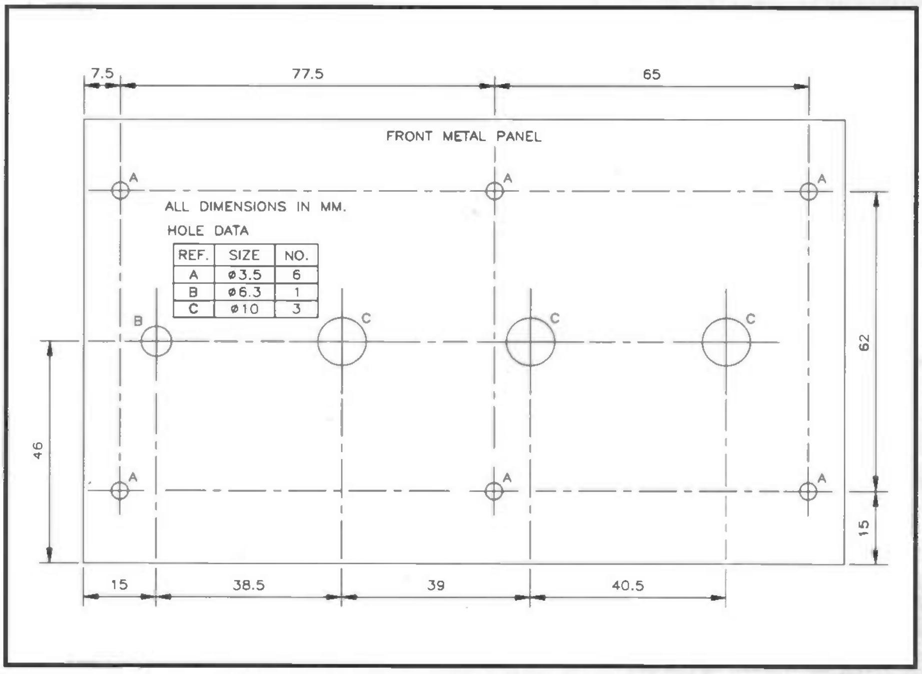


Figure 5b. Front panel drilling.

connection is made to another small terminal post, SKT3.

If the Aerial Activator is used in close proximity to a radio transmitter aerial, the high energy RF field could damage the sensitive components in the circuit. To help prevent this, two diodes, D3 and D4, are placed across the aerial input and earth connections. Under normal receiving conditions these diodes have no effect on the received signals.

The Aerial Tuning Unit (ATU) stage consists of two variable capacitors VC1 and VC2, and six miniature RF transformers, T1 to T6. For each given frequency range the appropriate transformer is selected by the rotary switch S1A & B. This circuit is similar to the standard transmatch configuration, where VC1, the aerial capacitor, matches the aerial load impedance to the tuned circuit formed by VC2 and one of the six primary windings of T1 to T6. The resonant impedance of this tuned circuit is dependent upon the combined L/C ratio of VC2, the primary winding of the RF transformer and the load impedance transferred by VC1. The prototype performed well over a range of frequencies from 150kHz to 30MHz; however, this may vary fractionally depending upon the type of aerial used. The secondary winding of each RF transformer steps the impedance down to the 50Ω level required by the input stage of the wide bandwidth RF amplifier IC1.

IC1, an SL560C, is used in its common-base input mode by decoupling pin 6 with C2, a 10nF capacitor. The RF signal is fed via C1 to pin 8, thus providing a correctly matched 50Ω input impedance. The output from the RF amplifier is taken from pin 3. As the SL560C has a gain of 15dB and a bandwidth of 220MHz, a simple lowpass filter is included in the design to prevent signals above 30MHz from swamping the radio's front end. This filter is formed by the coil L2 and capacitor C6, with C7 providing the DC blocking from IC1. The resistor R3 is used to ensure that the amplifier always feeds into a low impedance load, even if your radio is not connected. This filtered and loaded output is then connected to the output socket SKT4.

Because the transistors used in the SL560C exhibit an extended high frequency response, care must be taken to avoid instability. Capacitors and resistors of small physical size should be used and their leads must be as short as possible to avoid oscillation caused by stray inductance. There are several ceramic capacitors in the power supply circuit to provide decoupling for the prevention of instability at RF frequencies. C3, C4 and C5 provide multiple high-frequency decoupling as physically close to IC1 as possible. The RF choke, CH1, helps prevent any RF noise from the power supply being injected, or superimposed on to the DC input pin (pin 4) of IC1. The main supply LF decoupling is provided by C11, with C12 providing additional HF decoupling.

The aerial activator circuit has two possible DC power sources:

1. A set of four 1·5V AA cells (B1) providing a +6V DC internal supply for portable use.

2. A voltage regulator (RG1) for an external +10V to +16V DC supply for prolonged use.

The set of four AA cells (B1) is switched into circuit when the power ON/OFF switch (S2B) is closed. A diode, D2, prevents any current leakage from B1 entering the voltage regulator circuit. However, if an external DC supply is plugged into SK5 the batteries are disconnected from the entire circuit. The incoming DC voltage is switched by S2A and must be within the range of +10 to +16V DC and have the correct polarity. To prevent damage to the unit being caused by incorrect supply polarity, D1 affords protection by blocking a wrongly connected supply; D1 will only conduct when the positive supply voltage applied to its anode. Voltage stabilisation is achieved with RG1, a LM317LZ variable voltage regulator; the voltage output of RG1 is set by the values of R1 and R2. RG1's input and output are decoupled by C8, C9 and C10.

PCB Assembly

The Aerial Activator PCB is of a double-sided construction; this is so that a ground plane effect is produced, which is very important at RF. Figure 3 shows the PCB legend and track. The components will be mounted on the ground plane side and soldered on the underside.

It is best to solder the smaller components first such as resistors and diodes. Make sure that the diodes are correctly orientated on the board; refer to the PCB legend in Figure 3.

Identify the voltage regulator which looks like a transistor, fit and solder it in position. Next, making sure that the orientation is correct, fit and solder the SL560 IC. An IC socket must not be used as it is important that the device is as close to the ground plane as possible – RF instability may result if a socket is used.

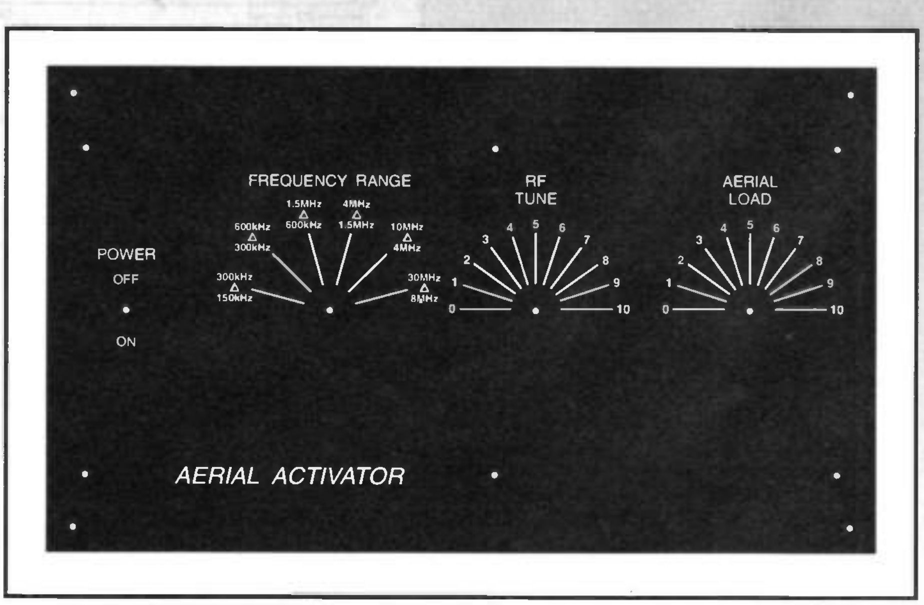


Figure 6. Front panel label (²/₃ scale).

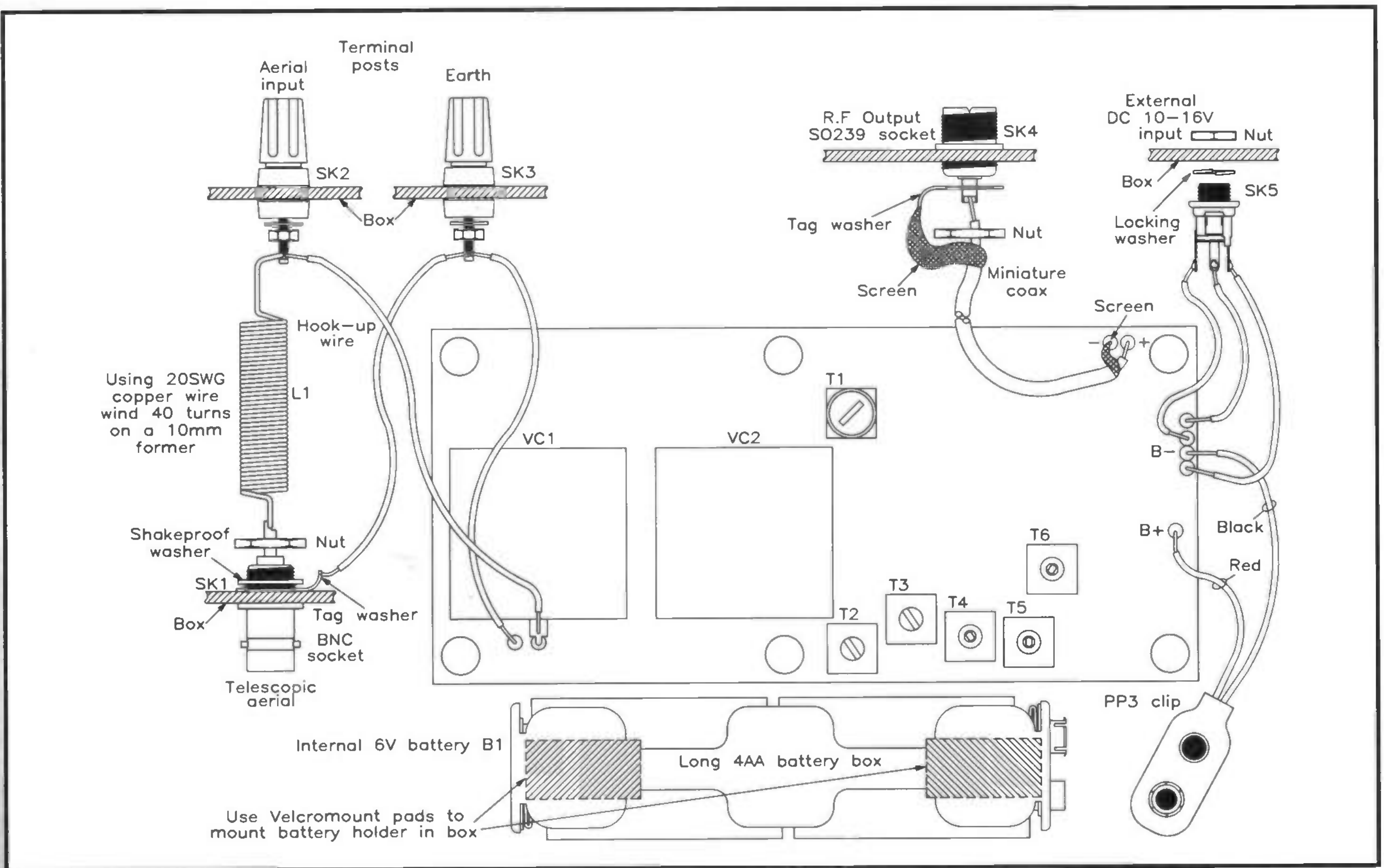


Figure 7. Wiring diagram of the Aerial Activator.

Next identify and fit the capacitors. Leave the fitting of the variable capacitors VC1 and VC2 to last. When fitting and soldering the electrolytic capacitors make sure that polarity is observed. The positive lead is normally longer than the negative lead, which is marked on the side of the capacitor as a series of negative symbols.

Identify and fit the axial choke, this component looks like a large diode. Be particularly careful when bending the leads as it is possible to damage the main body of the choke if excess force is applied or the leads are bent too close to the component body.

The main rotary switch is a 6-way 2-pole type. To avoid problems it is important that the retaining washer with locating spigot is not disturbed, otherwise it will have to be correctly repositioned. The switch will need to be prepared first before mounting. Refer to Figure 4 and measure off 12mm of spindle from the screw thread. Cut the spindle and trim off any excess plastic. Next bend the connecting terminals as shown in Figure 4. Mount the switch onto the PCB. There is a locating peg on the switch and this will locate in a hole ensuring that the switch is correctly positioned on the board. The switch is held in position by the shakeproof washer and nut; do not over-tighten the nut as either the thread on the switch may get stripped or, at worst, the switch mechanism itself may become damaged.

Included in the kit is a length of 22SWG tinned copper wire. This is required to wire all the switch connections (1 to 12) and C to the PCB. Refer to Photo 1 which shows the assembled Aerial Activator PCB.

Next identify the main ON/OFF switch. Again this requires fixing to the PCB by a shakeproof washer and nut; 22SWG wire is used to connect four of the switch connections to the PCB, see Photo 1.

There are a series of aerial transformers used in the kit T1 to T6, and these will have to be identified before fitting. Each metal-canned transformer is marked with its type number on the side. Make sure that each transformer is fitted into the correct position. Solder the connections on the underside; take care not to overheat the transformers.

Unpack the variable capacitors making sure that they are not opened out at this stage. It is important not to damage the vanes.

Mount the variable capacitors VC1 and VC2 as shown in Figure 4 and Photo 2, using the 4BA bolts, washers and shakeproof washers as supplied. Once in position solder the two side-tags between the variable capacitors. Using a length of 22SWG tinned copper wire, solder the side tag on VC2 nearest the aerial transformers to the rotary switch on position 'A'. Two more tags on the variable capacitors require soldering to the PCB by 22SWG wire. These go through the PCB and solder onto the underside.

Box Drilling

The drilling details for the optional box (WY02C) are given in Figure 5a. Drill the holes in the back of the plastic case. Note that the aerial connector holes should be squared off partially on one side so that when the connectors are fitted they do not rotate round whilst being fitted or in use. Drill a hole in the top of the case for the BNC socket, again noting that the hole should be partially squared off. This is to prevent the socket from turning when the project is completed. Looking inside the case, the 2·5mm power socket is fitted to the left, the SO259 socket in the centre, the two small terminal posts fitted to the right, with the white terminal post being in the higher position. The BNC socket is fitted to the top of the case.

Making sure that the front metal panel will not slide around, mark and then drill the holes, according to the details in Figure 5b. The holes should be in alignment with the capacitor and switch shafts. The PCB is held in position on the front panel by six nuts and bolts, so it is important that these hole positions are all accurately drilled. A pre-printed front label is included in the kit (KP68Y), and this is reproduced in Figure 6. Trim the label around all the front panel holes using a sharp craft knife, it should be fitted at this stage.

To hold the long AA battery box in position Velcro strip is used. Two pieces should be stuck to the inside of the box, and two to the back of the battery box.

Wiring

Solder the wires to the PCB before bolting it to the front panel. Refer to the wiring diagram in Figure 7 and Photo 2 for inside the finished unit. Suitable black 10m wire (BL00A) is included in the kit.

If the option of a load coil L1 is to be taken up, then solder this between the white terminal post and the BNC socket. Make sure that the battery clip leads are positioned on the PCB correctly, and note the position of the wires to the external power socket.

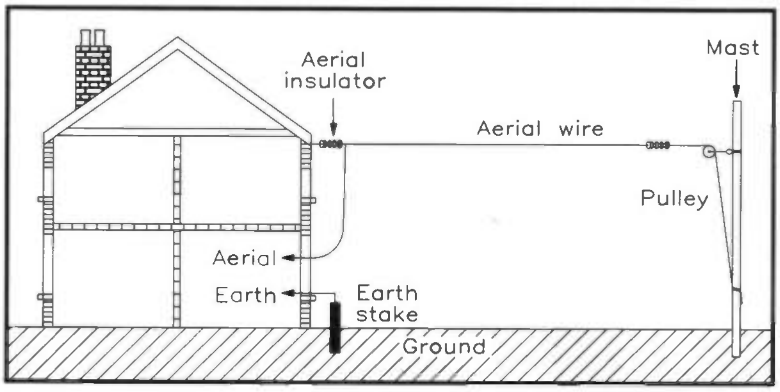


Figure 8a. Conventional end-fed, long wire aerial system.

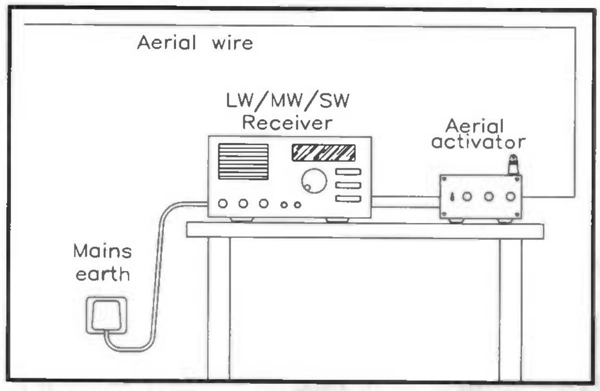


Figure 8b. Indoor room aerial system.

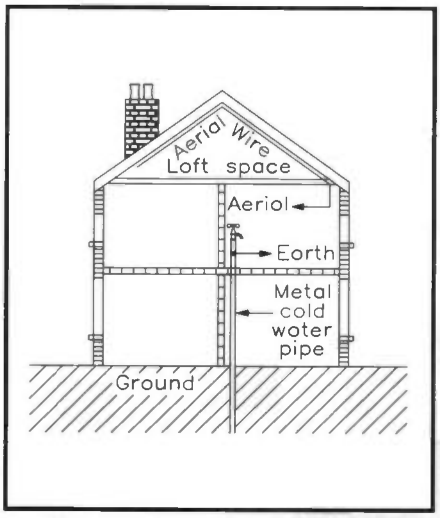


Figure 8c. Typical indoor loft aerial system.

Photo 3. Completed unit with a typical receiver and aerial.

Final Assembly

Once you are certain that the wiring to the PCB is correct, attach the front panel to the PCB by six M3 x 16mm steel bolts, using an M3 washer and an M3 shakeproof washer per bolt, and an M3 x ¼in. spacer. The spindles of the two variable capacitors and rotary switch should be free to move within each hole. The ON/OFF switch should locate exactly in the hole provided for it.

Finally mount the three knobs onto the spindles, making sure that they are not brushing against the front panel, otherwise they will be difficult to rotate and cut into the front panel and the lettering.

Testing and Alignment

Testing and aligning the Aerial Activator is straightforward. It is advisable to use the correct trimming tool (BR51F) for the cores in the aerial transformers as it is very easy to crack them if the wrong tool, such as a screwdriver, is used.

These preliminary adjustments will roughly locate the cores before final tuning:

Refer to Figure 7, and orientate the board in the same manner as in the drawing. Starting with T1 (the widest core), bring it so that it is approximately 1mm above the metal can. Next, rotate the core on transformer T2, so that it is as far down as it will go within the metal can (do not overtighten or the core will crack). With T3 the exact opposite needs to be done, rotate the core until it is against the top of the metal can. T4, T5 and T6, the cores need to be about halfway down. The core in L2 needs to be level with the top of the plastic former.

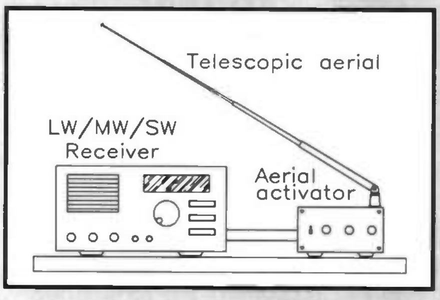


Figure 8d. Telescopic aerial system.

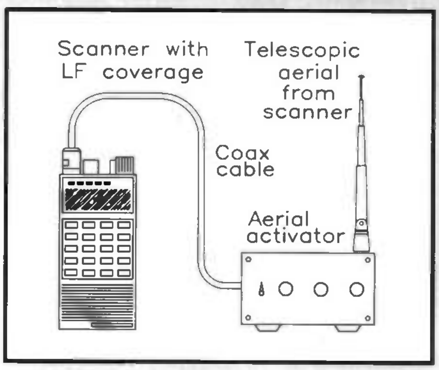


Figure 8e. Telescopic aerial and scanner.

To test and align the Aerial Activator, a shortwave receiver of some description is required, preferably with an 'S' meter. Connect a shortwave receiver by coaxial cable using a PL259 plug to the SO259 socket on the back of the Aerial Activator, and choose what type of aerial is to be used. See Figure 8 for some typical set-ups. Switch on both the receiver and the Aerial Activator. Tune to the lower part of the band, 150kHz; on the receiver. Switch the Aerial Activator to the first range of 150 to 300kHz. Place the RF tune control on position 10, the aerial load halfway, and using a trimming tool, peak T1 so that the 'S' meter shows that the signal is peaked. If a signal or bandnoise is not sufficient to align the Aerial Activator then retune the receiver to a station, such as BBC Radio 4 on 198kHz, place the RF tune control and the aerial load halfway and peak T1 using the trimming tool.

For the other ranges on the Aerial Activator, choose a station which is at the low frequency end of the range and make sure that the tuning capacitor is in its fully closed position (10 on the front panel). Peak the signals up by adjusting the appropriate transformer. Check the signal peak on the receiver further up each band by adjusting the tune capacitor. The load control may need to be adjusted, but this will probably be left in one position after initial adjustment.

Typical Receiver/Aerial Set ups

Once the Aerial Activator has been tested and aligned it can be used with any of the typical receiver/aerial set ups as shown in Figures 8a to 8e. Photo 3 shows one such set up.

A conventional shortwave end-fed, long wire aerial is shown in Figure 8a, with a separate earth obtained from an earth stake outside. These days due to a variety of reasons, it is not always practical to have such an aerial, and so this is where the Aerial Activator comes in, to match the aerial to the receiver, and to provide gain.

Another suggested aerial layout is to have an aerial wire placed across the ceiling in a room, see Figure 8b. The earth is obtained from a metal cold-water pipe, or through the mains earth.

A short wire aerial placed in the loft space does not have to be particularly long, but it will have to be kept clear of any mains wiring to minimise pick-up from the mains. Figure 8c shows a suggested indoor loft aerial system, with the earth obtained from a metal cold-water pipe, and connected to the earth terminal at the rear.

A telescopic aerial used with a receiver (see Figure 8b), should be mounted directly onto the BNC socket on the top of the Aerial Activator. Such an aerial is not normally supplied with a shortwave receiver, but is available from Maplin (JM12N). Often scanning receivers have a telescopic aerial supplied as part of the accessory pack, and so no extra purchase is necessary.

Figure 8e shows a typical set up using a scanning receiver with low frequency (LF) coverage, with the Aerial Activator, and the telescopic aerial from the scanner.

Using the Aerial Activator

With one of the set ups as suggested, choose a frequency within the range 150kHz to 30MHz on the receiver, and select the appropriate frequency range on the Aerial Activator; there are six ranges to choose from. Select a setting on the Aerial Load and peak up the signal using the RF Tune. On some occasions it is advisable to either advance or reduce the Aerial Load setting, and balance the two controls for best signal reception for the type of aerial in use. If the receiver has an S-meter then this can be used as an indication as to the strength of the signal.

When using a telescopic whip antenna it is best to advance the Aerial Load control fully clockwise (10 on the front panel). Whereas, when using a long wire it is usually best to have the controls between positions 2 and 3.

The battery life will be found to be reasonable, but do remember to switch off the Aerial Activator after use. For extended use it is recommended that an external supply is used, and a suggested unregulated power supply such as the 300mA unregulated (XX09K) is ideal.

If the batteries are not to be used for long periods then it is advisable to remove them, just in case they leak in the case and cause damage.

AERIAL ACTIVATOR PARTS LIST

RESISTORS: All 0·6W 1% Metal Film			
R1	1k1	1	(M1K1)
R2	240Ω	1	(M240R)
R3	470Ω	1	(M470R)
CAPACITORS			
C1	2n2F Metallised Ceramic	1	(WX72P)
C2,4,7	10nF Metallised Ceramic	3	(WX77J)
C3,6	100pF Metallised Ceramic	2	(WX56L)
C5,8, 10,12	100nF 16V Miniature Disc Ceramic	4	(YR75S)
C9	47µF 16V Miniature Radial Electrolytic	1	(YY37S)
C11	10µF 16V Miniature Radial Electrolytic	1	(YY34M)
VC1,2	365pF Variable Single-gang Capacitor	2	(FF39N)
INDUCTORS			
L1	See Text	1	
L2	RF Coil 297nH	1	(UF67X)
T1	Toko CAN1A350EK	1	(FD00A)
T2,3	Toko RWR331208	2	(FD01B)
T4	Toko KANK3333R	1	(FD02C)
T5	Toko KANK3334R	1	(FD03D)
T6	Toko KANK3335R	1	(FD04E)
CH1	Choke 47µH	1	(WH39N)
SEMICONDUCTORS			
IC1	SL560C	1	(DB46A)
RG1	LM317LZ	1	(RA87U)
D1,2	1N4001	2	(QL73Q)
D3,4	1N4148	2	(QL80B)
MISCELLANEOUS			
S1	Rotary Switch 2-pole 6-way Type SW6B	1	(FF74R)
S2	Sub-Miniature Toggle Switch Type E	1	(FH04E)
	PP3 Battery Clip	1	(HF28F)
	Long 4AA Battery Box	1	(HF94C)
	Miniature Coax Cable	1m	(XR88V)
	1·4A Black Wire 10m	1 Pkt	(BL00A)
	Enamelled Copper Wire 0·9mm 20SWG	1Reel	(BL26D)
	Tinned Copper Wire 0·71mm 22SWG	1Reel	(BL14Q)
	Fluted Knob Type K7B	3	(YX02C)
	4BA x ¼in Bolt	1 Pkt	(BF02C)
	4BA Washer	1 Pkt	(BF21X)
	4BA Shakeproof Washer	1 Pkt	(BF25C)
	Aerial Activator Front Panel	1	(KP68Y)
	PCB	1	(GH78K)
	Instruction Leaflet	1	(XU93B)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	Metal Panel Box M4005	1	(WY02C)
	M3 x 16mm Steel Screw	1 Pkt	(JY24B)
	M3 Steel Washer	1 Pkt	(JD76H)
	M3 Shakeproof Washer	1 Pkt	(BF44X)
	M3 Steel Nut	1 Pkt	(JD61R)
	M3 x ¼in. Spacer	1 Pkt	(FG33L)
	4 pairs 1in. Velcro Strip	1 Pkt	(FE45Y)
SK1	Round BNC Socket 50Ω	1	(HH18U)
SK2	Small Terminal Post White	1	(FD73Q)
SK3	Small Terminal Post Green	1	(FD71N)
SK4	Round UHF Socket	1	(BW84F)
SK5	Panel Mount 2·5mm Power Socket	1	(JK10L)
	Alkaline AA Cell	4	(FK64U)
	AC Adaptor Unregulated 300mA	1	(XX09K)
	Standard 2·5mm Power Plug	1	(HH62S)
	BNC Plug 50Ω	1	(HH17T)
	PL259 Plug	1	(BW81C)
	UHF Reducer Small	1	(BW82D)
	UHF Reducer Large	1	(BW83E)
	4mm Plug White	1	(HF67X)
	4mm Plug Green	1	(HF65V)
	144 to 430MHz BNC Aerial	1	(JM12N)

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 LT58N (Aerial Activator Kit) Price £44.99

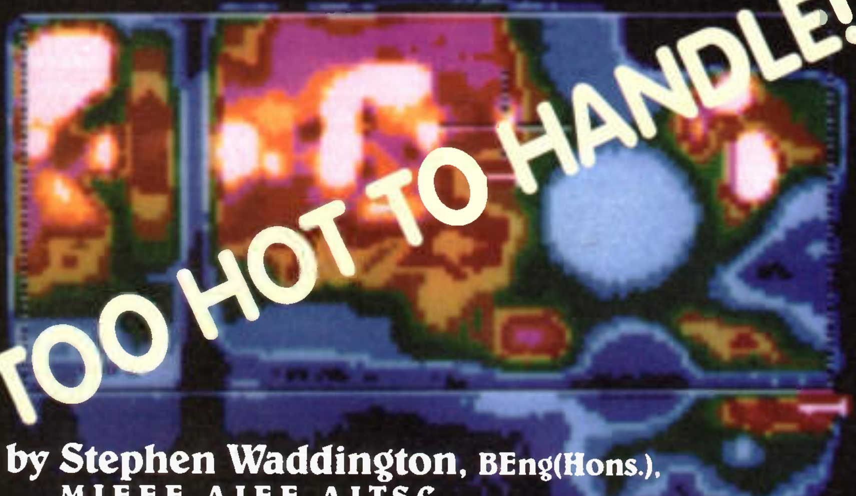
Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately, but are not shown in the 1994 Maplin Catalogue.

Aerial Activator PCB **Order As GH78K Price £8.99.**

Aerial Activator Front Panel **Order As KP68Y Price £1.99**

THERMAL PROTECTION



TOO HOT TO HANDLE!

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

Electronic thermal management is often regarded as a black art. While textbooks reel out three dimensional conduction equations and models of thermodynamic behaviour, Stephen Waddington shows that there is little more to heatsink selection than adapting Ohm's Law.

In the last ten years the demise of the heatsink has been predicted on numerous occasions. These forecasts would have been accurate if semiconductor devices had not constantly increased in function and decreased in size over the same period.

The semiconductor wafer, upon which integrated circuits are constructed, is a natural heating element. Pass an appreciable current through it, and it will get hot, just as the temperature of a piece of wire will rise if its current rating is exceeded.

Power Generation

Most of the heat generated in an electronic device is transferred to the case, from which it is dissipated into the environment. In small devices such as a signal diode or an RF transistor working at typical rating of 300mW, this is fine as the surrounding air is sufficient to cool the device. By contrast, the situation is quite different for power devices. Power transistors and rectifier diodes working at typical ratings of 10W, are seldom able to dissipate the heat generated by their operation.

Left to suffer temperatures in excess of 150°C, the life expectancy of a device will halve for every 10°C rise up to 170°C. Beyond this matters get worse, with the lifetime decreasing by 75% for every 10°C rise. Without adequate cooling these devices will fail at around 200°C. In fact, the life expectancy of an electronic junction varies as the inverse function of temperature – a fact more apparent when demonstrated graphically as shown in Figure 1.

Quite apart from an increased likelihood of failure, the properties of semiconductors change with temperature. The bandwidth and amplification of an audio amplifier can change dramatically for even a 20°C temperature rise above its nominal operating value. In practice this should not happen in well-designed equipment as key devices will be protected against thermal transients.

Academic texts will tell you that there are three physical tools that can be applied to cool a semiconductor namely conduction, convection and radiation. If we were to calculate the size of a heatsink based on these three properties, we would have to use complex three dimensional equations to determine the total heat dissipation effect of each interface. In the case of a transistor and heatsink, there are at least three such interfaces namely semiconductor junction to case, case to heatsink and heatsink to the ambient environment as shown in Figure 2. The mathematics soon becomes very complicated and is best avoided if personal sanity is to be preserved.

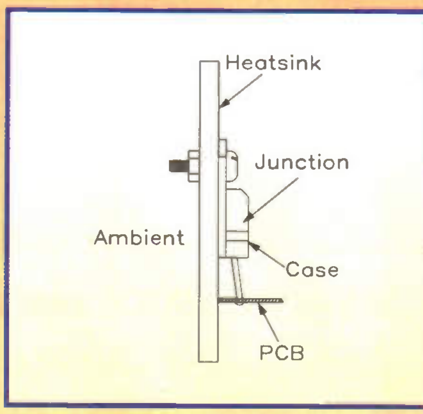


Figure 2. Heat transferring interfaces within a semiconductor system.

The Thermal Law

There is an easier way. While manufacturers have developed computer models to aid the selection of heatsinks including conduction, convection and radiation characteristics, the hobbyist designer is better advised to opt for a simpler thermal law. This states that the temperature difference between two materials is equal to the power dissipation of the system multiplied by the thermal

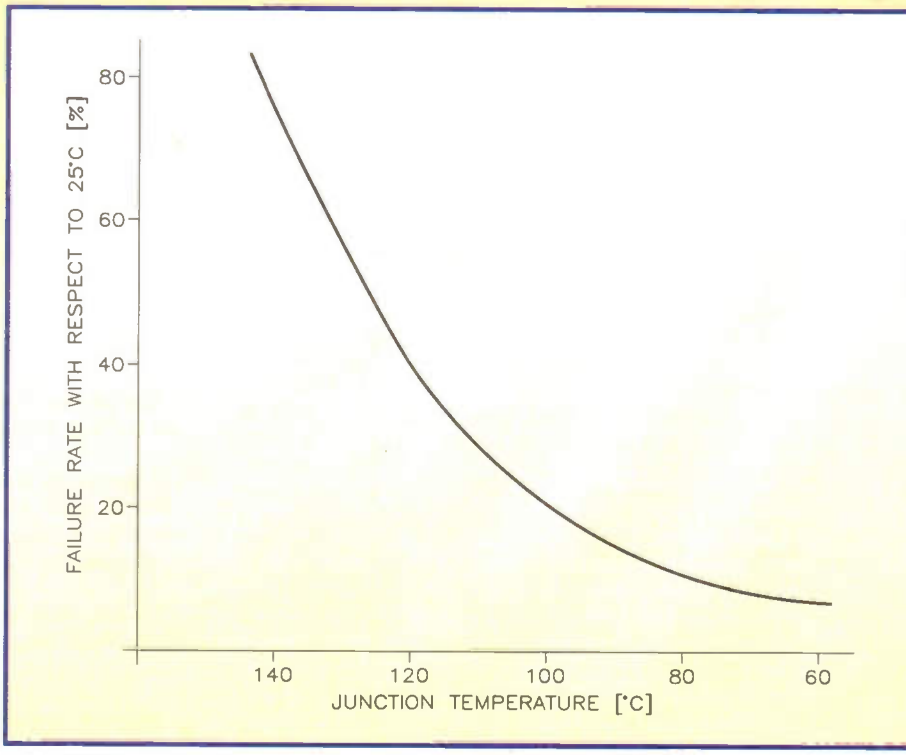


Figure 1. Failure rate of a semiconductor junction, versus temperature.

Photo 1. The thermal image of a PCB taken using a Thermovision 800 infra-red camera.

resistance across the interface, or in algebraic terms:

$$\triangle T = P_D.R_{th} \quad (1)$$

Where:

$\triangle T$ = Temperature difference
P_D = Power dissipation
R_{th} = Thermal resistance

If this seems a little complicated, please do not be put off, it gets easier. Considering the thermal law alone, this enables a heatsink to be selected using elementary calculations. In its simplest form the relationship between a semiconductor device and a heatsink can be treated as a one dimensional arrangement. In this sense the thermal mechanism linking the two elements shares a number of similarities with an electrical circuit. The temperature difference between the heatsink and the power device can be equated to potential difference, thermal resistance to electrical resistance and the resultant heat flow to current. The analogy is completed by the direct similarities between the thermal law and Ohm's Law.

The thermal resistance of a material provides a good indication of its ability to absorb heat and is quantified in degrees Centigrade per Watt (°C/W). The smaller the thermal resistance, the greater the absorption properties. This may seem obvious, but be careful. Many novice designers make the mistake of assuming that a heatsink with a large thermal resistance will make a good heat

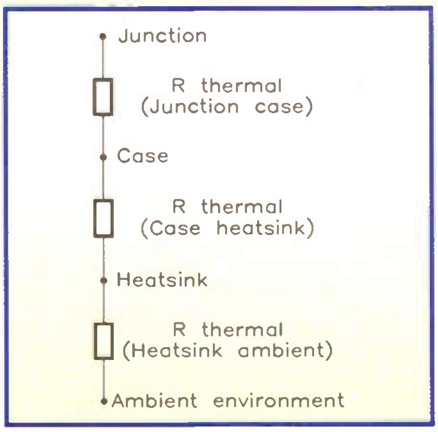


Figure 3. Electrical representation of a simple single power device thermal system.

Package type	Examples	Thermal resistance junction to case [°C/W]
Plastic	Dual-in-line	14 to 45
	Small outline integrated circuit (SOIC)	9 to 11
	Plastic leaded chip carriers (PLCC)	
Plastic and metal combined	TO220	1 to 3
	TO218	
Metal	TO3	1 to 3
	TO66	1 to 5

Table 1. Typical thermal resistance from junctions to case for a variety of semiconductor case styles.

absorber. In fact it is the complete opposite. For example, a heatsink with a thermal resistance of 4·2°C/W (one of the most efficient available) will exhibit far superior absorption qualities than a device with a larger rating.

Using the one dimension electrical analogue, the thermal resistance between power device and heatsink can be considered graphically as a series of three resistors as shown in Figure 3. The total thermal resistance of the arrangement (which ultimately provides an indication of whether the junction will be cooled sufficiently) is equal to the sum of the three parts:

$$R_{th(ja)} = R_{th(jc)} + R_{th(ch)} + R_{th(ha)} \quad (2)$$

Where:

$R_{th(ja)}$ = Thermal resistance from junction to ambient environment
$R_{th(jc)}$ = Thermal resistance from junction to case
$R_{th(ch)}$ = Thermal resistance from case to heatsink
$R_{th(ha)}$ = Thermal resistance from heatsink to ambient environment

Let us consider each of these in turn.

Semiconductor Junction to Case

A feature of electronic systems which complicates cooling analysis is that the semiconductor junction to be cooled is very small and is often buried deep within a plastic, ceramic or metallic package. In most situations the semiconductor die is soldered or adhesively bonded to a lead frame which itself is fixed to the case. The thermal resistance between the semiconductor junction and the case thus depends on the size of die, the fixing method, the construction of the lead frame and the type of package.

Although this value cannot be controlled by the design engineer, individual packages are usually segregated by their power handling capability – itself a good indication of thermal resistance. To aid device selection and thermal calculations, manufacturers usually quote values of thermal resistance from junction to case in their product data sheets. Table 1 shows some typical values.

Case to Heatsink

The thermal connection between the case of semiconductor package and heatsink is relatively straightforward. The situation can be potentially complicated by the nature of the two surfaces involved. At a microscopic level the surface of both the case and heatsink will be irregular as shown in Figure 4. Consequently the area of contact and thus the heat flow between the two devices is very small. This can be improved by either increasing the contact pressure between the two surfaces or by filling the gaps with a material that is a better conductor than air such as heat transfer grease.

Heat transfer grease is a highly efficient way of improving the thermal resistance of the arrangement. Before the heatsink is bolted or clipped on to a power device, a thin coating of grease should be smeared across each of the contact surfaces. This will fill any surface defects once the two devices are fixed together, ensuring good thermal conductivity. Using heat transfer grease and increasing contact pressure improves the thermal resistance to around 1°C/W. The separate effects of both the application of heat transfer grease and increased contact pressure are shown in the graph in Figure 5.

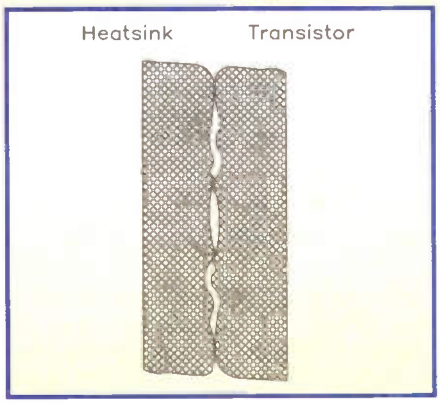
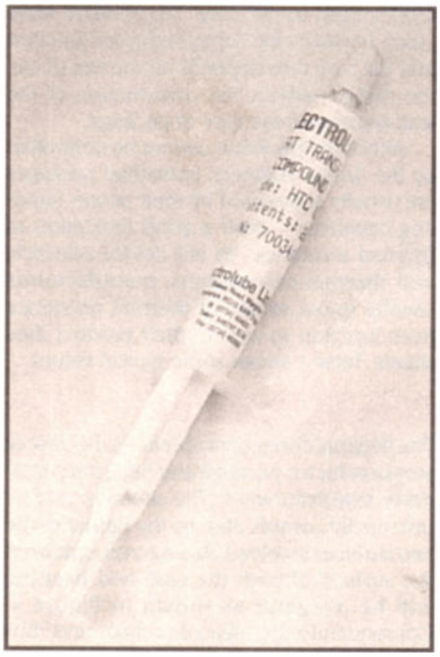


Figure 4. Typical microscopic appearance of the contact interface between a power device and a heatsink.



For ease of application the heat transfer grease is normally supplied in a syringe.

Heatsink to Air

A heatsink is used to extend the area of a semiconductor. This may be a simple flat piece of aluminium extracted from the depths of a junk box or a complex device with folded or finned extrusions used to increase the surface area. The thermal resistance is due to convectional losses to the surrounding air and radiative heat transfer from the surface of the heatsink to the surrounding environment.

The size of a heatsink is determined by applying the thermal law. Considering the thermal system that exists between a heatsink and a semiconductor device we can rewrite equation 1 in terms of the difference between the junction temperature and ambient temperature the maximum power dissipation of the device and the thermal resistance of the arrangement:

$$T_j - T_a = P_D.R_{th(ja)} \quad (3)$$

Where:

T_j = Junction temperature
T_a = Ambient temperature
P_D = Power dissipation
$R_{th(ja)}$ = Thermal resistance from junction to ambient environment

As equation 2 shows, the thermal resistance from the semiconductor junction to ambient environment is equal to the sum of the three thermal resistors it embraces. Consequently the thermal resistance from junction to ambient environment in equation 3 can be replaced by its three components:

$$\frac{T_j - T_a}{P_D} = R_{th(jc)} + R_{th(ch)} + R_{th(ha)} \quad (4)$$

Rearranging this we can obtain an expression for the thermal resistance from the heatsink to the ambient environment, equal to the desired thermal resistance of the heatsink:

$$R_{th(ha)} = \frac{T_j - T_a}{P_D} - (R_{th(jc)} - R_{th(ch)}) \quad (5)$$

Description	Stock Code	Price
Heat transfer grease 10ml	FL79L	£1.86
Heat transfer grease 2ml	HQ00A	£1.28

Heat transfer grease available from Maplin.

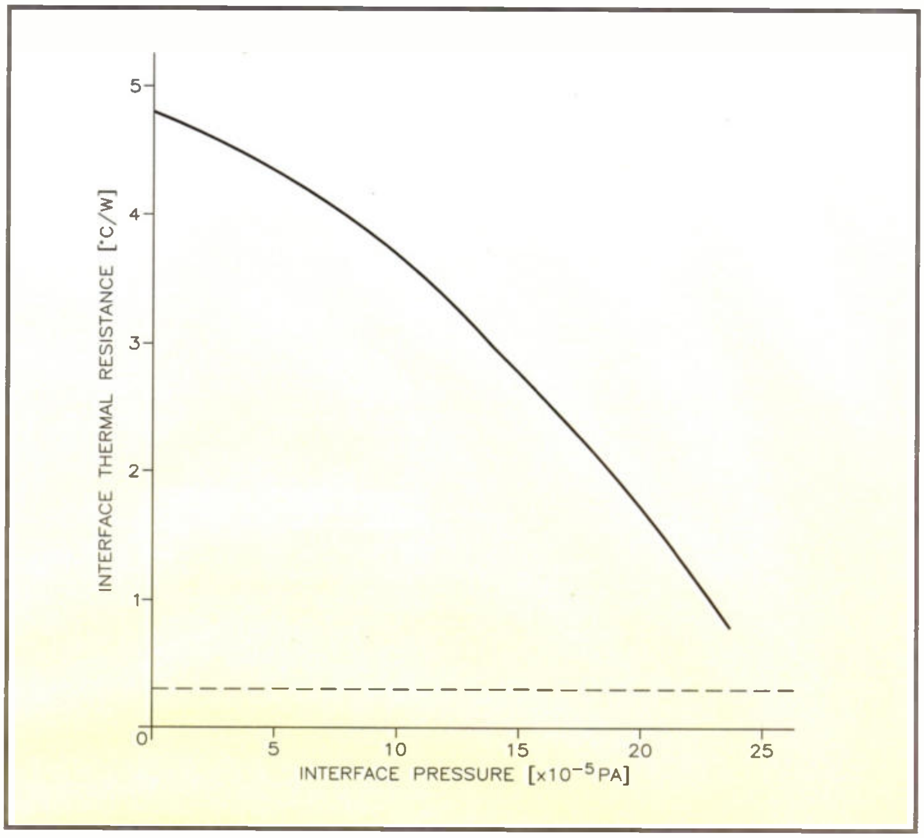


Figure 5. The effects of pressure and heat transfer grease on thermal resistance, when applied to the Interface between a power device and heatsink.

Practical Example

Equipped with this equation we can now accurately size heatsinks. Let us consider a practical example.

A BD539C audio power transistor is used in the output stage of a car radio. The power dissipation of the device is 12W and the ambient temperature is not expected to exceed 40°C. Calculate the required thermal resistance of the heatsink to ensure that the transistor remains within a safe operating temperature.

Solution

By examining a data sheet for the BD539C, we learn that the thermal resistance from junction to case is 2°C/W and that the maxi-

Device	Description	Thermal Resistance [°C/W]	Stock Code	Price
General	Slotted for plastic package	22	FL58N	32p
General	Twisted vane	9·9	FG55K	65p
TO3	High profile	4·2	FG51F	£1.10
TO3	Basic radiator	11	FG50E	52p
TO3	Low profile	6·9	KU45Y	60p
TO5	High profile	48	FL78K	25p
TO5	Low profile	80	KU43W	25p
TO18	Pushed fit	55	HQ80B	38p
TO92	PCB mounting	36	HQ79L	28p
TO92	Free standing	50	HQ79L	28p
TO126	Twisted vane	21	JX21X	52p
TO126	Miniature extended	28	JR93B	£1.60
TO202	Twisted vane	13	FG53H	65p
TO220	Low profile	7·1	KU48C	48p
TO220	Staggered vane	18·8	KU46A	58p
TO220	Vertical twisted vane	14	JW29G	56p
TO220	Top mounting	15	KU47B	28p
TO220	Clip on	25	KU50E	28p
TO220	Clip on	23	FG52G	40p
TO220	High performance	6	FG61R	65p
TO220	Clip on	13·6	KU51F	40p
TO220	Low profile high performance	6·5	KU53H	45p
TO220	5-Lead style	9·9	FG54J	£1.30
TO220	Twisted vane	14	JW29G	56p

Table 2. Heatsinks available from Maplin.

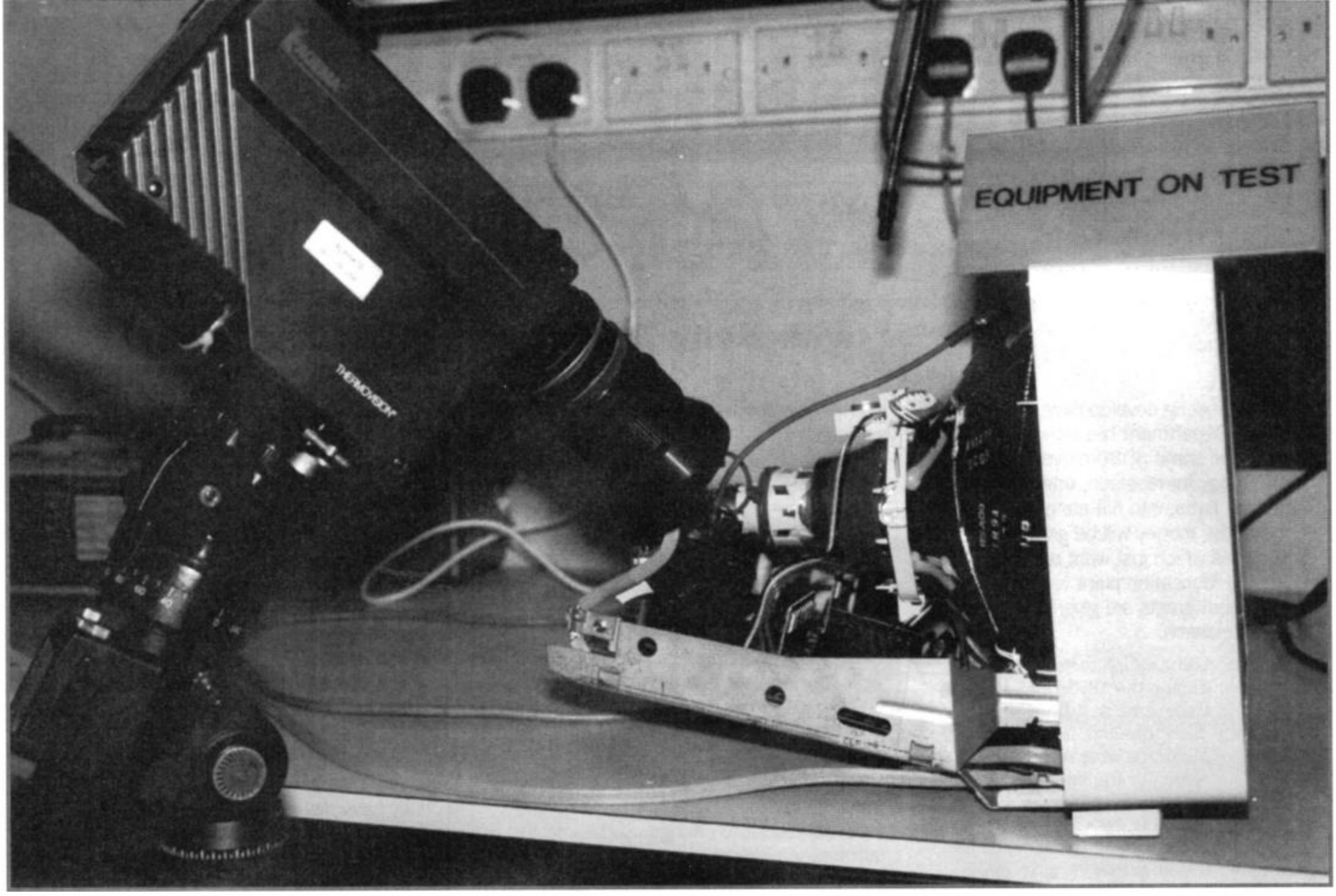


Photo 2. The test set-up for monitoring thermal images from the PCBs in a visual display unit, using the Thermovision 800 at IBM in Greenock.

mum permissible junction temperature is 200°C. The only remaining variable is the thermal resistance from case to heatsink. Assuming a thermal compound is used, we can assume this is approximately 1°C/W.

Plugging these values into equation 3 for the thermal resistance from junction to case gives:

$$R_{th(ja)} = \frac{200-40}{12} - (2+1) = 10{\cdot}3^{\circ}C/W$$

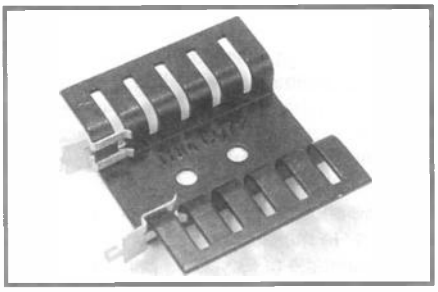
The case style of the BD539C is TO220. Thus to ensure that the transistor remains at a suitable temperature a TO220 heatsink with a thermal rating of 10·3°C/W or less is required. Table 2 shows a range of device heatsinks available from Maplin. Clearly there are a number of possibilities including KU48C, FG61R, KU53H and FG54J. Faced with various options, the heatsink should be selected by choosing the closest matching value or alternatively on the grounds of size or cost.

Equipment Design

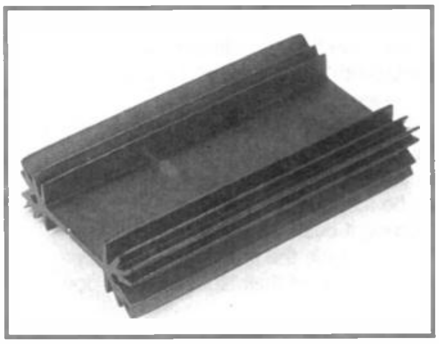
If you are designing a piece of equipment then a heatsink can be incorporated as part of the case or chassis. In this instance all power devices within the electrical circuit can be fixed to a multiple component heatsink. Its thermal resistance is selected on the basis of the minimum value required for each semiconductor device. This is aided by the fact that manufacturers quote the thermal resistance for each device position.

Thermal Imaging

An important technique that enables electronics manufacturers to study thermal characteristics is infra-red thermography. This allows a semiconductor die, integrated circuit or printed circuit board to be scanned for



PCB mounting matt black heatsink.



Low-profile, black anodised heatsink.

localised hot spots. Left undetected, high component temperatures will significantly impair the performance of a device or product and considerably reduce its lifetime.

Infra-red thermometry is based on the principle that hot objects emit electromagnetic radiation. Normally invisible to the naked eye, this radiation increases with temperature and can be detected with an infra-red camera. Electro-optics in the camera enable the infra-red radiation to be converted into an electronic video signal that can then be stored in a PC, displayed on a monitor as shown in Photo 1, or recorded on disk for subsequent analysis. Graduated colour levels or a continuous grey scale enables the temperature of different points on the object to be identified with ease.

Besides monitoring static images of a device, some cameras are able to monitor and record transient events. This is useful in printed circuit board inspection for monitoring the effects of bonded heatsinks and component cooling.

As a non-contact measurement technique, infra-red thermometry has many advantages over traditional forms of temperature measurement such as thermocouples. Aside from acting as a heatsink, conducting heat away from the object under test, thermocouples rely on prior knowledge of localised hot spots.

One company that actively uses thermographic measurement for research and development is IBM. The company uses two Thermovision Series cameras from AGEMA Infra-red Systems to analyse thermal transients across printed circuit boards. The cameras are lightweight portable instruments as shown in Photo 2, similar in size to a small video camera.

The Materials Technology Division of GEC Marconi also uses infra-red techniques to monitor the research and development of GaAs (Gallium-Arsenide) power devices for high frequency microwave applications.

As the reliability of these devices depends significantly on the quality of the bond between the GaAs material and its metal or ceramic base, it is essential to identify potential abnormalities. This is achieved by searching for localised hot spots over the Ga-As die. Once powered up, air bubbles or voids caused by a poor bond will impair the thermal resistance of the device from junction to case. Using an infra-red scanning camera it is possible to locate hot spots within seconds.

TECHNOLOGY WATCH!

with Keith Brindley

In an interesting development, the US Defense Department has announced that it is to spend some $580m over the next five years to pay for research, undertaken by American firms, into flat panel displays. It is not that the money will be given to companies which just want a grant for starting a fabrication plant (as UK Government grants are given), but is purely to fund *research.*

research Old English term, discredited during the 1980s and 1990s by Government, falling into disrepute and, latterly, disuse. Meaning: *n.* & *v.* **1.** n. Careful search or inquiry after, for, or into; endeavour to discover new facts, etc. by scientific study of a subject; course of critical investigation. **2.** *v.* To make research. (Historical note: research was usually undertaken by companies before new products were developed.)

In the US – indeed, just about everywhere – manufacturers generally have to rely on Japanese makers of flat panel displays for products. The right product is not always available (and not always at the right time), and not always at the right price. In terms of defence products, the US likes to keep 'one up' over everyone else, and having to wait for another country's manufacturers does not tally well. But, there are no flat panel display manufacturers of any significance in the USA.

However, by giving research grants, the US government argues that its own companies will become more proficient at developing new products (and, what is more, the products which are actually wanted) and (holy moley – here is a turn-up for the political books) actually be able to make them better.

In a similar vein, a new research institute has been set up by the US electronics industry to study printed circuit board technology. The Interconnection Technology Research Institute (ITRI) is part of the Interconnecting and Packaging Electronic Circuits (IPC) and intends to look, initially, at volume production methods of miniaturised printed circuit board assemblies.

One More Time...

Sooner or later – and sooner would be better – we are all going to have to think along the lines of product recycling. In other words, when your telly or Hi-Fi system gives up its ghost, kicks its clogs, or pines for its fjord, it will not be just a case of chucking it on the skip.

Currently, no more than 5% of electronics products can be recycled in any way, but that is all about to change. Sometime this summer, an industry group will report back to the Government on ways to improve the amount of a product which can be recycled. On the continent, a task force (a much more impressive term than *an industry group*, don't you think?) is to produce a report by July next year. Germany is currently introducing preliminary legislation, which will be in place in just a few months. There is no doubt about it; product recycling is a fact, not a fantasy, which we should all be aware of.

But, we should also be aware of what this all means. To make a product, which has a large percentage of recyclable parts, costs money. It costs to design and develop new methods of manufacture. You cannot just stick a label on the box and pretend that the washing machine inside is any more eco-friendly than the one without the label. New casings with snap-together (and apart) joints are needed.

It costs for the new materials used in the manufacture. New plastics, which can be remoulded, have to be used. Metals which can be recycled are a must.

Finally, it costs for the very processes used to recycle the products when they reach the end of their life. Would old Joe, down at the council tip, know what to do (safely) with a high-vacuum cathode ray tube even if he knew what it was?

A recent report by ERA Technology here in the UK, *Survey on the Implications for Recycling Electronic and Electrical Equipment*, states that German industry expects product costs to increase in the move by as much as £15 for a typical personal computer, and £30 for a typical television. Costs will, inevitably, be passed on to the consumer.

Ribbit, Ribbit. Watch Me Now!

It is not often that I take a close look at any particular company, but a couple of things recently have drawn my attention to one of our own home-grown firms – which, you might say, is in the pond in our very own back garden, so to speak.

Cambridge-based Tadpole Technology has specialised somewhat over the last few years, in the design and manufacture of computers – specifically, small computers. Tadpole has already developed portable workstations for Sun Microsystems, and has recently produced a portable version of the PowerPC 601 workstation for IBM. Tadpole is also rumoured to be developing a PowerPC 603-based notebook machine (although this is totally unconfirmed). A product for a major company in the US is also in the offing for next year (putting 2 and 2 together – maybe a PowerPC notebook for IBM, Sun or Apple? – to get 4).

Rumours also abound that Tadpole has been approached by both Intel and Digital Equipment, to develop and manufacture portable computers based on both companies' new microprocessors – Intel's Pentium, and DEC's Alpha. What it is like to be popular, eh?

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

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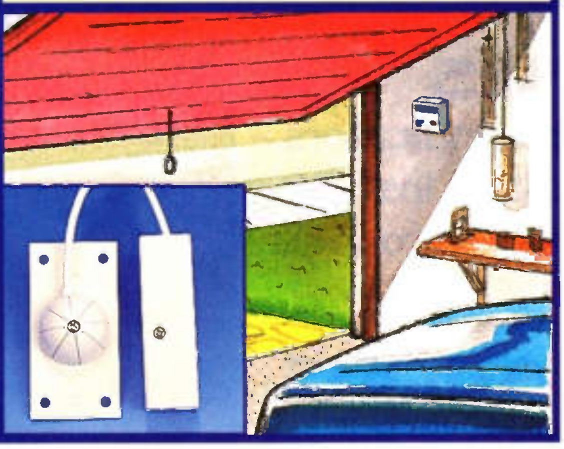

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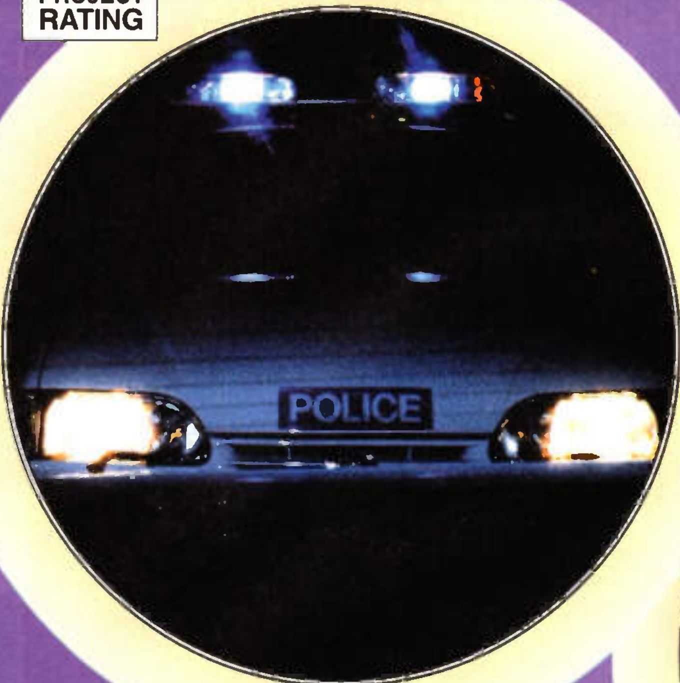
2
PROJECT RATING

by Joe Fuller

It is surprising how few people take the trouble to check, on a regular basis, that their car's lights are fully functional. This can be a hazard to the driver of the vehicle itself and other road users. In today's tougher-than-ever driving conditions it is important that a car's lights are operating as they should. Faulty lights can and do contribute to accidents.



Don't get caught out with faulty lights, build this ingenious project!

CAR LAMP MONITOR

FEATURES

* Single/multiple indicators
* Easy to build and install
* Can be interfaced to logic
* Self powered

APPLICATIONS

* Cars * Caravans * Trailers

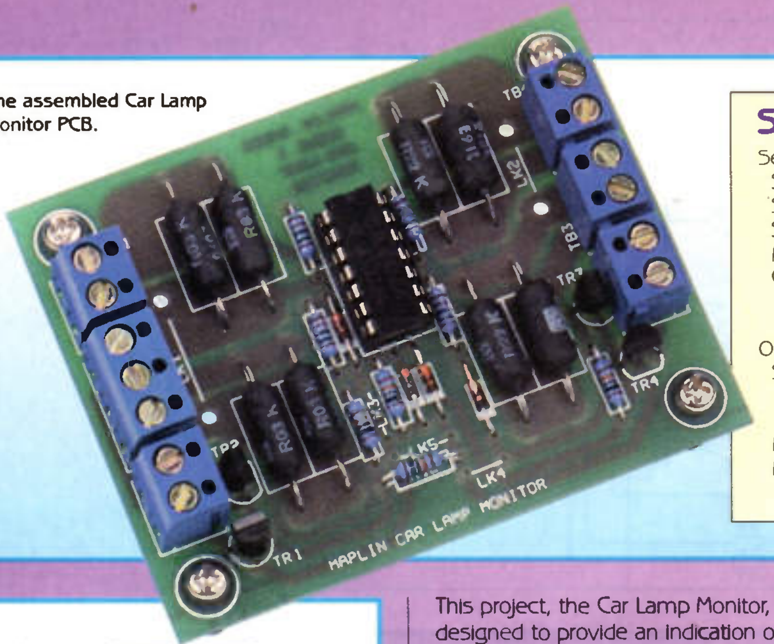
KIT AVAILABLE (LT63T) Price £9.99

Please note that the box shown is not included in the kit and must be purchased separately.

The standard method of checking that lights are functional is to enlist the help of another person to confirm that the lights are operating as each set is switched on in turn. Whilst this indicates that a lamp has failed, some considerable time may have elapsed between the lamp failing and it being noticed. Periodic checks of this nature often fail to reveal intermittent faults such as those caused by ageing or corroded lamp holder contacts. What is needed is a method of indicating that a lamp has failed or has become intermittent at the time of the fault developing.

Many new top of the range cars have such lamp failure indicator devices fitted, but the vast majority of cars do not have. However, it is probably older cars that are more likely to suffer from failed or intermittent lights.

The commonest lamp failure modes are an open circuit filament, lamp holder contact failure and loose connectors or terminals. Fortunately, short circuits in wiring are relatively uncommon.



The assembled Car Lamp Monitor PCB.

Specification

Sensing Section	
Supply voltage range $+V_S$:	+10V to +16V DC
Sense Threshold V_{SENSE}:	≈ 20mV
Supply Current I_S:	≈ 1·5mA per lamp/group
Maximum Sense Circuit Current $I_{L(MAX)}$:	10A (derated according to sense resistor power dissipation)
Output Section	
Saturated collector voltage $V_{CE(SAT)}$	
$I_L = 10mA$:	600mV
$I_L = 300mA$:	800mV
Maximum sink current $I_{C(MAX)}$:	300mA
Maximum collector voltage $V_{CE(MAX)}$:	30V

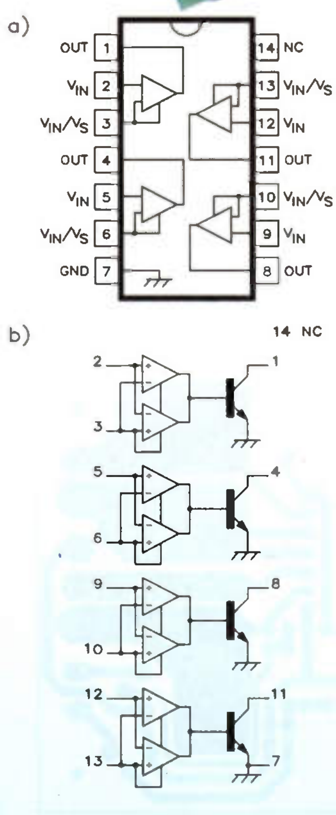


Figure 1. Block diagram/pinout of ULN2455A.

Important Safety Warning

Before starting installation work, consult the vehicle's manual regarding any special precautions that apply. Take every possible precaution to prevent accidental short circuits occurring since a lead-acid battery is capable of delivering extremely high current. Remove all items of metal jewellery, watches, etc., before starting work. Disconnect the vehicle's battery before connecting the module to the vehicle's electrical system. Please note that some vehicles with electronic engine management systems will require reprogramming by a main dealer after disconnecting the battery. Assuming a negative earth vehicle, disconnect the battery by removing the (–) ground connection first; this will prevent accidental shorting of the (+) terminal to the bodywork or engine. It is essential to use a suitably rated fuse in the supply to this project. For the electrical connections, use suitably rated wire able to carry the required current. If in any doubt as to the correct way to proceed, consult a qualified automotive electrician.

This project, the Car Lamp Monitor, is designed to provide an indication of lamp failure and is based around a custom designed IC. The Car Lamp Monitor has been designed to be as flexible as possible, so as to cater for the inevitable differences in electrical wiring between makes and models of cars. However, two basic assumptions have been made: first, the car's electrical supply is negative earth; second, the car's lights are switched in the positive supply line to the lamp (i.e., one side of the lamp is connected to the vehicle's chassis). The vast majority of cars will satisfy both of these requirements.

A single Car Lamp Monitor module can be used to monitor up to four groups of lamps; a group can comprise a single lamp or a number of lamps connected in parallel. The monitor works by detecting the current drawn by working lamps, if a lamp fails the current drawn will drop (to zero for one lamp).

Fault indication can be in the form of a buzzer, an LED, a filament lamp or by interfacing the Car Lamp Monitor to more complex electronics, such refinements as digitised spoken warnings could be provided. To cover all of a car's lamps

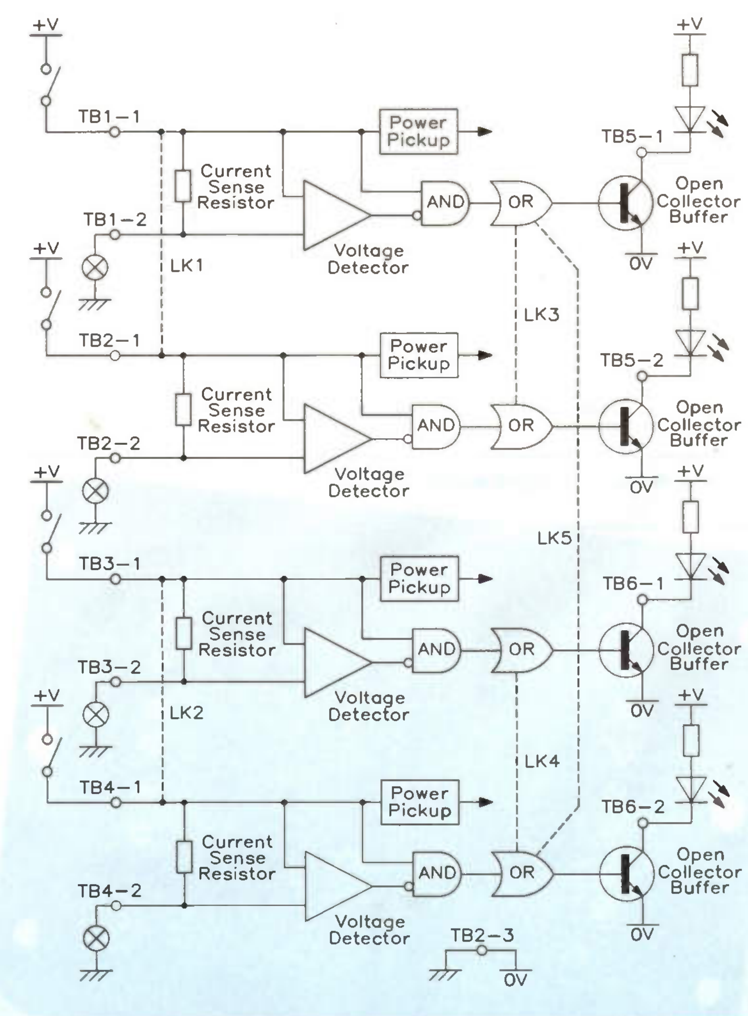


Figure 2. Block diagram of the Car Lamp Monitor.

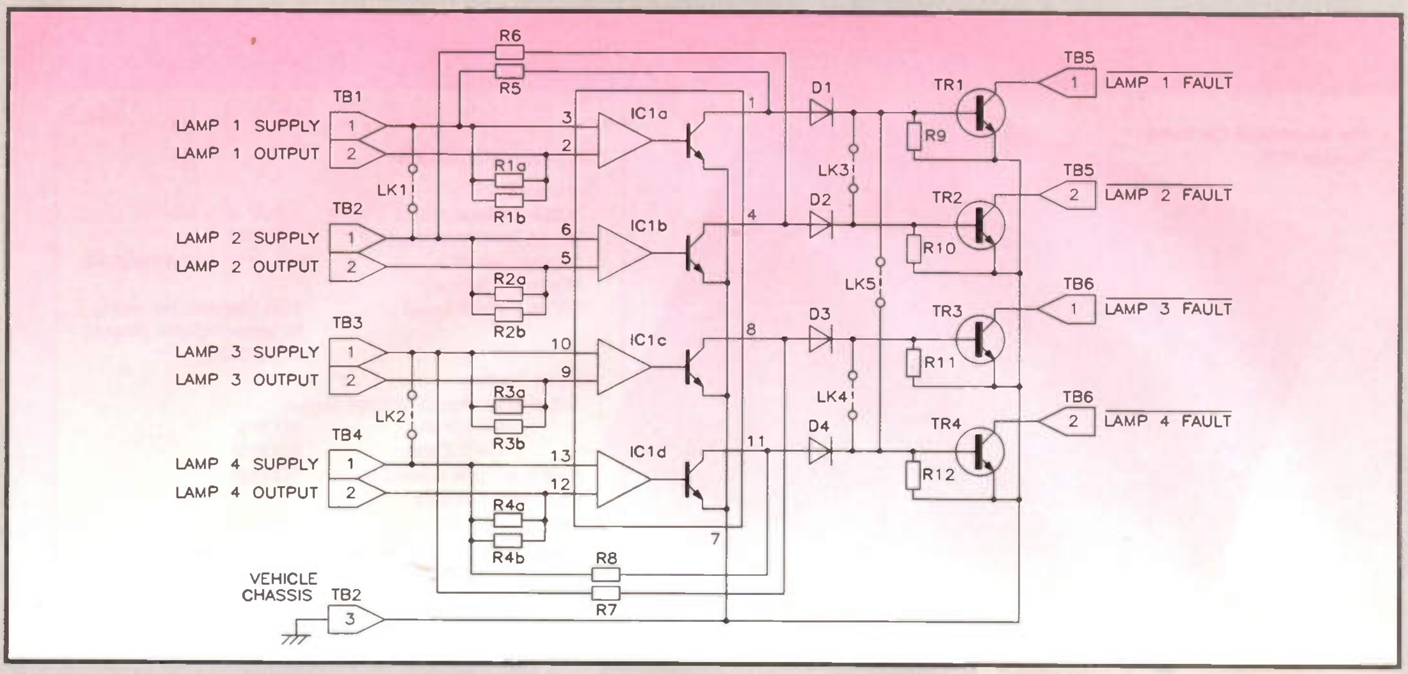


Figure 3. Circuit diagram of the Car Lamp Monitor.

will require several modules to be built. The module may also be used to confirm operation of lights on a caravan or trailer.

Circuit Description

The heart of the Car Lamp Monitor is a ULN2455 lamp failure monitor IC; the pinout and internal block diagram of which are shown in Figure 1. The IC comprises four voltage comparators with open collector output transistors and cleverly obtains power to operate from the supply to the lamps it is monitoring. A voltage difference of approximately 20mV between the input and output terminals of one of the comparators will cause the respective output transistor to switch on. To detect operation of a lamp, it is necessary to monitor the current drawn by the lamp – not the voltage applied to it. A voltage comparator can be made to detect current by simply connecting a resistor across its input terminals.

Figure 2 shows how sense resistors are employed in the Car Lamp Monitor. The voltage developed across any of the sense resistors is determined by Ohm's Law:

$$V = I \times R$$

Therefore, for the ULN2455 IC to detect a current of a given magnitude it is simply a matter of transposing Ohm's Law and filling in a few values to calculate the value of sense resistor required:

$$R_s = \frac{V_C}{I_L}$$

Where:

R_S is the value of sense resistor in ohms
I_L is the current drawn by the lamp in amps
V_C is the comparator threshold level in volts

Therefore:

$$R_s \geq \frac{20mV}{I_L}$$

Since an indication of lamp *failure* is required, the *absence* of current flow needs

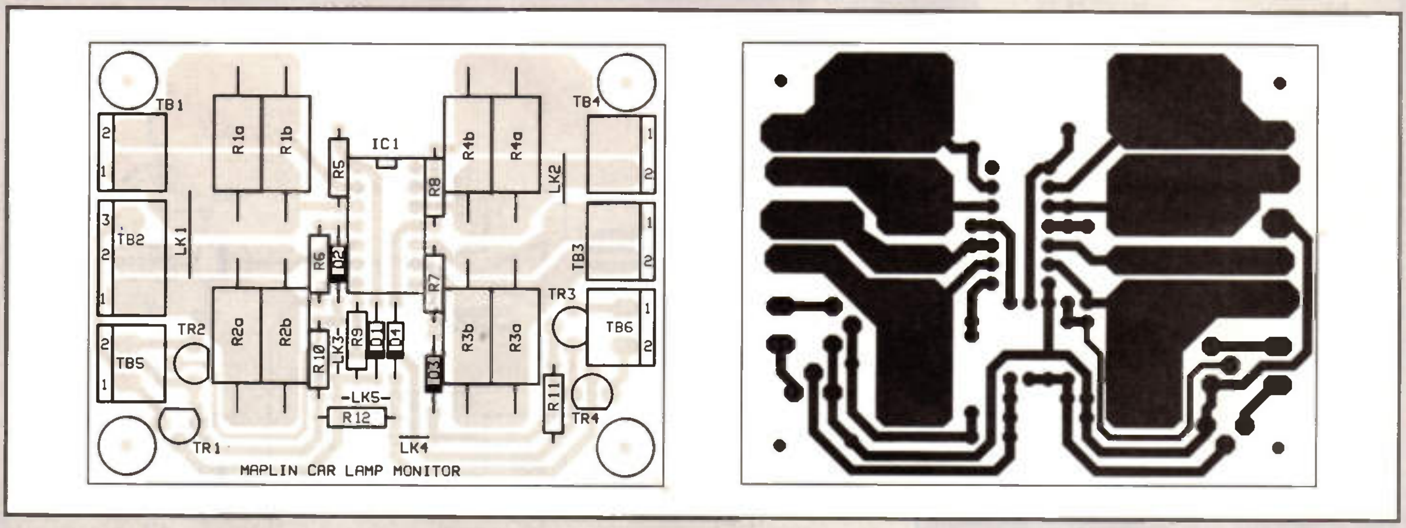
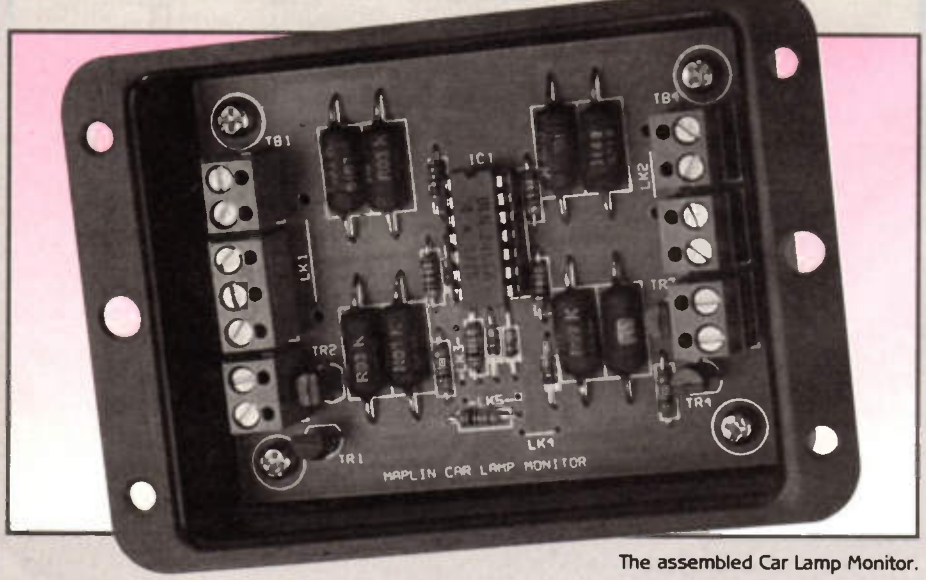


Figure 4. Car Lamp Monitor PCB legend and track.



The assembled Car Lamp Monitor.

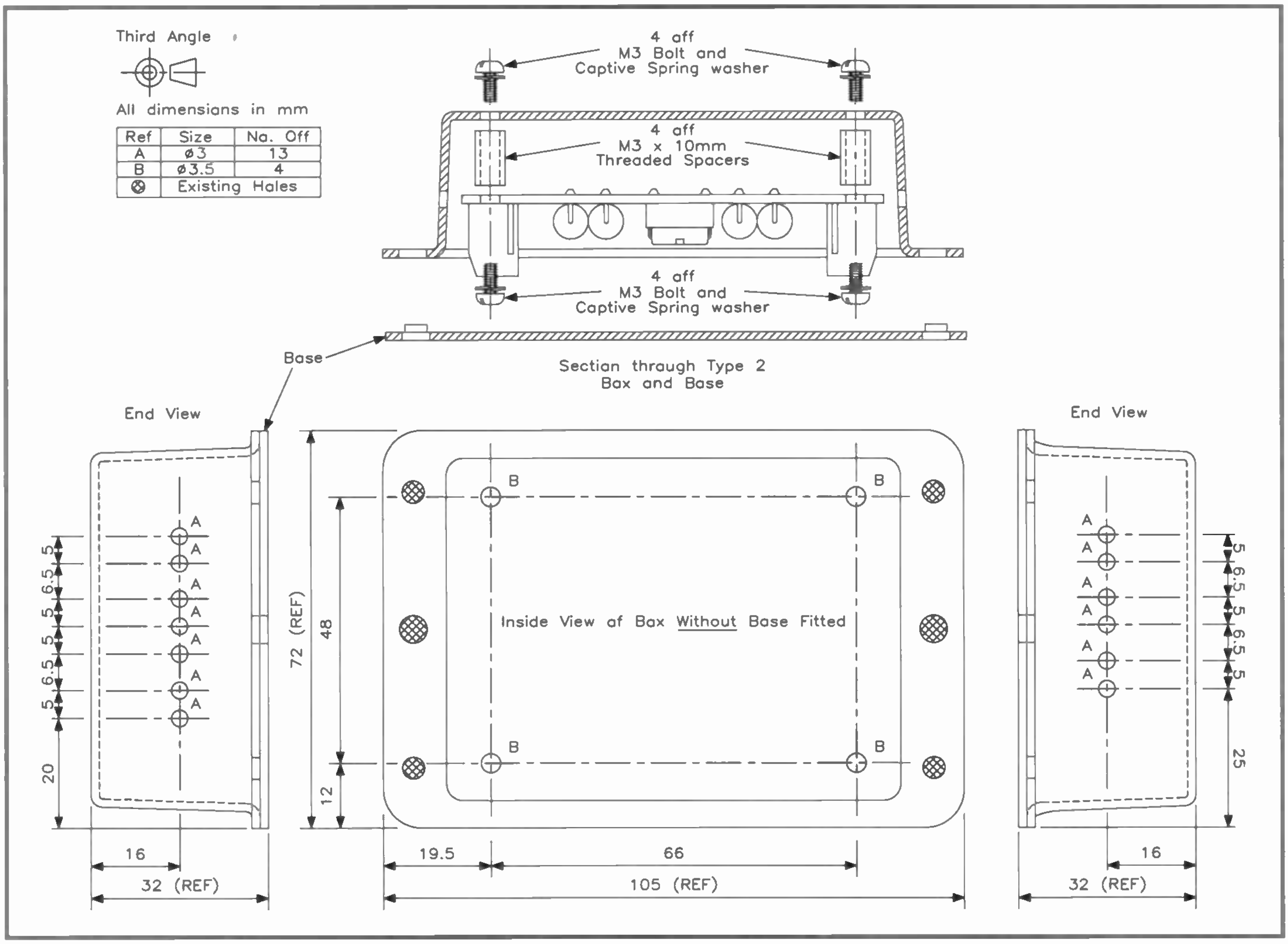


Figure 5. Car Lamp Monitor box drilling details and exploded assembly.

to be detected – but only when the supply voltage to the lamp is present! It may also be desirable to have one common indicator for a group of lamps. These features can be seen in Figure 2. The output from the AND function is 'high' when the lamp supply is present *and* the lamp has failed. The OR function allows several or all of the outputs to be combined to give a single or group indication of lamp failure. The output from the OR function is 'high' when its input or inputs are 'high'. Finally, open collector buffers are provided to drive the lamp failure indicators.

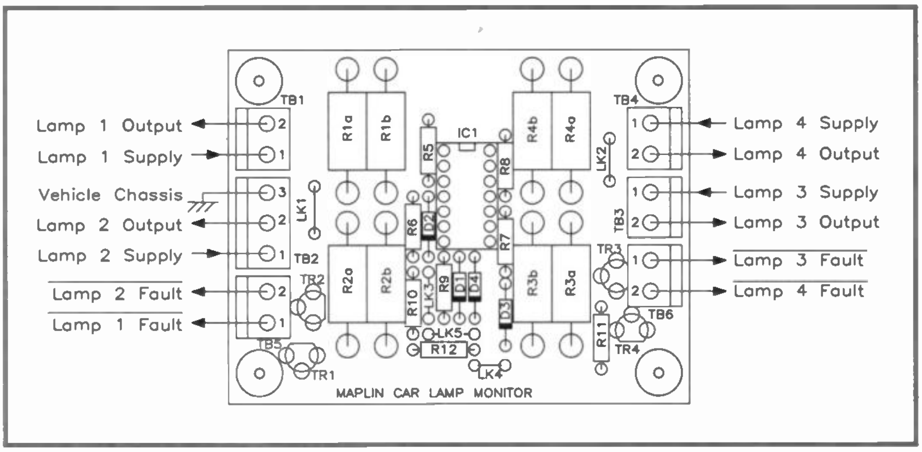


Figure 6. Car Lamp Monitor terminal functions.

Lamp Rating	Theoretical Sense Resistance Required	Actual Sense Resistance Used	Resistor Values Rn_a	Rn_b
5W	≥ 48mΩ	68·75mΩ	100mΩ	220mΩ
5W + 5W	≥ 24mΩ	30mΩ	30mΩ	–
21W	≥ 11·4mΩ	15mΩ	30mΩ	30mΩ
55W	≥ 4·4mΩ	Use resistance of wiring	–	–

Note: To allow for component tolerances, variations between lamps and variations in supply voltage, the actual sense resistance used is higher in value than the theoretical resistance value.

Table 1. Lamp ratings and sense resistor values.

The circuit diagram of the Car Lamp Monitor is shown in Figure 3; since the circuit consists of four identical sections, only the section will be described.

R1a and R1b together with IC1a form a current detector. The values of these resistors are very low – in the order of tens or hundreds of milliohms. Table 1 gives the corresponding sense resistor values for standard lamp ratings found in cars. The open collector output transistor contained with IC1a, together with R5, form the required AND function. D1 and R9 provide the output OR function – sections can be grouped by fitting links LK3, LK4 and LK5 as required. TR1 a Darlington transistor, is configured as an open collector buffer. LK1 and LK2 allow lamps fed from a common supply to be separately monitored.

Construction

Decide whether you require four individual fault indicators, one for each lamp group to be monitored; two fault indicators for two lamp groups; or one fault indicator for all lamp groups. The various configurations are shown in Figures 6a to 6c; component options are listed on each diagram. It is possible to use the resistance of the cable supplying the lamps instead of using the on-board sense resistors. This can be useful for high power lights such as 55W headlights, driving lights, foglights, etc. This is illustrated in Figure 6d. The choice of 'build options' must be determined by the constructor and, in part, are dictated by the arrangement of the electrical circuits in the car into which the unit is to be fitted. It is

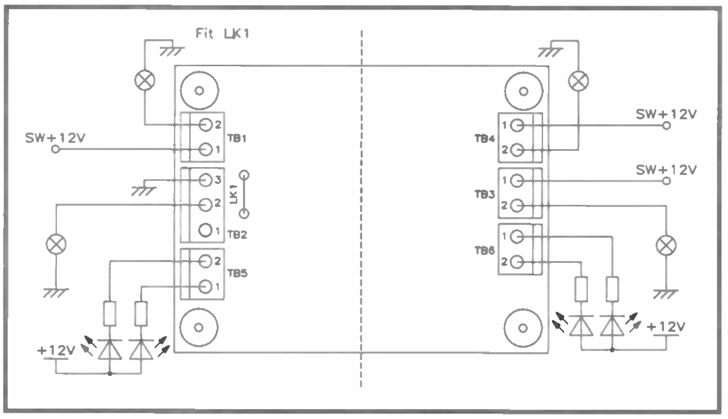


Figure 7a. Separate fault indicator LEDs for each lamp.

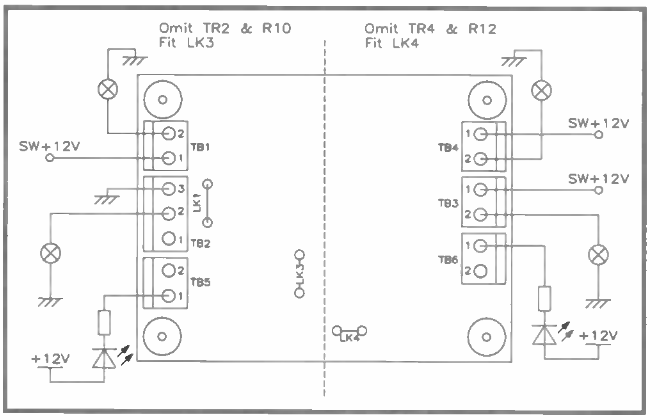


Figure 7b. Shared fault indicator LEDs for pairs of lamps.

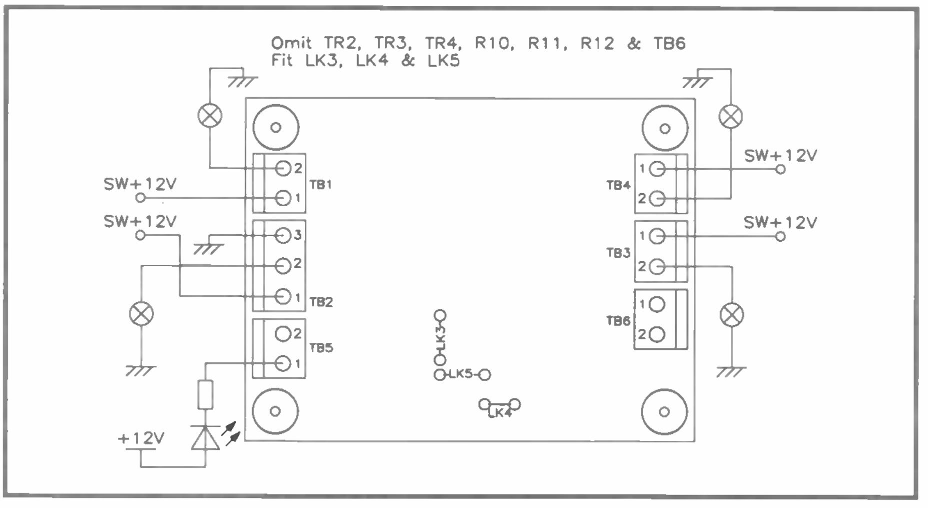


Figure 7c. Shared fault indicator LED for all lamps.

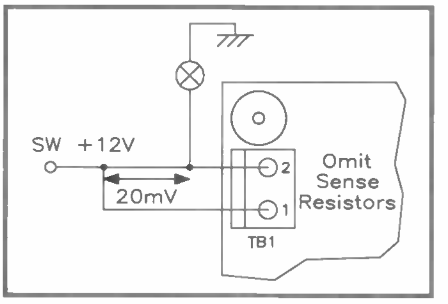


Figure 7d. Sensing voltage drop across wiring.

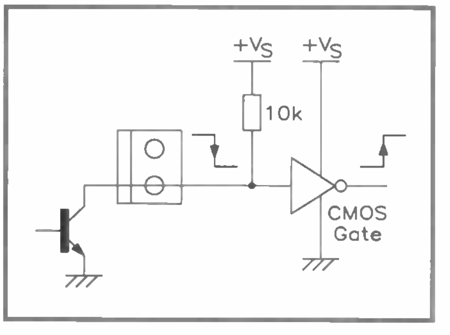


Figure 8. Interfacing the Car Lamp Monitor to CMOS logic.

Terminal	Function
TB1-1	Lamp 1 Supply
TB1-2	Lamp 1 Output
TB2-1	Lamp 2 Supply
TB2-2	Lamp 2 Output
TB2-3	0V/Vehicle Chassis
TB3-1	Lamp 3 Supply
TB3-2	Lamp 3 Output
TB4-1	Lamp 4 Supply
TB4-2	Lamp 4 Output
TB5-1	Lamp 1 Fault
TB5-2	Lamp 2 Fault
TB6-1	Lamp 3 Fault
TB6-2	Lamp 4 Fault

advisable, therefore, to read the Installation section before proceeding with construction. The kit, as supplied, is intended to monitor two 5W 'tail lights' plus two 21W 'stop lights' – the commonest application. If it is required to monitor lamps of a different rating, extra sense resistors will need to be purchased separately.

Referring to Figure 4 and the Parts List, start by fitting the thin wire links LK3 to LK5 (if required). Next, fit the signal diodes, D1 to D4, ensuring correct orientation. Fit the large wire links LK1 and LK2 (if required). Next, fit resistors R5 to R12 (as required). Fit in IC socket in the IC1 position, but do not fit IC1 itself at this stage. Fit R1a to R4b (as required), bend a short length of each of the leads flat against the bare track. Next, fit TB1 to TB6, ensuring that the wire entry apertures face towards the edge of the PCB. Apply a thick coating of solder to the bare track areas around TB1 to TB4/R1a to R4b. Fit, TR1 to TR4 (as required), ensuring correct orientation. Finally, fit IC1 into its socket, again ensure correct orientation.

Check over your work to ensure that there are no short circuits caused by solder splashes, incorrectly fitted components, etc. Excess flux residue may be removed from the PCB using a suitable solvent; preferably one of the newer 'environmentally friendly' types that are not trichloroethane based or use Chlorofluorocarbon (CFC) propellant.

If the optional box is to be used, Figure 5 gives drilling details.

Installation

Before proceeding with installation, observe the warnings given at the beginning of the article. A workshop manual, such as the popular *Haynes* series, will greatly assist wire tracing. Use a multimeter or a circuit tester to confirm wiring arrangements *before* wires are cut. It may be useful to obtain help from another person to operate the lights whilst you check the wiring. When tracing wiring, look out for other parallel connected lamps – often number plate lights are supplied from the tail-light circuit – decide whether or not these additional lamps are to be monitored or not.

Figure 6 and Table 2 give the Car Lamp Monitor module connections and Figures 7a to 7d show various wiring configurations. If it is necessary to lengthen existing wiring, the wire used must be suitably rated. All connections must be both mechanically and electrically sound. Where wires are to be joined, solder, crimp or terminal block connectors should be used. All connections should be fully insulated to prevent short circuits – heat shrink sleeving is ideal for this purpose.

Low current cable may be used for the wiring to TB5 and TB6 (fault indicators) – four core 'burglar alarm' cable is ideal. A +12V ignition switched supply is required to power the fault indicators and may be derived from a convenient point. A 100mA fast acting fuse should be inserted between the supply and the fault indicators to protect the low current wiring against short circuits.

Once installation is complete, check over your work thoroughly before reconnecting the vehicle's battery.

Testing

Switch the ignition on (but do not start the engine) and switch on each lighting circuit in turn. Assuming that all of the filament lamps are in working order, none of the fault indicator LEDs should illuminate. Remove the lamps from each circuit in turn and repeat the tests; the appropriate fault indicator LED should illuminate in each case.

Expansion

Several Car Lamp Monitor modules can be built and interconnected. Since the transistors that switch the fault indicator LEDs are open collector, multiple modules may have their outputs connected in parallel. A fault detected by any one module will be registered.

This is an extremely useful feature if all exterior lights are to be monitored. Interfacing to other electronic circuits may be achieved by using a pull up resistor connected between the appropriate output and the positive supply of the logic circuit, see Figure 8. Remember, the fault outputs are active low (i.e., the output goes low when a fault is detected).

Happy Motoring!

CAR LAMP MONITOR PARTS LIST

RESISTORS: All 0·6W 1% Metal film (Unless specified)			
R1a,1b,2a,2b	30mΩ 2·5W Wire Wound	4	(50R03)
R3a,4a	100mΩ 2·5W Wire Wound	2	(50R1)
R3b,4b	220mΩ 2·5W Wire Wound	2	(50R22)
R5,6,7,8	10k	4	(M10K)
R9,10,11,12	100k	4	(M100K)
SEMICONDUCTORS			
D1,2,3,4	1N4148	4	(QL80B)
TR1,2,3,4	MPSA14	4	(QH60Q)
IC1	ULN2455M	1	(GX53H)
MISCELLANEOUS			
TB1,3,4,5,6	2-Way PCB Terminal Block	5	(JY92A)
TB2	3-Way PCB Terminal Block	1	(JY94C)
	14-pin DIL Socket	1	(BL18U)
	PCB	1	(GH85G)
	Instruction Leaflet	1	(XU81C)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	620Ω 0·6W 1% Metal Film	As Req	(M620R)
	Red 5mm LED	As Req	(WL27E)
	Green 5mm LED	As Req	(WL28F)
	6A Black Wire	As Req	(XR32K)
	6A Red Wire	As Req	(XR36P)
	1·6mm/16SWG Tinned Copper Wire	1 Reel	(BL11M)
	4-Wire Low Current Cable	As Req	(XR89W)
	8-Wire Low Current Cable	As Req	(CW70M)
	Box with Base Type 2	1	(YN36P)
	M3 x 10mm Insulated Spacer	1 Pkt	(FS36F)

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 LT63T (Car Lamp Monitor Kit) Price £9.99

The following new item (which is included in the kit) is also available separately, but is not shown in the 1994 Maplin Catalogue

Car Lamp Monitor PCB **Order As GH85G Price £2.99**

NEWS Report

Nose on a Chip

IBM scientists have developed what is claimed to be the world's most sensitive heat-measuring instrument. Called a calorimeter, it is a thousand times more sensitive than any similar instrument available today; it can measure the heat generated in chemical reactions with a sensitivity to temperature changes as small as a hundred-thousandth of a degree.

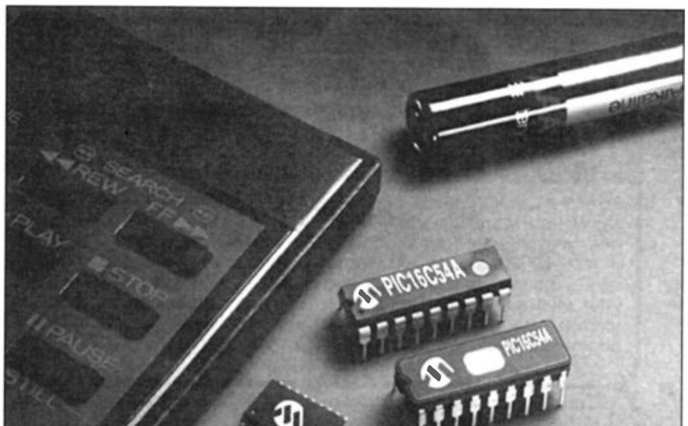
The calorimeter is micro-fabricated from integrated-circuit technology and is relatively inexpensive. It should prove useful in a large variety of chemical observation, detection, measurement, and analysis applications such as drug design, forensics, and catalysis. So sensitive is the calorimeter that it can function as a supersensitive 'nose on a chip', capable of 'smelling' extremely minute quantities of substances.

Developed at the IBM Research Division's Zurich Research Laboratory, the technique employs a microchemical silicon lever that is coated with aluminium. When heated, the lever bends because the two materials expand by different amounts similar to a mechanical thermocouple. The amount of bending directly indicates how much heat has been absorbed by the lever.

A typical person can discern several hundred odours, and a trained expert might be able to identify several thousand. While computers have been given the ability to see, hear and touch, they are as yet unable to emulate the olfactory organ – they can't smell. This may soon change.

The IBM scientists believe that the apparatus for this technique could be incorporated into a portable package, with the 'nose on a chip' and a laptop computer, to provide an instrument capable of detecting gases and pollutants such as ozone and carbon monoxide and even odours such as that of fish. Contact: IBM, Tel: (0705) 561000.

Microchip Improves Microcontrollers



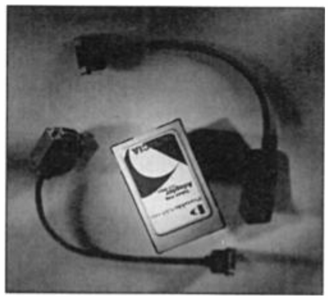
Microchip's PIC16C54 8-bit microcontroller is now available with reduced power consumption, improved electrical characteristics and denser packaging. Using an advanced 0·9-micron double-layer metal wafer fabrication process, the new one-time programmable PIC16C54A can be powered from a single lithium-ion battery making it an ideal solution for portable applications such as pagers and remote controls.

The PIC16C54A is the first of the PIC16C5X family to be manufactured using the 0·9 micron process. The high-speed RISC-like 8-bit device operates at up to 20MHz and provides faster instruction execution than any other 8-bit microcontroller in its price range. An on-chip EPROM fuse configuration allows designers to select on-chip R/C timing circuits and crystal/resonator clock options to reduce component count, cost, and board space requirements.

On-chip memory facilities include 512 words of EPROM space for program storage and 25 bytes of static RAM for data. On-chip peripherals include an 8-bit real time clock/counter with programmable prescaler, a watchdog timer, and 12 I/O lines with individual directional control. The PIC16C54A operates between 2·5 and 6·0V and includes a power down or sleep mode which reduces current drain to less than 4µA.

The PIC16C54A is available in plastic DIP and SOIC, and in a compact SSOP configuration. Contact: Arizona Chip Technology, Tel: (0628) 851077.

Networking Enters the PCMCIA Age



Guildford-based PCMCIA specialist Portable Add-ons has announced a range of credit-card sized PCMCIA 2.0 compliant network adaptors. Three cards are available, one model for Token Ring networks and two that comply to Ethernet standards.

Prior to the introduction of these products, there was no easy way to connect laptop PCs into a network. This was a particular issue for organisations providing executives with laptop computers for use at home, in the office or on the move.

The introduction of PCMCIA network cards means that laptops can now be used on the office network, dispensing with the need for permanent office-based desktop PCs and costly docking stations.

The Portable Add-ons PCMCIA Token Ring adaptor is equipped with a 16K buffer and operates at speeds of either 16 or 4Mbits/s. As it plugs directly into the PC's bus via the PCMCIA socket, it offers performance equivalent to that of a conventional PC fitted with a network card.

The Token Ring adaptor can be used with Novell Netware, IBM PC LAN, Microsoft LAN Manager (DOS and OS/2), Banyan Vines and any other system that supports IBM LAN Support Program services. It operates with DOS 5.0 or later, and supports the Intel PCIC, Cirrus and Databook host controller standards.

The Portable Add-ons Ethernet adaptors for use with twisted pair (10 BaseT) and coaxial cable (Thin + 10 BaseT) are fully NE2000-compatible, giving instant connectivity to all major network operating systems – including Novell Netware, Microsoft LAN Manager and Banyan Vines. Host controllers recognised include Intel PCIC 82365SL, ASCII J6941/2, Databook, Sharp PHIC and the proprietary Toshiba standard.

Both Ethernet adaptors are equipped with a 64K buffer, will support DOS 3.1 or later, and include drivers for Novell Netware and NDIS. All three network adaptors derive their power from the host PC, so there is no need for an external power supply. Retail price details; Token Ring £399; 10 BaseT £199; Thin + 10 BaseT £239. Contact: Portable Add-ons, Tel: (0483) 440777.

GATT Phonographic Agreement

The recording industry can take heart from the fact that the recent GATT Agreement on Trade Related aspects of Intellectual Property Rights (TRIPS) secures rights vital to fundamental problems facing the industry – global piracy and bootlegging.

Recent legislation under TRIPS protects reproduction rights, commercial rental, and provides measures for criminal enforcement worldwide.

But according to the International Federation of the Phonographic Industry, the Agreement has left lost opportunities, with mention of private copying, public communication rights – particularly in digital, satellite and cable configurations – or protection of copyright management technologies. Contact: International Federation of the Phonographic Industry, Tel: (071) 434 3521.

Speech Recognition for Windows

The WordPerfect Corporation has announced a strategic alliance with US based Dragon Systems to bring fully-integrated, highly-productive speech recognition applications to end users. Using Dragon Systems' speech technology, WordPerfect will voice-enable its applications and provide other developers with access to the jointly developed technology.

Dragon Systems' expertise lies in command and control, and large vocabulary speech recognition products. WordPerfect will integrate Dragon Systems' speech technology into its Windows products through a jointly defined application programming interface (API).

So next time you are searching for the 'bold' function or trying to change font in a header, you can swear at your PC, instead of fumbling with the keyboard. Whether the application will respond any better, we have yet to see. Contact: WordPerfect, Tel: (0932) 850500.

Low-Cost Surface Mount Crystal Package

Crystal manufacturer International Quartz Devices (IQD) has launched a surface mount crystal version of the popular HC49/4H crystal package. Designated the HC49/4HSMX, the package provides a cost-effective surface mount crystal with a small footprint of only 4·9 x 13·4mm and a height of 4·3mm.

Available over the frequency range 3·2 to 50MHz, the HC49/4HSMX offers standard frequency tolerances (at 25°C ±2°C) and frequency stabilities of ±50ppm and ±100ppm. Tighter specifications are available for many frequencies to special order.

Load capacitance is specified between 5 and 75pF, or series; drive level at 100µW maximum. Shunt capacitance is rated between 2 and 9pF.

Sample quantities of standard frequencies are available from stock to enable design engineers to progress new designs. Detailed specifications are available in the surface mount section of IQD's 1994 Crystal Product Data Book. Contact: International Quartz Devices, Tel: (0460) 77155.

90 and 100MHz Pentium Processors

Intel Corporation has introduced new Pentium processors running at frequencies of 90 and 100MHz.

The new Pentium processors will be manufactured in volume at Intel's advanced microprocessor production factories in Ireland and Santa Clara. With the 3·3V, 0·6μm, 4-layer metal advanced process technology, the chip is approximately half the size of other members of the Pentium processor family. This announcement comes on the heels of Intel's demonstration of a 150MHz Pentium processor at the IEEE International Solid State Circuits Conference (ISSCC) in San Francisco last February. Contact: Intel, Tel: (0793) 430763.

Software Magazine for the PC

OUTLET, the successful software magazine for the Spectrum since 1987, is now on disk in PC format. This is now totally PC related, not just a variation of the Spectrum issues.

The aim of *OUTLET* is to give users the chance to exchange ideas, help each other with problems, and to exchange home-grown routines – in fact any computer related subjects can be covered. The very fact that the magazine consists of virtually 100% readers' contributions largely dictates its contents and, therefore, is more related to their interests and needs.

The PC issue has an estimated 2MB compressed onto a 1·4MB 3·5in. HD disk, and is intended for a system with VGA graphics. The magazine can be run from the floppy, or installed onto hard disk. Individual items can be extracted and transferred to the chosen media.

Chezron has a no-quibble guarantee, and special introductory offers. Further information from: Chezron Software, 34 Saltersgate Drive, Birstall, Leicester LE4 3FF.

Smart Card Technology to Become ARM Powered

Advanced RISC Machines Limited has joined forces with a group of European companies under the European Community EITC (previously ESPRIT) initiative to develop smart card security systems incorporating analysis techniques such as voice recognition.

Called CASCADE (Chip Architecture for Smart CArds and portable intelligent DEvices), the project was initiated by the French smart card manufacturer GEMPLUS and is part of the OMI (Open Microprocessor Systems Initiative).

Despite continual advances in microprocessor technology, smart cards have not evolved beyond the traditional 8-bit based CISC processors, such as the 8051 or 6805, developed in the late seventies.

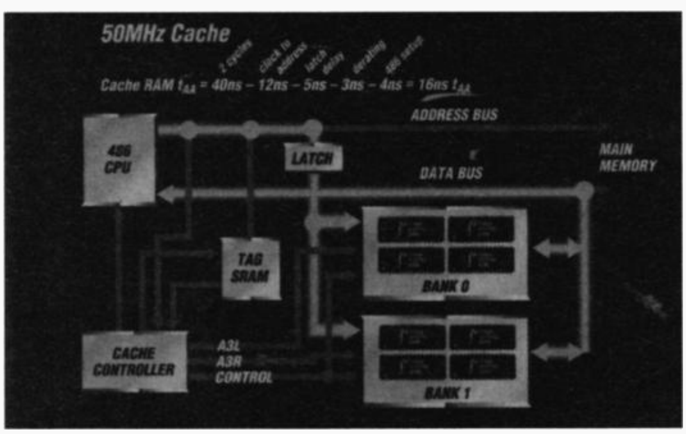
By developing a new ASIC based on ARM's 32-bit RISC technology, GEMPLUS expects to make dramatic gains in the performance and functionality of smart card technology.

The ARM processor is ideal for smart card applications since the core has been optimised for small die size, high processing performance, low power consumption and high code density.

The ARM has over a hundred times the processing power of existing smart card chips. This, coupled with ARM's high level programming language support and its ability to handle 32-bit data, will handle problems involving complex algorithms such as voice recognition.

With the ARM processor, smart card technology will reach a previously unobtainable level of security; bringing inviolable protection against fraud to the consumer market. The technology is expected to be applied initially to personal digital assistants.

The CASCADE project started in December 1993 and is running for two and a half years. The objective of the project is to have a new smart card architecture designed and integrated into a working demonstrator. Contact: Advanced RISC Machines, Tel: (0223) 400400.



1MB SRAM in JEDEC Packaging

Integrated Device Technology's 128K x 8 SRAMs are now available in JEDEC standard 300 mil SOJ packaging. At 15ns, the IDT71024 is the ideal cache solution for Pentium, PowerPC, Intel 486 and MIPS RISC applications.

The new 32-pin, SOJ packaging provides significant space savings while the standard JEDEC pinout simplifies both speed and density upgrades to existing cache designs.

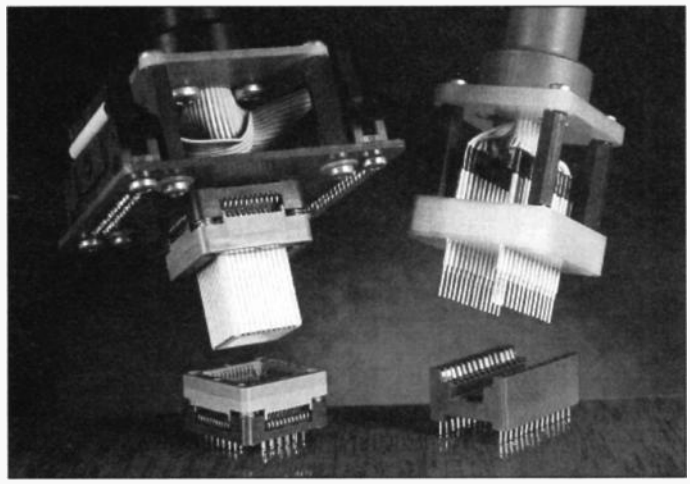
Systems using slower 128K x 8 SRAMs can achieve an immediate speed improvement while those using fast 32K x 8 SRAMs can rapidly implement a density upgrade.

The IDT71024 is the ideal choice for secondary cache in high-end PCs and workstations. At 15ns, the IDT71024 allows systems to work with higher clock rates and with a wider timing margin, without introducing wait-states into the timing equation. The 7ns output enables time simplified designs such as interleaved fast cache systems.

The SRAMs are equally good as high-density, general-purpose SRAMs for applications such as data communications buffers; DSP memory; and avionics memory, where large amounts of high-performance memory are required.

The IDT71024 is available in 32-pin 300 mil and 400 mil SOJ packaging. IDT also offers high-density modules based on the IDT71024. The 20ns 4MB (512K x 8) IDT7M4048 module is available in 32-pin JEDEC DIP packaging while the 15ns 4MB (128K x 32) IDT7M4013 is available in a 66-pin Hex in-line package that occupies approximately one square inch of board area. Contact: IDT Europe, Tel: (0372) 363734.

Test Probe Blocks for DIP and PLCC Sockets



Now available from Peak is a range of test probe blocks for use with PLCC and DIP integrated-circuit sockets in burn-in and emulation applications.

The DIP test probe is a block of spring probes which forms part of a hand-held unit linked via a cable to the test equipment.

The PLCC probe uses a glass-fibre block incorporating gold-plated tracks to link the socket with the hand-held unit. This innovative concept allows the track block to be separated from the main unit, making it a cost-effective long-life solution to the problems presented by continual replacement of the test socket. Contact: Peak, Tel: (091) 387 1923.

IBM's New Disk Format Boosts Data Capacity 28 Per Cent

A new formatting technique developed at IBM's Almaden Research Centre permits IBM to pack 28% more data into its latest line of magnetic hard-disk drives designed for use in laptop computers.

The new format increases data-storage capacity by removing all of the disk-section identification (ID) information that until now has preceded every block of data on the disk. The necessary functions formerly served by the ID fields are now handled electronically.

The move frees up about 10 to 15% of the disk area for storing more user data. When used in conjunction with the sensitive magnetoresistive (MR) recording head, another IBM innovation, this new format also permits the data tracks to be closer together, further raising the capacity gain.

IBM's No-ID sector format also permits faster and more reliable data reading and writing operations through a variety of other, more subtle impacts. Impressive, huh! Contact: IBM, Tel: (0705) 565339.

UK Firm Wins Hong Kong Number Study

UK technology consultancy Ovum has been awarded a contract to study the feasibility of number portability in Hong Kong by The Office of the Telecommunications Authority (OFTA).

Number portability provides users with the ability to retain their telephone number when they change address, telephone or operator. A change in telephone number can be expensive for the customer – because of ordering new stationery and loss of contacts – and may act as a barrier to changing supplier. This makes number portability an important issue in the development of a competitive telecommunications market in crowded Hong Kong.

If number portability is adopted in Hong Kong it will be a world first. Portability has yet to be implemented anywhere in the world for the basic telephone service.

Ovum will therefore be giving special attention to the feasibility and reliability of various technical solutions, to ensure they provide the security and integrity needed for Hong Kong's telephone service. Contact: Ovum, Tel: (071) 255 3670.

Manufacturing Fuels Recovery

A significant rise in the number of start-up businesses in the manufacturing sector confirms the industry's recovery and puts it in a strong position to take advantage of improving conditions in 1994, according to Barclay's latest Small Business Bulletin.

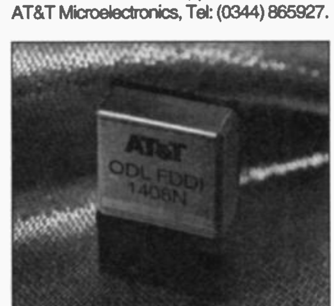
In 1993, around 53,000 manufacturing-led businesses were formed, giving an increase of 18% in the number of start-ups for the sector on the previous year.

Furthermore, despite weaker economies in the EU and difficult export markets, manufacturing output in the UK rose 2% last year, the first annual rise since 1989, welcome news for British businesses. Contact: Barclays Bank plc, Tel: (071) 696 4243.

Low-Cost Transceiver Family

AT&T Microelectronics has introduced the 1408N low-cost transceiver which has the flexibility to be used in SDH, ATM and fibre channel applications. Designed for short to medium distance data communications, the 1408N is the latest addition to AT&T's low-cost optical data link family of transmitters, receivers and transceivers.

The 1408N can be used for point-to-point links such as connecting Local Area Networks (LANs) together in large organisations. This is made possible by the design of the transceiver, which features a link budget of approximately 11dBM between the transmitter and receiver. Typical transmission distances of around 2km are supported. Contact: AT&T Microelectronics, Tel: (0344) 865927.



by Keith Brindley

Getting to know Test EQUIPMENT

PART 1

Identifying the needs and applications

In this new multipart series Keith Brindley looks at the types of test equipment available, and how they work, and tells you what equipment you need to test the projects you build.

If you ever build a project from the pages of *Electronics – The Maplin Magazine*, or any magazine for that matter, you need to have test equipment. Oh sure, there is the odd chance you might get your project to work first time. It might all come together easily, and fit into its case beautifully. You will plug it in, turn it on, and your digital dice will roll, or your car will be alarmed, or your amplifier will amp. But, it is usually a safe bet to assume it will not!

Electronics, and all that goes with it, is a complex affair, in which Murphy's law is the only real hard-and-fast proviso – *what can go wrong, does!* As far as your project is concerned, what is wrong is invariably not obvious. So what do you do when you cannot find the problem by sight? You have to resort to the use of test equipment.

Test equipment is used in all technical areas – not just project building. Whether in the commercial manufacture or servicing of electronic appliances or in education, or in the sciences, test equipment is required simply to observe how the appliance operates and, more specifically, to find out what part of the appliance is not operating when a problem occurs. Once you have isolated the part which *is not* working properly, you can set about repairing it.

The types of test equipment you might need when building projects (although the same constraints apply to commercial appliance manufacture, too) depend largely upon three things:

1. The project that is being tested.
2. How serious you want to be about project building
3. Your cash situation – test equipment is often very expensive, and gets even more expensive when specialised test equipment is concerned.

In the 'good old days' of electronics – either on the hobbyist's bench, or in large industrial manufacturing applications – the complete range of test equipment usually comprised an Avometer, an oscilloscope, and perhaps a signal generator of some description. In fact, things really have not changed much, as far as the project-builder is concerned, but more about that later. With this limited test gear, most appliances and projects of the day could be manufactured, serviced, or studied quite adequately. The electronics world was virtually all analogue so the analogue test instruments that were available were more than adequate.

However, today the situation has changed dramatically. Projects and appliances are often digital in nature, microprocessor-based in technique, and far more complex in operation. They generally perform better, and are usually more reliable.

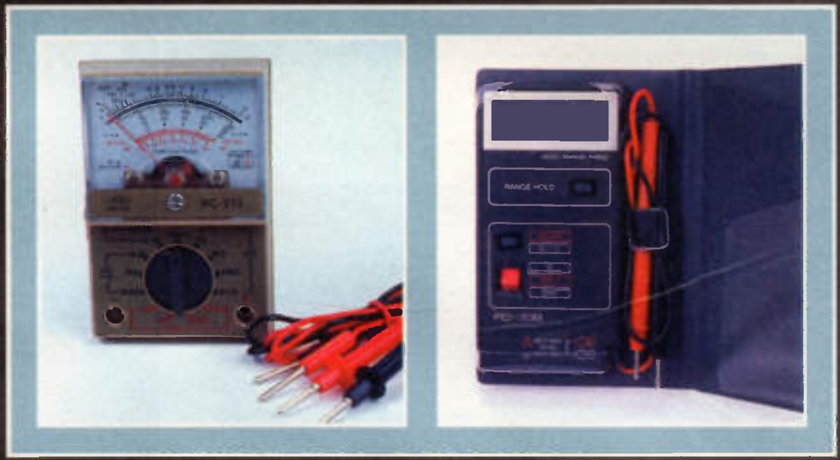
But more complex projects and appliances require correspondingly more complex test equipment, and the development of a new generation of test equipment, such as the logic analyser. This was developed in response to the need to observe basic internal operations of microprocessor-based systems. Prior to the microprocessor, testing an appliance was often as simple as applying a suitable signal at the appliance's input and observing signals obtained at each stage throughout the appliance – one at a time. When the microprocessor bus came along, it brought with it the requirement to observe a great deal more than just one signal – and all of them, simultaneously. And so the logic analyser was born. Doubtless, further generations of test instruments will be spawned by future appliance needs.

What Do You Want?

An understanding of the requirements of the projects you would like to build is important, so that you can weigh up the three constraints noted earlier. You have to decide what you are going to build, how serious your requirements are, and finally you have to decide what your pocket-money can afford.

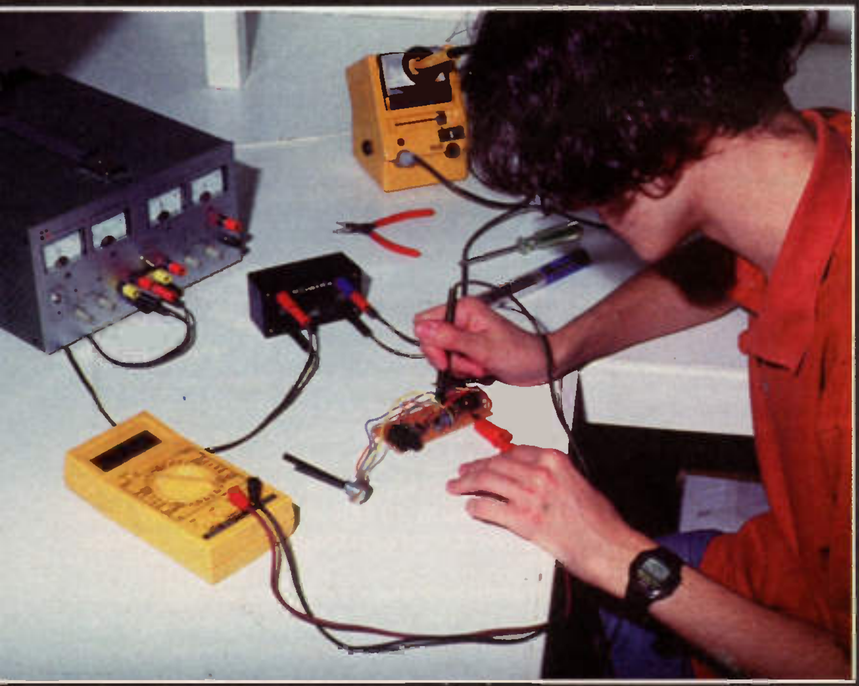
However, there is a minimum requirement for testing any project. Certain parameters are so fundamental to any circuit performance, such as voltages, currents, input and output signals, that you cannot afford not to measure them. As a consequence, there is a small group of test equipment which you should have. Fortunately, while these are basic necessities, you do not need to fork out too much money to get at least acceptable (if not too versatile or complex) models. These low-cost models are normally quite good, and can be used in many test applications to give the desired results, and take the measurements needed for a successful project.

There are three items of test equipment which fall into this fundamental group: a multimeter, a signal source, and a power supply. You could argue that the last two items are not actually test equipment. But because any circuit you are going to test must have an input signal of some type and a power supply of whatever voltage, you just cannot test the circuit on your workbench *without* either a signal source or a power supply.



Above: A couple of inexpensive basic analogue and digital multimeters.

While expensive variants are available, you do not have to spend more than about £20 to get yourself a capable multimeter. Prices of multimeters from Maplin start at £7.95 for a basic analogue multimeter (YJ06G), while digital multimeters start at £19.95 A1 (ZA37S). However, no multimeter at this price will provide you with earth-shattering features, just the basics.



Left: A typical workbench area with power supply and digital multimeter.

Also, as soon as your finances allow, then an oscilloscope should be purchased. While measurements of voltages, currents, signals and so on can be made (to a limited extent) with some multimeters, it is not until you have an oscilloscope that you can see rapid fluctuations, or signal frequencies. Indeed, the oscilloscope is of such great use in any test equipment facility that we can but stress its importance in a single statement – *if you can afford one, buy one.*

Multimeters

One of the most basic tests you can undertake on a circuit is to measure the voltages and currents involved in its operation. The type of instrument you need to do this task is a multirange, multifunction meter, usually known as a multimeter.

Multimeters allow you to measure, via a range switch and a pair of probes, a wide range of DC and (usually) AC voltages and currents. Most multimeters also have the ability to measure resistance, and a few will measure capacitance.

Signal Sources

Most electronic circuits are concerned with processing waveforms or signals of one sort or another. Everything from the humble op amp to the complex microprocessor chip functions by producing something at its output dependent on something occurring at its input. Whether these 'somethings' are of an analogue nature (say, an audio signal) or a digital nature (maybe a string of data to a printer), waveforms or signals are nearly always present. To test an isolated circuit it is often necessary to create a waveform at its input which emulates the waveform it would experience when in situ. After this, you can measure what is happening at the circuit's output to make sure it is preforming as expected.

It is a signal source which does this job. Of course, what type of waveform or signal you need depends on the circuit under test. Correspondingly there are different types of signal sources, each creating signals for specific test purposes.

Signal sources are often classified either by the type of waveform they generate e.g., sine, square, pulse, etc., or by the frequency range covered e.g., AF, LF, RF, VHF etc., or by the technique used to generate the waveform such as RC, LC, phase-locked, function etc.

The type of signal source required will depend on the type of projects that you choose to build. If you are mainly interested in audio, then an audio frequency generator is best. If you are going to build digital circuits then a pulse generator may be your best option.

Try and choose the most versatile signal source you can afford, although they tend to be more expensive than multimeters. Often, of course, *Electronics* feature signal source projects. As a result, it may be that one of your first projects is to make yourself a reasonable signal source, suiting both your requirements and your pocket. Issue 63 features a sine and square wave generator which is available as a kit (LT25C). Complete kits of parts for projects are also available for different signal sources in the Maplin Catalogue.

Above left: An audio frequency sine and square wave generator (LT25C), available as a kit, and just right to build.

Above right: A high quality dual tracking 32V 2·5A DC bench power supply.

Power Supplies

Of course, if your project is to be battery-powered, your test bench power supply need be nothing more than a simple battery. However, not all circuits are battery-powered. Where a circuit requires a higher voltage, or higher current, than batteries can provide, then a mains-powered power supply is the only option. As a result, when you are testing such circuits, you will need a power supply which can generate the voltages and currents the circuit requires.

Price inevitably depends on what you want from your power supply, and power supplies do tend to be quite expensive. But do try to invest as much as you can, and to aim for a dual-voltage supply if possible. Many circuits you will build, and test, will run from a three-rail power supply, such as 0V and ±15V with a reasonable current output of at least 1A, and ideally with current limiting.

Like a good signal source, it may be a good idea to put a decent power supply high up on your list of projects to build. *Electronics* regularly features power supplies as projects in its pages. The Maplin Catalogue also gives details about power supply projects and kits of parts.

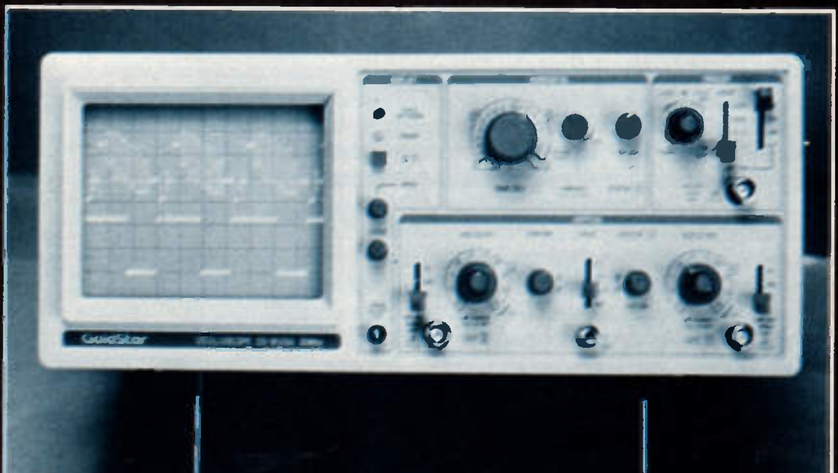
Oscilloscopes

Where all the items of test equipment discussed so far can and often are the subject of construction projects, the oscilloscope is a different story. It is perfectly possible to build your own oscilloscope (I know, I have done it!), but it is not the sort of job you would undertake unless you are a very proficient project-builder in the first place!

Of all the items of test equipment ever invented and built, the oscilloscope is probably the most versatile. Its main feature is its display, a cathode ray tube (CRT), which presents measurements and test results in a recognisable manner.

If you are serious about building and testing projects and appliances then the first three items of test equipment on the list (a multimeter, a signal source, a power supply) are musts. If you can afford an oscilloscope as well – get one!

Below: A DC to 20MHz 2-channel dual trace general-purpose oscilloscope.



Explanation of Terms

Before we go any further into our look at test equipment, we have to consider a few terms that we are going to use. These terms are all related and require rigid definitions before they can be used, and are by no means the *only* important terms with respect to test equipment, but they are the main ones.

Often writers, particularly North Americans, use terms such as 'system under test (SUT) or 'unit under test' (UUT), to describe both the appliance being tested and the measurements taken on the appliance. I cannot say that I like these terms and I am certainly not going to use them in such an indiscriminate way. I shall instead refer to the quantity being measured by the test equipment as the 'measurand' – a term regularly used in the electronic field of study known as instrumentation.

The *accuracy* of a measurement, that is, the closeness of the measured value of a measurand to its actual value, is generally specified in terms of error, that is the maximum possible difference between measured and actual values. For example, a 300mm rule may have an error of say, ±1mm, which means that the rule itself may have an actual length of any value between 299mm and 301mm – it might be exactly 300mm, on the other hand it is probably not! Any measurement taken with the rule therefore has a maximum possible error of 1mm, high or low. Sometimes, in special cases, error is specified as a percentage of full scale deflection, that is, as a percentage of the maximum reading. In the case of the rule, error could be specified as ±0·33%, which sounds much more accurate than ±1mm even though they mean the same thing!

The fineness with which a measurement can be taken is known as the 'resolution'. If the rule is graduated in millimetres, then it should be possible to interpolate between two millimetre markings when measuring, to give a resolution of 0·5mm. However, the fact that the resolution may be lower than the specified error does not mean that the reading has a lower error – an important point. The overall error in the example of the rule is still greater.

It is vitally important to remember that errors are not only due to the test instrument used, but can equally be user-generated. It is no good buying the most expensive test equipment you can find, with the highest accuracy and lowest error, if you are not going to use it properly. It is better to get a reasonably accurate measurement from a reasonably accurate, and cheap, piece of test equipment, than it is to be sloppy and get error-laden readings from an accurate, and very expensive unit. In other words, you don't need expensive test equipment to get good results, as low-cost equipment, that is properly used, can give results that are perfectly adequate for our purposes.

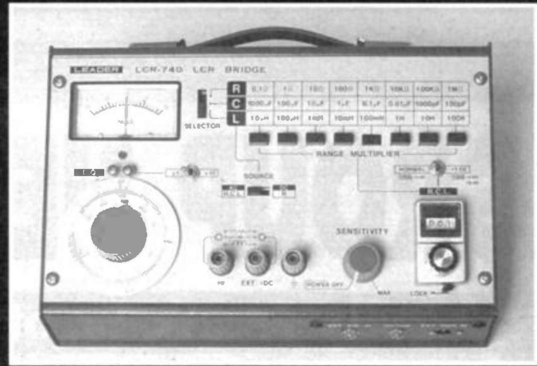
Types of Test Equipment

There are several types of test equipment available, but in general we can group all test equipment into one of just three categories: analogue, digital and automatic.

However, it is important to remember it is the test equipment we are classifying here – not what we are measuring. An analogue measurand, such as a varying voltage, can be measured by analogue, digital or automatic test equipment. However, a digital measurand can be measured by digital or automatic test equipment and only occasionally by analogue test equipment.

It is these three categories which we are going to follow in our look at test equipment over the coming months. Having said that, many modern items of test equipment breach the category walls, spilling over into two, or all three, categories.

In our in-depth journey into the various items of test equipment around, we are going to concentrate on the items of equipment a well-equipped project-builder would want to own. Initially, we will be looking at the three or four types listed earlier. However, where prudent, we will consider more complex equipment which you may come across, and at the sorts of test equipment available for the professional working in industry. Hopefully, this will give readers a balanced insight into the whole world of test equipment.



Left: Typical LCR Bridge.

In Part Two we will take a close look at the most basic of analogue test equipment – the analogue multimeter. We will look at how it works, and how to use it. Despite being the most basic type of test equipment available, as well as being one of the oldest, the analogue multimeter is still one of the most versatile and widely used instruments.

What's On?

The London Planetarium – Watch This Space

The London Planetarium is to undergo a dramatic £4·5 million transformation this winter.

The Planetarium has changed little since it opened in 1958. As part of the refurbishment programme throughout the site, the original Zeiss star projector will be replaced with a Digistar Mark 2.

For the first time ever the Planetarium will be accessible to wheelchair users. The transformation project commences on 31 October 1994 when the Planetarium will close, reopening for Easter 1995. Contact: The London Planetarium, Tel: (071) 486 1121.

Anniversary Celebrations at Jodrell Bank

A question. What happened twenty-five years ago, in July 1969?

Got it yet? It was the date of the first manned landing on the Moon. This summer Jodrell Bank is opening its doors and joining in the 25th Anniversary celebrations with a number of special events. We have picked out the most prestigious, but there are numerous others. For further details contact the Jodrell Bank visitor centre.

23 June – Evening, Illustrated talk by Claude Nicollier; Astronaut on the Hubble Servicing Mission.
Admission – book tickets in advance. *Cost:* Normal admission price to Science Centre.

18 July to 2 September, Exhibition – Fragments of the Moon.

20 July – 8.00pm, 25 Years On – Patrick Moore Remembers the Day. *Cost:* Normal admission price to Science Centre. Book tickets for Dr Moore's lecture in advance.

16 to 22 July, Worldwide Jupiter Watch. *Cost:* Normal admission price to Science Centre. No need to book in advance, other than the 20 July for Dr Moore's lecture.

Opening times: 10.30am to 5.30pm daily until 30 October.

Cost: Adults £3.50; Senior Citizens £2.50; Children £1.90; Family Tickets £10.50.

Location: A535 between Holmes Chapel and Alderley Edge, J18 off M6.

Contact: Jodrell Bank, Tel: (0477) 571571.

DIARY DATES

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

4 to 7 July. HF Radio Systems & Techniques Conference, Institution of Electrical Engineers, University of York. Tel: (071) 240 1871.

5 July. Talk on Propagation, Sudbury and District Radio Amateurs. Tel: (0787) 313212.

14 July. Special Event Station at Woodhall School, Sudbury and District Radio Amateurs. Tel: (0787) 313212.

16 July. Annual Outing, Crystal Palace & District Radio Club, All Saints Parish Church Rooms, Beulah Hill. Tel: (081) 699 5732.

16 to 17 July. Special Event Station GB0LBS, WAB 25th Anniversary Appeal, on Southend sea-front, Southend & District Radio Society, Southend. Tel: (0702) 353167.

19 to 21 July. 6th Electronic Engineering in Oceanography Conference, Institution of Electrical Engineers, Churchill College, Cambridge. Tel: (071) 240 1871.

20 to 24 July. Electrotech '94, National Exhibition Centre, Birmingham. Tel: (071) 240 1871.

20 to 27 July. The 27th International Conference on High Energy Physics at the Scottish Exhibition and Conference Centre, Glasgow, Scotland. Tel: (041) 339 8855.

2 August. Talk on Aerials, Sudbury and District Radio Amateurs. Tel: (0787) 313212.

7 August. Toy and Trade Collectors Fair, National Exhibition Centre, Birmingham. Tel: (0526) 398198.

7 August. Radio Society of Great Britain, Annual Spares Sale, Woburn Abbey, Woburn. Tel: (0525) 290666.

21 August. Southend & District Radio Society Radio & Computer Rally, Rocheway Centre, Rochford, Essex. Tel: (0702) 353676.

3 September. Wight Wireless Rally, National Wireless Museum, Arreton Manor, near Newport, Isle of Wight. Free admission and free stands to both public and traders. Tel: (0983) 567665.

4 September. Applied Optics & Optic-Electronics Conference, Institute of Physics, York. Tel: (071) 235 6111.

5 September. EMC – 9th Electromagnetic Compatibility Conference, Institution of Electrical Engineers, Armitage Centre, Manchester. Tel: (071) 240 1871.

20 to 25 September. Live 94, The Consumer Electronics Show, Earls Court, London. Visit the Maplin stand, and have a chance to speak to us in person. Tel: (0891) 500 103.

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

Please mention *Electronics – The Maplin Magazine* when replying to advertisements

WORKGROUP NETWORKING

by Frank Booty

WORKGROUP local area networks (LANs) are the basic building blocks of enterprise networks. In today's large companies there is a growing awareness of the importance of information resources as a primary corporate asset. In more and more industries from banking and financial services to transportation, manufacturing and even retailing, information management is now at the core of the entire business. As the importance of the corporate network grows, and the complexity of potential solutions increases, the necessity of a powerful and uncluttered vision of network building becomes more apparent.

In applying technological solutions to problems found in organisations, it is necessary to bear in mind that it is ultimately the productive processes of the organisation that drive the acquisition of networking technology rather than the reverse. To ensure that the correct networking solution for an enterprise is achieved, an understanding of the organisation's hierarchical foundations is necessary. A building block approach has to be adopted, and the specific locations where productive efforts begin in an organisation should be first examined.

So the philosophy is that effective productivity support at the local level with flexible LAN solutions leads to the appropriate inter-connectivity decisions, and, in turn, to an efficient enterprise wide networking strategy

Workgroups

A Workgroup is a group of people in close contact sharing resources to achieve a common business goal. In the Workgroup, operational decisions are made on a regular basis that determine the pace and often the manner and quality of production. These small and tightly knit groups are the primary building blocks of modern industry. A Workgroup is usually a small department or section within a large department and a Workgroup computer network or LAN is the smallest but most numerous element in the corporate network hierarchy.

The typical Workgroup of today comprises between five and 20 workers sharing a LAN, with workstations, servers and a common set of applications (see Figure 1). It is here, at the level of the Workgroup, that the real productivity of an organisation is determined. It could be argued that all management functions, as well as all information processing, exist in support of these groups. The importance of the Workgroup is mirrored in the flow of computing technology, moving ever outward from the data centre, under the aegis of what has been dubbed distributed or departmental processing, which now in its more advanced form is called the client/server architecture or model.

As more computing power is driven toward the end user, greater power and influence is concentrated in the Workgroup. It becomes the task of networking solution suppliers to provide the appropriate network services for various kinds of Workgroups and to provide the means to interconnect Workgroups over a backbone network and wide area links with comprehensive network management tools.

Once the nature of the Workgroup is defined, it becomes important to understand its specific requirements. Three important aspects – application requirements, the computing platform, and organisational and social needs – should be carefully studied.

Today, an increasing number of mission critical business applications are being found running on desktop systems, or on Workgroup LANs linking a number of desktops. Increasingly, the information available to such Workgroups is accessed through a client/server distributed application, and then presented in the form of coloured graphs and charts for fast assimilation of complex data. In many industries there has been a tremendous growth in the demand for integrated or networked applications. Typical Workgroup applications include: word processing, integrated with business graphics, spreadsheets and electronic mail; desktop publishing packages and computer illustration programs; image processing, using optical disks for document storage and retrieval; CAD/CAM, with or without three-dimensional graphic modelling; and business specific networked applications.

More and more desktop systems are not only networked, but also have the capability to display high quality graphics and run

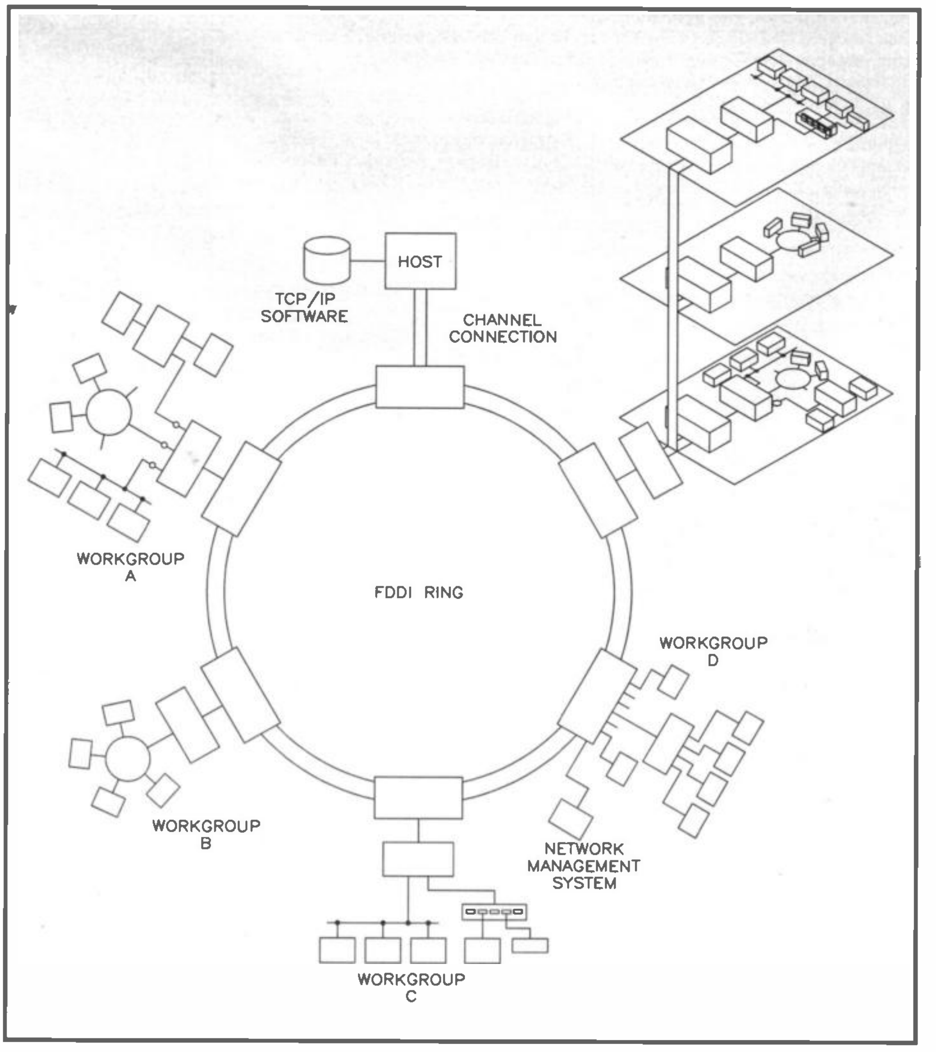


Figure 1. Workgroup networking.

more than one program at a time. Previously, files generated by typical PC applications ranged from 50 to 500K-bytes. Today, the typical file from the desktop containing graphics integrated with alphanumeric data may be as much as 50 times larger. In the future, multimedia applications incorporating video and audio data, even in compressed form, will increase the size of the average file even further.

The growth of new networked applications is, in turn, determining the choice of new computing platforms. What kind of computing resources will the Workgroup need to fulfil its tasks – mainframe, minicomputers, high powered workstations or PCs? Changes in traditional computing platforms are already apparent. As the cost of both microprocessor speed and fast disk access falls, desktop systems are setting the pace for the entire computing industry. Research shows a continuing strong growth in RISC (Reduced Instruction Set Computing) based Workstations. By 1992 over two million RISC based workstations had been installed. According to the industry market researcher Gartner Group, business PCs have an installed base of over 60 million units, the majority of them being based on the Intel 80386 and 80486 microprocessors. According to another leading researcher, Dataquest, there is a large growth in the number of Workgroup LANs as the percentage of LAN attached stations increased to over 60% in the same year.

There is a strong correlation between the proliferation of Workgroup LANs and the importance to the modern company of the section or small department. It is a well-known axiom of modern management theory that successful management is able to support increased productivity at the level of the Workgroup. The Japanese success in implementing 'quality control circles' in manufacturing is one example of Workgroup productivity resulting in increased competitiveness.

Most modern organisations are divided into small groups organised as departments and sections, each optimised for productivity and each with a different set of requirements, from the organisational or social point of view. Each Workgroup sub-organisation requires independence regarding equipment, information resources and certain decision making functions. In addition, each Workgroup must be linked to upper management for monitoring and control and, in terms of purely human communications, to other Workgroups at a peer to peer level.

Connectivity

Local Workgroup communications packets travelling from a workstation to a local server or laser printer or from workstation to workstation may constitute 60 to 70% of the total Workgroup LAN traffic. Backbone communications that interconnect Workgroups to corporate resources and wide area link nodes may comprise another 20 to 25%. Finally, 10 to 15% of Workgroup communications is peer to peer or between Workgroups. With this in mind one should look from Workgroup requirements to corporate network connectivity solutions. Local communications or horizontal distribution must be flexible, responsive and deliver a low-cost per connection. This means that the appropriate network solution at the level of the individual Workgroup must be easy to configure and reconfigure, simple and inexpensive to install and must provide ample bandwidth for fast local response.

In offices today, physical movement of employees and desktop systems takes place almost continually. Wiring systems must be structured flexibly to allow for this movement. Now that Ethernet and 4/16M-bit/s Token Ring LAN services are all provided by a number of vendors via unshielded twisted pair (UTP) wiring, UTP and the modular RJ45 data connector have emerged the clear winners in the Workgroup LAN wiring arena.

As Workgroup LANs proliferate, the need for effective vertical distribution, or the backbone network, has become acute. The purpose of this technology is to address the problem of interconnectivity between islands of installed Workgroup LANs. Instead of flexibility and low cost, which is required for the horizontal LAN distribution system, backbone networks emphasise high capacity, reliability and security. In contrast to office floor wiring systems, backbone networks are expected to provide service to an entire building or campus untouched after installation for a number of years. All network users in the area covered by the backbone will share its services so the requirements for bandwidth capacity and security are higher by an order of magnitude.

Recently, fibre optic based technology for backbone networks has grown rapidly, in acceptance with the drop in fibre optic cable prices, to the point where it compares favourably in price, performance and metre per metre with traditional copper cabling. The standardisation of fibre based Ethernet, Token Ring and higher speed LAN services, by international bodies such as the IEEE and ISO committees, has paved the way for the entry of numerous vendors into this market. There has been an explosive growth in the number of companies prepared to install and service fibre based cables and equipment.

Hence, fibre optic based technology like FDDI (Fibre Distributed Data Interface) with its built-in failure recovery features, is becoming the backbone technology of choice for linking numbers of Workgroup LANs. An FDDI backbone using 10 and 16M-bit horizontal systems is viewed as the most advanced office communications system today. This configuration should provide effective capacity for many customers through the decade.

The enterprise network has grown not only in size and complexity but also in its importance as a 'nervous system' that provides the corporate body with the ability to respond appropriately to rapidly changing business conditions. The intelligence of every network is found in the monitoring and controlling functions of the network management system. Comprehensive network management must provide for centralised control of all workgroups as well as the capability to selectively distribute management functions.

The complexity and importance of today's networks require the management functions to display ever higher levels of intelligence and to communicate more and more effectively across the man-machine interface. In other words, the network management system is required to report not only what has gone wrong with the network but what to do about it – the old axiom that pictures are worth many words really does apply. Today, graphics based user interfaces for management systems have become standard features. The network management system must be intuitive, self-learning and based on international or industry standards such as SNMP or CMIP.

Bandwidth Bottlenecks

A major problem facing the growth in productivity of the modern Workgroup is the rising bandwidth requirements of the desktop system. As more bandwidth hungry networked applications come into use and the number of MIPS (Millions of Instructions Per Second) represented by the PC, workstation or super server increases, throughput capacity of LAN technology supporting the Workgroup must grow proportionally. In many cases this means reducing the number of devices on a single LAN segment, dividing segments with local bridges or upgrading to faster LAN technology.

As bandwidth requirements at the desktop grow, there has been a deal of debate on when the time will be ready for 'fibre to the desk' – a phrase which refers to the extension of FDDI to the individual workstation or PC. Some industry analysts say the market will wait until the unshielded, twisted pair, 100M-bit/s standard (TPDDI) is finalised, and commercially available products begin to appear. Others contend that the great majority of desktop systems will not need 100M-bit/s bandwidth for several years, and that the price of adaptor cards must fall dramatically before widespread acceptance.

An intermediate step that is attractive to many of today's LAN users is 'fibre to the Workgroup'. Here, FDDI attached Workgroup communication servers in centrally located wiring closets provide high-speed interconnectivity between workgroups and clustered corporate resources. This is while relying on the existing Ethernet or Token Ring infrastructure to provide LAN distribution within the Workgroup itself. Star topology local distribution increases reliability and available bandwidth, while standards-based network management features provide the integrating factor between Workgroup LAN and backbone.

This may be seen as an extension of FDDI from its primary use as a corporate or enterprise backbone resource to a new position as a departmental LAN linking workgroups. The 100M-bit/s bandwidth of FDDI today provides more than enough capacity to function both as departmental LAN and corporate backbone in most installations. In the future, FDDI to FDDI bridging may be incorporated to provide separation between the LAN and backbone functions.

GLOSSARY

LAN Local Area Network. A computer network operating over a small area linking to computers, electronic mail, wordprocessors (WP) and various other equipment. It can provide communication from site-to-site or provide access to other networks, such as the public telephone network and a data transmission network.

WorkStation A microcomputer, such as an IBM PC or an Apple Macintosh, which is attached to a network but retains its independence as a desktop PC. At the same time it is a network workstation, able to access a server's hard disk as if it were it's own. To the workstation the server's hard disk, and the software and files stored on it, are known as 'resources'.

Server A microcomputer usually operating as a modern 'file server'. Unlike the older 'disk server', a file server runs special networking software such that parts of its hardware are configured as 'resources' and made accessible to workstations. There is no need to partition the server's hard disk into separate 'volumes' for each workstation, all that is required is to configure a directory, or sub-tree of directories, as a resource. The workstation views this as a complete 'hard disk'.

RISC Reduced Instruction Set Computer. A concept that helps achieve higher processor performance, and works on the basis that there is a smaller vocabulary of machine code instructions, making the processor execute code more efficiently.

Ethernet A networking standard which uses *baseband coaxial cable*, single channel coax of ⅜in. diameter capable of carrying single messages, or data packets, at a time at very high speed, typically at a data rate of typically 10 to 80M-bit/s. It is an improvement in performance over the simpler normal coax usually found in most LANs, and has been supported by Xerox Corporation and DEC.

Token Ring A network topology consisting of several nodes (workstations) joined together in a circle. Messages proceed from node to node, usually in one direction only. The topology permits verification that messages have been received; when a node receives the message, it sends a copy back to the sender with a flag that indicates its receipt.

FDDI Fibre Distributed Data Interface. A standard established by the American National Standards Institute for a fibre-optic connected network, using lasers or LEDs to send signals through the core portion of the cable. The Physical Media Dependent (PMD) layer of FDDI is designed to work in conjunction with data transmission of 100M-bit/s, though it is possible to achieve rates up to 1G-bit/s.

TPDDI Twisted Pair Distributed Data Interface. A connection standard using unshielded twisted pairs of wires, but which can operate at data rates up to 100M-bit/s. It is hoped that the standard will be a viable cheaper alternative to FDDI, particularly for direct connections to workstations and servers.

UTP Unshielded Twisted Pair wiring, as used with the modular RJ45 data connector.

RJ45 A connection standard based on the American telephone connector, commonly used to make twisted-pair carriers for a LAN.

IEEE Institute for Electrical and Electronics Engineers. This body is responsible for standardising the ways in which information can be transmitted within a network.

ISO International Standards Organisation. A specialised agency of the United Nations, founded in 1947, concerned with international standardisation across a wide variety of industries and their products.

SNMP Simple Network Management Protocol. A protocol installed for simple network management systems to use.

CMIP/CMIS Common Management Information Protocol (CMIP) and Common Management Information Services (CMIS) are two OSI (Open Systems Interconnection) protocols that provide a standard way of managing an OSI network.

OSI Open Systems Interconnection. A logical structure model for network operations standardised within the ISO. It is a 7-layer network architecture used for the definition of network protocol standards to enable any OSI-compliant computer or device to achieve a meaningful exchange of information.

MIPS Millions of Instructions Per Second. A comparative measure of computing power, the number of commands that can be processed per second.

Star Topology the oldest type of network, using the same approach for sending and receiving messages as a telephone system. 'Calls' from one workstation to another are handled by a central switching station, a central computer which controls the flow of data. Although old, the network is easily expandable, and the topology also allows certain nodes to have higher status, or priority, over others.

Client Running on a file server under OS/2, an *SQL server* (written with a special *Structured Query Language* developed by Microsoft and Ashton-Tate) can provide database management service to applications simultaneously running on network workstations. This type of distributed processing is called *client/server computing*, in which the workstation is the *client*. The *client* is a 'front-end' which accesses a 'back-end' server. The 'front-end' application – a spreadsheet, accounting or project management program – processes the data it requested and displays it on the screen, while the 'back-end' server maintains the database's integrity and ensures that the network will function with optimum efficiency.

Hub The central component of a 'star' topology network, where a 'smart hub' interfaces each workstation to the server via dedicated lines.

TCP/IP Transmission Control Protocol/Internet Protocol. A common communication protocol that different LAN operating systems can share and use to communicate with each other. For different LAN operating systems, e.g. NetWare, Vines and IBM, to be able to talk to each other, *routers* are needed that can understand the different protocols and translate them for the destination network. *Bridges*, which work at a far less sophisticated level, will not be able to distinguish the differences. However, a TCP/IP protocol, working on top of the server protocol, only requires routers that just need to handle TCP/IP, with no translation during transmission required.

Host Any network node that a user can access for processing power, information files, and applications. Hosts are general purpose nodes that are not designed to perform network-specific functions.

CAD Computer Aided Design. Refers to the capability of a computer to be used for automated industrial, statistical or architectural design by visual means. Advanced CAD software allows graphical images to be drawn and manipulated, from which design parameters, such as dimensions, can be extracted and passed directly to automated manufacturing machinery. Prototype and production PCB manufacture is a good example.

CAM Computer Aided Manufacture. An automated manufacturing production process directly resulting in finished products. Such products, even in worked metal, can be made very accurately and quickly using Computer Numerically Controlled (CNC) machines.

WAN Wide Area Network. A computer network that covers a large territory, up to and including an entire continent. The term has come into common use to distinguish it from a Local Area Network (LAN).

Terminal Servers in the '90s

Some 10 years ago, many asynchronous terminals were concentrated on star topologies and connected to Ethernet backbones. In the 1990s, PCs and workstations will use Ethernet in star topologies connected to FDDI backbones. The Ethernet terminal server is a store and forward device that receives and stores individual data frames from each terminal until the Ethernet medium is available. The terminal server then transfers the frame into the appropriate field of the Ethernet packet, and forwards it across the backbone. In the same way the workstation server receives Ethernet packets and forwards them either to other locally attached Ethernets, or to the FDDI backbone for connection to other workgroups, direct FDDI attached servers or other computing resources.

Consider now a workstation server that is a dual attached FDDI device distributing up to 12 Ethernet connections in modular increments of two ports to a single Workgroup. Each Ethernet port on this workstation server may be dedicated to a single device giving an unimpeded 10M-bit/s to that station, or a port may be shared by up to four workstations. No modifications are required to existing Ethernet adaptor cards, types of cabling or software applications. Connections between the local Ethernet ports are achieved through high-speed matrix switching, resulting in a low transit delay, or latency, for a rapid local Workgroup response. A 320M-bit/s parallel bus controls multiple simultaneous connections that provide an increase of over 500% in Ethernet throughput, with high-speed access to FDDI.

Because of a translation matrix architecture which is unique to the workstation server, traffic that is local to the Workgroup is never passed through to FDDI. This feature effectively insulates the FDDI ring from local traffic, conserving bandwidth on the FDDI ring and protecting the investment that customers have made in backbone resources. As the dual FDDI ring attachment shares the same chassis as the modular Ethernet ports, the workstation server can be seen as an FDDI Ethernet distribution hub. In actual usage it functions as an FDDI terminal server for Ethernet connected PCs or workstations or a host cluster server for Ethernet hosts in a computer room. Because FDDI translation frames are generated, it may be additionally defined as both a backbone FDDI node or a front end direct FDDI attachment node for workstations or servers.

As more and more different products are introduced into the LAN market, the complexity of designing state of the art interconnectivity solutions is growing. Increasingly, the network management system is being seen as the integrating factor in heterogeneous networks, and the part of any vendor's, product offering that provides the essential differentiating ingredient. It is no secret that once the network is installed and up and running, the hardware seems to decrease in importance while the network operators must interface with the management system on a daily basis. It has become standard practice for today's network management systems to be based on industry standards like SNMP, and to have a high resolution colour graphical user interface.

The Future

The 1990s will see the continued distribution of computing resources more evenly throughout the corporate enterprise. The price versus performance increases of desktop systems are outpacing the rest of the computer industry, and linking these personal systems will continue to drive the networking and interconnectivity market. The Workgroup has been identified as the basic building block for enterprise-wide networking. Network building is fast becoming an exercise in managing the logical flow of information between increasingly standardised Workgroup islands. All functions and devices on the network from the enterprise or global level down to the individual connection in the Workgroup must be managed under an integrated umbrella of user-friendly, standards-based management tools. The functions of network monitoring and control are major issues today, and will continue to attract much attention and development resources in the future.

These descriptions are necessarily short. Ensure that you know exactly what the kit is and what it comprises before ordering, by checking the issue of *Electronics* referred to in the list.
The referenced back-numbers of *Electronics* can be obtained, subject to availability, at £2.00 per copy.
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MODEL STEAM TRAIN CHUFFER

Add the extra dimension of sound to your layout with this realistic steam engine sound simulator. The rate of chuffing varies with the track voltage, i.e. train speed, and when the engine is stationary the sound of escaping steam can be heard. The unit requires a supply of +15·5 to 36V DC and the audio output connects to your existing amplifier. (Optional case not included.)
Order as: LT39N, **£9.99**. Details in *Electronics* No. 79 (XA79L).

REUSABLE ELECTRONIC FUSE

Help eliminate the hazards of accidental short-circuits during your experimental and development work with this simple-to-build project. The unit is connected in series with the unit being tested, and if the current drawn exceeds 200mA the electronic fuse will emit a short bleep and the LED will flash continuously. The current then falls to a very low holding level until the fault has been corrected. (Optional case not included.)
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INTELLIGENT Ni-Cd BATTERY CHARGER

Charging Ni-Cd batteries isn't as straightforward as you might think! Improper charging can damage the battery, cause reduced storage capacity or even result in an explosion! This intelligent charger is fully automatic and removes all these worries. Suitable for Ni-Cd batteries with voltages of 1·2V to 12V and capacities from 110mAh to 1·5Ah. (Optional case not included.)
Order as: LT55K, **£39.99** C2. Details in *Electronics* No. 79 (XA79L).

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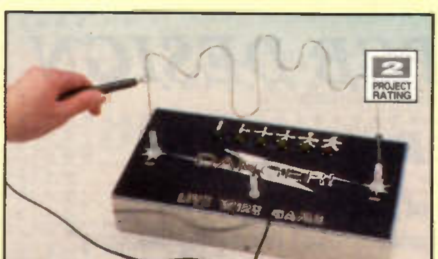
TV COLOUR BAR GENERATOR

Essential for accurately setting up TV and video equipment. The generator consists of two modules, a colour bar generator and a colour encoder. Although the modules are available separately, both are required for this project. The generator has both PAL composite video and PAL UHF RF outputs and can produce EBU, 100% and 75% colour bars.
Order as: LT50E, Colour Bar Kit, **£19.99**. Order as: LM66W, Colour Encoder Kit, **£24.95**. Details in *Electronics* No. 77 (XA77H).

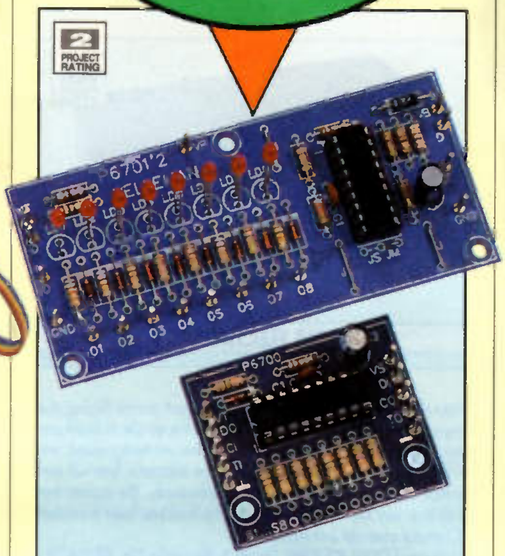


LIVE WIRE GAME

Roll-up! Roll-up! All the fun of the fair – and less of the hassle! This electronic variation on the traditional theme puts an end to the problem of whether a gentle touch actually rang the bell or not. A contact is clearly registered and the number of 'lives' can be preset helping to ensure fair play.
Order as: LT57M, **£19.99**. Details in *Electronics* No. 78 (XA78K).

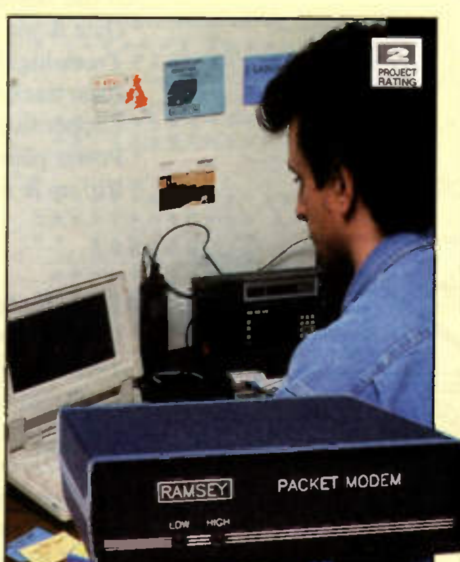
12V DC/230V AC INVERTER

Ever wished your car or shed had a mains outlet in it? Now it can, with this high efficiency 230V AC inverter. Powered from a car battery or alternator, the unit is ideal for emergency power backup and field service applications. Maximum continuous power output is 250W, drawing a maximum current of 25A from the DC supply.
Order as: VF35Q, **£119.95** B4. Details in *Electronics* No. 78 (XA78K).



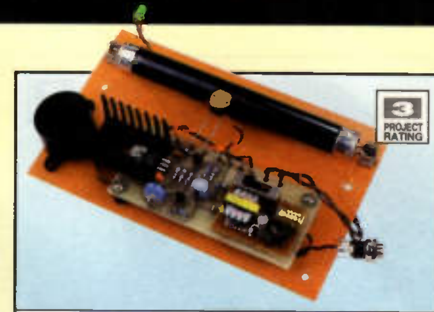
2-WIRE MULTI-CHANNEL SIGNALLING

How do you get up to 16 channels and a power supply down two wires? This clever project scans the transmitter inputs and converts them to serial data pulses superimposed on the DC power supply. The data is then decoded by the receiver and operates the relevant channel. Each transmitter and receiver pair can handle 8 channels, expandable to 16 by adding further modules.
Order as: VE70M, Transmitter, **£9.95**. Order as: VE71N, Receiver, **£17.95.** Details in *Electronics* No. 77 (XA77H).



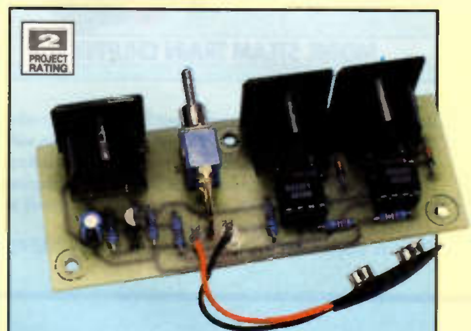
PACKET RADIO MODEM

Combine your amateur radio and computing hobbies with this radio MODEM! The project is supplied with software compatible with the IBM PC/AT but could also be used with other computers provided suitable software can be obtained. The unit communicates via the host computer's RS232 port and operates at 1200 baud. Power consumption is very small and the unit can, in fact, be powered direct from the serial data port of most compatible computers!
Order as: CP36P, **£59.95** A0. Details in *Electronics* No. 78 (XA78K).



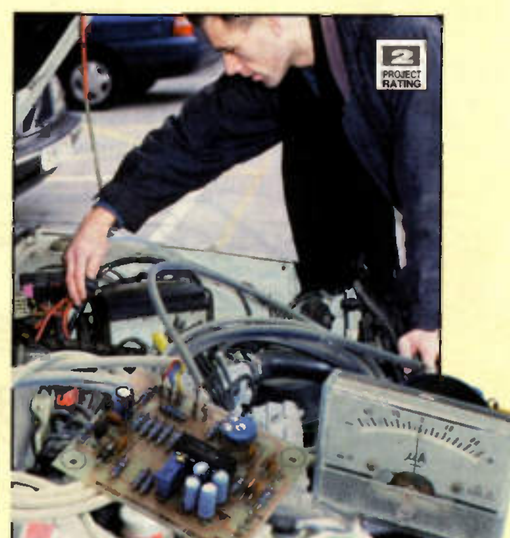
FORGED BANK-NOTE DETECTOR

Sort out fake bank-notes with this notable Maplin project! Unlike counterfeit notes, the genuine article absorbs ultra-violet light from the built-in UV tube. A light dependent resistor in the detector changes its resistance depending on the amount of light reflected. If the note is genuine, an LED indicator lights and a buzzer sounds.
Order as: LT54J, **£14.99**. Details in *Electronics* No. 77 (XA77H).



SIMPLE MIDI MERGE UNIT

This easy-to-build project allows you to control a single MIDI sound module from two different sources. Apart from simultaneous operation from two MIDI sources, this simple unit can perform all the tasks normally undertaken by complex microprocessor controlled units costing many times more.
Order as: LT52G, **£14.99.** Details in *Electronics* No. 77 (XA77H).



CAR BATTERY CHARGE/DISCHARGE IDLE INDICATOR

Is your car's battery being charged as you drive, or is it waiting for the next cold, rainy morning for you to find out that it isn't? Keep an accurate eye on where the current is going with this inexpensive project. A 3-colour LED, mounted on the dashboard, indicates whether the battery is being charged, discharged or if a balanced condition is achieved.
Order as: LT56L, **£7.99**. Details in *Electronics* No. 78 (XA78K).

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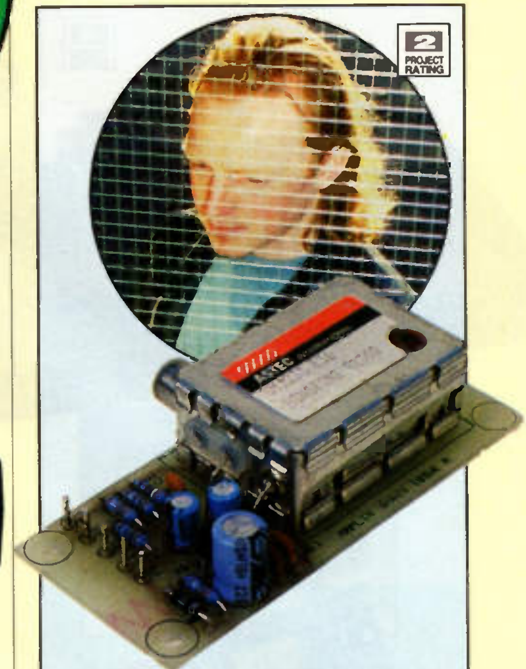
An essential device for those of us with older cars and classics, that weren't built with anything more sophisticated than an on/off switch on the wipers! This simple to build project produces three delay periods, and has an LED indicator which lights during the delay period, reminding you that the unit is operating.
Order as: VE03D, **£12.95**. Details in *Electronics* No. 75 (XA75S).

AIRCRAFT BAND RADIO RECEIVER

Listen in on pilot and control tower communications with this super AM airband receiver. The kit is simple to build and requires little alignment. Frequency range is 118 to 135MHz and the receiver operating voltage is 9V. (Optional case not included.)
Order as: CP17T, **£29.95**. Details in *Electronics* No. 75 (XA75S).



CCD CAMERA TV MODULATOR

A low-cost unit which allows the Maplin colour and black & white CCD Camera Modules to be linked to any normal domestic TV with UHF aerial input. Applications include closed-circuit security systems, and interfacing equipment that only has video outputs to a normal TV receiver.
Order as: LT37S, **£9.99**. Details in *Electronics* No. 75 (XA75S).

The assembled receiver in its optional case (not included).

20 METRE ALL MODE RECEIVER

A 'direct conversion' 'DC' type receiver that is both simple-to-build and easy-to-use as there is no 'intermediate frequency' (IF). Frequency range is 13·85 to 14·50MHz and the receiver operates from a standard 9V PP3 battery (not supplied).
Order as: CP13P, **£31.95**. Details in *Electronics* No. 76 (XA76H).

The assembled transmitter in its optional case (not included).

20 METRE CW TRANSMITTER

A crystal controlled CW transmitter operating on the 20m band. The crystal frequency can be shifted by up to 5kHz by the VXO control. The transmitter operates from a +12 to +15V DC supply and has an RF output of 1W. Note: To operate this transmitter legally, either a full Class A Amateur Radio Licence or a restricted Novice Licence is required.
Order as: CP09K, **£31.95**. Details in *Electronics* No. 76 (XA76H).

FRIDGE CHECK

Is your fridge always as cold as it should be? This easy-to-build unit constantly monitors the temperature inside your fridge. If it exceeds a preset limit the alarm sounds, alerting you to the potential dangers of bacterial growth and food poisoning.
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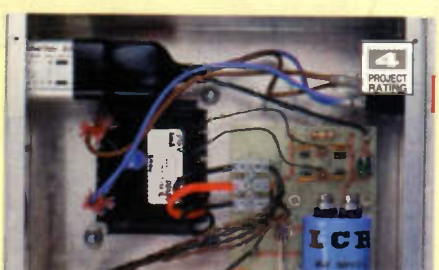
MILLENNIUM 4-20 VALVE POWER AMPLIFIER

A superb 4-valve, non-hybrid, class A31 push-pull amplifier with an output of 20W r.m.s. and low output distortion, producing that characteristic valve sound. Construction is simplified by the use of printed circuit boards and no setting up is required.
Order as: LT45Y, **Price £74.95** C6. Details in *Electronics* No. 74 (XA74R).

SAVE MONEY by buying these combined Millennium Amplifier kits:
Save £10! Complete Millennium Monobloc Amplifier Kit (1 x PSU & 1 x Amplifier kit)
Order as: LT71N, **Price £114.90** H12.
SAVE £20! Complete Millennium Stereo Amplifier Kit (1 x PSU & 2 x Amplifier kits)
Order as: LT72P, Price **£179.85** H18.



MILLENNIUM VALVE AMPLIFIER PSU

A Power Supply kit for the Millennium 20W Valve Power Amplifier. The supply is capable of powering up to two amplifier modules for a stereo system, or alternatively you could use two PSU kits and two amplifier modules to produce a pair of 'monobloc' amplifiers.
Order as: LT44X, **Price £49.95** C6. Details in *Electronics* No. 73 (XA73Q).

TWILIGHT SWITCH

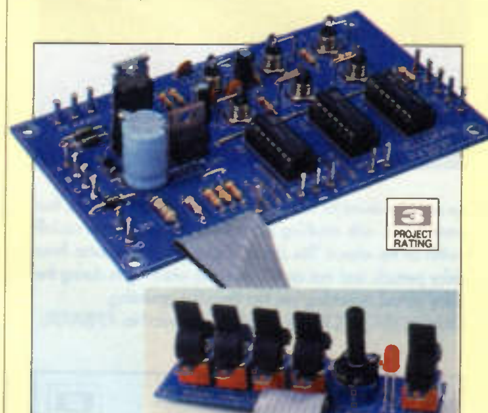
Using the ULN3390T opto-electronic switch, this versatile project senses the ambient light level and operates the built-in relay at dawn and dusk. Typical applications are automatic control of lighting, night-time security or anywhere that daylight related switching is required.
Order as: LT47B, **Price £5.95**. Details in *Electronics* No. 73 (XA73Q).

EXTRA LARGE LED DISPLAY

A choice of two 20cm (7½in.) 7-segment LED displays, catering for open-collector and open-anode circuits. Ideal for educational equipment, public displays, exhibitions, demonstrations, clocks etc. Connects to existing 7-segment display drivers. Operating voltage: 22 to 26V DC, maximum supply current: 400mA.
Order as: VF01B, Common Cathode Version, **Price £32.95,** or: VE63T, Common Anode Version, **Price £32.95**. Details in *Electronics* No. 74 (XA74R).

MODULAR GRAPHIC EQUALISER FRONT PANEL

A pre-drilled front panel and pre-printed foil to give a professional look to your completed equaliser project. The panel is suitable for a standard 19in. housing having a height of 2 units (2U).
Order as: VE41U, **Price £32.95** A1. Details in *Electronics* No. 74 (XA74R).



GRAPHIC EQUALISER PSU & SWITCHING UNIT

Part of the Modular Graphic Equaliser System. This project provides a regulated power supply for various of the other units in the system, a front panel mounted line input sensitivity control and also provides all of the necessary switching functions.
Order as: VE45Y, **Price £32.95**. Details in *Electronics* No. 73 (XA73Q).

AUTOMATIC REAR WIPER CONTROL UNIT

At last! Comprehensive control for rear window wipers, tied into the operation of the front windscreen wipers and gearbox. Facilities include: Single shot (when front wipers turned on), Intermittent operation (when front wipers on), and Auto wipe (Reverse gear selected and front wipers on).
Order as: LT46A, **Price £9.95.** Details in *Electronics* No. 74 (XA74R).

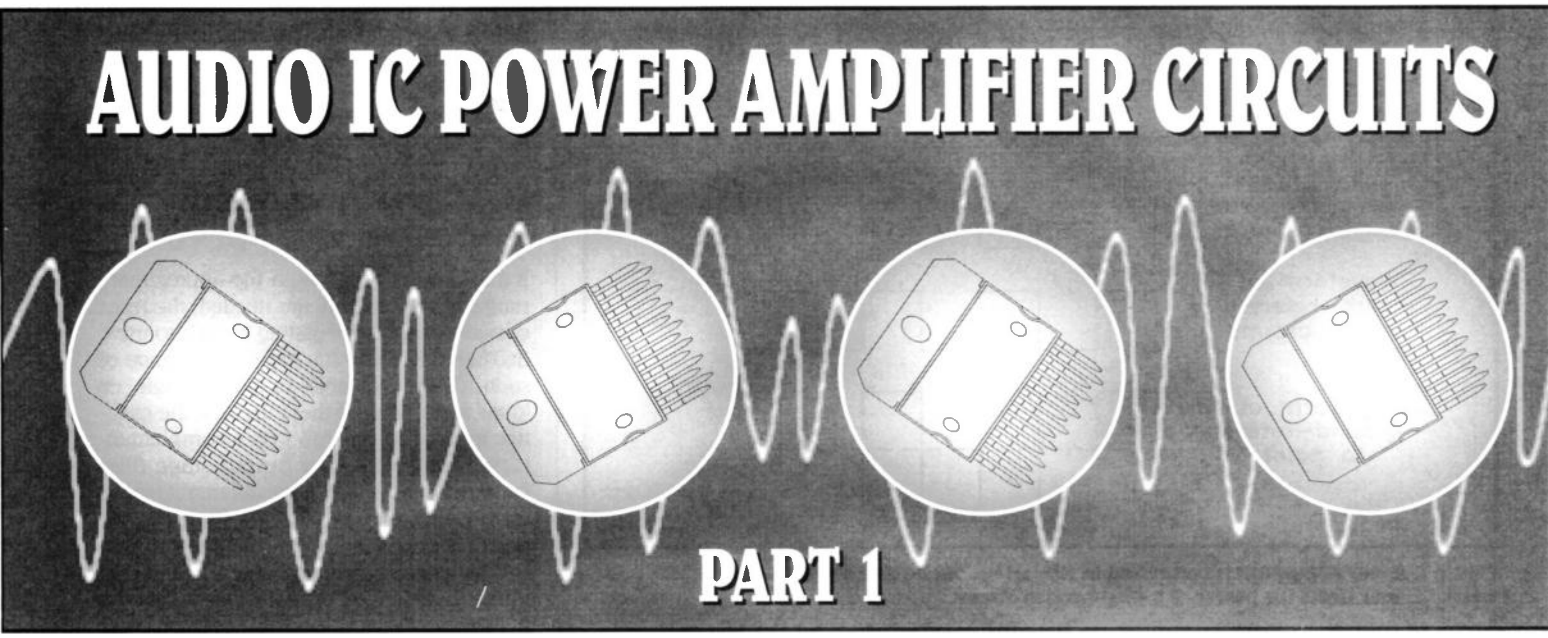
Ray Marston takes an in-depth look at practical IC-based audio power amplifier circuits in this new three part mini-series.

An 'ideal' audio power amplifier can be defined as a circuit that can deliver audio power into an external load without generating significant signal distortion and without overheating or consuming excessive quiescent current. Circuits that come very close to this ideal can easily be built using modern integrated circuits. Simple audio power amplifiers with outputs up to only a few hundred milliwatts can be easily and cheaply built using little more than a standard op amp and a couple of general-purpose transistors. For higher power levels, a wide range of dedicated 'single' or 'dual' audio power amplifier ICs are readily available, and can provide maximum outputs ranging from a few hundred milliwatts to above 40W.

The specific IC chosen for a given application depends mainly on the constraints of the available power supply voltage and on the required output power level or levels. A total of twenty different audio power amplifier ICs and their practical application circuits are described in this mini-series; all but two of these ICs are listed in the current (1994) edition of the Maplin Catalogue. The two non-listed types (the LM831 and LM384) are still in production. Another IC, the LM389 has just recently been discontinued although it is listed in the 1994 Catalogue. Parts 1 and 2 describe circuits with maximum power-output ratings up to about 5W; Part 3 describes circuits with maximum power ratings in the range 6 to 40W.

Low-power Op amp Circuits

The popular 741 general-purpose operational amplifier can supply peak output currents of at least 10mA, and can provide peak output voltage swings of at least ten volts into a 1k load when powered from a dual 15V



AUDIO IC POWER AMPLIFIER CIRCUITS

PART 1

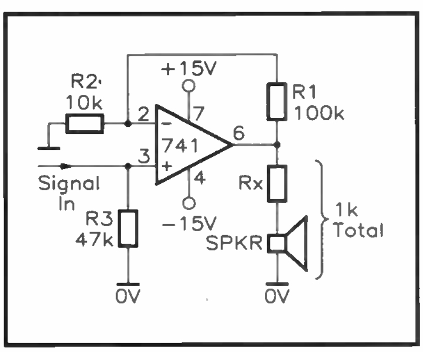


Figure 1. Low-power amplifier using dual power supplies

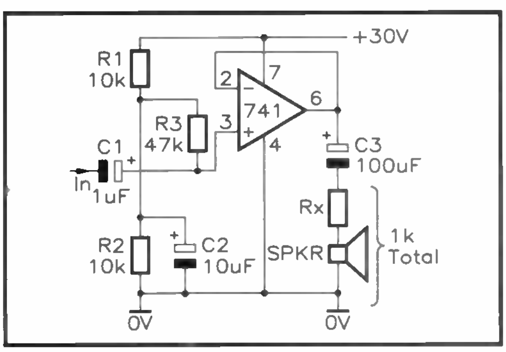


Figure 2. Low-power amplifier using a single-ended power supply.

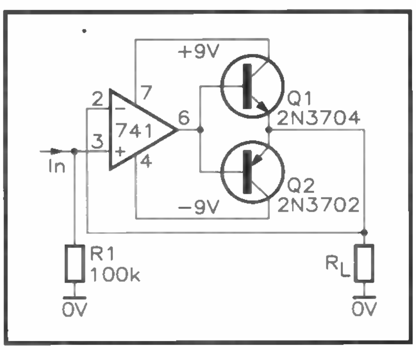


Figure 3. Basic 'boosted output current' unity-voltage-gain op amp circuit.

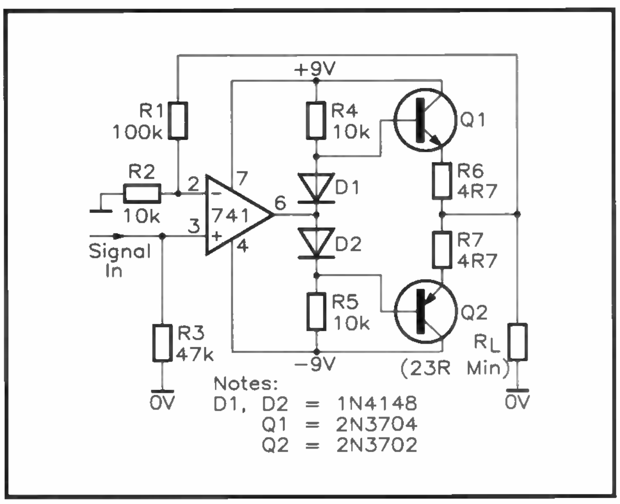


Figure 4. Op amp power amplifier using dual supplies

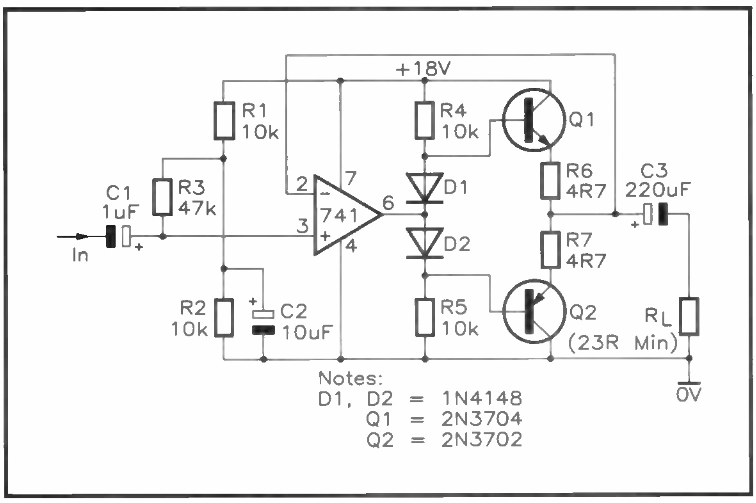


Figure 5. Op amp power amplifier using a single-ended supply.

supply. This IC can thus supply peaks of about 100mW into a 1k load under this condition, and can easily be used as a simple low-power audio amplifier, as shown in Figures 1 and 2.

Figure 1 shows how to use the 741 op amp as a low-power amplifier in conjunction with a dual power supply. The external load is direct-coupled between the op amp output and ground, and the two input terminals are ground-referenced. The op amp is used in the non-inverting mode, and has a voltage gain of x10 (= R1÷R2) and an input impedance of 47k (=R3).

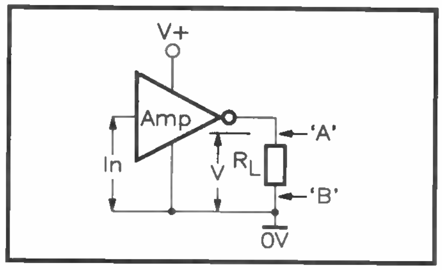


Figure 6. An amplifier connected in the 'single ended output' mode gives a peak output of $V^2 \div R$ watts.

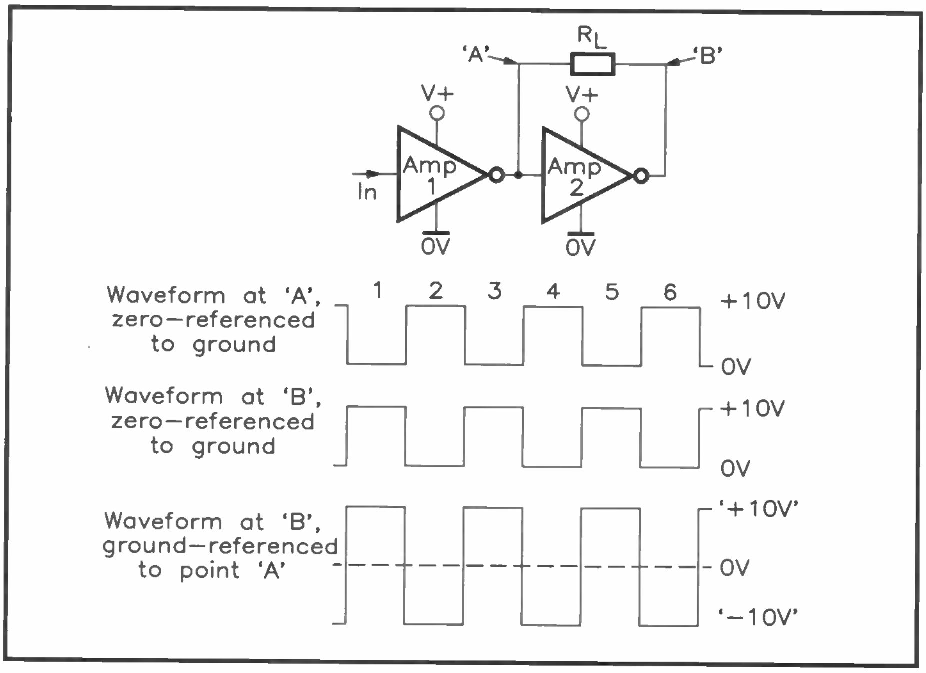


Figure 7. A pair of amplifiers connected in the 'bridge' mode give a peak output of $2V^2 \div R$ watts, i.e. four times the power of a single-ended circuit.

Figure 2 shows how to use the circuit with a single-ended power supply. In this case the external load is AC-coupled between the output and ground, and the output is biased to a quiescent value of half-supply volts (to give maximum output voltage swing) via the R1/R2 potential divider. The op amp is operated in the unity-gain non-inverting mode, and has an input impedance of 47k (= R3).

Note in the above two circuits that the external load must have an impedance of at least 1k. If the external loudspeaker has an impedance lower than this value, resistor Rx can be connected as shown to raise the impedance to the 1k value: Rx inevitably reduces the amount of power reaching the actual loudspeaker.

Boosted-output Op amp Circuits

The available output current (and thus power) of an op amp can easily be boosted by wiring a complementary emitter follower between its output and its non-inverting input terminal, as shown in Figure 3. Note that this circuit is configured to give an overall voltage gain of unity, but that the Q1 and Q2 base-emitter junctions are both wired into the circuit's negative feedback loop, so that their effective forward voltage values (about 600mV) are reduced by a factor equal to the open-loop voltage gain of the op amp. Thus, if this gain is x10,000 the effective forward voltages of Q1 and Q2 are each reduced to a mere 6μV, and the circuit generates negligible signal distortion.

In practice, op amp open-loop voltage gain falls off at a rate of about 20dB/octave, so although the signal distortion of the Figure 3 amplifier may be insignificant at 10Hz, it can rise to objectionable levels at (say) 10kHz. This problem can be overcome by applying a slight forward bias to Q1 and Q2, as shown in Figures 4 and 5, so that their forward voltage values are reduced to near-zero and distortion is minimised.

The specific circuits of Figures 4 and 5 are designed to produce output currents up to at least 350mA peak or 50mA rms into a minimum load of 23Ω, i.e., to produce powers up to 280mW rms into such a load. These limitations are determined by the current and power ratings of Q1 and Q2, and by the power supply voltage values. The Figure 4 circuit is designed for use with dual power supplies, and gives a voltage gain of x10. The Figure 5 circuit uses a single-ended supply, and gives unity voltage gain.

IC Power Amplifier Basics

If audio output powers in the approximate range 200mW to 20W are needed, the most cost-effective way of getting them is to use a dedicated IC to do the job. A wide range of such ICs are available, in either 'single' or 'dual' form. Most of these ICs take the effective form of an op amp with a complementary emitter follower output stage (like Figures 4 and 5); they have differential input terminals and can provide high output power, but consume a low quiescent current.

When an IC power amplifier is connected in the single-ended output mode, as shown in Figure 6, the peak available output power equals $V^2 \div R$, where 'V' is the peak available output voltage. Note, however, that available output power can be increased by a factor of four by connecting a pair of amplifier ICs in the 'bridge' configuration shown in Figure 7, in which the peak available load power equals $2V^2 \div R$. This power increase can be explained as follows:

In the single-ended amplifier circuit of Figure 6 one end of R_L is grounded, so the peak voltage across R_L equals the voltage value on point 'A'. In Figure 7, on the other hand, both ends of RL are 'floating' and are driven in anti-phase, and the voltage across R_L equals the difference between the 'A' and 'B' values.

Figure 7 shows the circuit waveforms that

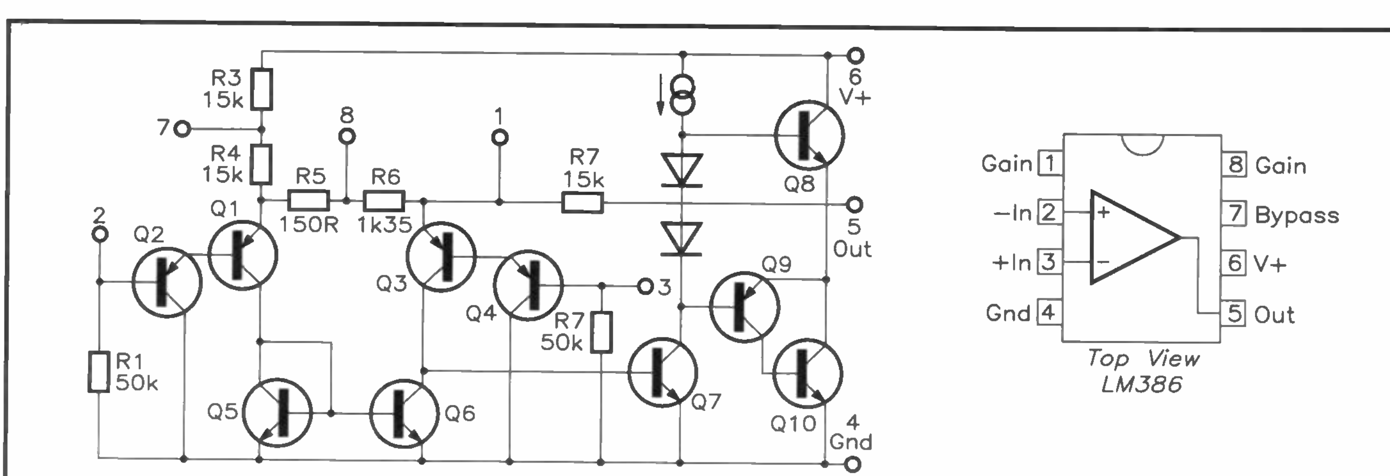


Figure 8. Internal circuit and pin connections of the LM386 low-voltage audio power amplifier.

DEVICE NUMBER	STOCK CODE	AMPLIFIER TYPE	MAXIMUM OUTPUT POWER	SUPPLY VOLTAGE RANGE	DISTORTION INTO 8Ω	INPUT IMP.	VOLTAGE GAIN	BAND-WIDTH	QUIESCENT CURRENT
LM386	UJ37S	MONO	325mW into 8Ω	4 to 15V	0·2%, V_S = 6V P_O = 125mW	50k	26dB	300kHz	4mA
LM389	WQ36P DIS	MONO + 3-Transistor Array	325mW into 8Ω	4 to 15V	0·2%, V_S = 6V P_O = 125mW	50k	26dB	250kHz	6mA
LM831	RA78K DIS	DUAL into 4Ω	220mW/Channel	1·8 to 6V	0·25%, V_S = 6V P_O = 50mW	25k	46dB	20Hz to 20kHz	6mA
TDA7052	UK79L	MONO	1·2W into 8Ω	3 to 15V P_O = 100mW	0·2%, V_S = 6V	100k	40dB to 20kHz	20Hz	4mA
TDA2822	UJ38R	DUAL	1W/Channel into 8Ω	1·8 to 15V	0·3%, V_S = 9V P_O = 0·5W	100k	40dB	120kHz	6mA
LM1877	QH38R	DUAL	2W/Channel into 8Ω	6 to 24V	0·4%, V_S = 9V P_O = 2W/Channel	4MΩ	34dB	65kHz	25mA
TBA820M	WQ63T	MONO	2W into 8Ω	3 to 16V	0·4%, V_S = 9V P_O = 0·5W	5MΩ	34dB	20Hz to 20kHz	4mA
LM380	QH40T	MONO, with protected output	3W into 4Ω	8 to 22V	0·2%, V_S = 18V P_O = 2W	150k	34dB	100kHz	7mA
LM384	WQ34M DIS	MONO, with protected output	5·5W into 8Ω	12 to 26V	0·25%, V_S = 22V P_O = 4W	150k	34dB	450kHz	8·5mA

Table 1. Basic details of nine popular ICs described in Parts 1 and 2 of this mini-series. DIS after Stock Code means discontinued.

are applied to the load when fed with a 10V Pk-to-Pk square-wave input signal. Note that although waveforms 'A' and 'B' each have peak values of 10V relative to ground, the two signals are in anti-phase (shifted by 180°). Thus, during period '1' of the drive signal, point 'B' is 10V positive to 'A' and is thus seen as being at '+10V'. In period '2', however, point 'B' is 10V negative to point 'A', and is thus seen as being at '–10V'. Consequently, if point 'A' is regarded as a 'zero voltage reference point', it can be seen that the point-'B' voltage varies from +10V to –10V between periods '1' and '2', giving a total voltage change of 20V across R_L. Similar changes occur in subsequent waveform periods.

Thus, the load in a 10V bridge-driven circuit sees a total voltage of 20V Pk-to-Pk, or twice the single-ended input voltage value, as indicated in the diagram. Since doubling the drive voltage results in a doubling of drive current, and power is equal to the V-I product, the bridge-driven circuit thus produces four times more power output than a single-ended circuit. We'll look at a range of IC-based single-ended and bridge-driven power amplifier circuits throughout the rest of this mini-series.

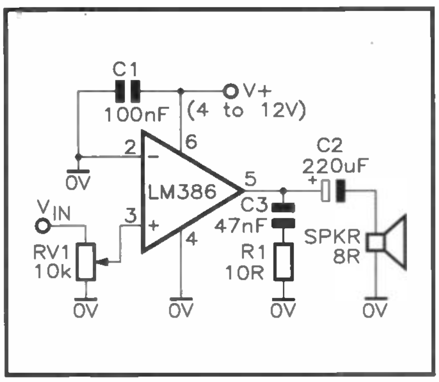


Figure 9. Minimum-parts LM386 amplifier with AV = 20.

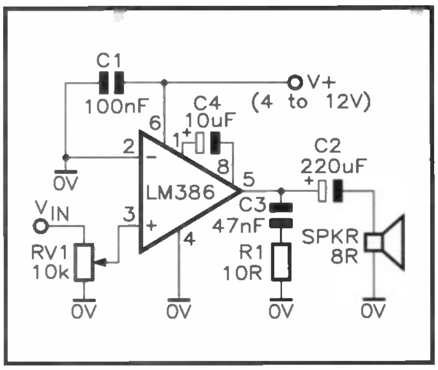


Figure 10. LM386 amplifier with AV = 200.

Practical ICs

A large range of audio power amplifier ICs are readily available. Some of these ICs house a single (mono) amplifier, while others house a pair (dual) of amplifiers. Table 1 lists the basic characteristics of nine popular audio power amplifier ICs with maximum output power ratings in the approximate range 325mW to 5·5W. Note, that the LM831, LM1877, and TDA2822 are 'dual' types, and that only the LM380 and LM384 have fully protected (short-circuit proof) output stages. The rest of this month's article and the whole of next month's are devoted to detailed descriptions of each of the above nine IC types.

LM386 Basics

The LM386 audio power amplifier (manufactured by National Semiconductor) is designed for operation with power supplies in the +4V to +15V DC range. It is housed in an 8-pin DIL package, consumes a quiescent current of about 4mA, and is ideal for use in battery-powered applications. The IC's voltage gain is variable from x20 to x200 via external connections, its output automatically centres on a quiescent half-supply voltage value, and it can feed several hundred mW into an 8Ω load when operated from a

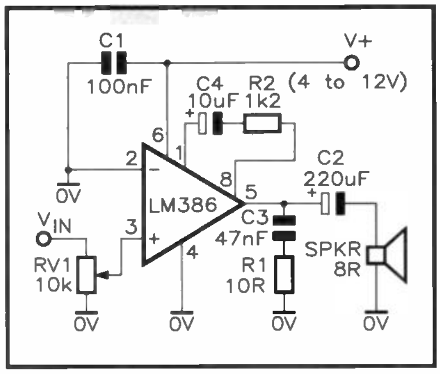


Figure 11. LM386 amplifier with AV = 50.

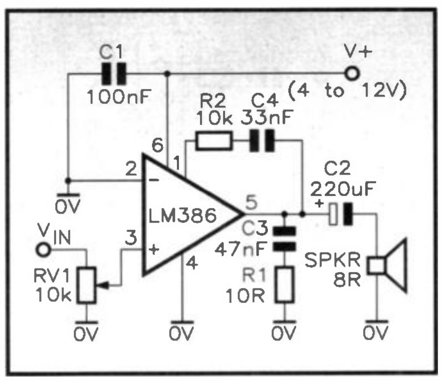


Figure 12. LM386 amplifier with 6dB of bass-boost at 85Hz.

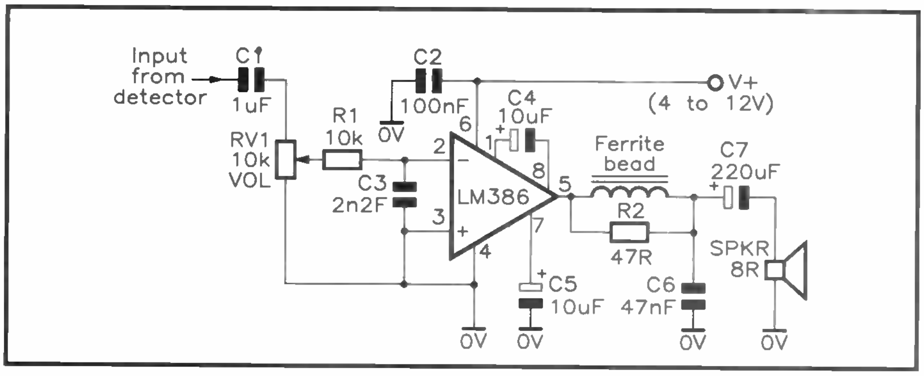


Figure 13. AM-radio power amplifier.

12V supply. Its differential input terminals are both ground-referenced, and have typical input impedances of 50k.

Figure 8 shows the LM386's internal circuit. Here, Q1 to Q6 form a differential amplifier in which both inputs are tied to ground via 50k resistors (R1 and R2) and the output (from Q3) is DC coupled to the input of common emitter amplifier Q7. The Q7 collector signal is DC-coupled to the IC's output terminal via Class-B unity-gain power amplifier stage Q8-Q9-Q10 which, to minimise internal volt-drops and maximise the available output power, is not provided with overload protection circuitry.

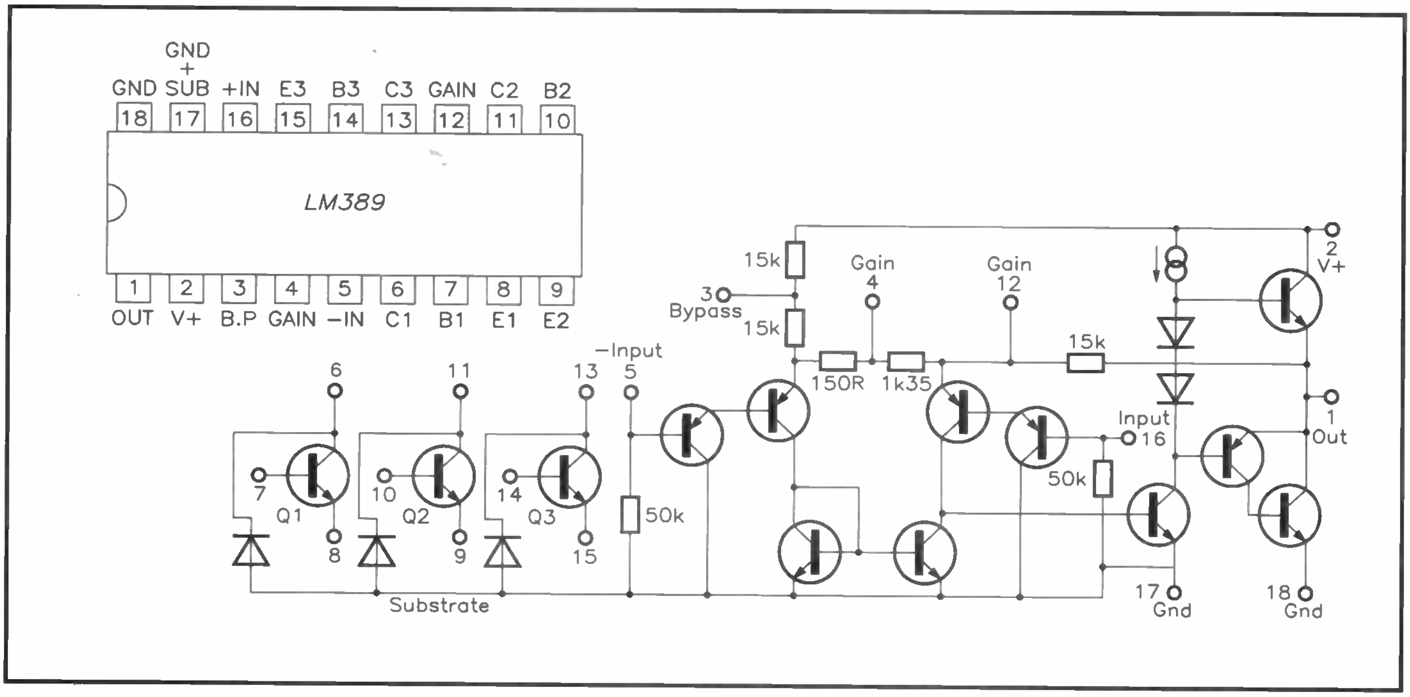


Figure 14. Circuit and outline of the LM389 low-voltage audio power amplifier with npn transistor array.

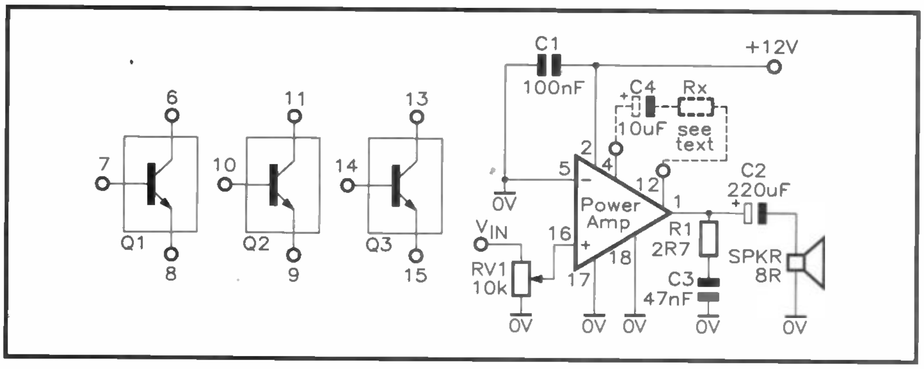


Figure 15. Basic circuit connections of the LM389 IC.

LM386 Applications

The LM386 is very easy to use. Its voltage gain equals double the pin-1 to pin-5 impedance value (15k in Figure 8) divided by the impedance between the emitters of Q1 and Q3 (=R5+R6). Thus, the IC can be used as a minimum-parts amplifier with an overall voltage gain of x20 (= 2 x 15k/1·5k) by using the simple connections shown in Figure 9, where the load is AC-coupled to the IC output via C2, and the input signal is fed to the non-inverting terminal via RV1. Note that C1 is used to RF-decouple the '+Ve' supply pin (pin-6), and R1 & C3 is an optional Zobel net-

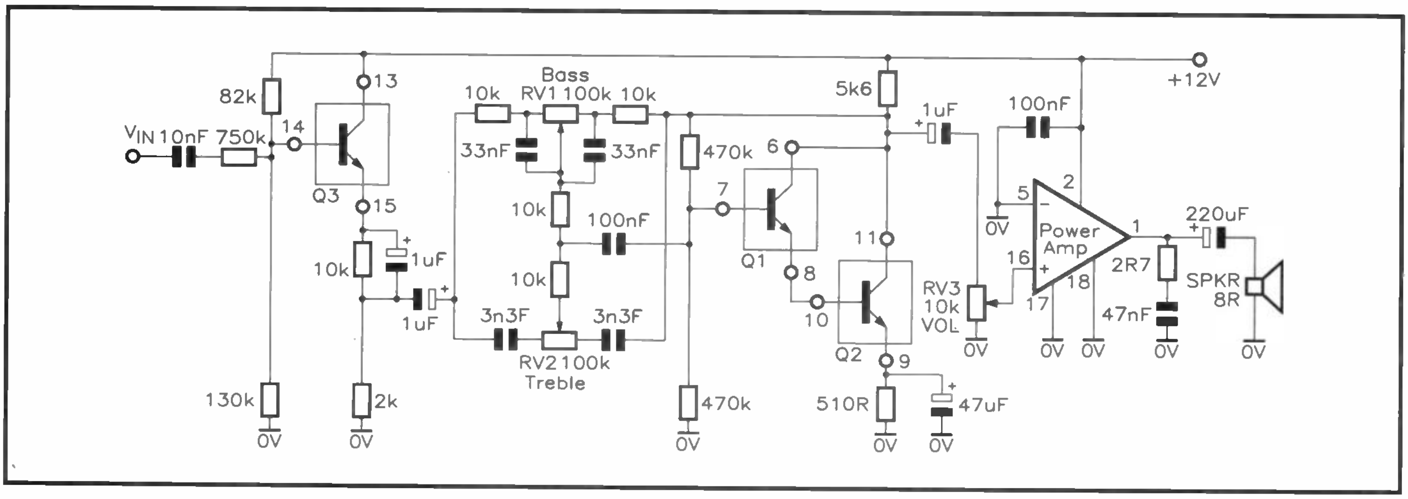


Figure 16. Ceramic phono amplifier, with tone controls, using an LM389.

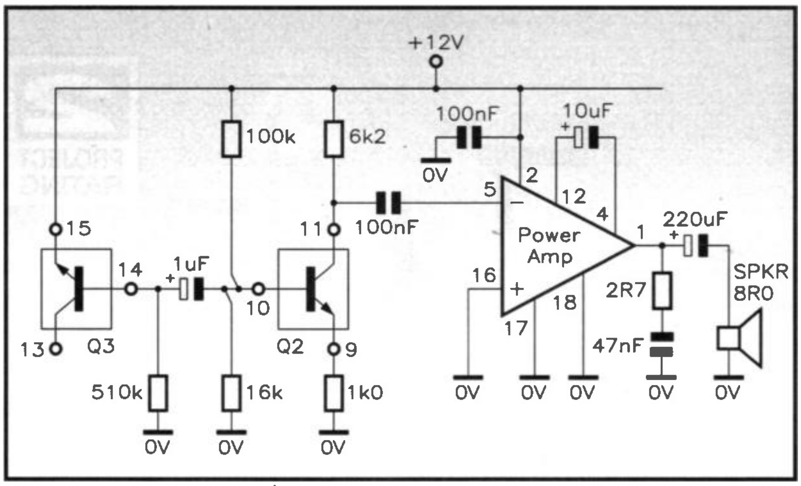


Figure 17. LM389 white-noise sound generator.

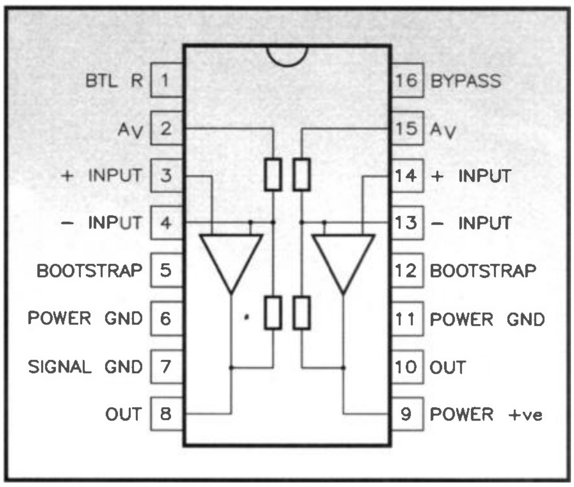


Figure 18. LM831 dual low-voltage audio power amplifier.

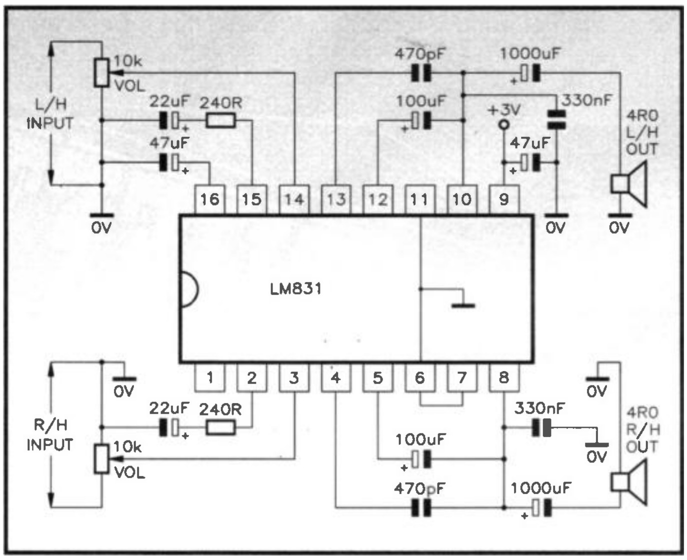


Figure 19. LM831 stereo amplifier.

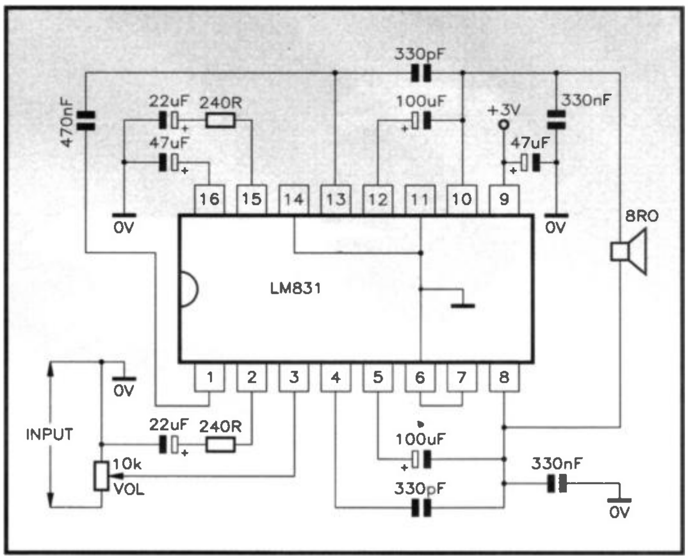


Figure 20. Bridge-connected LM831 amplifier.

work that ensures HF stability when feeding an inductive loudspeaker load.

Figure 10 shows how the above circuit can be modified to give an overall voltage gain of x200, by using C4 (between pins 1 and 8) to short-circuit effectively the internal 1k35 resistor of the IC. Alternatively, Figure 11 shows how the gain can be set at x50 by wiring a 1k2 resistor (R2) in series with C4.

The voltage gain of the LM386 can also be varied by shunting the effective value of the internal 15k pin-5 to pin-1 feedback resistor. Figure 12 shows how to shunt this resistor with C4 and R2, to give 6dB of bass boost at 85Hz, to compensate for the poor bass response of a cheap loudspeaker.

Figure 13 shows how the LM386 amplifier can be modified for use as a built-in amplifier in an AM radio. Here, the detected AM signal is fed to the non-inverting input of the IC via volume control RV1, and is RF-decoupled via R1 and C3; any residual RF signals are blocked from the load via a ferrite bead. The voltage gain of the amplifier is set at x200 via C4. Note that this circuit is provided with additional power-supply ripple rejection by wiring C5 between pin-7 and ground; this ripple-rejection capacitor can also be used with the Figures 9 to 12 circuits if required.

LM389 Circuits

The LM389 (Figure 14) contains an array of three independently accessible wide-band npn transistors on the same substrate as an audio power amplifier that is almost identical to that of the LM386. The three npn transistors have closely matched characteristics, can be operated with collector currents in the range 1μA to 25mA, at frequencies up to 100MHz, and each have typical current gain values of x275. The IC can use any power supply in the range +4 to +15V DC.

Figure 15 shows the IC's basic connections. The internal power amplifier is used in the same way as the LM386, with its voltage gain controlled by C4 and Rx, between pins 4 and 12. If C4 and Rx are absent, the power amplifier voltage gain is x20; if they are fitted and Rx has a value of 1k2, the gain is x50; if Rx is a short circuit, the gain rises to x200. The power amplifier can be used as either an inverting or non-inverting unit by connecting the external signal to the appropriate input terminal. Note that Q1, Q2 and Q3 of the IC are independently accessible.

Figures 16 and 17 show practical applications of the LM389, making use of the internal transistors. In the phono amplifier of Figure 16, which is intended for use with a ceramic pick-up, Q3 acts as a voltage following input buffer giving an input impedance of about 800k. Q1 and Q2 are used to make an active tone control network with its output feeding to the non-inverting input of the power amplifier via volume control RV3.

In the white noise generator circuit of Figure 17, Q3 is wired as a noise-generating Zener diode, and this noise signal is amplified via Q2 and then fed to the inverting input terminal of the power amplifier, which is wired in the 'x200' voltage-gain mode.

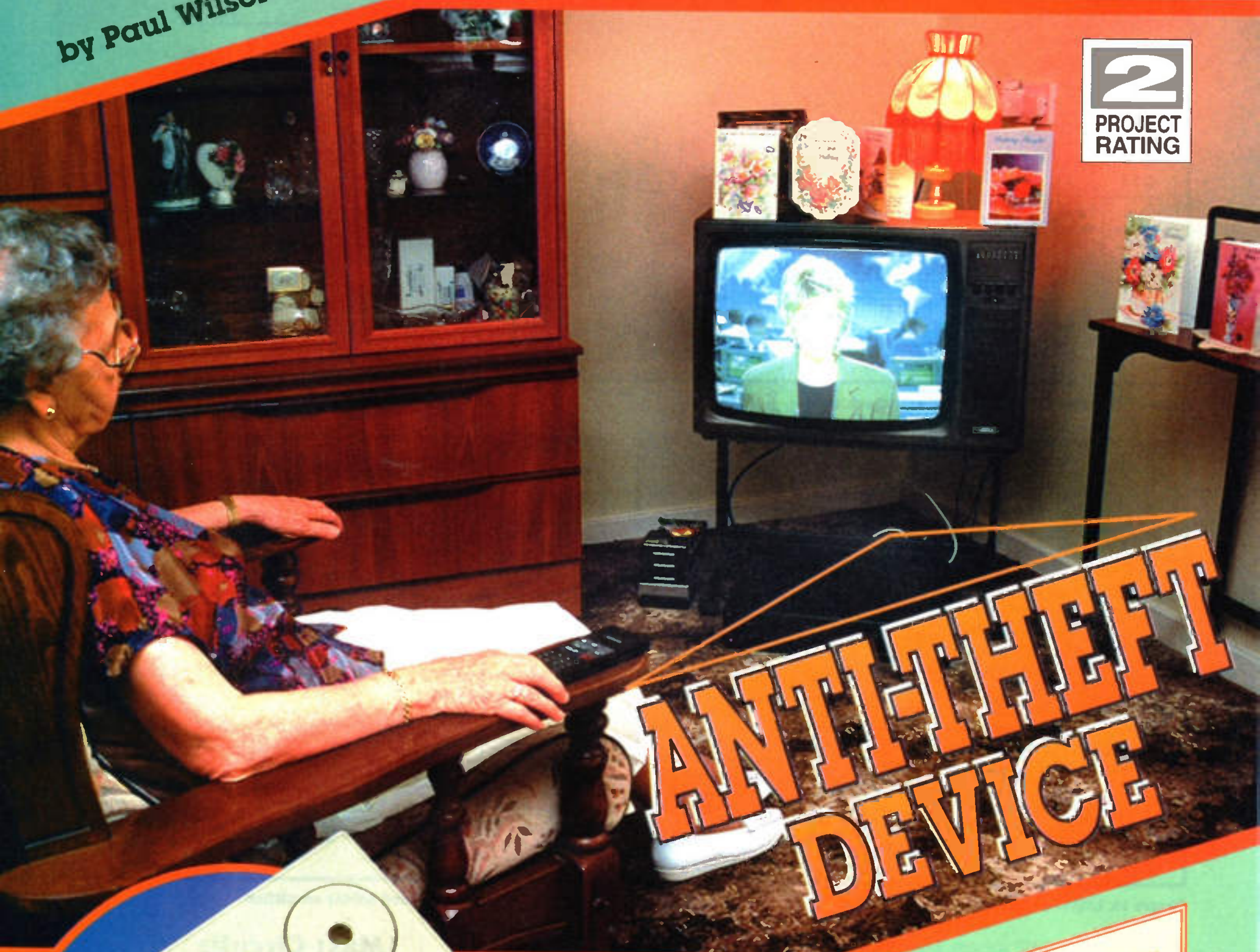
LM831 Circuits

The LM831 is a dual power-amplifier IC that is specifically designed for very low voltage operation; it can use supplies in the +1·8 to +6V DC range. The device was last listed in the 1992 edition of the Maplin Catalogue, but it is still in production and many readers are likely to have samples of it in their 'spares' boxes. Its two independent amplifiers give good low-noise and low-distortion performances, and generate minimal RF radiation, thus enabling the IC to be used in close proximity to an AM receiver. The IC is housed in a 16-pin DIL package (see Figure 18).

The two amplifiers of the LM831 can either be used independently to make a low-voltage stereo amplifier, or can be interconnected in the bridge mode to make a boosted-output mono amplifier. Figures 19 and 20 show the circuit connections of these two options. When these circuits are powered from a +3V supply derived from two 1·5V cells, each channel of the stereo amplifier can deliver 220mW into a 4Ω speaker load (and will give a 3dB signal bandwidth of 50Hz to 20kHz). The bridge amplifier can deliver 440mW into an 8Ω load (and gives a 20Hz to 20kHz bandwidth).

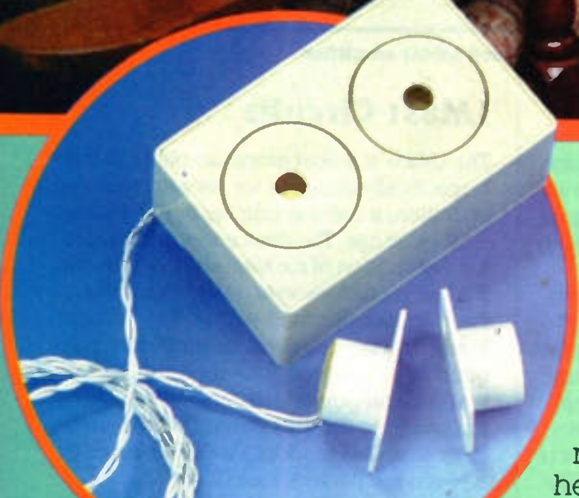
When constructing these two circuits, the PCB must be laid out with large earth planes, and the pin-9 decoupling capacitor must be as close to the IC as possible and must have a minimum value of 47μF. The two 330nF decoupling capacitors must also be as close as possible to the IC.

by Paul Wilson



2 PROJECT RATING

ANTI-THEFT DEVICE



The completed unit.

The design for the Anti-Theft Device (ATD) came about because of a story that I know will be familiar to many readers. After spending all of Sunday morning at the local casualty department with my wife, who had broken her wrist, we returned home at lunch-time to find that our house had been broken into.

FEATURES

* Twin piezo sounders
* Long battery life
* Low cost

APPLICATION

Individual alarm protection of valuable items

The intruder, for lack of a printable description, had gone round the back of the house and forced a kitchen window open, then climbed through leaving a trail of muddy footprints all over the worktops and floor. By the time he had got to the dining room door all hell must have broken loose as the PIR sensor picked him up and set off the burglar alarm. The two sounders in the kitchen, the two in the lounge, plus the two upstairs and the external siren all going off in unison. It must have been a shock to his system, because he didn't get any further, the muddy footprints showed it was a quick exit back the way he came. All this and he didn't get any swag. One up for the good guys. Of course the police were called, but we became just another statistic and nothing has been heard of the matter since. For those of you who I can still hear muttering those immortal words "It will never happen to me", I say "Don't be so complacent – after all, it happened to me!"

Paranoia

I know the alarm worked and scared him off, but you start getting paranoid and asking yourself questions. Like:

"What if I hadn't switched the alarm on, or for some reason it had not worked?" "What if he had just grabbed the microwave or portable TV from the breakfast bar and ran off, what good would the burglar alarm had been then?" Some sort of back-up system was required.

The Cure

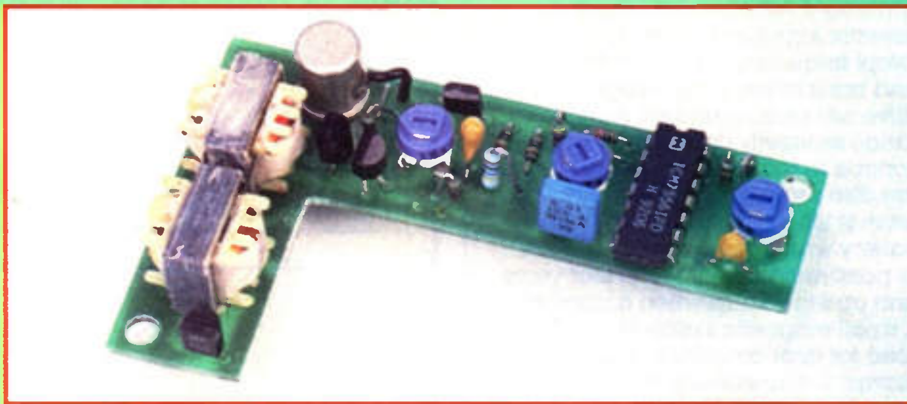
What was needed was a small device that could be hidden away inside almost any domestic appliance or piece of furniture such as a TV, video, hi-fi, microwave or computer and just lay there dormant for two or three years. If the host appliance was moved a loud screeching sound would be emitted which would go on and on until either the battery ran out or the alarm was switched off. No one would go walking down the street with a screaming microwave under their arm, or would they? The alarm would have to be able to be switched off from outside the appliance and as I didn't fancy drilling any holes for an on-off switch in my new video recorder, some other method of switching was required. It would have to be simple to make and last but most importantly because of the trace of Scottish blood in my veins, cheap.

A Case of Something for Nothing

Usually most home made projects, no matter how good the electronics, suffer from the same old problem. That is, what the finished article looks like. Most attractive housings are usually expensive, the cost can easily be two or three times that of the electronics that goes in them. As most individuals can't afford the thousands of pounds involved in getting an injection moulded case made for their Mk.V micro-controlled egg timer, most projects end up being housed in standard off the shelf plastic or metal boxes. All the holes for controls etc. have to be drilled by hand and any legends have to be put on with Letraset or Dymo tape. Its all too easy to end up with something that – well how can I put this? – looks home made. A stick-on overlay can cover a multitude of sins and turn even the humblest of boxes into something quite presentable. But this is still an expensive option for an individual who might only want to build two or three egg timers. Even for large firms like Maplin who want to sell hundreds or better still, thousands of their designs, an overlay would still add to the overall price. So how can Maplin stock a custom designed injection moulded case for this project and provide a pair of piezo sounders (ready fitted), two output transformers and two driver transistors for only £3.75? Turn to page 126 of the 1994 Maplin Catalogue to find out.

Full of Eastern Promise

The answer is by using the case and other components from a Twin-unit Piezo Siren which has been mass produced somewhere in the Far East. A new PCB has been designed that



The assembled PCB.

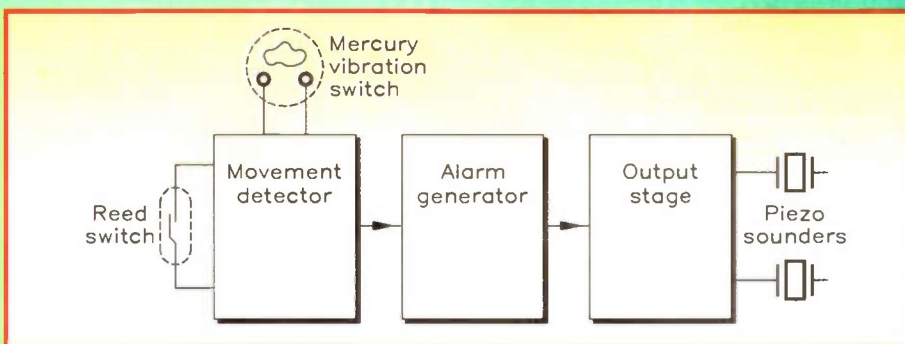


Figure 1. The ATD block diagram.

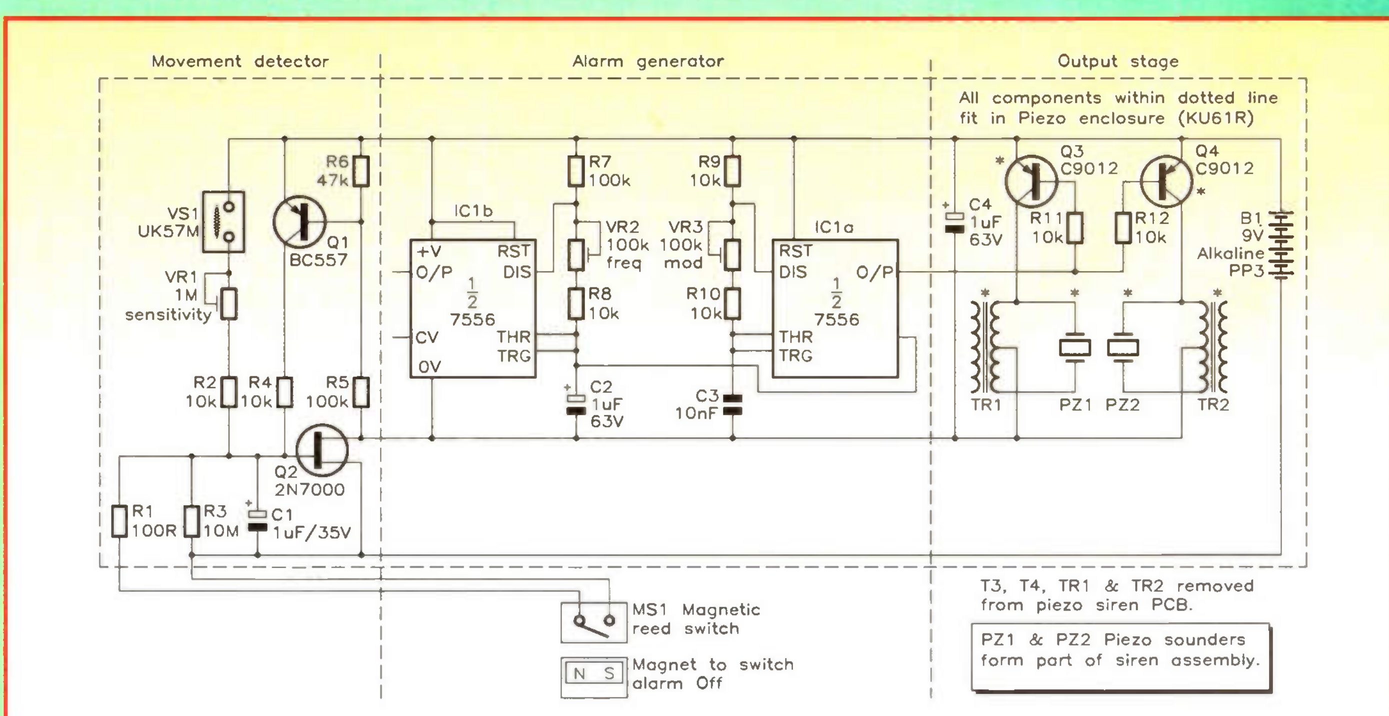


Figure 2. The ATD circuit diagram.

contains a sensitive movement detector together with latch, a swept frequency audio oscillator and transformer output stage to drive two piezo sounders. A wide range sensitivity control together with controls to maximise the sound output are also provided on board. Enough room is left in the case for a 9V PP3 battery which will power the ATD in its passive state for three to four years, and up to 10 hours when activated. A small magnetic switch of the type used for door contacts in burglar alarms is connected to the main box by a short length of cable. This allows the main box to be placed in any convenient spot inside the appliance. The magnetic switch can be located elsewhere so that a magnet can be wiped over the outside of the appliance to switch the alarm off, or stop the alarm from sounding whilst the rightful owner moves it.

Circuit Description

The circuit for the ATD can be split up into three distinct sections: these are shown in the block diagram in Figure 1, and in the circuit diagram of Figure 2.

Movement Detector

This is based around mercury vibration switch VS1. No matter what the orientation of VS1, its contacts are always open, while it is stationary. As VS1 is moved, its contacts open and close, producing a stream of short pulses (see Figure 3). Providing the magnetic switch MS1 is open, each pulse will cause C1 to acquire some more charge. VR1 is the sensitivity control and the higher its resistance the more pulses are needed to charge C1. Due to the very low gate current (10nA) of the 'Fetlington' (FET Darlington) transistor Q2, its presence does not affect the charging of C1. As the voltage on C1 rises to approximately +1V, Q2 starts to turn on. As the voltage on its drain starts to fall the voltage across resistors R5 and R6 rises, turning on transistor Q1. R4 is then pulled high, quickly charging C1. Once latched in this state power is applied to the rest of the circuit. If the magnetic switch MS1 is closed the ratio of R1 to R2, VR1 & R4 ensures that Q2 is turned off even if VS1 is closed. The purpose of R1 is to discharge C1 when no charge pulses are being generated, this ensures that a number of short duration knocks over a long period of time will not activate the ATD.

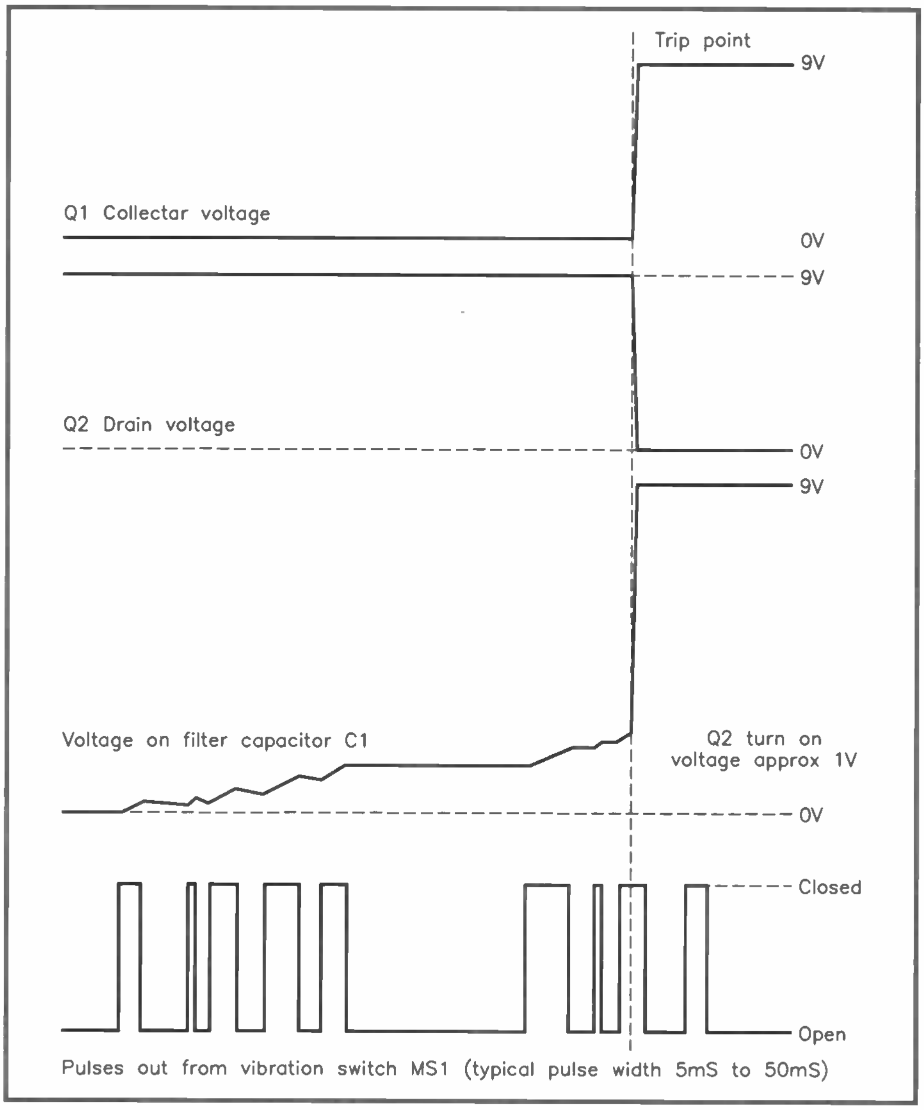


Figure 3. Movement detector, typical waveforms.

Alarm Waveform Generator

The alarm waveform consists of an audio frequency square wave being swept up and down in frequency by a low frequency modulation waveform. This is achieved by using IC1, a 7556 dual CMOS timer. IC1b, R7, R8, VR2 & C2 form the classic 555 astable multivibrator. The modulation frequency may be adjusted from approximately 6Hz to 50Hz by VR2. The charge/discharge voltage on pins 1 and 5, see Figure 4, is applied to the voltage control pin (pin 10) of the other astable multivibrator (IC1a, R9, R10, C3 & VR3). This sweeps the audio frequency up and down around the centre frequency which is set by VR3 (600Hz to 5kHz).

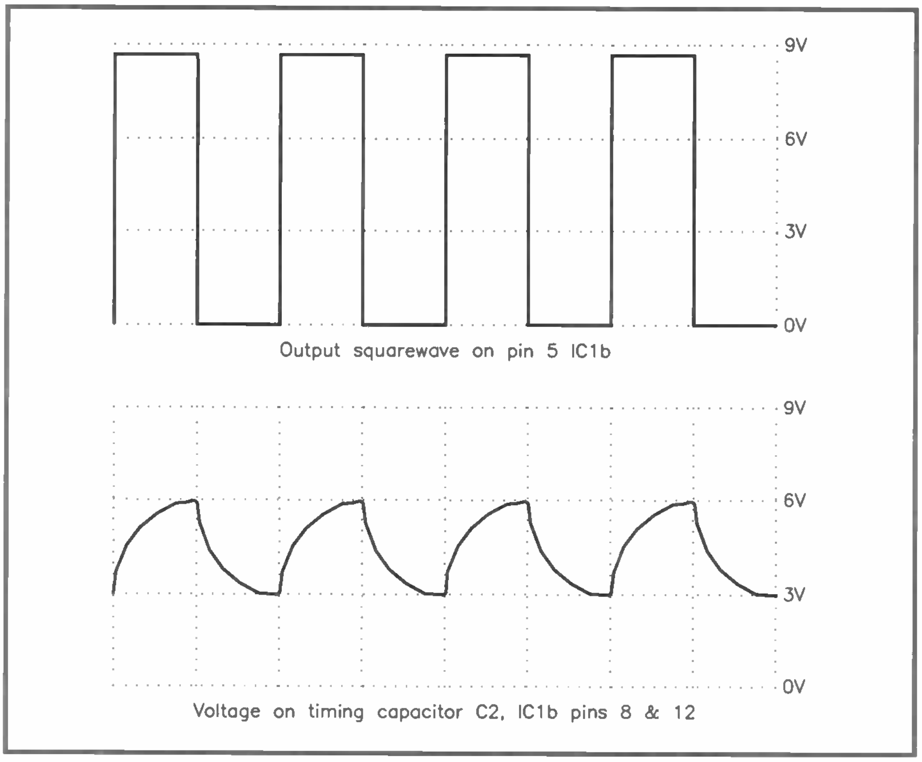


Figure 4. Modulation waveform.

Output Stage

The output stage consists of two identical circuits (R11, T3, TR1 & R12, T4, TR2) each driving a piezo sounder (PZ1 & PZ2). The output transistor is driven on (0v) and off (+9v) by the square wave output (pin 5) of IC1b. The centre tap of the transformer is connected to the switched 0V line, and one end is connected to the collector of the output transistor. As the other end is left floating, transformer action dictates that 18V Pk-to-Pk (twice the drive voltage) will be developed across the two outer ends of the transformer. Each time the drive transistor switches off a voltage is produced, due to the inductance of the transformer. With no load connected to the transformer this manifests itself as a negative going spike, which can vary between 50 to 150V depending on frequency. This brings the average voltage across the sounder to approximately 40 to 50V Pk-to-Pk, which accounts for the high level of sound generated by the unit.

Cannibalism

The first thing that needs to be done is to remove the four cross-head screws from the back of the Twin-unit Piezo Sounder and remove its cover. The PCB should then just drop out, if not, ease it out with a small screwdriver. Desolder the four wires from the PCB that go to the sounders.

If the PCB from your sounder has the reference number S100(A), then the components to remove are marked on the board as Q3, Q4, T1 & T2. Be careful when desoldering the transformers, as the leads are quite fragile. Make sure that all the leads are free from the pads before pulling them out of the board (see Desoldering Tips).

If you have a different PCB then you will have to trace the tracks from the transformer to its transistor to find the ones to remove. If the transistors you remove do not have the type numbers A1270 or C9120, then to make sure it is a PNP type, check that its emitter (see Figure 5), goes to the positive rail. If in doubt then refer to the Parts List for an alternative.

First Things First

Construction of the ATD is relatively straightforward, and does not require the use of specialist tools or test equipment, but before assembling the PCB a few things should be done. Firstly, the backplate as supplied has two triangular shaped mounting brackets on it. These need cutting off with either a sharp Stanley knife (be careful), or a junior hacksaw.

Next, a hole needs to be drilled in the backplate to allow access to the sensitivity control. The size is not too important, approximately 5mm diameter, and Figure 6 shows its position. Last of all remove the five screws from the back of the magnetic

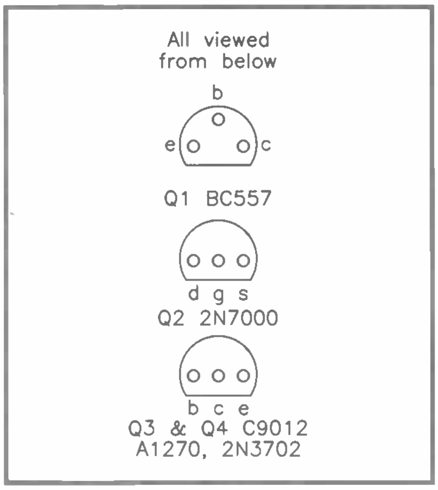


Figure 5. Transistor bases.

switch MS1, and carefully bend up the wires coming from the reed switch. Cut out three nicks in the back of MS1 for the cable to sit in as shown in Figure 8. Solder a 1m length of zip connecting cable ('figure of eight' type) to the wires and push the cable into the nicks. Before going on to the next stage strip the other end of the cable and check that the switch still works. Mix up some 5-minute epoxy resin and fill the back of the switch with it, ensuring the cable stays in place. Wipe off any excess glue with a damp cloth and leave to set.

Constructing the PCB

The circuit is constructed on a PCB to achieve a compact and reliable circuit. Using the track layout diagram Figure 7 for reference, start by inserting and soldering links LK1 and LK2, followed by resistors R1 to R12 and preset resistors VR1 to VR3. Capacitors C1 to C4 can then be fitted, observing the correct polarity of the three $1\mu F$ electrolytics. The negative lead is denoted by negative signs on the case and should be inserted away from the positive (+) sign shown in Figure 7.

Next insert and solder the four transistors Q1 to T4, ensuring that the transistor cases match the outlines in Figure 7. Then, ensuring you

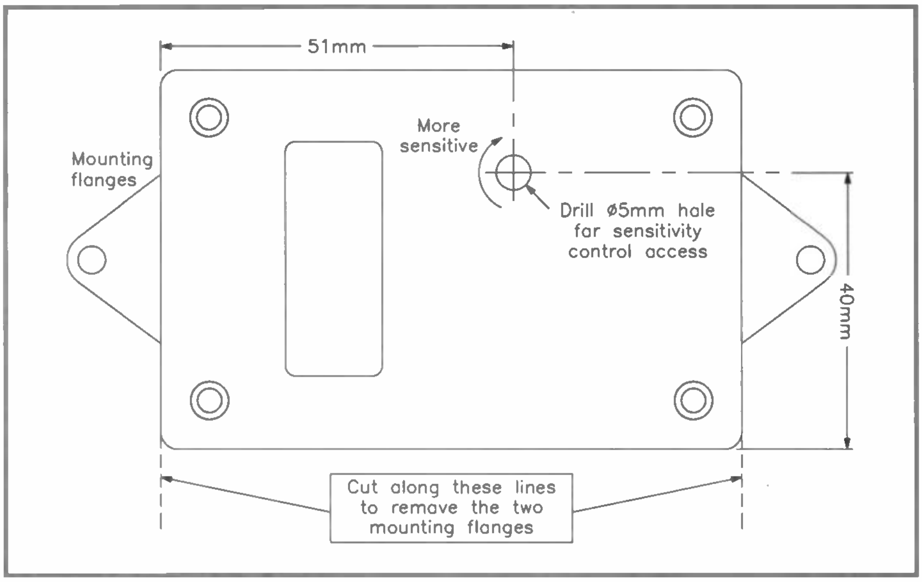


Figure 6. Backplate drawing.

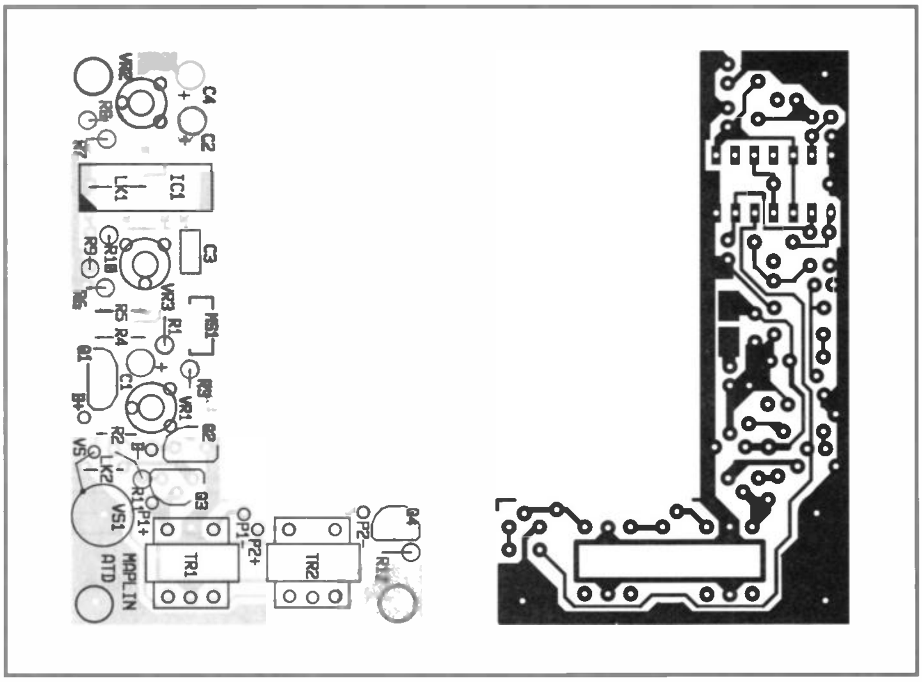
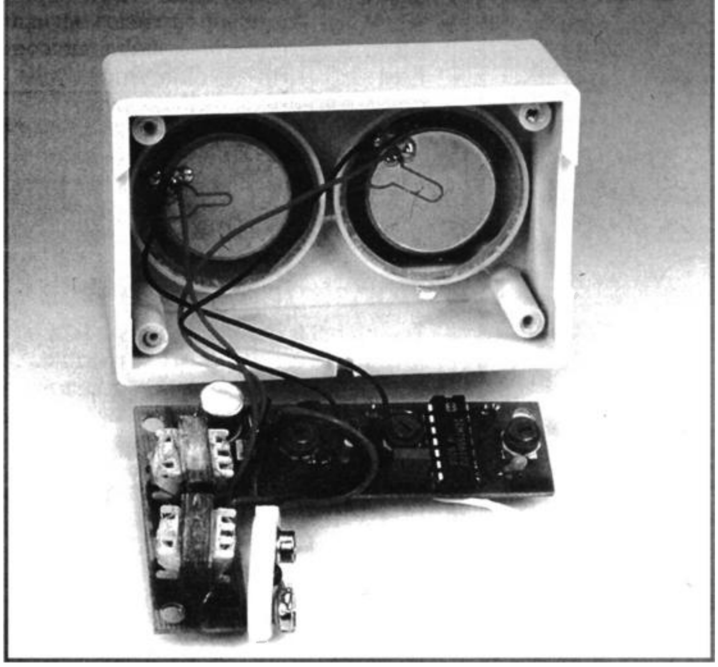
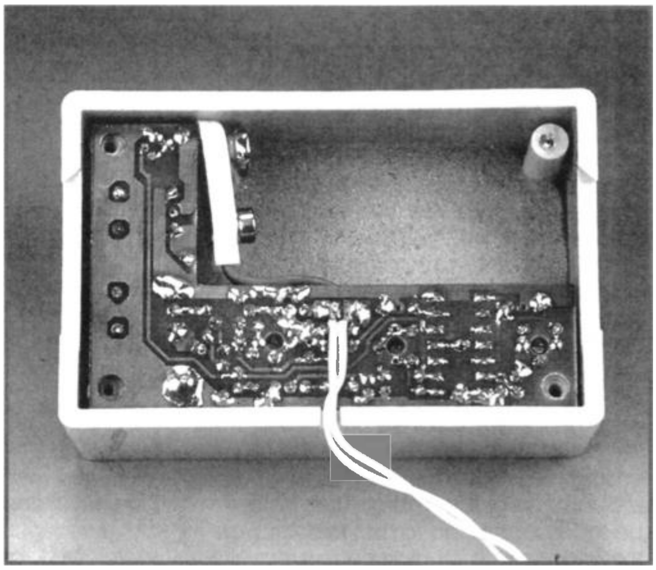


Figure 7. PCB legend and track.





Left: Inside the case.
Above: Fit the PCB in the case.

have taken the usual precautions against static damage, insert and solder IC1 into the PCB aligning the notch denoting pin 1 as shown in Figure 7. Transformers TR1 and TR2 may then be soldered into the PCB (see notes on transformers).

Vibration switch VS1 can then be inserted and soldered. Solder a short length of wire between the outer case of VS1 and the hole marked VS in Figure 7. Next, strip back the insulation on the PP3 battery clip so that there is approximately 60mm of red and 50mm of black wire left. Insert and solder into the holes marked B+ and B– respectively. Because there is no diode to protect against battery reversal, check that the red wire is the one nearest the longest edge of the PCB.

Before going any further check that all the components are fitted correctly and that there are no dry joints or solder bridges on the track side of the board. Using a PCB Cleaning Solution (DM83E) remove all the flux from the PCB. Using a small screwdriver centre the wipers of presets VR1, VR2 & VR3.

Solder the red and black wires from one of the sounders into the holes P1+ and P1– respectfully, repeat the process for the other sounder using the holes P2+ and P2–.

Transformer Identification

The Twin-unit Piezo Siren design is not likely to change in the near future. Therefore, these tests should only be needed if you are building the project some time after the publication date, or you are using a siren from a different source. It is a good idea to check the transformers anyway, just in case one has been damaged during removal from the siren PCB.

There are number of similar sirens on the market (at least 4) and the design of the transformer varies from manufacturer to manufacturer. All the ones tested so far use a centre tapped 20Ω-0-20Ω winding (approximately) to drive the sounders. Some simple tests have to be done to find this winding, Figure 9a shows the primary and secondary winding connections. Once found the transformers can be put into one of two groups (A or B), this determines which way round they are to be inserted into the PCB.

Measure the resistance between the pairs of pins shown in Table 1. Compare your results with those in the table to determine if it is a type A or type B transformer. Figures 9b & 9c show which way round the transformers have to be inserted into

Resistance between Pins					**Type**
1 & 2	2 & 3	2 & 4	2 & 5	4 & 5	–
42Ω	42Ω	21Ω	21Ω	42Ω	A
21Ω	21Ω	N.C.	N.C.	2Ω	B
24Ω	24Ω	N.C.	N.C.	45Ω	B
All Resistances are approximate					

Table 1. Transformer identification.

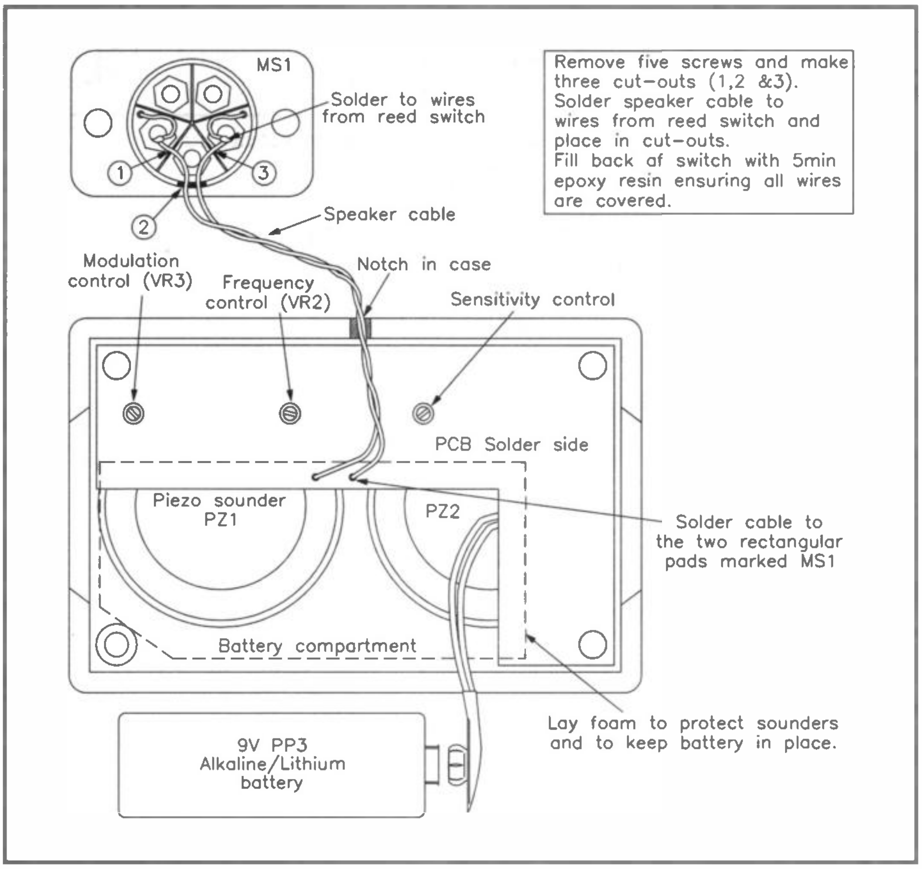


Figure 8. Final assembly.

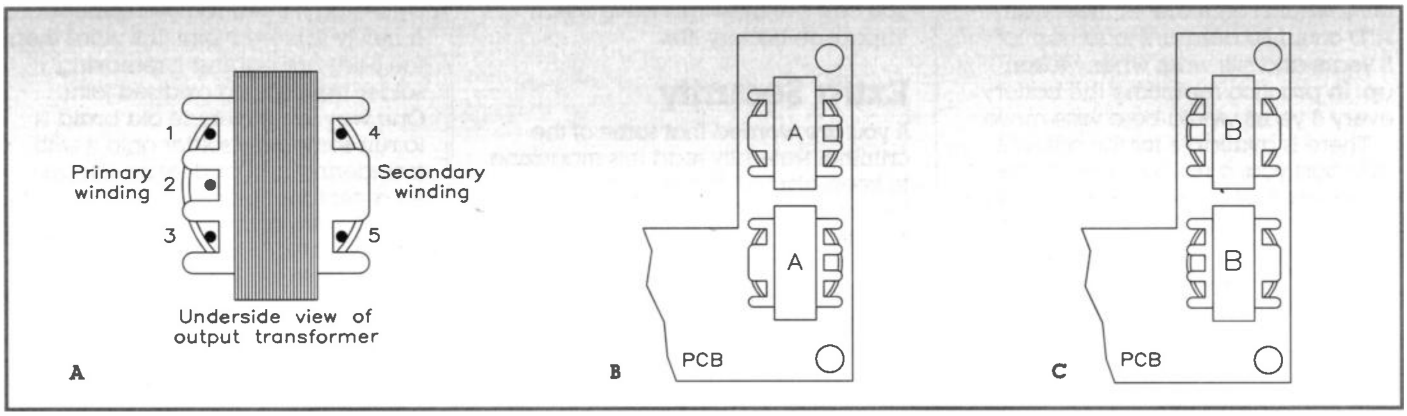


Figure 9. (a) Underside view of output transformer. (b) Type A orientation. (c) Type B orientation.

the PCB. The PCB legend shows the orientation of a type A transformer, as found in sounders with the variant number S100(A) on the PCB.

Finishing Off

Once again double-check that all the components are fitted correctly and that there are no dry joints or short circuits, then referring to Figure 8 for guidance, the finished PCB can be fitted into the box. Carefully tuck the wires from the sounders under the PCB. Fit the piece of foam into the bottom of the battery compartment. Finally, the wires from the remote magnetic switch (MS1) can be soldered to the two rectangular pads on the track side of the PCB and taken out of the notch in the edge of the case.

Testing

Put a magnet against MS1 and then connect the battery, if possible through a current meter. The ATD should remain silent and less than 50nA (0·05μA) leakage current should be flowing. If the ATD is shaken the current consumption will rise. If it rises to more than 1mA there is a fault.

Remove the current meter and the magnet from MS1 and shake the ATD, it should start sounding. Adjust the frequency control (VR3) until maximum volume is achieved (at approximately 2·8kHz). The modulation control (VR2) can be adjusted to create the most disturbing noise possible. Returning the magnet to MS1 should silence the alarm. The sensitivity control (VR1) can be turned clockwise to make it more sensitive and anticlockwise to become less sensitive. When the ATD is active measure the current consumption once again, it should be in the region of 50mA. Also check that the voltage across the drain and source of the 2N7000 is less than 200mV. Once you are happy that all is well the back can be put on, making sure the hole lines up with the sensitivity control.
It is a good idea to do a long-term test on the ATD to be a hundred per cent sure that it won't just start and then pack up half an hour later because of a faulty component. Start it sounding and then bury it in the linen basket or wrap it in towels, anything to muffle the sound and just let it run for a couple of hours or so, checking occasionally.

Warning about Guarantees

If the TV or video that you want to fit the ATD into is rented, then you will have to get the permission of the rental company before you do so. Most guarantees will be invalidated if covers are removed and alien objects inserted. Because of the chance of fatal electric shock ALWAYS switch the appliance OFF and remove it from the mains supply before removing any covers. Be especially careful when working on TVs because the high-voltage section can still have capacitors charged up to many thousands of volts long after the power has been removed. YOU HAVE BEEN WARNED!!

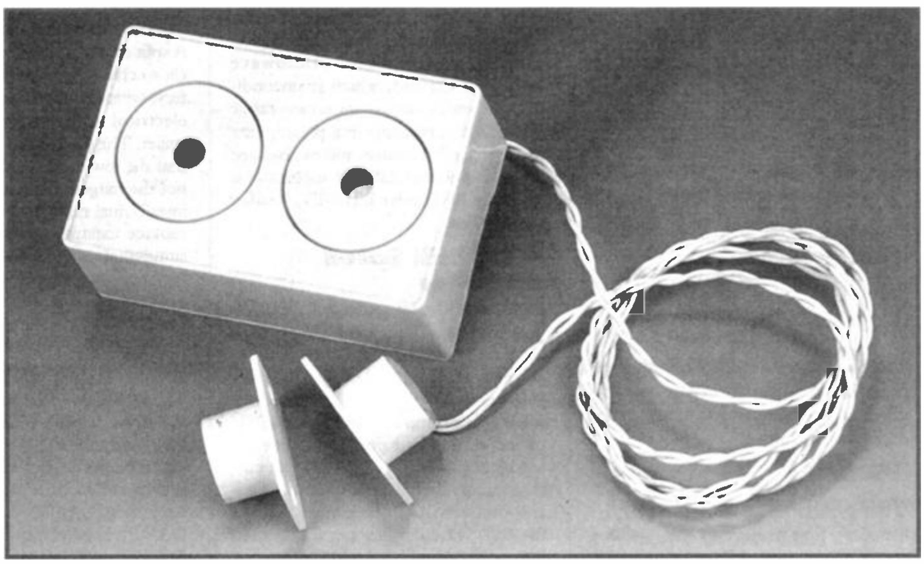
Fitting the Beast

Three or four double-sided sticky pads will usually secure the ATD to the inside of its host, but make sure you brush off any dust and clean the surface before doing so. The magnetic switch (MS1) can be secured by one sticky pad so that a magnet can be easily wiped over from the outside. When looking for a suitable place to fit the ATD try to avoid sources of heat such as large heatsinks and transformers. Keep well away from any moving parts and if fitting inside a TV, don't fit the main box above the tube in case it falls off and damages the tube, and keep away from the high-voltage section. Also make sure that when replacing any covers they do not foul on the ATD or the remote wire and switch.

The sensitivity control will need adjusting to suit each installation and will be a compromise between sensitivity to movement and the odd knock with the hoover etc. It is a good idea to mark the location of the magnetic switch on the outside of the case with a small sticky label etc., so that if the ATD gets woken up in a year's time you will know where to put the magnet. Don't forget where you put the magnets either! From experience, it is a good idea to keep a record of where the magnetic switches are in each appliance, and also when the battery needs replacing. Also checks should be made every month or so to make sure it is doing the job it was designed for.

Not all Batteries are Equal

The ATD has been designed to work off a standard alkaline 9V PP3 battery which has a 500mAH capacity, even more if it has the famous 'copper coloured top'. As the shelf life of these batteries is quoted as 5 years and the ATD takes virtually no current when



The ATD, ready to fit.

off, it would seem that in theory an ATD could lie dormant in its host for 5 years and still work when woken up. In practice replacing the battery every 3 years would be a wise move.

There is available for the affluent amongst you, a relatively new type of battery that on paper looks like it is ideal for the job. It is a 9v Mercury PP3 battery with a 10-year shelf life, 1300mAH capacity and a maximum continuous current drain of 125mA. At the moment these batteries retail at over £6.00, but no doubt the price will fall as they get more popular. If an ATD has to be installed in something that can't easily be taken apart, then this might be the ideal choice.

Under no circumstances use a zinc-carbon or zinc-chloride type battery as they do not have as long a shelf life or the capacity of an alkaline battery, and are more likely to leak.

Moving House

If something that has an ATD installed has to be moved a long distance, i.e. moving house, use masking tape to hold a magnet over the concealed switch. Even a five hour journey will only use up a maximum of 1% of an alkaline PP3's 500mA capacity. So as you can see this won't have much impact on battery life.

Extra Security

If you are worried that some of the criminal fraternity read this magazine to keep abreast of the latest technology that's trying to put them out of business, and that they will now go to work armed with a couple of magnets, then you can wire up two magnetic switches in series. This will make disarming the ATD almost impossible for anyone who does not know both their positions, especially in the short time a burglar wants to spend in your house.

Note: The circuit and information presented here must be considered as a basis for your own experimentation. No warranty is given or implied for suitability in particular applications – Maplin cannot support this information in any way. However, where possible, we endeavour to check that information is correct and that circuits will function as stated.

Desoldering Tips

Tip 1. When using desolder braid to remove components, check that the braid has not passed its 'sell by date' by seeing if it will remove solder from a newly soldered joint. If it won't then the odds are against it removing solder from an old oxidised joint. One way to rejuvenate old braid is to run some new solder onto it with a soldering iron and let it wick up for a centimetre or so. Cut off all but a millimetre of the newly soldered braid. Desolder joints using this end and keep trimming it off as required.

Tip 2. When using a desolder pump always keep the nozzle clear and check that it is working by pressing the nozzle hard into the palm of your hand. If the plunger does not move a lot slower than normal and you cannot feel any suction then its not working properly. When desoldering heat the joint up with the iron, keeping the nozzle as close as possible. At the last second remove the iron from the joint, and then press the button. This might take a bit of practice to get right but it will stop the iron from damaging the tracks on PCBs.

Tip 3. Whatever the method you choose to desolder components, always add some new solder to old joints to make them shiny again. The flux in the new solder makes the joint more fluid when heated and a lot easier to desolder.

ANTI-THEFT DEVICE PARTS LIST

RESISTORS: All ⅛W Carbon Film (Unless specified)			
R1	100Ω	1	(U100R)
R2,4,8-12	10k	7	(U10K)
R3	10M	1	(B10M)
R5,7	100k	2	(U100K)
R6	47k	1	(U47K)
VR1	1M Cermet Preset	1	(WR45Y)
VR2,3	100k Cermet Preset	2	(WR44X)
CAPACITORS			
C1,2,4	1µF 63V Sub-miniature Electrolytic	3	(YY31J)
C3	10nF Monolithic Ceramic	1	(RA44X)
SEMICONDUCTORS			
Q1	BC557	1	(QQ16S)
Q2	2N7000 Fetlington (FET Darlington)	1	(UF89W)
Q3,4	2N3702, (A1270 or C9120 Type)	2	(QR36D)
IC1	ICM7556 CMOS Timer	1	(CP96E)

MISCELLANEOUS			
VS1	Vibration Switch	1	(UK57M)
MS1	Magnetic Reed Switch	1	(JU65V)
PS1	Twin Piezo Sounder	1	(KU61R)
BC1	PP3 Battery Clip	1	(HF28F)
B1	9V PP3 Battery Alkaline	1	(JY49D)
	Zip Connecting Cable	1m	(XR39N)
	Self-adhesive pads	1Strip	(HB22Y)
	PCB Single Sided (See Text)	1	(HX01B)
	Constructors' Guide	1	(XH79L)

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

The above items are not available as a kit.

NEXT issue

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

PROJECTS

VHF/UHF Preamplifier

Maplin's first project to use 'surface mount' components! This preamplifier was designed to be a replacement for the previous Maplin VHF preamplifier kit. The new design is based around a MAR-6 MMIC (Monolithic Microwave Integrated Circuit), which is unconditionally stable across its entire range (DC-2GHz), resulting in a preamplifier which is highly versatile, and can be used for any number of different applications, including VHF radio, UHF TV, weather satellites, etc.

PWM Drill Speed Controller

Many of us who own mini drills for making PCBs and drilling project boxes, only have a general-purpose bench PSU to power it up. More often than not, the PSU voltage collapses when asked for more than an amp or two. This drill PSU project is overload proof and provides 100W of power for even the most current-hungry drill. The drill speed is variable from zero to the maximum RPM of the drill. The controller can also be used to control the speed of model trains, cars and boats.

Split Charge Unit

A split charge unit is employed in a vehicle to charge an auxiliary (second) battery, which is often used to power 12V electrical accessories in a caravan or trailer. The use of such a battery ensures that the towing vehicle's main battery is not discharged. This easy to build (and install) dual split charge unit can directly replace existing units, and is able to simultaneously charge an auxiliary battery and supply power to a 12V DC operated appliance (a refrigerator for example).

20m 20W HF Amplifier

The QRP 20m Transmitter introduced in *Electronics* Issue 76, had a maximum RF power rating of 1W. For those wanting more power but still within the low power range, the 20m 20W Linear Amplifier (QAMP) can be used. The QAMP range of power amplifiers are designed to be driven by transmitters with output powers of ½ to 2W. (There are other kits available in the QAMP range, covering 80m and 40m bands.)

Mini Projects

Six useful little circuits for you to build.

FEATURES

Special features include a fascinating look at 'SETI' – the Search for Extra-Terrestrial Intelligence; 'Circuit Switched Networks' explores the present state of these types of network; 'Improve Your Circuit Design' explains how a scientific calculator may be used to aid with design; 'Minitram' takes a look at novel tram systems. Other features continue with the second instalments of 'Audio Power Amp ICs' and 'Test Equipment', plus the concluding part of 'Surround Sound'. All this, plus all your favourite regulars as well!

ELECTRONICS – THE MAPLIN MAGAZINE

BRITAIN'S BEST SELLING ELECTRONICS MAGAZINE

Stray Signals

by Point Contact

Come back Germanium, all is forgiven. When PC was a student assistant on a sandwich course in the 1950s, germanium was the mainstay of the developing semiconductor industry. If memory serves me aright, the main source of germanium at that time was the chimney-sweep: apparently it occurs in minute quantities in coal. In those days before the Clean Air Act, millions of households up and down the land burned coal for heating, and the germanium tended to be deposited in the flues and chimneys. How it was extracted from the soot I cannot recall, but I do know how it was thereafter purified to the necessary degree for semiconductor work. Placed in a long thin silica boat, it was put in an evacuated furnace tube and a surrounding RF induction heating coil was slowly moved along its length. Thus a locally melted area gradually worked its way along the material, and it transpired that the impurities were more soluble in the melt than in the solid. So repeated passes gradually swept all the impurities along to one end, which was then discarded, joining the next batch to be treated by this 'zone refining' method.

At that time, silicon was just beginning to make its presence felt, but was mainly limited to rectifiers, where it excelled in high voltage devices due to its much lower leakage current. Only in the 60s did silicon overtake germanium as the preferred material for high frequency linear and switching transistors, and ever since then, germanium has taken a back seat – indeed has been all but forgotten. But now, both France Telecom's research centre and GEC Plessey Semiconductors at Swindon are more than a little interested in germanium again – not in its own right, but as an additive. An alloy of silicon with somewhere between 10 and 30% germanium offers better high frequency performance than either material alone: the higher the proportion of germanium the better the performance, but the more tricky the subsequent processing to retain a defect-free material under the heating involved in the subsequent manufacturing process steps. Performance is apparently excellent, with 0·25 micron devices operating to 50GHz and beyond, equalling gallium arsenide devices. A big advance, as SiGe is much cheaper and easier to fabricate than GaAs.

New Uses For Old Tyres

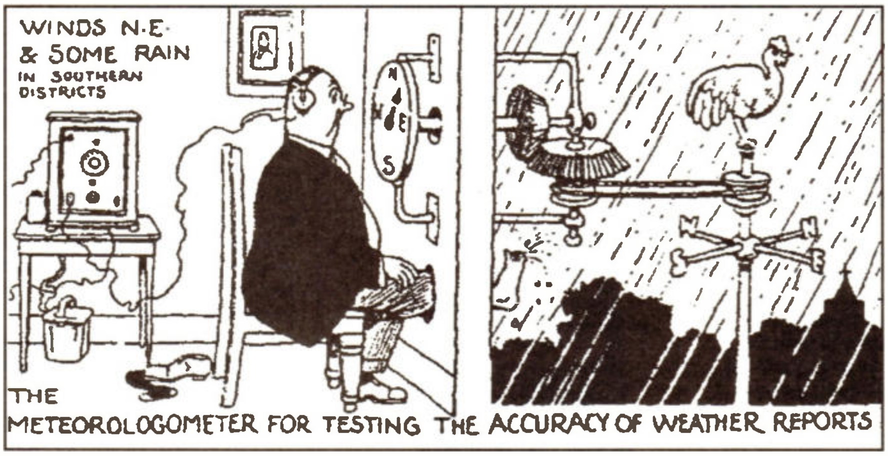
PC appreciates the convenience of the mobility afforded by the private motor car, as does Mrs PC, while both of our offspring have their own cars as well. Between us, them, thee and me, them being the rest of the inhabitants of this sceptred isle, get through around 35 million tyres each year. Around one in five go for remoulds, most of the rest finishing up in increasingly hard-to-find landfill sites or just dangerously dumped in great piles on the surface. One such 2-acre dump recently burned for four days before being brought under control. Now, a new power station at Wolverhampton (opened last November) will burn each year 90,000 tonnes (one in five) of those old tyres and produce 30MW of electricity in the process. At over 30MJ/kg, old tyres have a higher calorific value than coal, together with a lower sulphur content to boot. Furthermore, you don't have to buy them: people actually pay you up to £30 per tonne to take them away! Of course there are snags; despite the low sulphur content, close control of the combustion conditions (doubtless under an extensive electronic control system) plus expensive flue-gas cleaning is needed to avoid unacceptable pollution. Much of the particulate material recovered is zinc oxide, which is recycled to the metal recovery industry, some 3,000 tonnes annually, Not to mention the recovery of around 20,000 tonnes of steel scrap and 7,000 tonnes of calcium sulphite (used in the building industry and elsewhere) per annum. Some 5MW of power is consumed internally in the plant, leaving 25MW net for export to the national grid. Just three more plants like that one would mop up all the old tyres which don't go for remoulds! Two more are currently planned, but unfortunately each is only a fifth of the size of the Wolverhampton one. Let's hope they come to fruition, and some more as well.

Tailpiece

Browsing again through a copy of *The BBC Yearbook for 1930*, picked up some time ago for £2.50 at a book sale in the crypt of a church in Oxford, I see in a chapter headed Wireless Research that "During the past year two important new designs of valves have been brought into general use, namely, the screen-grid valve and the pentode. The general use of the screen-grid valve is likely to put high frequency amplification upon a more satisfactory basis". Reproduced on this page is one of the lovely cartoons for which W. Heath Robinson was so famous (describing the Meteorologometer).

Yours sincerely,

Point Contact



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

NEW BOOKS

Killer Car Stereo on a Budget

by Daniel L. Fergusion

Car stereo systems have come a long way in the last few years, particularly in the field of electronics. However, what the driver and passengers hear has remained largely unchanged, normally due to the severe limitations posed by the loudspeaker systems installed by the car manufacturer. Unfortunately, the high quality signals being created by modern in-car entertainment systems are being 'wasted' as a result of mediocre loudspeakers. This is particularly true of the bass notes, and one way to improve the system is to install a sub-woofer. This is a driver that is capable of producing very low notes and is usually powered by an electronic' crossover and power amplifier. Such a system can be constructed relatively easily at a fraction of the cost of commercial units. The purpose of this handy little book is to describe in detail how to build and install a high-powered, biamped in-car loudspeaker system.

Although an American book, there are many suggestions and ideas that can be adapted by anyone with enthusiasm and a reasonable understanding of electronics and loudspeakers. The book includes circuit and construction details for an electronic filter-crossover designed for use with a sub-woofer, that can be made from readily available components. There are suggested systems for saloon, hatchback and pickups, with in-depth guides on installation.

1989. 126 pages. 216 x 152mm, illustrated. American Book.

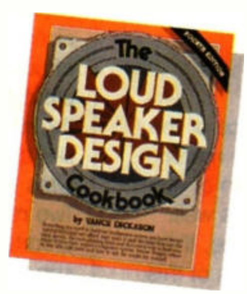
Order As AA77J
(Budget Car Stereo) **£7.99 NV**

The Loudspeaker Design Cookbook – Fourth Edition

by Vance Dickason

The first edition of this highly regarded book was one of the very few books that showed the loudspeaker constructor how to use the relatively new loudspeaker box design technology that had been developed by Thiele and Small. At the time, very few loudspeaker driver manufacturers could supply such information. Today the situation is very much altered with almost all manufacturers providing very detailed driver specifications, which often includes three-dimensional, time-delay plots. With this information now readily available, and the high cost of commercial high quality loudspeakers, the prospect of designing and building your own loudspeaker becomes more attractive.

In this latest edition, the book provides a comprehensive listing of the most widely accepted engineering procedure that can be used to construct a pair of high quality loudspeakers – with the minimum of test gear. Additionally, the text describes the science of loudspeaker design, and using all this information, will yield numerous possible variations in loudspeaker design, with a wide range of subtle and not so subtle differences.



The opening chapter gives a very detailed but easily understandable insight into how loudspeakers work. The following chapters delve into closed box, vented-box, passive radiator and transmission-line low frequency systems. These chapters are followed by cabinet construction, mid and high frequency drivers, passive and active crossover networks and loudspeaker testing.

A highly recommended book for all those who wish to build a pair of high quality loudspeakers to be proud of.

1991. 192 pages. 279 x 214mm, illustrated. American Book.

Order As AA75S
(Loudspeaker Cookbook) **£19.99 NV**

First Look At Lotus 1-2-3 for DOS Release 3.1+

by Alan Skinner

The aim of this book is to provide simple step-by-step instructions that enable the reader to become competent in Lotus 1-2-3 in the shortest possible time. The book commences with the lesson on Understanding Lotus 1-2-3 and proceeds with more advanced features in each succeeding lesson. Each lesson incorporates the same learning-aid features which enhance the reader's comprehension of the topics discussed.

The learning-aids are set out under the headings of objectives which provide an overview of what the reader will learn in the current lesson. To make this enormous topic easy to understand, the

lessons are set out in logical blocks that take you through from the simple tasks to the more complicated. Lessons 1 to 4 enable you to understand Lotus 1-2-3, how to create and design a spreadsheet, edit a spreadsheet and print your work. Lesson 5 explains how to use the numerous number of functions found in Lotus 1-2-3. The next three lessons, 6 to 8, will expand the reader's knowledge of manipulation of large worksheets, using multiple files and multiple worksheets. The final lesson takes you into the world of graphs.

At the end of the book there are sections that give the answers to the review questions, a reference and command summary and finally a troubleshooting guide. This is a book that the beginner and the more experienced user of Lotus 1-2-3 will find extremely useful.

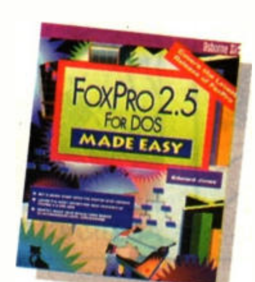
1993. 176 pages. 232 x 186mm, illustrated. American Book.

Order As AA72P
(Lotus 1-2-3 For DOS) **£7.95 NV**

FoxPro 2.5 for DOS Made Easy

by Edward Jones

In this third edition of the acclaimed FoxPro Made Easy, you will find a complete step-by-step guide that is simple, yet thorough. The first chapter is an introduction and explains the concepts of relational databases; illustrates how you will use FoxPro, using the keyboard and mouse, choosing menu selections, and entering FoxPro commands. You'll find easy-to-follow chapters on database creation, data manipulation and entry form creation. The later chapters deal with programming with FoxPro, where the reader will learn to create command files (or programs) to perform tasks in FoxPro, together with learning how functions, variables, expressions, and operators can be used within a FoxPro program. The final chapter provides tips on using FoxPro with other popular software packages, including Lotus 1-2-3 and WordPerfect.



The hands-on lessons and helpful exercises will help build skills and confidence. For those of you who are familiar with FoxPro, all the new features of Release 2.5 are explained and discussed in great detail. The appendices comprehensively cover a glossary of FoxPro commands and functions for beginners and those who are reasonably familiar with FoxPro.

Throughout this book, the reader will be instructed to enter various commands. Each of these entries will either appear in boldface or be visually set apart from the text. Menu selections that you should make will be detailed within the text in a step-by-step format. Highly recommended

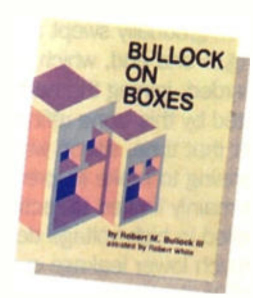
1993. 714 pages. 230 x 185mm, illustrated. American book.

Order As AA73Q
(FoxPro 2·5 For Dos) **£19.95 NV** A2

Bullock on Boxes

by Robert M. Bullock III

Before Thiele, vented loudspeaker design was simple, but more often than not, produced poor quality sound. This is because earlier methods did not allow for a vented systems critical dependence on certain amplifier and driver characteristics.



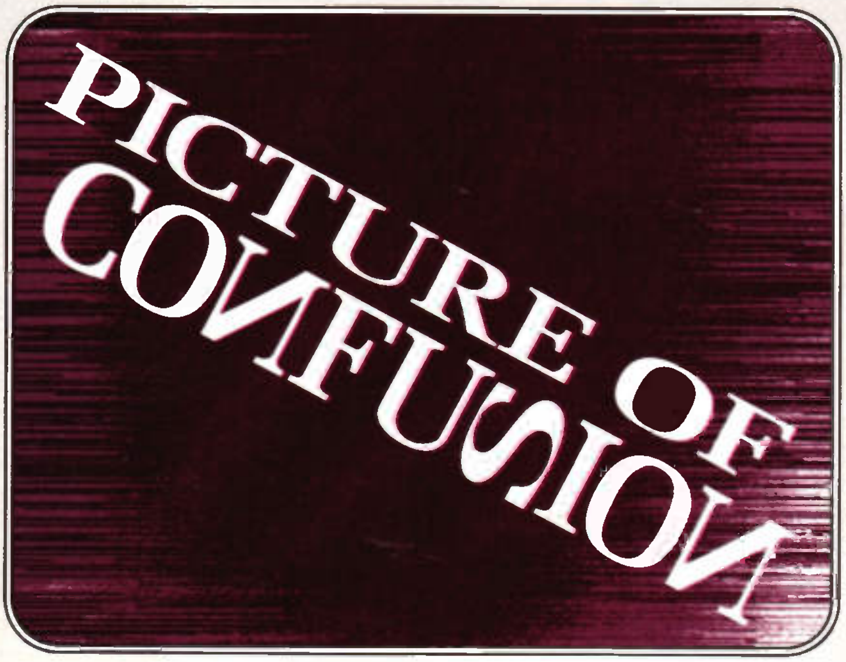
Thiele and Small's work lead to a set of procedures that do allow for these important characteristics to be taken into account, and thus produce accurate and predictable results – that is they will produce quality sound.

This book is a compilation of a series of articles written by the author for the highly regarded magazine *Speaker Builder*. It is an easy to read guide to designing and building vented-box systems based on Thiele-Small models. In addition to the background theory and descriptions of the models, the text covers a host of related information drawn from a variety of sources. By far the best way to tackle the design of a loudspeaker box is to use a computer program of the model to investigate the various options. The use of computer programs is explained in clear detail with programs supplied and developed by the author.

Filled with tables, graphs and design tables this book is a must for the serious home loudspeaker constructor.

1991. 79 pages. 279 x 215mm, illustrated. American Book.

Order As AA76H
(Bullock On Boxes) **£8.99 NV**



Television may be a global medium but there are three technical standards in use around the world and they're not compatible. So how do the broadcasters convert the pictures? Andrew Emmerson investigates.

PROBABLY the only thing most viewers know about television picture conversion is the slight judder on horizontal movement they see on some American programmes; any tracking shots or rapid sideways movement seems to dissolve into a blur. The rest of the time they probably never realise the problems involved in adding or subtracting lines and fields, or the subtleties of turning NTSC into PAL and PAL into SECAM.

This, of course, is exactly how it should be. People watch television to be entertained or to be informed, not to worry how the technologists make it work. Programme makers take the same attitude; if they are making programmes for international audiences they expect foreign viewers to see their material with the same clarity as when it was first screened. What they really fear is 'overseas rejection', as it is called. People still recall the outcry in Britain in 1987 when the BBC screened *Dallas* from a standards-converted video tape instead of the 35mm film prints used previously. The smeary, juddery pictures looked atrocious, yet the quality of the source material was first-rate.

STANDARDS OF EXCELLENCE

All this is in the past, though. Fortunately the best modern standards converters have made this a problem of the past and can produce PAL pictures from an NTSC videotape that look indistinguishable from direct film transfer in PAL. That is not to say it's a simple process, however, and as in so many fields, you only get what you pay for. The best broadcast standards converters go to enormous lengths to overcome the limitations of the conversion process, employing complex motion estimation or prediction processes. For non-broadcast material, such as video tapes for business training use, advertising or home viewing, somewhat lower cost machines can be used, whilst on the home front there are now some domestic video recorders with a built-in standards converter.

To add to the problem, most tele vision standards conversion is done on the fly, in real time. When you watch CNN live from Atlanta at home in Britain you are seeing a signal which originated in the American NTSC system and has been converted instantaneously into our PAL system. And whilst television undoubtedly has an all-digital future, our existing systems are all entirely analogue which complicates the conversion process even more. For the time being, perhaps in 'another' 20 years, we shall be stuck with television sets and VCRs together with a variety of differing analogue signal formats.

SOFT CELL

Why is picture conversion such a major assignment? Simply because it involves making something from nothing, which is never easy. Going back to our example of *Dallas*, we have a series of pic-

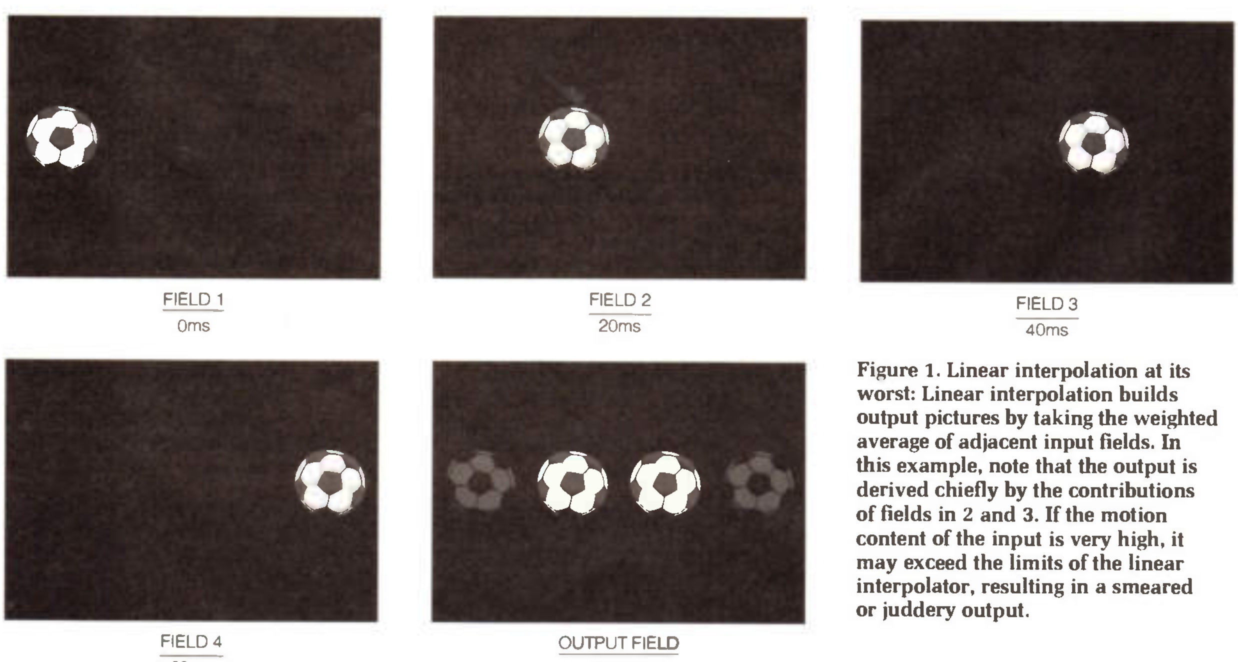
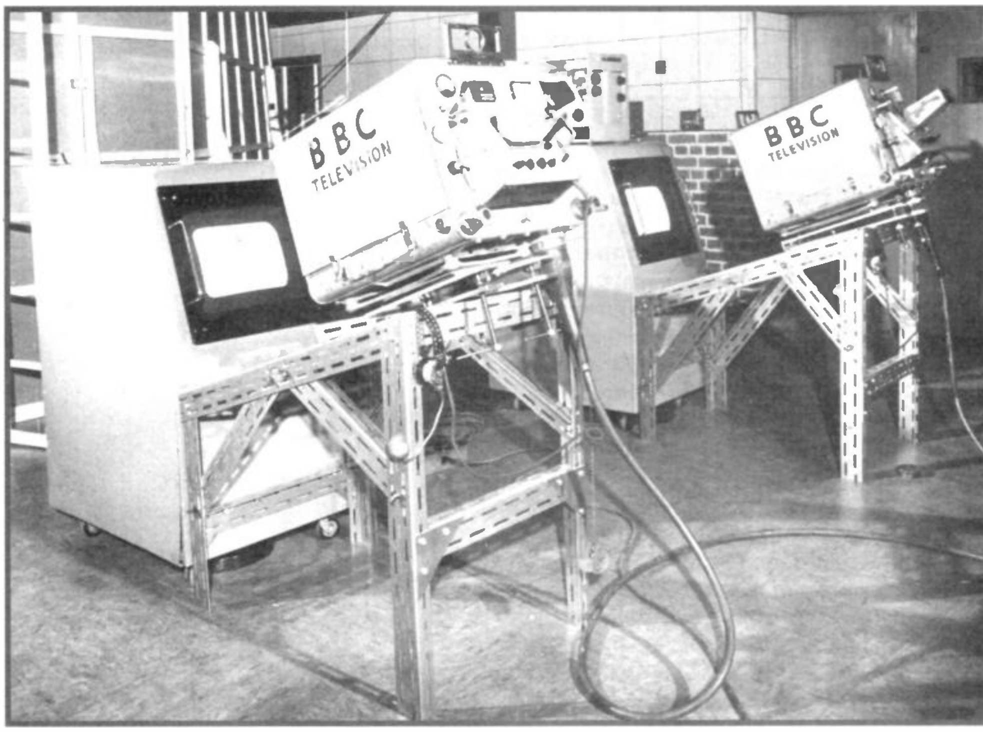
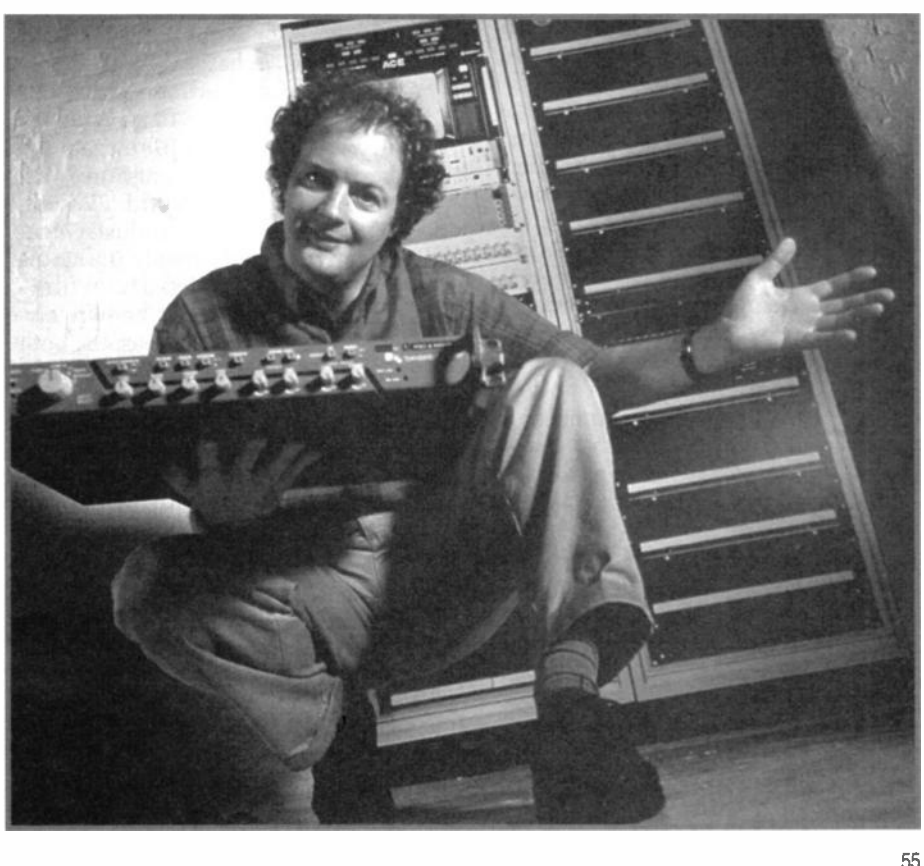


Figure 1. Linear interpolation at its worst: Linear interpolation builds output pictures by taking the weighted average of adjacent input fields. In this example, note that the output is derived chiefly by the contributions of fields in 2 and 3. If the motion content of the input is very high, it may exceed the limits of the linear interpolator, resulting in a smeared or juddery output.





Right: Photo 1. Early optical Standards conversion method using a monitor and camera. Used by Permission of BBC Archives.

Bottom right: Photo 2. The ACE (two 6ft. racks) in the background, and the Kudos CVR45 for high-end standards conversion and HDTV applications. Used by Permission of Snell & Wilcox Ltd.

tures each made up of 525 lines refreshed 60 times a second (although each new picture or field contains only half the information. This is because of the way in which a TV picture is made up from alternate lines taken from each field, to reduce transmission spectrum bandwidth). But to convert from NTSC to PAL (see Alphabet Soup), we need to create pictures of 625 lines but only 50 of them per second. On the one hand, for each instantaneous image we have to 'stretch' the picture material to 'invent' another hundred, lines, yet at the same time we must throw away ten pictures (technically fields, see panel Apology) in every second.

This is not at all easy, and up to now has always involved a compromise, producing either soft and smooth pictures or sharp and juddery ones. We can achieve the first task of creating images by repeating some picture material according to a predetermined mathematical formula, the process is known as *interpolation*, but when we discard images it is little wonder that what remains can look jerky. Figure 1 shows linear interpolation at its worst. That said, in practice the results are so successful that viewers seldom if ever notice the trickery that is going on. Converting pictures in the other direction, from PAL or SECAM to NTSC has similar problems in reverse: the number of lines must be reduced, compressing detail, but the 50 images per second must be expanded to 60, which again calls for complex mathematics.

Linear interpolation is a very artificial process. It works by selecting and storing some of the lines making up a television picture and then repeating them. To reduce the errors in this sampling process, the converter should take a weighted average, ideally over four fields. Used carefully, the technique can produce pretty good pictures, but they still remain an approximation and to disguise this, some converters soften the detail in moving images and sharpen still images in proportion to the speed of movement on the screen.

EARLY DAYS

Much of the early work on standards conversion was done in Britain, first with optical converters (camera pointing at monitor, see Photo 1), then analogue electronic and finally digital electronic. The IBA's DICE was the first digital converter, followed by the BBC's ACE in the early 1980s. ACE was the innovator of the linear interpolation process and nearly every electronics standards converter designed anywhere in the world since then is based on the principles defined by ACE. Indeed, the vast majority of converters in use today use this principle. Photo 2 shows the ACE in the background with the Kudos CVR45 in the foreground.

Linear interpolation is not the ultimate solution, however, and in these days of rising viewer expectations, and highly advanced computer graphics and image technologies, its defects such as spurious effects start to show. These *artefacts*, as they are known, become particularly intrusive in footage containing a high degree of motion, such as news or sports, and the linear interpolation technique just cannot keep pace. For that reason, broadcasters like Channel Four set higher standards and no longer accept these linear interpolation conversions for broadcast.

ALTERNATIVE MEDICINE

To overcome these limitations designers looked to an alternative process to eliminate the judder and blurring. They found the answer in *motion estimation* or *motion prediction*, which uses powerful computer processing to actually create new images for the intervening periods based on the source information. In other words the aim of motion estimation is to measure every pixel

Right: Photo 3. The Alchemist Universal Standards Converter with Ph.C. Used by Permission of Snell & Wilcox Ltd.

(picture element) in an input scene to determine where it is going and how fast. The corresponding scene can then be created in terms of the output television standard. Clearly far more processing power is necessary, which means the cost is significantly higher than for the simpler linear interpolation converters. Moreover, whilst the obvious defects of the linear interpolator converters are eliminated, some more subtle visual effects may be noticed by some viewers in the same way as an expert ear can detect the differences when listening to the same recording with two different types of loudspeaker. Processing images for standards conversion is, according to the experts, still more of an art than a science.

REVERSE TREND

As an art, it is a field in which European companies excel even to the extent of a brain drain in reverse whereby standards conversion experts worldwide are coming to European firms. Arguably the most sophisticated motion compensation technology developed is the 10-bit digital phase-correlated technique embodied in the Alchemist converter, (see Photo 3), made by Snell & Wilcox, a British firm. For the broadcast industry this is a major breakthrough and according to the company's Group Marketing Manager, Joe Zaller, it's as significant as when digital videotape recorders enabled broadcasters to make multi-generation edits without picture degradation.

MOTION PICTURES

Phase correlation (Ph.C) is a two-stage process. The first stage involving the Fourier Transform of the scene is a method of taking a broad look at a scene and estimating the motion it contains. The results from this are then applied to a second process which considers which of the observed motions applies to each pixel of the picture. Using Fourier Transforms to process video is analogous to using logarithms to multiply numbers, it cuts down the amount of calculation required. The frequency spectra of two fields of video are obtained using Fourier Transforms and the phase differences of their two-dimensional spectrum are used to estimate motion.

INTO THE EQUATION

So far we have only looked at the mechanics of translating picture information but colour comes into the equation as well. Because there are three fundamental, colour, coding systems, PAL, SECAM and NTSC, the colour information in a source picture must be analysed as well and recreated in the different system of the destination format. Compared with motion prediction and estimation, this is a relatively minor task, however.

When it comes to counting the cost, you can start as low as a few hundred pounds. Aiwa has a very basic standards-converting VHS recorder for around £400, whilst four times that price will buy you Panasonic's W1 world machine which handles every television standard currently used. For professional use the cost of ownership ranges from as low as £5,000 for minimum-specification machines to between £80,000 and £100,000 for top-end, no compromise broadcast machines. Programme makers should not be looking at either of these extremes, however, and will find very adequate machines in the £40,000 price bracket. An alternative is to take work to a bureau; facilities' houses will carry out this work for around £80 an hour plus normal VTR charges, whilst for the consumer market there are numerous firms charging around £15 an hour.

Will we ever be able to relegate the standards converters to a museum? Will there ever be a single world TV standard? Yes, and no. Many industry cynics will tell you there already is a single universal standard, called 35mm film - it is compatible with every known television system. For many reasons, both technical and economic, a single electronic television broadcast standard is less likely, even if a universal digital recording standard is agreed.

Ultimately images, those of film for instance, could be stored digitally in the form of descriptions of each frame and the information then read out and processed for television broadcasting in a number of ways. The snag here, as with a notional universal digital standards converter, is the sheer amount of computing power necessary and the problem of retrieving this huge bulk of data sufficiently rapidly. Suffice to say that with current technology neither is a realistic proposition. In the meantime, however, we should live with today's technology, which is capable of results which satisfy all but the most fastidious of viewers.

ALPHABET SOUP FOR ENGINEERS

Most people are happy enough with PAL, SECAM and NTSC but for the sake of completeness, these abbreviations are described here:

NTSC National Television Standards Committee (or Never Twice the Same Colour). Developed in the USA. Used in the USA, its dependencies and Japan.

SECAM Sequence à Memoire (or System Essentially Contrary to the American Method). Developed in France and used there, in Russia and countries formerly influenced by them, and the Middle East.

PAL Phase Alternate Line (or Perfection At Last). Developed in Germany and used in all other parts of the world.

These are the three basic systems used throughout the world, whilst variants known as PAL-M and PAL-N are used in South America. In addition some hybrid systems (not broadcast) are used to simplify the process of video recording, such as NTSC 4·43 (NTSC using a subcarrier of 4·43MHz instead of 3·58MHz) and Middle-Eastern SECAM (MESECAM or Saudi SECAM), a simplified method of recording SECAM on domestic VHS machines.

APOLOGY TO TECHIES

The explanations in this article do take a few liberties in order to keep things simple. Because of interlacing, television pictures are made up of 50 (or 60) *half* images and not every line in the television picture contains visual information. But if you already know that, you shouldn't be reading this article.

STANDARDS GALORE

Why do television standards differ, though? If we can standardise sound broadcasting (well, more or less), why not television as well? Historical accident is the main reason, and in the beginning few people thought international programme exchange was either likely or possible.

Strangely enough, the frequency of mains electricity has a major influence on television standards and in this respect North America has differed from Europe since the early days. Television depends on light, often artificial light, and this has a direct bearing on the choice of picture repetition frequency. You probably know this as the field rate or frame rate according to your own leanings or the refresh rate if you are a computer person. In electronic television this frequency has always been the same as the mains frequency, either 50 or 60Hz according to country, for two very good reasons. Studio lighting generally uses alternating current lamps and if these were not synchronised with the field frequency, an unwelcome strobe effect could appear on TV pictures. Secondly, in days gone by, the smoothing of power supply circuits in home TV receivers was not as good as it is today and mains ripple superimposed on the DC could cause visual interference. If the picture was locked to the mains frequency, this interference would at least be static on the screen and thus less obtrusive.

Having determined our vertical scan rate, we now need to choose a horizontal scanning rate which will produce the degree of picture detail required. This is always a compromise because high definition displays are more complex and expensive than simpler ones and occupy more bandwidth in the radio spectrum. Nowadays countries using 50Hz electricity have pictures made up of 625 lines, and 60Hz countries (much of America and Japan for instance) use 525 lines.

To add to the complications three different and incompatible colour systems have developed; each was said to be an improvement on the previous scheme but in truth the justification for the variation was more political and commercial than technical. Certainly, with today's equipment, TV sets using the original American NTSC system can give pictures every bit as good as any PAL or SECAM display, the more frequent picture repetition compensating for the reduced number of lines.

DAYS GONE BY

There was never a 'golden age' of compatible television, although all the early television systems used either 405, 441 or 455 lines which meant in practice that one receiver could display all programmes with a slight tweak of the Line Hold control. French television from the Eiffel Tower, was received regularly on the South Coast of Britain before the war, and afterwards it even interfered with the programmes from London in weak reception areas of the BBC. During the war the Germans in occupied Paris kept the 441-line television service running as a propaganda exercise and a special receiving station was set up near Beachy Head to eavesdrop on these programmes. Freak reception also enabled British television to be seen several times before the war in the USA on American 441-line sets readjusted.

All the early international TV programme exchanges relied on optical standards conversion; that was how the Coronation was shown in Europe and around the world in 1953, and how Eurovision started a year later. A television camera working on one line standard viewed the screen of a high-quality monitor of the other standard. Results were very good, all considered.

Dear Editor

AIR YOUR VIEWS

S·T·A·R L·E·T·T·E·R

In this issue Mr H. P. Brannen, of Newcastle-upon-Tyne, wins the Star Letter award of a Maplin £5 Gift Token for his letter concerning Engine Management Systems.

Engine Management Systems

Dear Editor,

On the subject of automotive amnesia (Air Your Views May & June issues) – Whilst some engine management systems can lose data from their memories when power is disconnected (or from the battery going flat), which will affect engine performance and idle conditions, I have never come across (to date) a vehicle which does not start after rectifying the battery fault. Mr Mulvana (June issue) points out that he had disconnected his battery and, on reconnection, the ECU releamt the engine settings. That is correct for most, but not all engine management systems. If you have a Rover 820E SPI (Single Point Injection) and you disconnect the battery, the only way to get your engine running perfectly again is to visit your local dealer and have the ECU reprogrammed.

A temporary setting can be achieved with the following procedure:

1. Make sure all electrical circuits are switched off.
2. Run engine until cooling fan switches on.
3. When cooling fan stops switch off engine.
4. Switch ignition on, but do not start engine.
5. Depress accelerator pedal at least half its travel, then release it five times.
6. Wait until the high temperature warning light starts to flash.
7. As soon as the high engine temperature warning light stops flashing, start the engine and allow it to idle. Do not depress the accelerator pedal when starting the engine, or turn ignition off before starting engine, or switch on any electrical circuit, as this will terminate the calibration procedure This also applies to the interior light, so keep the doors closed during the calibration process.
8. Allow engine to idle for 2-3 minutes until warning light flashes again, indicating calibration is complete.

On Ford vehicles fitted with the EEC-IV Enhanced ECU, the self-learning mode is entered automatically when power is reconnected and the engine started. Although Ford systems appear to releam the engine by simply starting the engine and driving the vehicle, the procedure below is the correct procedure, as advised by Ford, for the ECU to releam the optimum settings for your engine.

1. Start the engine and allow it to idle for 3 minutes.
2. When the engine has reached normal operating temperature, increase engine speed to 1200 rpm and maintain this speed for a further 2 minutes.
3. Drive vehicle for approximately 5 miles of varied driving after which the ECU will have completed its learning of idle and drive values.

Engine settings are not all that is stored by the ECU; some also store fault codes relating to any faults that it may detect in sensors or actuators in the injection or ignition system. These codes help in the diagnosis of faults.

The Limp Home Mode, referred to by Mr Mulvana, has no effect over the engine settings stored in the ECU. It is more correctly referred to as LOS (Limited Operations Strategy). All this means is that, in the event of a sensor or actuator failure, the ECU will use a set of predetermined parameters for that particular sensor, which should allow you to at least get to a garage and have it repaired.

ABS does indeed stand for Anti-Lock Braking System. I think you will find that Anti-Blockier System is probably German.

Waste in Photocopier Industry

Dear Sir,

I changed my photocopier recently for a machine capable of printing on A3 paper, the old one, a Sharp SF-740, being A4/B4 only. I wanted to sell the old one, which is in perfect working order. Before selling, I checked to see if toner was available, and was told that it was not.

I made various enquiries in order to find some, all to no avail. I was also told that some machines are no longer supported in respect of toner after they are only five years old. One copier shop told me that they throw away three perfectly good machines each week as supplies are no longer available. The parts are not interchangeable, and they are just thrown in the skip. Maybe electronics hobbyists should visit their local copier shops and try and buy these for a few pounds for the parts; many contain motors, switches, power supplies and even microprocessors, not to mention lenses, prisms and mirrors.

All copiers, these days, work on the electrostatic principle, using a black fusible toner. The image is optically transferred to a drum which attracts particles of charged toner, according to the density of each point. This is then transferred by pressure onto the sheet of paper, where it is fixed by heat, fusing the toner in place. Would it be possible to modify machine A to work with toner intended for machine B by altering the electrostatic charges on the wires? Alternatively, an agency could possibly be set up to supply different toners for different obsolete machines.

It does seem absurd that, in this day and age where we are so environmentally conscious, we are willing to discard perfectly good machines that have an environmental cost in their manufacture. Hopefully, some of your readers may have ideas on how this situation can be remedied.

John de Rivaz, Cornwall.

Unfortunately, the matter is a lot more complicated than simply altering the electrostatic charges present in photocopiers. Toners vary greatly between manufacturers – some machines even use liquid toners! All toners are polymer based, and this, along with toner particle size, differs between manufacturers. Toners also contain 'developers' to aid with attracting particles to the drum; iron dust is commonly used, but again, developers vary according to manufacturer. I agree that it does seem to be a terrible waste; would any readers in the photocopier industry care to comment on this one?

Global Positioning Systems

Dear Editor,

I have been a regular reader and subscriber to *Electronics – The Maplin Magazine* for several years, and have always found it most interesting with its wide-ranging technical disciplines, and projects to build, suiting both beginners and experienced constructors. As a retired professional electronics engineer, well into my seventies, I still enjoy design and construction. I have built several items of test equipment for use in development of my designs, covering DC, to light! Have your Project Team considered the development of a GPS (Global Positioning System) receiver? This would be an ambitious project, although now that some GPS ICs are available from GEC-Plessey, it looks a possibility for an experienced constructor. It would need built-in computer chips to perform the calculations required to output the GPS data as latitude/longitude (or O.S. grid refs) on an LCD.

However, I doubt that the receiver would be any more complex than, say, the NICAM TV System Project which appeared in *Electronics* No.38 in 1990.

Regarding cost, a commercially available receiver made in the USA and marketed by Trimble UK, sells at around £550. I would think that a receiver with the simplest possible function could be produced in kit form, for home construction, at less than half that price. It might have to be somewhat larger than the commercial small hand-held receivers currently available, but could still be sufficiently portable for mobile use.

Maybe you feel that such a project would only be of minority interest, and not a commercial proposition for Maplin. I would like to know your opinions.

J. R. Muddell, Malvern, Worcs.

Glad that you enjoy reading the magazine.

We have mentioned the idea of a GPS to the development team in the lab. Nowadays, a commercially available GPS can be purchased for around £200 to £300, and the price is falling all the time. It is unlikely that a home-built version would be any cheaper.

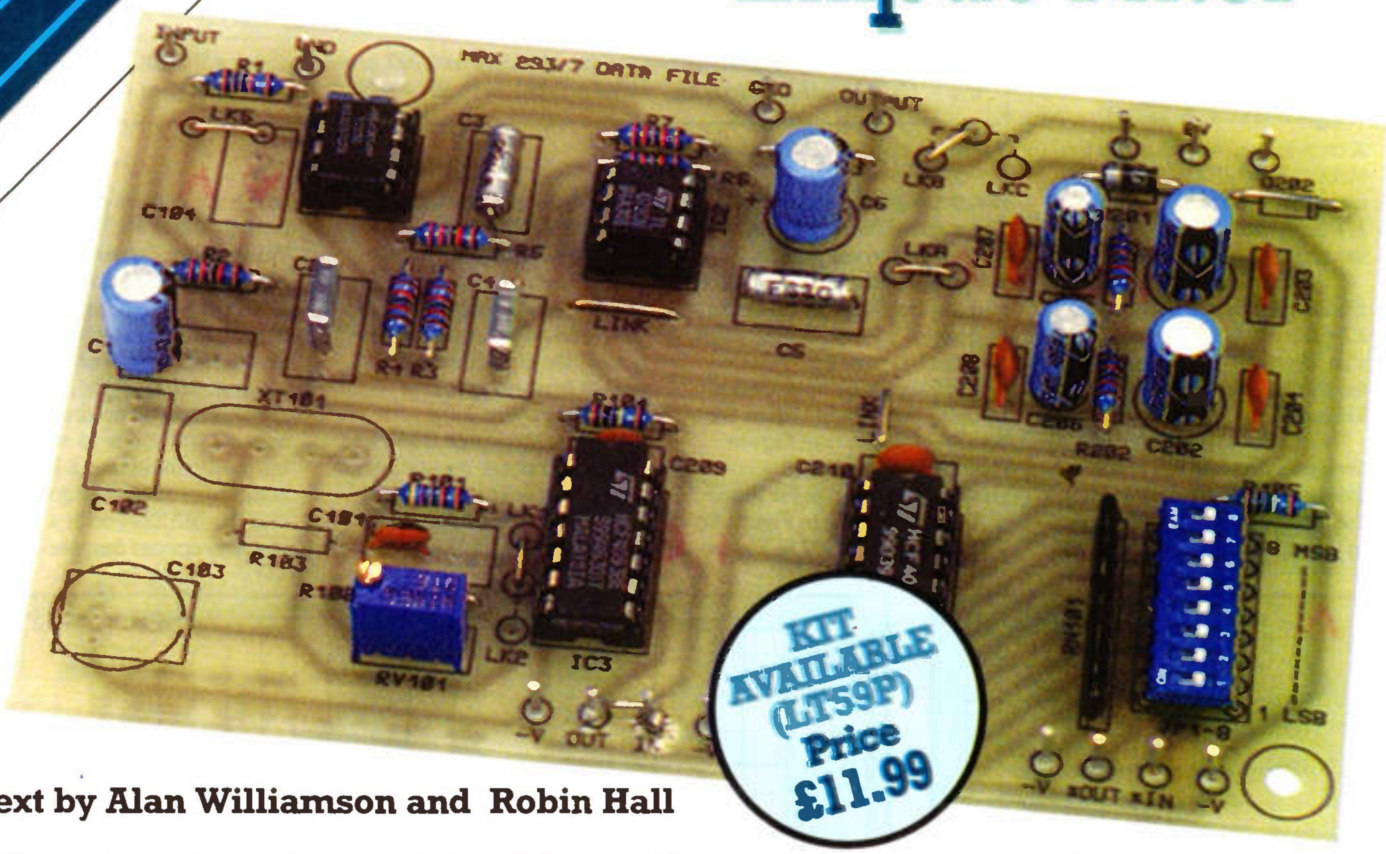
'Data Files' are intended as 'building blocks' for constructors to experiment with, and the components suggested provide a good starting point for further development.

DATA FILE

2 PROJECT RATING

MAX293/297 Elliptic Filter

The assembled PCB.



KIT AVAILABLE (LT59P) Price £11.99

Text by Alan Williamson and Robin Hall

FEATURES

* 8th-order elliptic filters
* Internal or external clock
* Operates with a single +5V supply or dual ±5V supplies
* External op amp for clock noise filtering

APPLICATIONS

* Voice and data signal filtering

Specification

Supply voltage:	+5V DC
Quiescent current:	1·1mA
Operating current:	10·3mA
Onboard oscillator range	
Minimum frequency:	8kHz
Maximum frequency:	1·2MHz

The MAX293 or 297 Integrated Circuits (ICs) have been developed for a number of audio or data applications that require easy to use low-pass filters. Both ICs contain 8th-order (eight-pole) (24dB), lowpass, elliptic, switched-capacitor filters, with an uncommitted op amp and internal oscillator. This circuitry is contained in an 8-pin DIL (Dual-In-Line) package as shown in Figure 1a. The MAX293 is easily set up from 0·1Hz to 25kHz and the MAX297 from 0·1 to 50kHz.

The MAX293/297 ICs have a 1·5 transition ratio providing sharp rolloff and −80dB of stopband rejection. The filters have fixed responses, so that selecting the clock frequency controls the filters corner frequency. The clock frequency being generated from either internal or external oscillators.

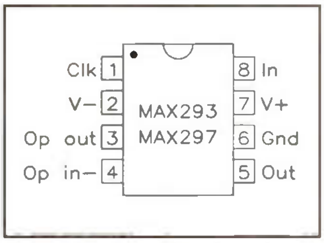


Figure 1(a). MAX293/297 pin connections.

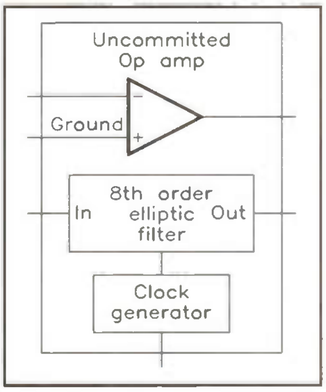


Figure 1(b). MAX293/297 internal diagram.

An internal block diagram of the MAX293 or 297 IC is given in Figure 1b. The absolute maximum ratings and electrical characteristics of the IC are detailed in Tables 1a and 1b. Note: Do not exceed these absolute maximum ratings.

The MAX293/297 Elliptic Switched-capacitor Filter

A choice is given whether the MAX293 or MAX297 ICs are used in the Data File, and are therefore included in the Optional Parts List.

The main differences are in the frequency range of each IC, plus clock frequencies. The identical pin connections for the ICs, are shown in Table 2.

The internal oscillator is set up to provide the clock frequency. Figure 2a shows the internal oscillator period in µs versus capacitance in nF which is applied to both ICs. The normalised oscillator frequency versus supply voltage is shown in Figure 2b, and the normalised oscillator frequency versus temperature shown in Figure 2c.

The frequency response of each IC is given in Figure 3a for the MAX293 and Figure 3b for the MAX297. The passband response for the MAX293 is shown in Figure 3c and for the MAX297 in Figure 3d, and the phase response for the MAX293 in Figure 3e and in Figure 3f for the MAX297.

Using an external clock, as provided as an option on the board, the supply voltage versus supply current is shown in Figure 4.

Typical harmonic distortion (THD) and noise versus input signal amplitude are shown in Figure 5a (MAX293), and Figure 5b (MAX297), with harmonic orders given for both in Table 3a. Refer to Table 3b for labels A & B, and Figures 5a and 5b for C & D, the labels explain the characteristics as obtained for various values of clock frequencies f_{CLK} (Hz).

The MAX293 operates with a 100:1 clock to corner frequency ratio and a 25kHz maximum corner frequency, and the MAX297 with a 50:1 clock to corner frequency and

Characteristic	Value
Supply voltage	(+V to –V) 12V
Input voltage at any pin	(–V –0·3V) x Vin x (+V +0·3V)
Continuous power dissipation	727mW (derate 9·09mW/°C above 70°C)
Operating temperature range	0°C to +70°C
Storage temperature range	-65°C to 160°C
Lead temperature	(soldering 10 seconds) +300°C
Typical operating characteristics for the MAX293 and 297 are as follows: +V = 5V, –V = –5V, f_{CLK} = 100kHz (MAX293) or f_{CLK} = 50kHz (MAX297), TA = +25°C. Unless otherwise noted.	

Table 1a. Absolute maximum ratings.

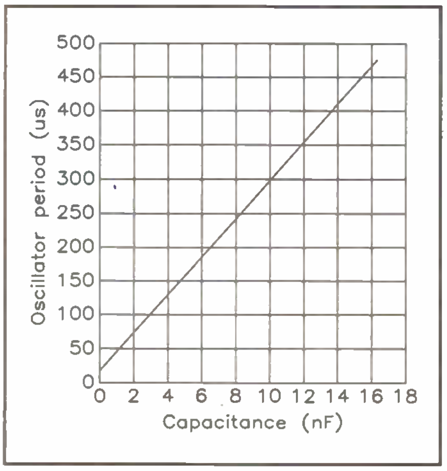


Figure 2(a). Internal oscillator period vs. capacitance value.

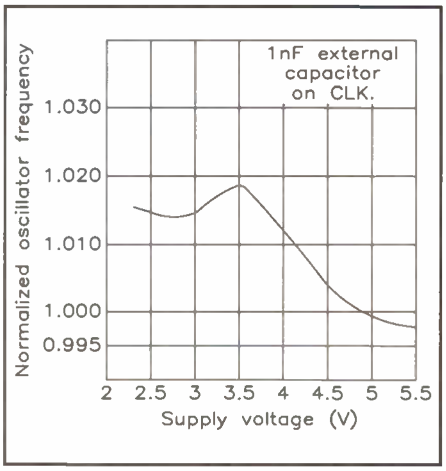


Figure 2(b). Internal oscillator frequency vs. supply voltage.

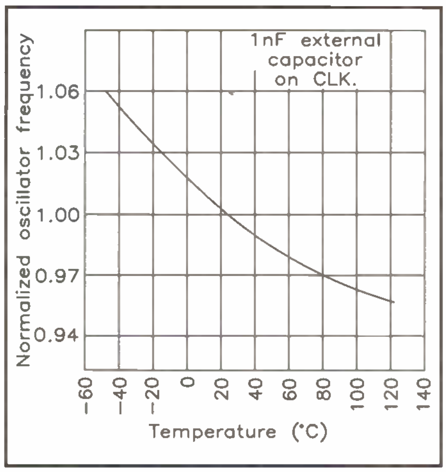


Figure 2(c). Internal oscillator frequency vs. temperature.

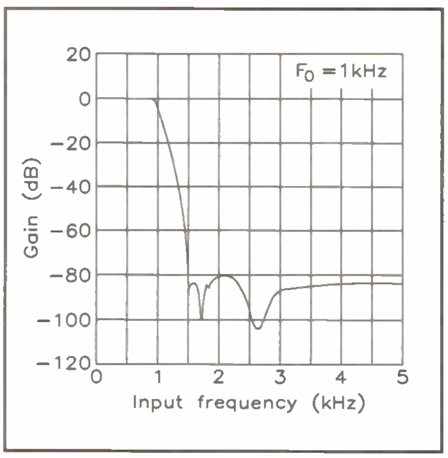


Figure 3(a). MAX293 frequency response.

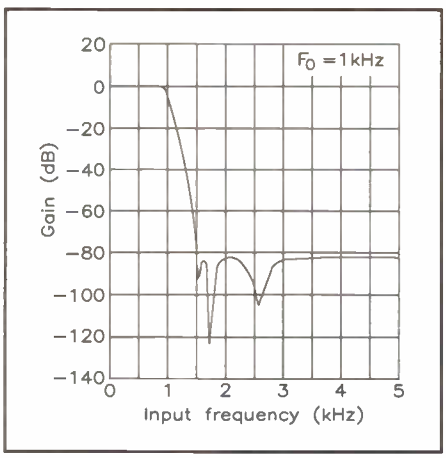


Figure 3(b). MAX297 frequency response.

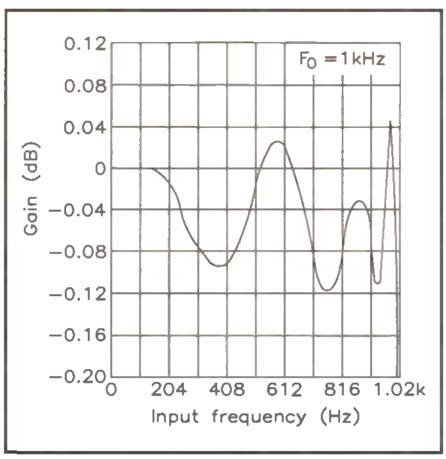


Figure 3(c). MAX293 pass band.

Parameter	Conditions		Minimum	Typical	Maximum	Units
Filter Characteristics						
Corner-Frequency Range	MAX293 MAX297			0·1 to 25k 0·1 to 50k		Hz
Clock to Corner Frequency Ratio	MAX293 MAX297			100:1 50:1		
Clock to Corner Frequency Tempco	MAX293			8		ppm/°C
	MAX297			4		
Insertion gain relative to DC gain (Note 1)	MAX293	f_{IN} = 0·381 F_o	0·12	−0·10	−0·17	dB
		f_{IN} = 0·594 F_o	0·12	0·02	−0·17	
		f_{IN} = 0·795 F_o	0·12	−0·11	−0·17	
		f_{IN} = 0·866 F_o	0·12	−0·03	−0·17	
		f_{IN} = 0·939 F_o	0·12	−0·11	−0·17	
		f_{IN} = 0·993 F_o	0·12	0·04	−0·17	
		f_{IN} = 1·000 F_o	0·12	0·01	−0·17	
		f_{IN} = 1·500 F_o	−75	−78		
		f_{IN} = 1·610 F_o	−80	−87		
		f_{IN} = 2·020 F_o	−80	−84		
		f_{IN} = 4·020 F_o	−80	−84		
	MAX297	f_{IN} = 0·377 F_o	0·10	−0·11	−0·17	dB
		f_{IN} = 0·591 F_o	0·10	0·03	−0·17	
		f_{IN} = 0·754 F_o	0·10	−0·12	−0·17	
		f_{IN} = 0·873 F_o	0·10	0·02	−0·17	
		f_{IN} = 0·944 F_o	0·10	−0·07	−0·17	
		f_{IN} = 0·996 F_o	0·20	0·11	−0·17	
		f_{IN} = 1·000 F_o	0·20	0·10	−0·17	
		f_{IN} = 1·500 F_o	−75	−79		
		f_{IN} = 1·610 F_o	−80	−87		
		f_{IN} = 2·020 F_o	−80	−84		
		f_{IN} = 4·000 F_o	−80	−85		
Passband ripple	MAX293			0·15		dB
	MAX297			0·23		
Output DC swing			±4			V
Output offset voltage	IN = GND			±150	±400	mV
DC insertion gain with output offset remove			−0·15	±0·01	0·15	dB
THD + noise	T_A = +25°C	MAX293		−71		dB
		MAX297		−77		
Clock feedthrough	T_A = +25°C			5·0		mV Pk-to-Pk
Output drive capability			20	10		kΩ
Clock						
Internal oscillator Frequency	C_{OSC} = 1000pF		29	35	43	kHz
Internal oscillator current source/sink	V_{CLK} = 0V or 5V			±70	±120	µA
Clock input (Note 2) High			4·0			V
Clock input (Note 2) Low					1·0	
Uncommitted Operational Amplifier						
Input offset voltage				±10	±50	mV
Output drive capability			20	10		kΩ
Output DC swing			±4			V
Gain-bandwidth product				4		MHz
Power Requirements						
Supply voltage	Dual		±2·375		−5·5	V
	Single	−V = 0V, GND = +V/2	4·75		11·0	
Supply current		+V = 5V, −V = −5V, V_{CLK} = 0 to 5V		15·0	22·0	mA
		+V = 2·375V, −V = 2·375V, V_{CLK} = −2 to 2V		7·0	12·0	

Note 1: Test frequencies selected at ripple peaks and troughs.
Note 2: Guaranteed by design.

Table 1b. Electrical Characteristics.

Pin	Name	Function
1	CLK	Clock input – use internal or external
2	–V	Negative supply pin, dual supplies: –2·375 to -5·5V, single supply: –V = 0V
3	Op IN	Uncommitted op amp output
4	Op OUT	Inverting input to the uncommitted op amp. The noninverting input of the op amp is internally tied to ground
5	OUT	Filter output
6	GND	Ground, in single supply applications, GND must be biased to half the supply voltage
7	+V	Positive supply pin, Dual supplies: +2·375 to +5·5V, Single supply: +4·75 to +11·0V
8	IN	Filter input

Table 2. Pin connections.

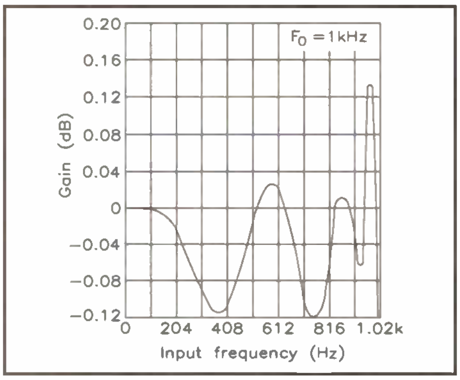


Figure 3(d). MAX297 pass band.

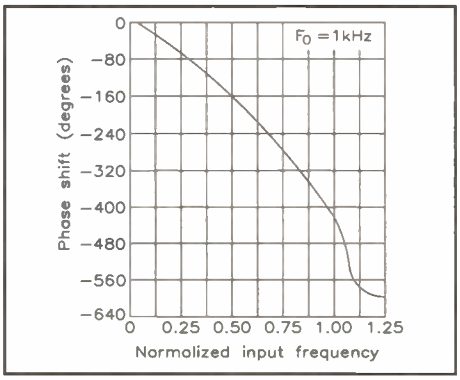


Figure 3(e). MAX293 phase response.

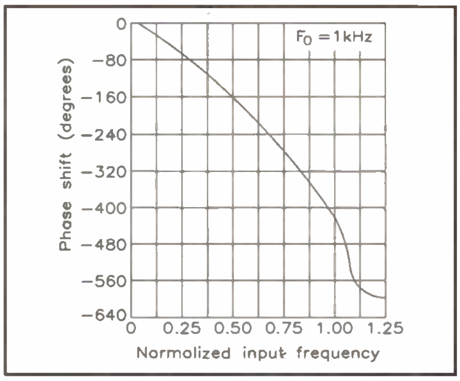


Figure 3(f). MAX297 phase response.

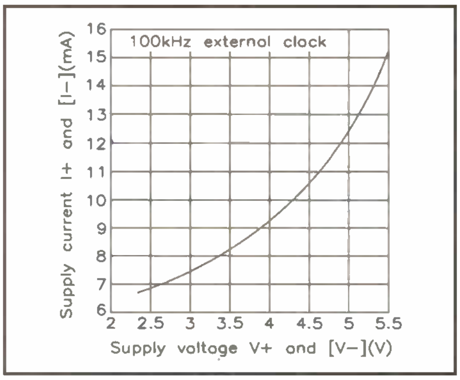


Figure 4. Supply current vs. supply voltage of the MAX293/297 ICs.

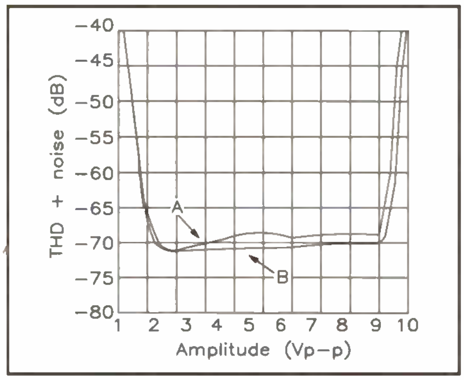


Figure 5(a). MAX293 THD and noise graph.

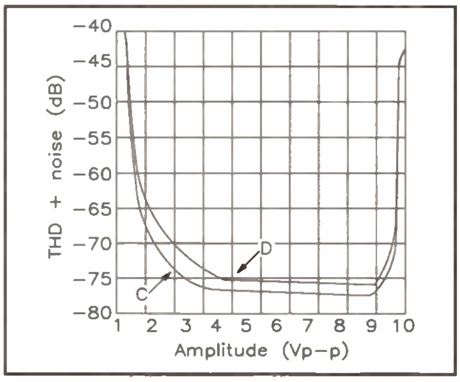


Figure 5(b). MAX297 THD and noise graph.

Filter	Harmonic			
	2nd	3rd	4th	5th
MAX293	70	90	88	92
MAX297	84	89	93	99

Table 3a. Typical harmonic distortion (dB).

Label	f_{CLK} (Hz)	F_O (kHz)	Input Freq. (Hz)	Measurement Bandwidth (kHz)
A	200k	2	200	30
B	1M	10	1k	80
C	200k	4	400	30
D	1M	20	2k	80
(+V = 5V, -V = –5V, RLOAD = 20kΩ, TA = +25°C, unless otherwise noted.)				

Table 3b. Typical clock frequencies f_{CLK}(Hz)

a 50kHz maximum corner frequency. The corner frequency is defined as the point where the filter output attenuation falls just below the passband ripple and is shown in Figure 6. The passband ripple for the MAX293 is typically 0·15dB, and for the MAX297 the passband ripple is typically 0·23dB.

Circuit Description

A block diagram for the MAX293/297 Elliptic Filter Data File is shown in Figure 7, and Figure 8 shows the circuit diagram, these will assist the reader in understanding the circuit.

The PSU

Diodes D201 and D202 are for reverse polarity protection. Resistors R201/2 form a potential divider to provide a

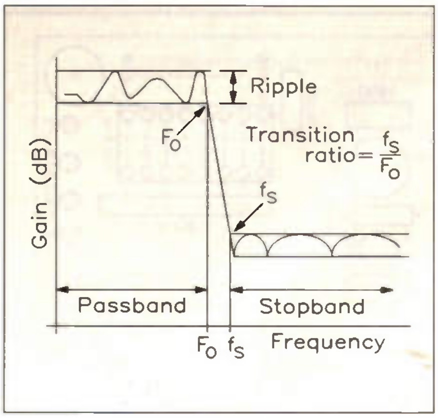


Figure 6. Typical filter response.

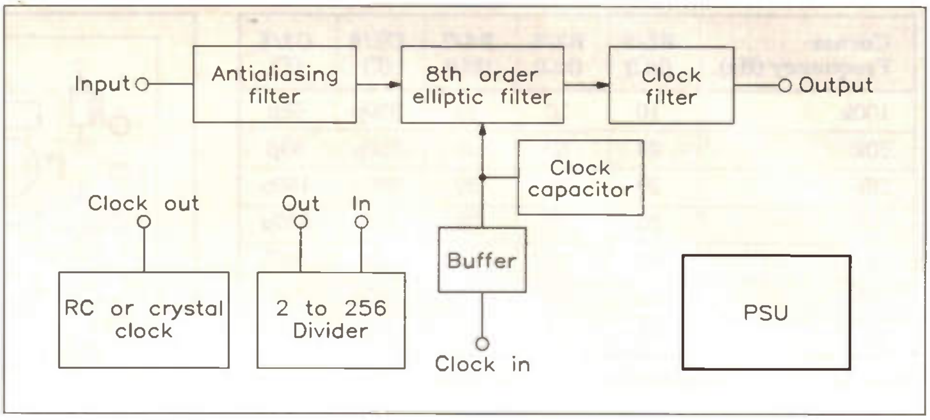


Figure 7. MAX293/297 block diagram.

voltage reference for the half supply generator op amp IC2b. The resistors are decoupled by capacitors C201/2, which also provide the main decoupling of the circuit.

The capacitors C205/6 decouple the output of the half supply generator; the capacitors improve the AC performance. The capacitors C203/4/7/8 provide high-frequency decoupling.

The links A, B & C, allow several options; link A should be fitted only if a single supply is used (do not fit link A, in the dual supply application).

Fit link B or C if a dual supply is used.

Link B is used to reference the input and output ground (GND) connections to V_{ref} (half supply) or 0V in symmetrical supply applications, and link C will reference the ground (GND) connections to –V.

The Clock

The clock is based around a 4093 which is a two-input quad Schmitt NAND gate. Two clock configurations are possible; a two-gate RC oscillator (IC3a and IC3b) plus buffer (IC3c) for non critical applications; or, a single gate crystal oscillator (IC3b) plus

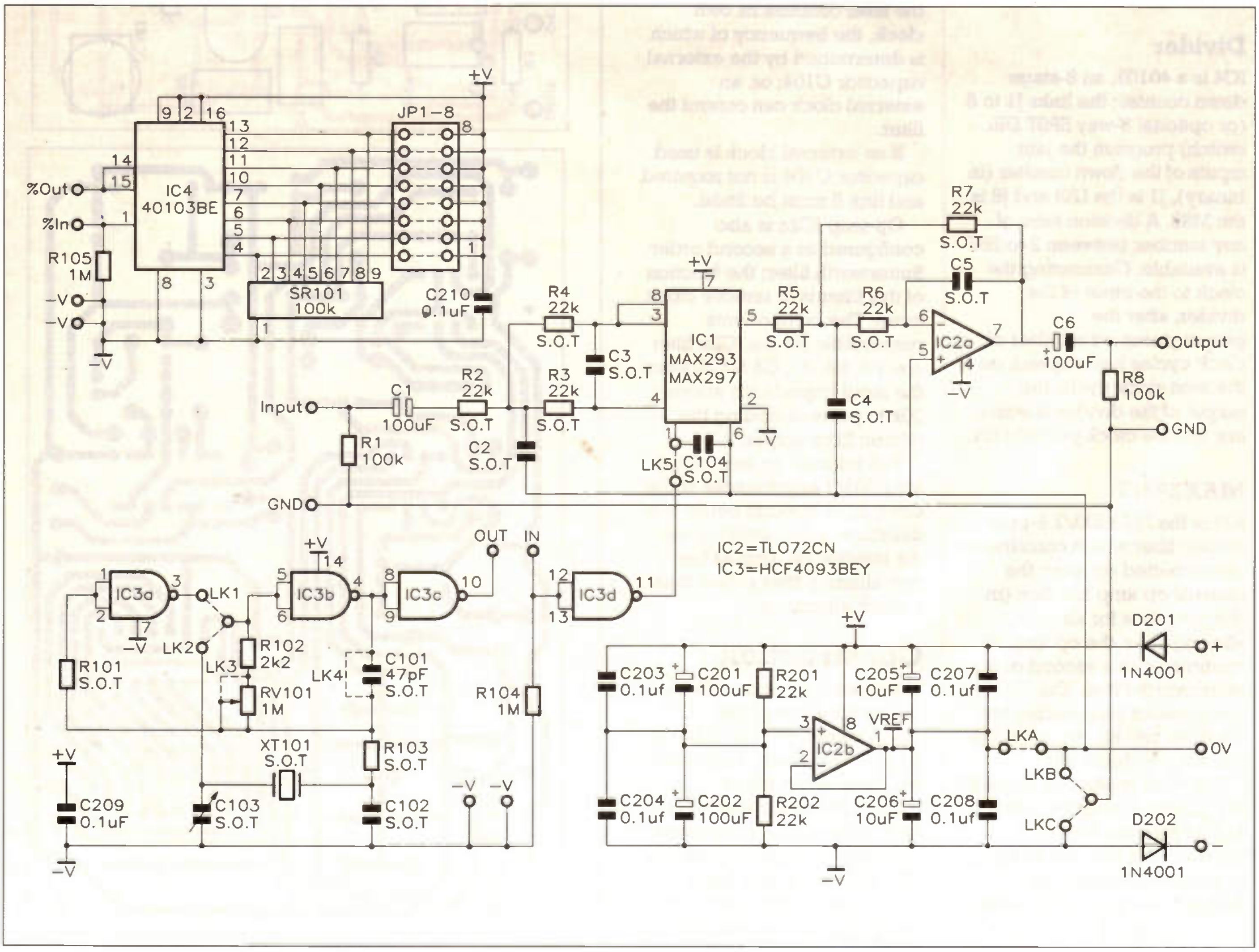


Figure 8. MAX293/297 circuit diagram.

Corner Frequency (Hz)	R2/5 (kΩ)	R3/6 (kΩ)	R4/7 (kΩ)	C2/4 (F)	C3/5 (F)
100k	10	10	10	330p	68p
50k	20	20	20	330p	68p
25k	20	20	20	680p	150p
10k	22	22	22	1n5	330p
1k	22	22	22	15n	3p3
100	22	22	22	150n	33n
10	22	22	22	1µ5	330n

Table 4a. Typical component values for 2nd order Butterworth filters.

Elliptic corner frequency (Hz)	Butterworth corner frequency (Hz)	C2/4 (F)	C3/5 (F)
100	500	33n	6n8
1k	5k	3n3	680p
15k	75k	1n	220p

Table 4b. Typical component values for DATA FILE.

buffer (IC3c). The IC3d gate is to provide buffering for external clocks.

Divider

IC4 is a 40103, an 8-stage down counter; the links J1 to 8 (or optional 8-way SPST DIL switch) program the jam inputs of the down counter (in binary), J1 is the LSB and J8 is the MSB. A division ratio of any number between 2 to 256 is available. Connecting the clock to the input of the divider, after the preprogrammed number of clock cycles has elapsed, on the next clock cycle, the output of the divider is active low for one clock period only.

MAX293/7

IC1 is the MAX293/7 8-pole elliptic filter which contains an uncommitted op amp; the internal op amp function (in this circuit) is for an anti-aliasing filter, the op amp is configured as a second order Butterworth Filter. The components responsible for the filter are: R2, R3, R4, C2 & C3, refer to Table 4a.

The filter frequency should be chosen at least 2·5 times higher than the corner frequency of the elliptic filter; to avoid problems with component tolerances, a filter frequency five times higher than the corner frequency is recommended.

The elliptic filter's corner frequency is dynamically adjusted by the clock speed; the filter contains its own clock, the frequency of which is determined by the external capacitor C104; or, an external clock can control the filter.

If an external clock is used, capacitor C104 is not required and link 5 must be fitted.

Op amp IC2a is also configured as a second order Butterworth filter; the function of this filter is to remove clock noise. The components responsible for the IC2a filter are: R5, R6, R7, C4 & C5. Keep the input impedance above 20k to prevent loading the elliptic filter output.

The internal op amp of the MAX293/7 experiences some clock feed-through noise; it is, therefore, more useful to use the internal op amp as the anti-aliasing filter rather than a clock attenuator.

Construction

There are a number different values for some of the components, refer to Table 4b for the component values for the Butterworth filters.

Note: Some approximations have been made in selecting preferred component values. Where components have been marked with select on test (SOT), choose the values for the appropriate filter configuration.

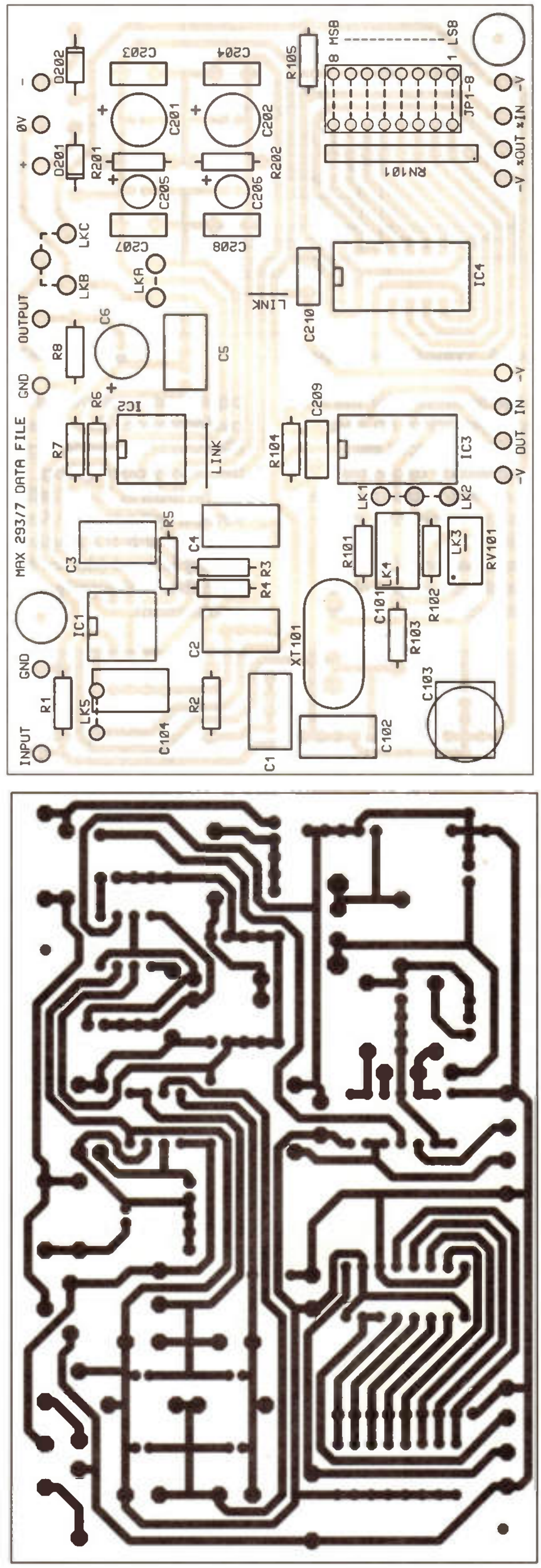


Figure 9. PCB legend and track.

The passband error caused by a 2nd order Butterworth filter is calculated using the following formula:

Gain error = $-10\log[1+(f/fc)^4]$dB

The value of the clock components depends on the type and speed of oscillator; the components and links fitted for each oscillator are as follows:

RC oscillator, Link 1, Link 5, R101, R102, RV101 & C101.

The approximate frequency is equal to $1 \div (2{\cdot}5 \times R102 \times C101)$.

To reduce the effect of the parallel capacitance of R101 (which slows the oscillator down), use the lowest value possible, minimum value = 2 x R102. The minimum value for R102 is 2k2, and the minimum value for C101 is 47pF. The R/C oscillator is adequate for frequencies up to 1MHz.

Crystal oscillator, Link 2, Link 3, Link 4, Link 5, R101, R102, R103, X101, C102 & C103. The frequency and the values of the oscillator components are determined by the crystal or resonator; as a guide, the nominal values are: R102, 100k to 1M; R103 2k2; C102 & C103, 0 or 20 to 30pF.

The nominal maximum frequency for CMOS is around 5MHz.

The PCB legend and track are shown in Figure 9. Construction is fairly straightforward. Begin with the smallest components first working up in size to the largest. Be careful to orientate correctly the polarised devices, i.e. diodes, electrolytics and ICs. The polarity of C1 depends upon the link B or C, if link B is fitted, orientate the (+) terminal of C1 towards the input pin.

Insert the ICs into their sockets last of all. Thoroughly check your work for misplaced components, solder whiskers bridges and dry joints. Finally, clean all the flux off the PCB using a suitable solvent.

The interwiring of the PCB is shown in Figure 10. Make sure that screened audio cable is used on both the audio input and output. A case is not supplied with the kit, but a suitable one can be found in the Maplin Catalogue.

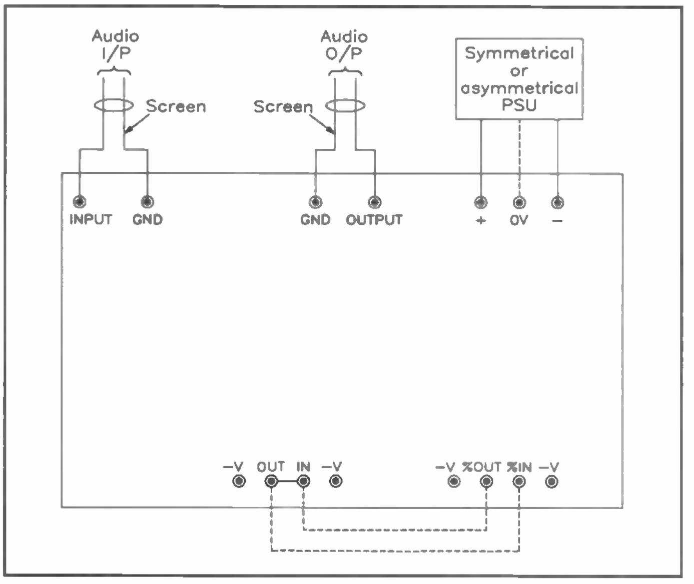


Figure 10. PCB connection diagram.

MAX293/7 ELLIPTIC FILTER PARTS LIST

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

R1,8	100k	2	(M100K)
R2-7	22k or SOT	6	(M22K)
R101	4k7 or SOT	1	(M4K7)
R101	27k or SOT	1	(M27K)
R101	100k or SOT	1	(M100K)
R101	470k or SOT	1	(M470K)
R101	2M2 or SOT	1	(M2M2)
R102	2k2	1	(M2K2)
R103	2k2 or SOT		
R104,105	1M	2	(M1M)
R201,202	22k	2	(M22K)
RV101	22-Turn Cermet 1MΩ	1	(UH28F)
SR101	100k	1	(RA32K)

CAPACITORS

C1,6, 201,202	100µF 25V Radial Electrolytic	4	(FF11M)
C2,4	1nF Polyester Layer or SOT	2	(WW22Y)
C2,4	3n3F Polyester Layer or SOT	2	(WW25C)
C2,4	33nF Polyester Layer or SOT	2	(WW35Q)
C3,5	220pF Polystyrene or SOT	2	(BX30H)
C3,5	680pF Polystyrene or SOT	2	(BX34M)
C3,5	6n8F Polyester Layer or SOT	2	(WW27E)
C101	47pF Metallised Ceramic or SOT	1	(WX52G)
C102	20pF to 30pF or SOT		
C103	5p5F to 65pF Trimmer or SOT		
C203,204, 207,208, 209,210	100nF 16V Miniature Ceramic Disc	6	(YR75S)
C205,206	10µF 50V Radial Electrolytic	2	(FF04E)

SEMICONDUCTORS

IC2	TL072CN	1	(RA68Y)
IC3	HCF4093BEY	1	(QW53H)
IC4	HCF40103BEY	1	(QW61R)
D201,202	1N4001	2	(QL73Q)
XT101	Crystal or Resonator SOT		

MISCELLANEOUS

Single-ended PCB Pin 1mm (0·04in.)	1 Pkt	(FL24B)
8-Pin DIL IC Socket	2	(BL17T)
14-Pin DIL IC Socket	1	(BL18U)
16-Pin DIL IC Socket	1	(BL19V)
PCB	1	(GH81C)
Instruction Leaflet	1	(XU78K)
Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

IC1	MAX293	1	(AY41U)
IC1	MAX297	1	(AY42V)
	8-way DIL Slimline Switch	1	(QY70M)

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

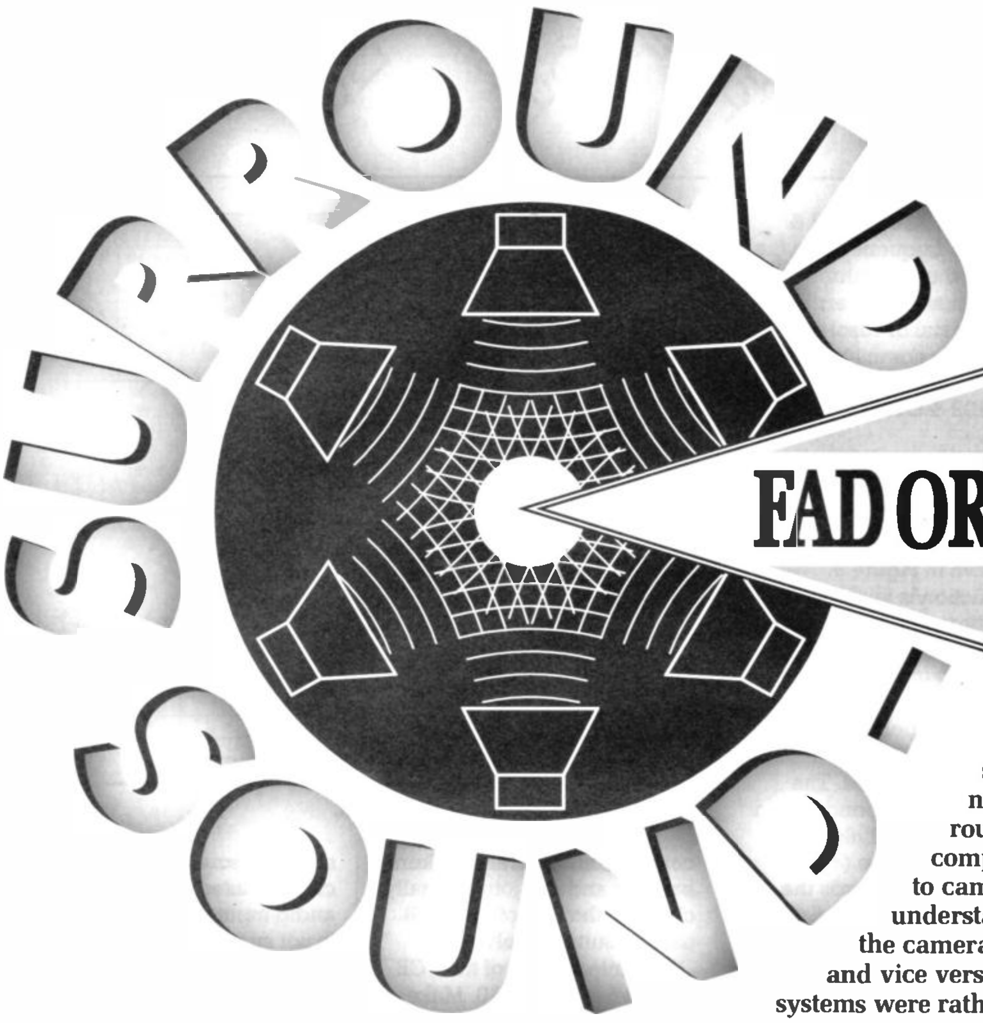
The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LT59P (MAX293/297 Elliptic Filter)
Price £11.99

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

The following new item (which is included in the kit) is also available separately, but is not shown in the 1994 Maplin Catalogue.

MAX293/297 Elliptic Filter PCB
Order As GH81C Price £3.99



Part Two Multichannel and Ambisonics

FAD OR FANCY?

The commercial exploitation of surround sound in the 1970s failed because the most heavily promoted systems were based on an incorrect notion of how we hear sounds all round us. The situation could be compared with what would happen to camcorders if the designers did not understand human colour vision, so that the cameras recorded all blue objects as yellow and vice versa, except that the defects in the audio systems were rather more subtle, of course.

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

MORE OF THE SAME

The trouble was that the problem looked too simple. Two-channel stereo works quite well, even with the loudspeakers at 45° angles to the listener's straight ahead axis. So, people reasoned, to get surround sound, all you have to do is to add two more loudspeakers in a square layout and feed each adjacent pair with stereo signals. This means that four separate signals are necessary, but in the USA this was not a problem, because 4-track and 8-track (Lear-Jet system) tape cartridge players were available.

The original recordings were mixed down to four-track master tapes, and in no uncertain terms it begged the question of accuracy of reproduction when comparing each playback system with the reproduction of the four-track master through the square of four loudspeakers. What should have been done, of course, was to compare the playback system output with the original sound in the recording studio. But this was clearly far too difficult for classical music, and often impossible for popular music, close miked or having electronic instruments fed into the mixer via DI (Direct Inject) boxes, so that there was no 'original sound' to compare.

Because of this fatal flaw in the evaluation, the defects of the various matrix systems (SQ, QS, RM, etc.) used to condense the original four channels into the two available on vinyl discs and FM stereo were not understood by their promoters. It was, however, sufficiently evident to audiophiles to prevent any of the systems being commercially successful; a situation complicated by the large number of incompatible systems on offer. Furthermore, Duane Cooper and Takeo Shiga in the USA, and Michael Gerzon in England, were producing reports and technical papers which progressively demonstrated the errors to which the main commercial systems were subject.

MICROPHONE TECHNIQUE

Clearly, any recording made using a system of microphones which does not respond properly to the direction of each sound source cannot possibly reproduce that sound in the correct direction. So what microphone system do we need? Well, in Part 1 we saw that a combination of an omnidirectional microphone and a directional microphone, with a figure-of-eight (lemniscate) response facing sideways, records two-channel stereo correctly. The microphone outputs are, respectively, the monaural (M) signal and the side (S) signal of the MS stereo system, while their sum and difference are the conventional left (L) and right (R) stereo signals.

Surprisingly, it can be shown that, if you keep your head perfectly still, and the sound sources are confined to the front semicircle, these two microphones correctly record surround sound! This, in fact, is the basis of the very simple Hafler system described in Part 1. However, this two-microphone arrangement does not record all the directional information which would be available to you at the live performance, if you were allowed to move your head even slightly. To deal with this, a third microphone, also with a lemniscate response, has to be added, with its greatest sensitivity in the front to rear direction. This arrangement, in fact, is like the original Blumlein crossed-lemniscate pair with the addition of the omnidirectional signal which allows the front-to-back ambiguity of the Blumlein arrangement to be resolved (Figure 11).

Another way of looking at this is to say that the omni-microphone records the sound pressure at the microphone position, while the lemniscates record the particle velocity components in the fore and aft or X-direction and the left to right or Y-direction. This is enough information to represent both the intensity and the direction of any sound source in the plane of the microphone.

It is possible to 'reverse-engineer' the discrete four-channel system by asking what directional characteristics would

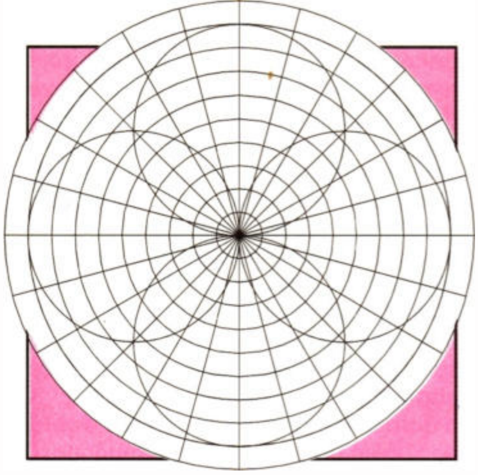


Figure 11. Directional responses of the three microphones for capturing full horizontal surround sound.

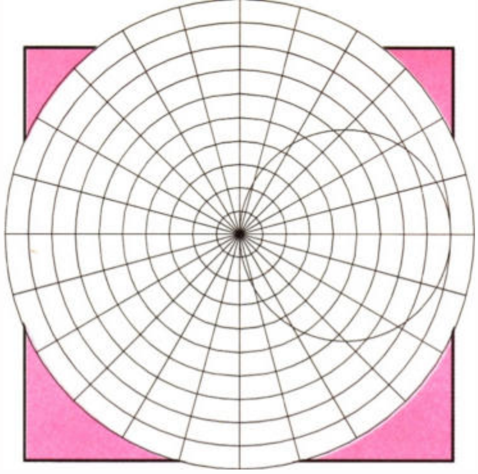


Figure 12a. Impossible half-lemniscate directional response required for correct capture of '4-channel stereo'.

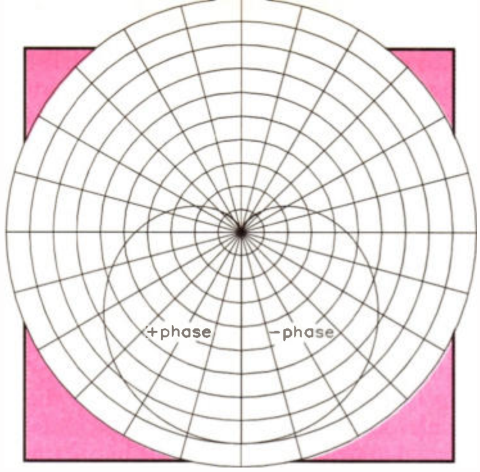


Figure 12b. Impossible directional response required for correct capture of rearward sound in a two-channel system.

four coincident microphones, angled towards the corners of a square, need to have to record the directional information correctly. The answer is 'half a lemniscate', i.e., a circle, not centred on the microphone as for an omnidirectional type, but displaced so that the response in the 'backwards' direction is zero (Figure 12a). Unfortunately, no such microphone can be made – it is a physical impossibility. The use of any other (not mathematically equivalent) microphone system results in a loss of directional information, which cannot be recovered by any means at all. Another example arises if we ask the same question about two-channel systems. It is possible to show that one microphone should be a cardioid type (i.e. with a heart-shaped directional response) facing forwards, which is not a problem. However, the other microphone would have to have a cardioid directional pattern facing backwards, with the response of the left half inverted ('180° out of phase') with respect to that of the right half (Figure 12b). This is another physical impossibility. In fact, it can also be shown that *any* attempt to compress full 360° directional information into two-channels results in this polarity reversal appearing somewhere. Although it can be spread around the 360° instead of appearing all in one place as in the above example, even a uniform distribution (as in Cooper's BMX not a bicycle but a Bimodal MatriX system) is not very satisfactory.

SPHERICAL HARMONICS

That title looks impressive, doesn't it? However, the concepts are actually not very difficult, and can be quite interesting, since there is a link between two apparently quite unrelated subjects in electronics – harmonic distortion and microphone directional responses.

Duane Cooper's original paper adopts a certain style that tends to obscure practical significance. We can approach the subject with advantage from, perhaps, the opposite end. Suppose that, instead of plotting the directional response of a microphone on polar graph paper, we plot it on conventional (Cartesian) paper with the angle scale along the horizontal axis. We can then consider the resulting graph as one cycle of a periodic waveform, and analyse it into sinusoidal components, perhaps with a constant (DC) component, by Fourier analysis, just as we can do for a square wave or a distorted sine wave. The resulting components are called spherical

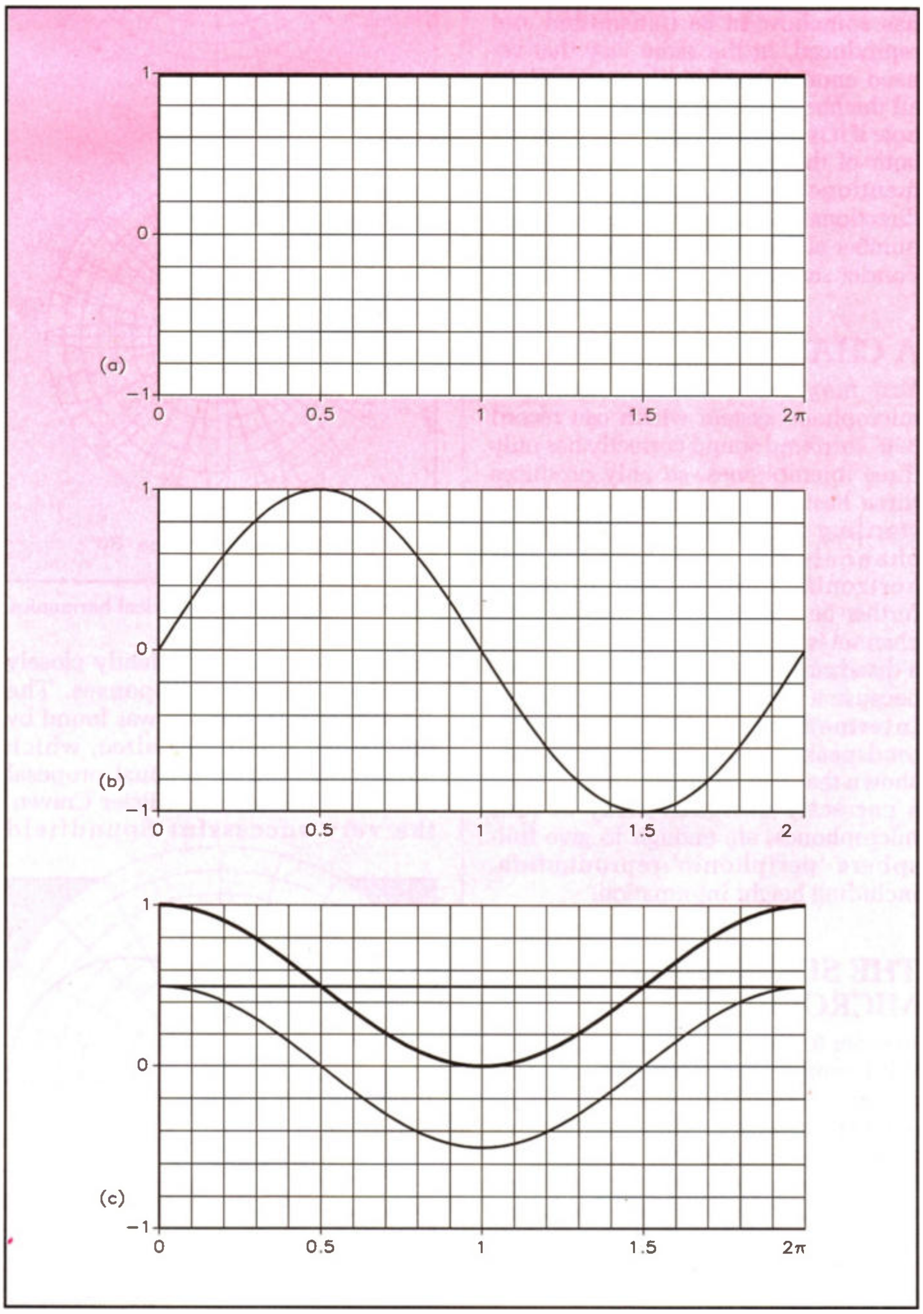


Figure 13. Directional responses plotted on Cartesian co-ordinates.
(a) Omnidirectional: zero order harmonic. (b) Lemniscate: first order harmonic.
(c) Cardioid and its two harmonic components.

harmonics (why not 'circular harmonics'?). For example, an omnidirectional microphone ($r = a$ in polar co-ordinates) produces only a 'DC component'(zero-order harmonic), a lemniscate ($r = a\cos\theta$) produces only a cosine term (first order harmonic), while a cardioid ($r = a(1 + \cos\theta)$) produces zero and first order harmonics of equal amplitude (Figure 13). Higher order harmonics correspond to sinusoidal curves of higher 'frequency' in Cartesian form, and 'daisies' in the polar form, with the number of 'petals' equal to twice the order of the harmonic if the absolute value of the function is plotted, as is usual (Figure 14). It is theoretically possible to make a microphone with a directional response equal to any linear combination of a finite number of spherical harmonics.

We can now say that a practicable sensing of the intensity and orientation of sound sources surrounding a point must involve only a finite number of spherical harmonics, for each of these has somehow to be transmitted and reproduced, in the same way that we need enough bandwidth to reproduce all the harmonics generated in a violin note if it is to sound right. This rules out both of the 'impossible' microphones mentioned above, for both of these directional responses require an infinite number of spherical harmonics in their Fourier series.

A CHANNEL TOO FAR

You may have noticed that the microphone system which can record 360° surround sound correctly has only three microphones, so only produces three basic output signals. This is a startling fact: only 'three' discrete channels are necessary for full horizontal surround sound! It can further be shown that adding an extra channel is of no advantage, and may be a disadvantage if applied without care, because it tends to force the sounds at intermediate angles towards the loudspeaker positions. It can also be shown that four channels, derived from a correctly designed array of four microphones, are enough to give full-sphere 'periphonic' reproduction, including height information.

THE SOUNDFIELD MICROPHONE

In order to obtain height information, a third lemniscate microphone, oriented in the up-down direction must be added to the system. However, there are two problems with this arrangement: first that it is not easy to make high-quality lemniscate microphones which are small enough to mount so close together that they are all effectively in the same place in the sound field, which means closer than 10mm. Secondly, it is not practicable to make lemniscate and omnidirectional microphones with sufficiently closely matched frequency responses. The solution to this problem was found by the British company Calrec, which developed, from an original proposal by Michael Gerzon and Peter Craven, the very successful Soundfield microphone. This has four identical hypercardioid capsules (which have directional responses $r = (1 / (1 + a))(a + \cos\theta)$, with a less than 1, looking like a cottage loaf, see Figure 15a) arranged in the directions of the corners of a regular tetrahedron (a four-sided solid, all of whose faces are equilateral triangles, see Figure 15b). This can be shown to give four output signals which are sufficient to define the intensity and direction of sounds in three dimensions, and these signals can easily be converted, if required, into the signals which would have been produced by a microphone of the 'omni plus-three lemniscate' type. In practice, the four microphone signals, 'A format' are converted by the microphone's auxiliary electronics into 'B format', whose four signals are denoted by Σ (sigma), Δ (delta), T and Q. Q is only necessary if source height information is to be included.

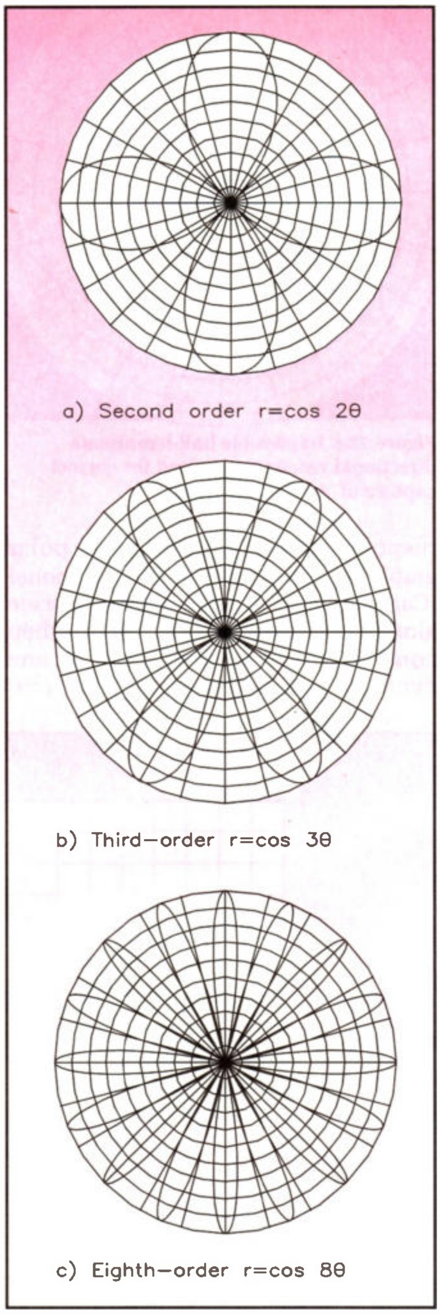


Figure 14. Higher-order spherical harmonics.

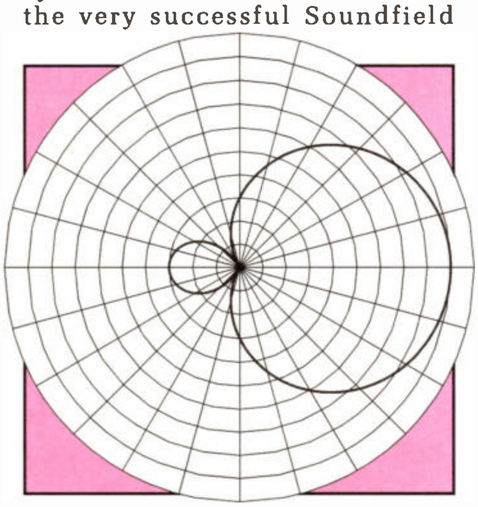


Figure 15a. Hypercardioid directional response of each capsule of the Soundfield microphone.

MORE WRONG IDEAS

Another misconception about surround sound is that the number of loudspeakers must necessarily, or even optimally, be the same as the number of transmission channels. In fact, it is possible to determine exactly how to derive, from any number of transmission channels, the optimum blended signals for any number of loudspeakers. It should be noted that there is no essential requirement for vanishingly small crosstalk between the loudspeaker signals, as might be deduced from two-channel stereo thinking and the 'more of the same' misconception. Indeed, the blends are likely to have rather a large amount of shared signal components; for many arrangements this is inevitable. In fact, the requirement for minimal crosstalk is often exaggerated even for two-channel stereo. Either the 'law of sines' or the 'moments law' described in Part 1 can be used to show that a modest crosstalk spec. of −30dB produces an image shift of just over one thirtieth of the base-line distance between the loudspeakers for an extreme left or right image, and in the worst case only one thirtieth for a central sound, which is 7·5cm for a

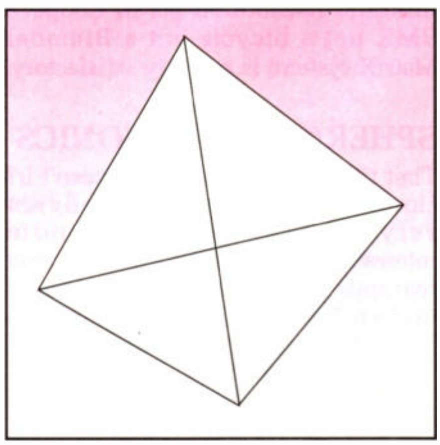


Figure 15b. Wire-frame view of a tetrahedron, towards whose vertices each capsule is directed.

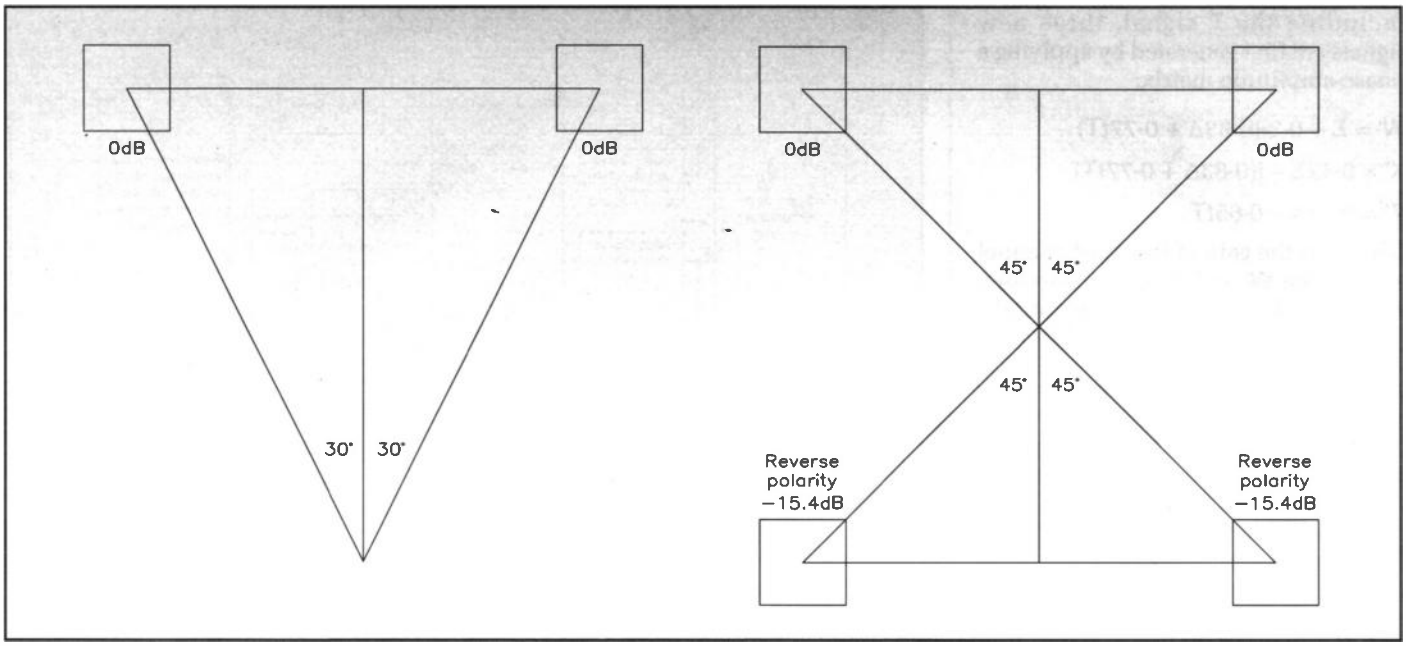


Figure 16. Optimum loudspeaker layouts for stereo and 2-channel Ambisonics.

2·5m base line, an angular displacement of 2° for the optimum loudspeaker layout.

IMPROVING TWO-CHANNEL STEREO

We saw above that a sound source at a given angle can be precisely recorded in terms of sound pressure and particle velocity. Normal two-channel stereo reproduction, however, does not produce quite the correct relationship between them if the loudspeakers are in the 45° directions each side of the listener's straight ahead direction. For a central front sound, the sound pressures add arithmetically (i.e., +6dB), but the velocities add vectorially, to give a value $2/\sqrt{2}$ times (i.e., −3dB relative to the pressure). If the loudspeakers are in the 30° directions, the velocity/pressure ratio is correct. It may be corrected in the 45° case by adding inverted signals at a level of −15·4dB in the two rear loudspeakers of a square layout, and again here we can see the Hafler system appearing out of theoretical ideas (Figure 16).

AMBISONIC TWO-CHANNEL ENCODING

Since even now the main media for distribution of sound programmes, i.e., analogue or digital disc or tape and FM radio, have only two (quasi-)discrete channels, it is still necessary to consider how to convert the three or four output signals from the Soundfield microphone to two-channel form, with minimum loss of information. In order to do this, we have to consider what *reversible* encoding operations can be applied to the signals, so that decoding can be as accurate as possible. There are only two such operations: we can change the relative amplitudes of the signals by fixed amounts, and we can introduce fixed, frequency-independent phase shifts between the signals. The reduction of four signals to two in this way is thus described as 'phase-amplitude matrixing'.

A very great deal of theoretical study and subjective testing resulted in the adoption of the following (slightly simplified) matrixing equations for the encoding of a source of strength S from a direction θ, measured anticlockwise from centre-front, without height information:

$$\Sigma = (0{\cdot}94 + 0{\cdot}26\cos\theta)S$$

$$\Delta = (-0{\cdot}34j + 0{\cdot}72j\cos\theta + 0{\cdot}93\sin\theta)S$$

$$T = (-0{\cdot}14j + 0{\cdot}92j\cos\theta - \sin\theta)S,$$

where j signifies the application of a wide-band 90° phase-shift relative to the Σ signal. In practice, the Σ signal is shifted 45° one way, and the others 45° the other way, since this can be done accurately while preserving a flat frequency response.

For transmission via a two-channel medium, only the first two signals are used.

AMBISONIC DECODING

To obtain reproduction via two loudspeakers, the L and R signals are very simply derived:

$$L = 0{\cdot}5(\Sigma + \Delta)$$

$$R = 0{\cdot}5(\Sigma - \Delta)$$

It is advisable to adopt a loudspeaker layout in which the angle between the lines joining the loudspeakers to the listening position(s) is close to 60°. For two-loudspeaker reproduction, the Σ and Δ signals are equivalent to the M and S signals of M-S stereo, but for reproduction through a larger number of loudspeakers, useful surround sound information can be derived just from these two signals.

In a simplified decoding process

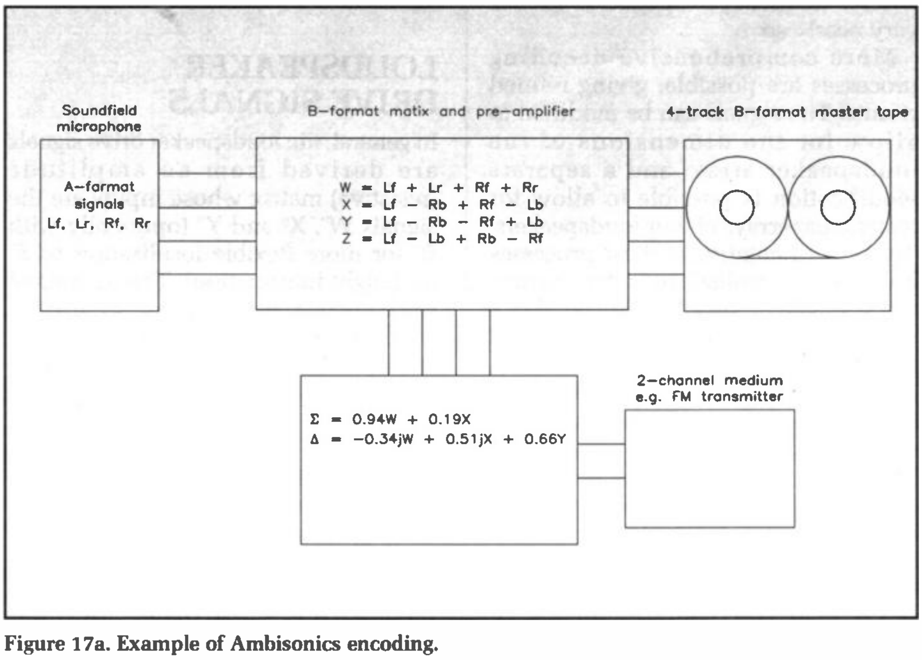


Figure 17a. Example of Ambisonics encoding.

including the T signal, three new signals are first generated by applying a phase-amplitude matrix:

$W' = \Sigma + 0{\cdot}2j(0{\cdot}83\Delta + 0{\cdot}77tT)$

$X' = 0{\cdot}42\Sigma - j(0{\cdot}83\Delta + 0{\cdot}77tT)$

$Y' = 0{\cdot}83\Delta - 0{\cdot}65tT$

where t is the gain of the third channel signal. The W' and X' signals are then subject to frequency-response modification, to allow for the different methods which the ear-brain system uses to localise sounds above and below about 700Hz. The W' signal receives in the region of 4dB cut at low frequencies and the X' signal receives 2dB boost, or thereabouts, depending on the value of t, while Y' receives about a 2dB cut. A further, pure amplitude matrix process then generates loudspeaker drive

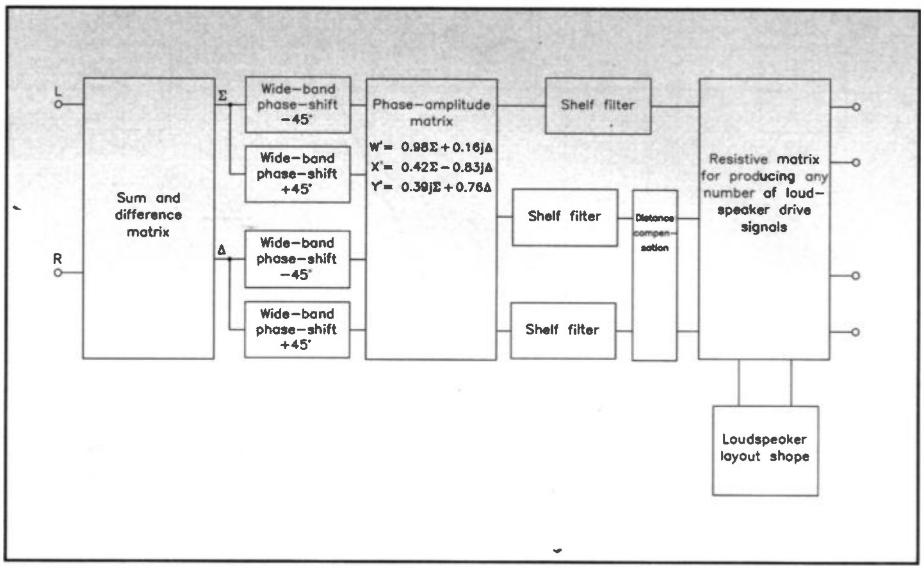


Figure 17b. Example of an Ambisonics decoder with 2-channel input.

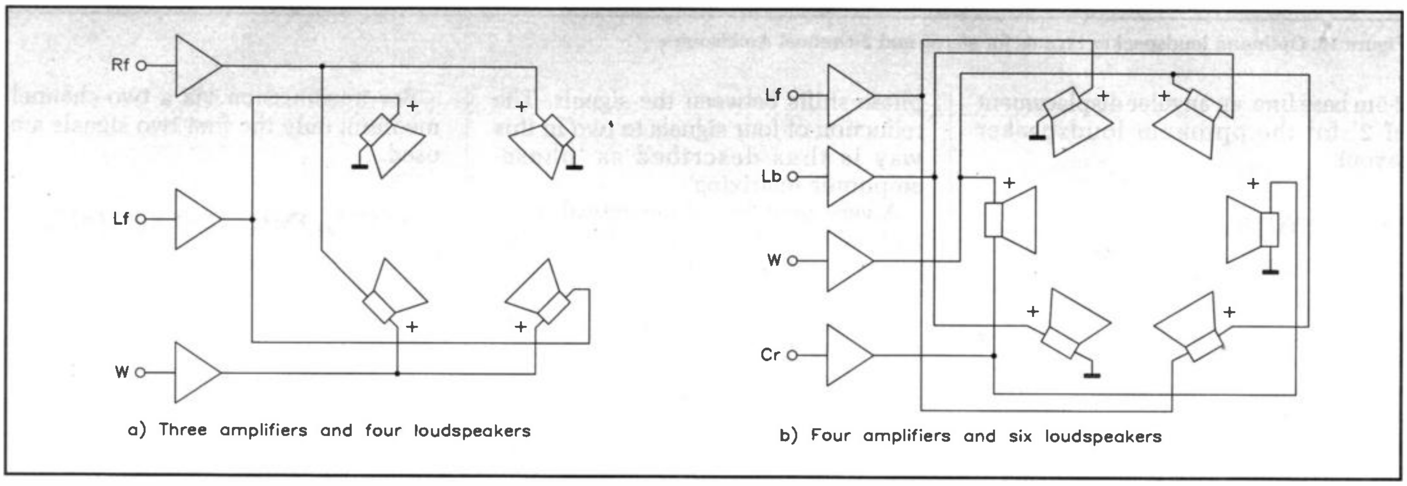


Figure 18. Arrangements of amplifiers and loudspeakers for Ambisonics.

signals, for any number n loudspeakers, regularly spaced around the listener(s). The loudspeaker at angle ϕ to the straight-ahead position receives a signal:

$$P_\phi = \frac{1}{\sqrt{n}}(W'' + \sqrt{2}(X'' \cos\phi + Y'' \cos\phi))$$

where W'', X'' and Y'' are the signals with modified frequency response. The overall frequency response is flat, or very nearly so.

More comprehensive decoding processes are possible, giving refined results. The signals can be modified to allow for the dimensions of the loudspeaker array, and a separate modification is possible to allow for rectangular arrays of four loudspeakers. The implementation of these processes is much more realistic now that opamps are available at very low prices. Block diagrams of two-channel encoding and decoding units are shown in Figure 17. If a fourth basic signal, B', is available, it can either be used to convey source height information, or to provide more flexibility in location in the horizontal plane. For some recorded material, and for some listening tastes, a concentration of source positions towards the loudspeaker positions seems preferable. The introduction of more transmission channels, however, should be accompanied by an increase in the number of loudspeakers, for optimum results. Four transmission channels are not really worthwhile unless at least six loudspeakers are used. Such a hexagonal layout can, in fact, often be more easily accommodated in a room than four loudspeakers, at least one of which seems always to need to be placed in a doorway!

LOUDSPEAKER DRIVE SIGNALS

In general, the loudspeaker drive signals are derived from an amplitude (resistive) matrix whose inputs are the signals W'', X'' and Y'' (optionally with B'' for more flexible localisation or Z'' for height information). The outputs of this matrix are passed to power amplifiers and thence to the loudspeakers. But there is no need to use one amplifier for each loudspeaker. Some of the matrixing can be done at loudspeaker level, simply by deriving the appropriate drive signals from the resistive matrix and connecting the loudspeakers correctly to the power amplifiers. Figure 18 shows just two of many possibilities, four loudspeakers with three amplifiers and six loudspeakers with four amplifiers.

SOFTWARE AND HARDWARE

Recorded material in Ambisonics format is available from several record companies, of which Nimbus is the most prominent. A wide range of programme material is available (but not Mr. Blobby), most of it of the 'serious music' variety. All software is labelled to indicate the use of Ambisonic techniques. Because of the careful attention to microphone placement inherent in Ambisonic recording, particularly good results are obtainable even with two-loudspeaker reproduction.

Ready-made Ambisonic decoders are available in a range of prices from Minim Electronics Ltd., Lent Rise Road, Burnham, Slough SL1 7NY. Tel: (0628) 663 724.

THINGS TO COME

Part 3 of this series will deal with Dolby Surround Sound and the LucasArts THX reproduction system.

ACKNOWLEDGMENT

Thanks are due to Roger Furness of Minim Electronics Ltd. for valuable discussions on Ambisonics.

KEYCODE LOCK

Text by Alan Williamson and Robin Hall

Are you tired of always losing your keys? Would you like a high tech way of locking up your valuables? Perhaps the Keycode Lock is what you have been looking for. It operates in the same way you see on many a James Bond film, that is, a small numerical keypad is placed by the door; and to open it, the correct code must be entered.

KIT AVAILABLE (VE76H) PRICE £24.95

2 PROJECT RATING

FEATURES

* More than 3,000 possible codes
* Relay output
* LED active indicator
* Pulse or switched output
* Nine keys for four digit code

It doesn't have to be confined to doors though, it could be used on cupboards, filing cabinets, desks, cars, caravans, trailers, lock-ups, garages, equipment, etc. Anything that normally requires a conventional lock to secure a door or lid; and enough room to be able to fit a solenoid lock, the number of applications are endless.

Circuit Description

The switches 1 to 9 on the keypad are arranged in a matrix. A four digit code is set up by fitting links in the circuit to select a combination, which register as Codes A to D. The completed Keycode Lock unit is shown in Photo 1, and the block diagram shown in Figure 1.

To assist the reader whilst reading the description, refer to the circuit diagram in Figure 2. Code A is the first digit (1 to 9), Code B is the second, Code C and D are the third and fourth digits; all other digits must be connected to the 'not used' line.

If the first digit is entered correctly; the analogue switch ES1 control line is connected to +V, causing the analogue switch contacts to become closed. Also when the first correct Code A is entered, the capacitor C1 charges via resistor R9. The charge on the capacitor C1 ensures that the analogue switch ES1 remains closed. Resistor R1 discharges the capacitor C1 to provide the time limit for entering the four digit code (approximately 5 seconds). To inhibit this time limit fit the link J1; the capacitor then charges via the resistor R10; ES1 remains closed until an unused code digit is entered.

When an incorrect (unused) digit is entered, transistor T2 is switched on; this discharges the capacitor C1 and connects the control line of ES1 to 0V, causing the switch to become open circuit.

Entering the second correct digit switches on ES2; the +V supply latches ES2 on via R10, ES1 & D2.

Entering the third and fourth digits

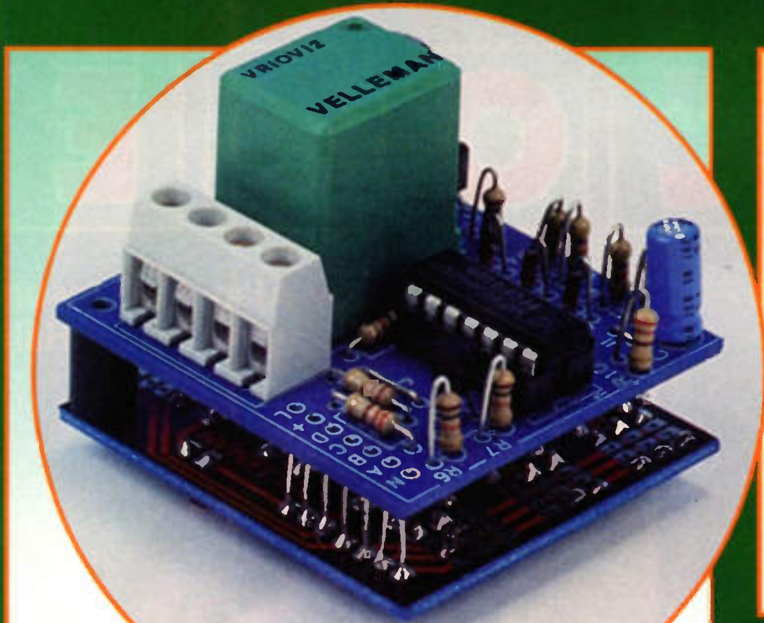


Photo 1. The completed Keycode Lock unit.

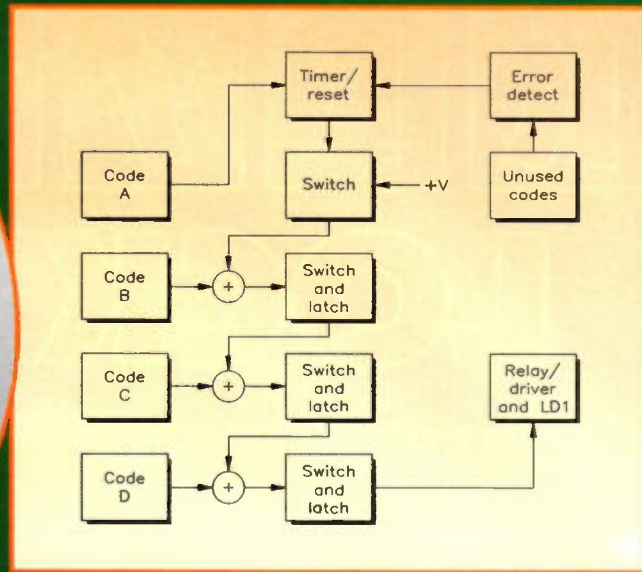


Figure 1. The block diagram of the Keycode Lock.

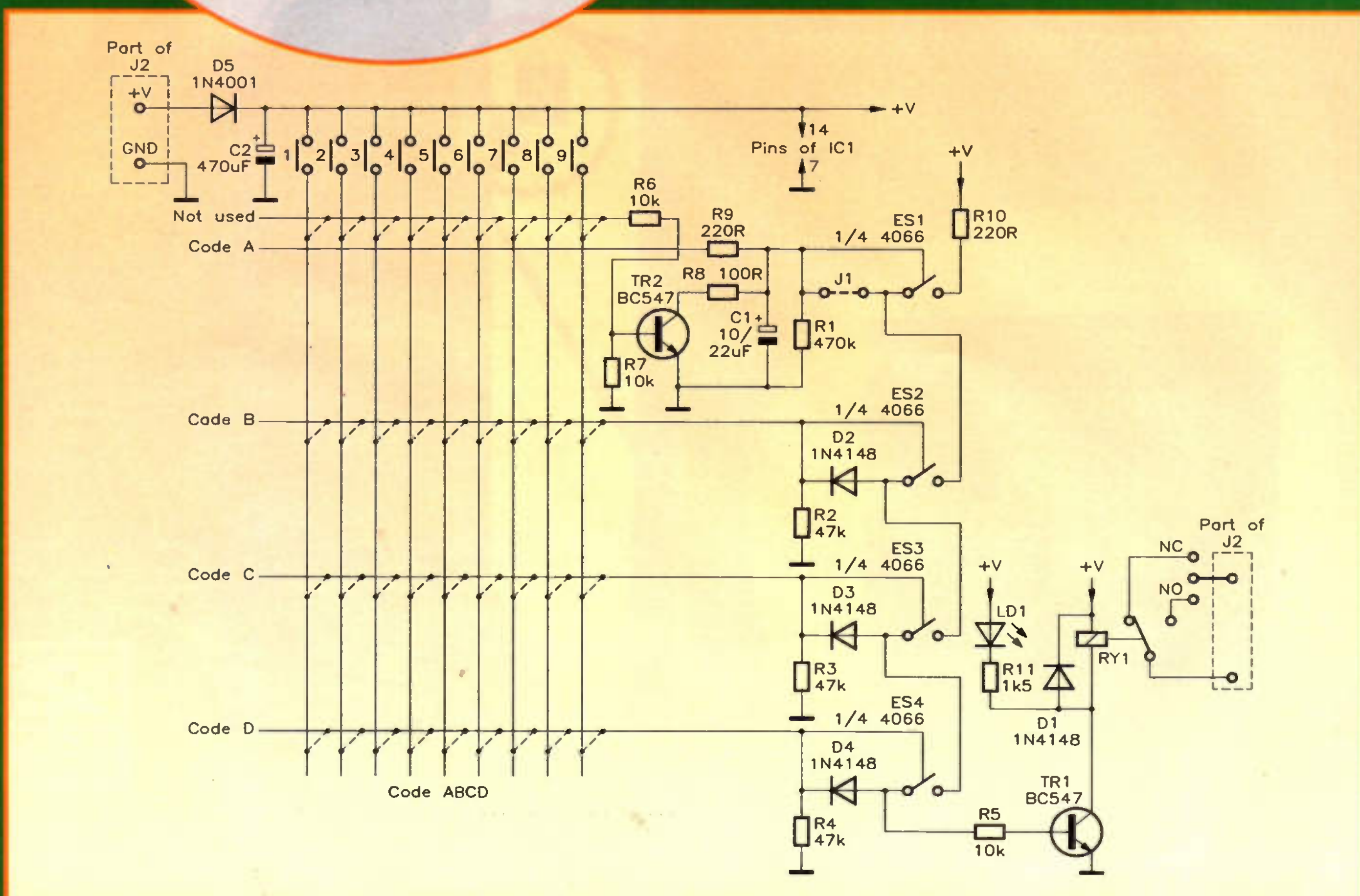


Figure 2. The circuit diagram of the Keycode Lock.

correctly switches on and latch ES3 and 4 in the same way as ES2.

The analogue switches ES1-4 only latches in the order: Code A, Code B, Code C, Code D, because of the cascading arrangement of the circuit.

When all analogue switches (ES1-4) are closed, transistor T1 switches on; LED (LD1) illuminates, and the relay (RY1) operates.

The diode D1 is required to prevent damage to the driver transistor T1, from the induced emf, during the decay of the magnetic field within the relay coil.

Setting the Code

To set the codes, the wire links are positioned in different locations; at first this may seem a little confusing.

In deciding the codes, select any of the switches for the first digit in the code sequence, or use the same switch for all four digits if this is required.

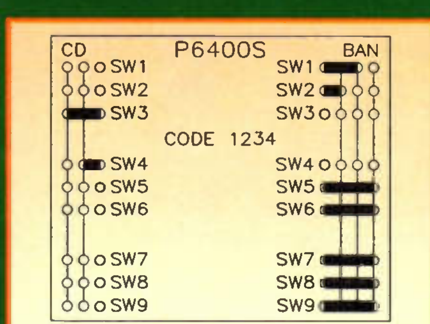


Figure 3. The wire links set up for code '1234'.

Code A is the first pressed in the sequence, B the second, C the third, D the fourth; all other unused switches are connected to the 'not used' line.

Example, if the code 1234 is required, then the following links are made as shown in Figure 3 (see also Table 1).

Construction

The Codelock kit comprises of two PCBs, the switch PCB and the relay PCB. Build either of them first but the construction of the keypad switch PCB is described first. If you are new to project building, refer to the Constructors' Guide (XH79L) for details of how to recognise, handle and solder specific types of components.

To assist in the construction of the PCB, use Photo 2a which shows the completed switch PCB. Fit the light emitting diode (LED) LD1 (observing correct polarity) according to the legend on the PCB. Next fit the nine miniature tactile switches on the PCB, making sure that they are flush against the board.

Decide on what code is required for the switch, and set the code with wire links, and solder in position, making sure that they are as close to the PCB as possible, so as not to touch the aluminium front panel, see Figure 3, the example shown is 1234. Any four numbers will do, just as long as they are remembered – pick a number, like your pet goldfish's birthday!

Before assembly of the supplied seven bandoliered wire links, cut the individual lengths of wire as shown in Figure 4, and locate in position on the board. Solder the wires on the track side, making sure that the wires on the component side are trimmed to prevent accidental shorting against the aluminium front panel.

SWITCH	CODE
SW1	A
SW2	B
SW3	C
SW4	D
SW5	N
SW6	N
SW7	N
SW8	N
SW9	N

Table 1. Example switch-code settings.

Constructing the Second PCB

Again to assist in the construction of the PCB, use Photo 2b which shows the completed relay PCB.

Locate position 'J' on the PCB and with one of the bandoliered wire links, fit and solder in. If the latching operation is required, as mentioned in the circuit description, then fit and solder in position J1 a small wire link. If the latching operation is not required then leave the position open circuit.

Before fitting the relay, again decide on whether to fit a wire link between 'NC' for normally closed contact of the relay, or fit 'NO' for normally open contact use. NOTE that once the relay is fitted the link will *not* be accessible.

Identify the diodes, and fit and solder in according to the legend on the PCB. Preform the leads for horizontal or vertical mounting. Note that the bar on the diode denotes the cathode and this is marked 'c' on the PCB for the vertically mounted diodes and by a bar on the horizontal. Next identify the resistors, again the leads should be preformed before mounting the resistors on the board and soldering in position.

Next identify the electrolytic capacitors.

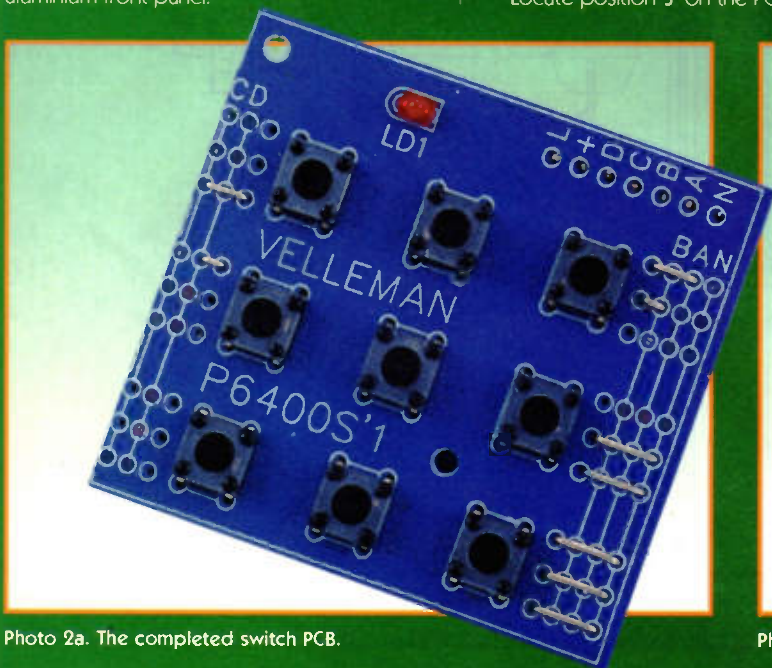


Photo 2a. The completed switch PCB.

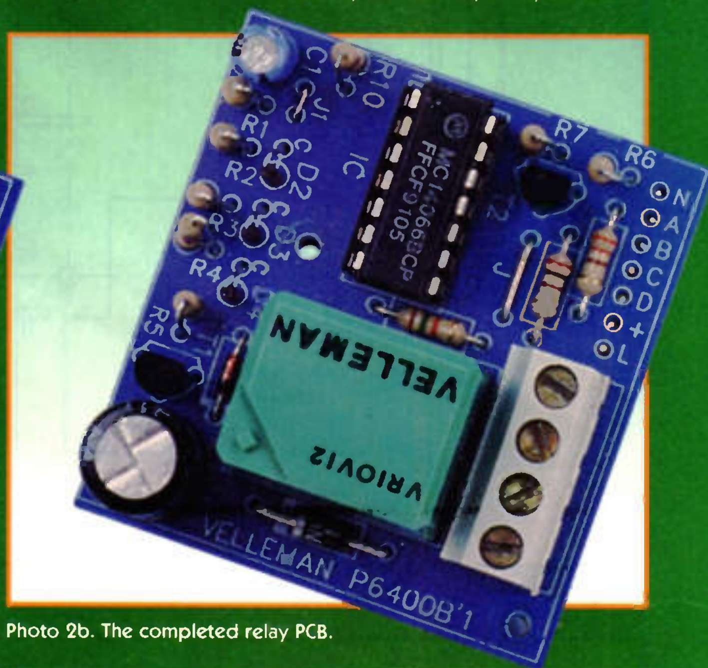


Photo 2b. The completed relay PCB.

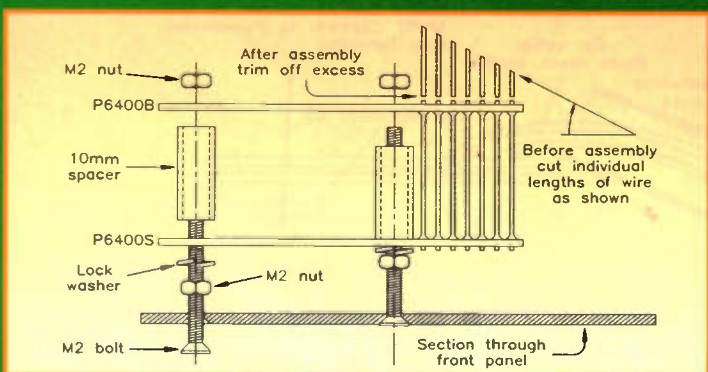


Figure 4. The exploded assembly including the fitting and cutting of the seven interconnecting wires.

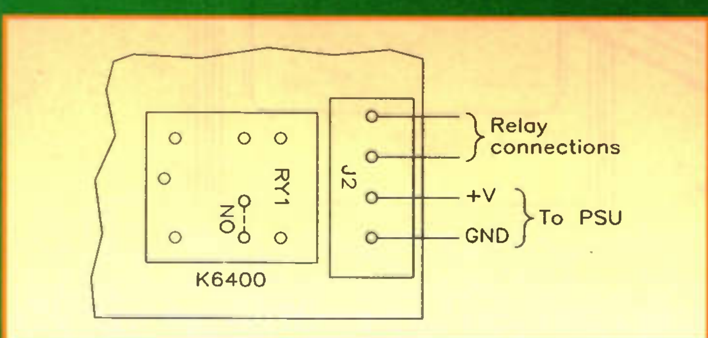


Figure 5. External connections to the terminal block on the PCB.

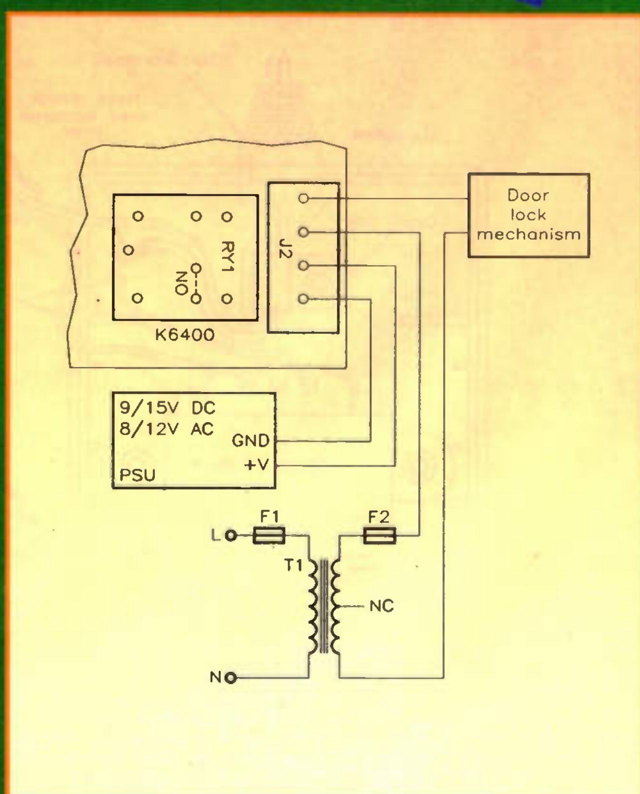


Figure 6a. Suitable interconnections to PSU and to door lock mechanism.

The positive lead is normally longer, the negative is denoted by (–) symbols running down the body of the capacitor. Fit the capacitors with the positive lead denoted by a (+) symbol on the board, and solder in position.

Fit the 16-pin DIL IC socket, with the notch matching that on the PCB legend. Make sure before soldering in position, as it is very difficult to desolder the leads if a mistake is made.

Next fit the transistor according to the legend on the PCB and solder in position.

Locate the 4-way terminal block onto the PCB, and mount with the terminal contacts pointing away from the board, and solder the leads.

Next mount the relay; it will only go in one way, and then solder, making sure that it is located squarely over the wire link.

Finally insert the IC, with the notch on the IC correctly orientated with the notch on the legend and the IC socket.

Fitting the Boards Together

The boards are now mounted back to back and fitted together as shown in Figure 4. First pass the two M2 bolts through the aluminium panel, the heads are located into countersunk holes. Then fit an M2 nut and lockwasher to each, and tighten up the M2 nuts. Now locate the switch PCB onto the M2 bolts, and make sure that the LED is in its correct position. Readjust if necessary.

Next fit the two 10mm plastic spacers onto the M2 bolts. Carefully mount the relay PCB onto the two M2 bolts, and at the same time locate the seven wires from the switch PCB, passing them through the PCB. Fit the two remaining M2 nuts onto the bolts and ensure that the two PCBs are securely bolted together as there is no access to the screw heads once the front membrane panel is fitted. Now solder the seven wires on the

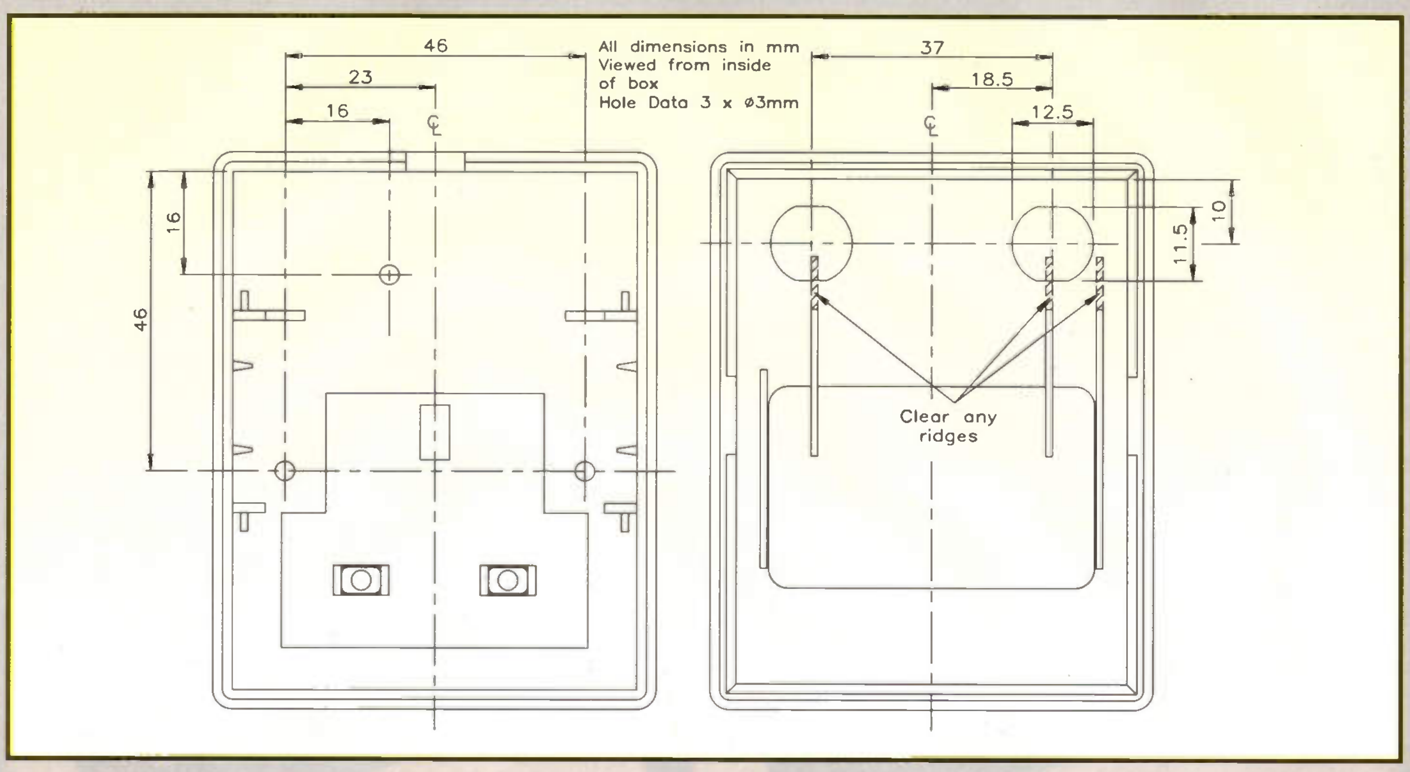


Figure 6b. PSU box drilling details.

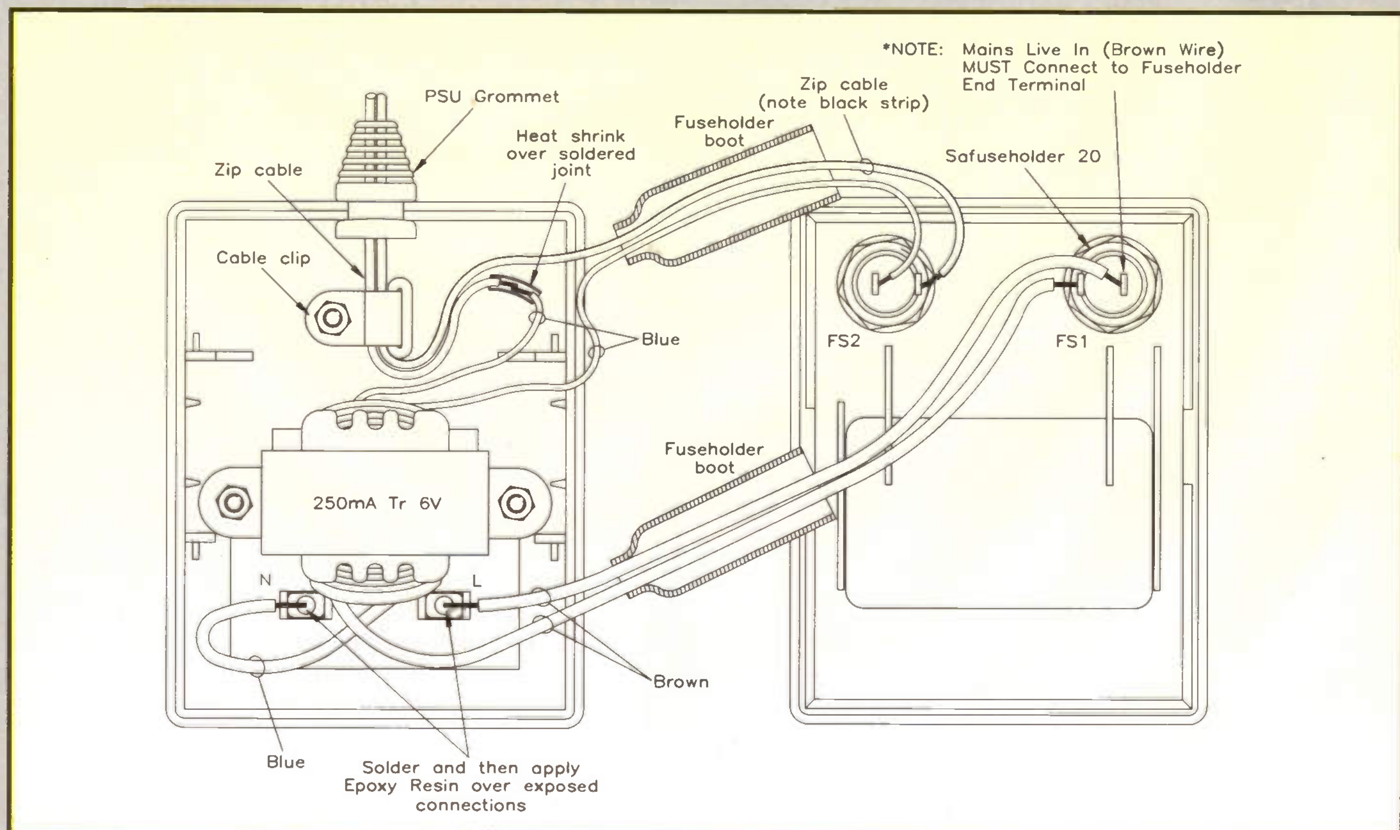


Figure 6c. PSU assembly details.

SPECIFICATION

Power supply:	9 to 15V DC or 8 to 12V AC
Current consumption:	Off 0·3μA, on 40mA
Time limit for code input:	5s (only in pulse mode)
Dimensions:	80 x 80 x 40mm

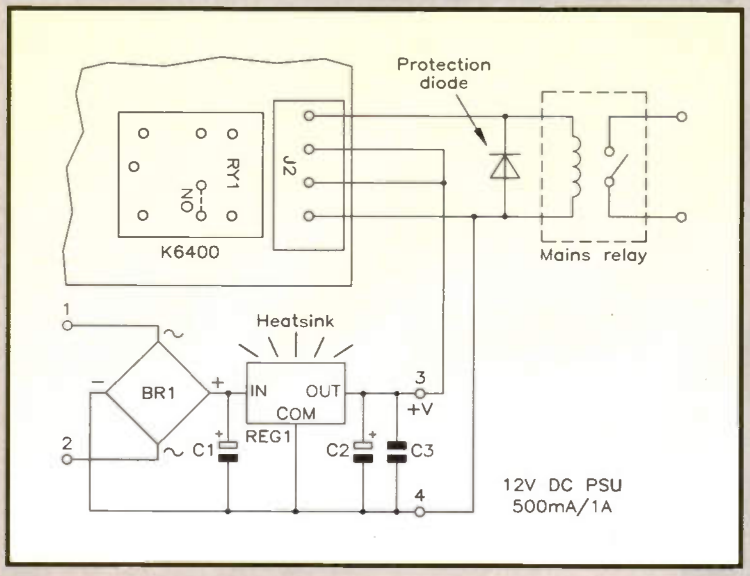


Figure 7. Mains relay and suitable DC PSU.

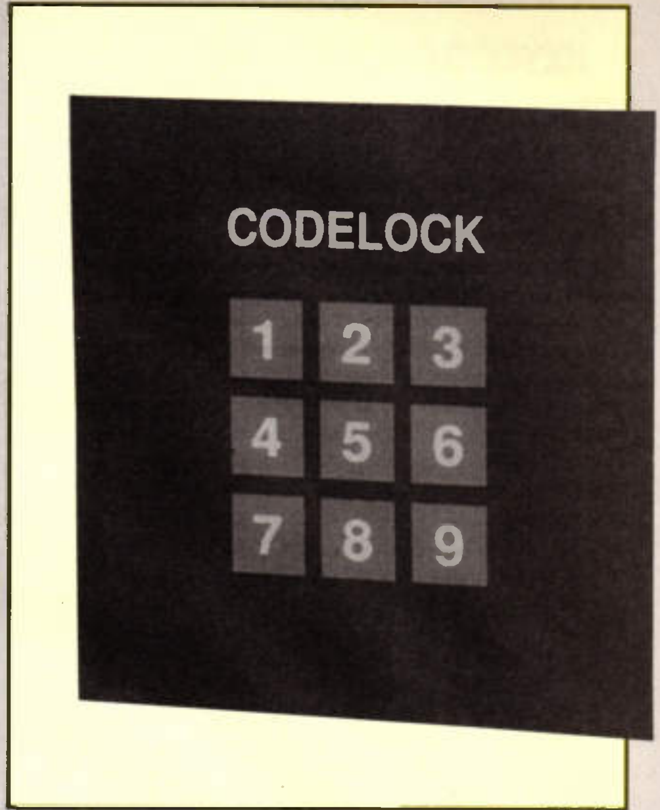


Photo 3. The membrane front panel.

track side of the relay PCB, and trim off the excess.

This completes the construction of the Keycode Lock. Before attaching the membrane front panel, see Photo 3, mount and fix the unit into the enclosure it is to operate from using security screws, available from all good hardware stores.

If using the Keycode Lock outside then it is essential to build it into a weatherproof enclosure. The membrane front panel is splash proof only.

Using the Keycode Lock

The applications for the Keycode Lock are many, however, for it to operate it will need an external power supply.

The external connections to the Keycode Lock are shown in Figure 5. The relay connections are available on the connector block J2, and would have been set earlier by the link under relay RY1 to either normally open (NO) or normally closed (NC). The power connections are also fed to J2; note the ground is marked as GND on the PCB.

To test the unit, simply turn on the power to the unit, key in the code previously set, and the onboard relay RY1 will operate. Also the front panel LED will illuminate. To reset the lock, push any unused key.

A suggested wiring layout is given in Figure 6a, using the Keycode Lock with an external power supply unit (PSU), and a door lock mechanism with an external PSU.

A suitable PSU for the door lock mechanism can be constructed in a large PSU box (YU31J). Figure 6b shows the box drilling of the door lock mechanism PSU. Fit the mains transformer into the large PSU box with the fuses as shown in Figure 6c. Don't forget to fit the fuseholder insulation boots! The transformer secondary centre tap, which is not used, cut short and then insulate 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 mechanism. Secure the zip wire with a 'P' cable clip. Reassemble the case; a multimeter set to its AC range and connected across the output wires will read 13V or so when the unit is plugged in. Once testing is complete, glue the two halves of the box together.

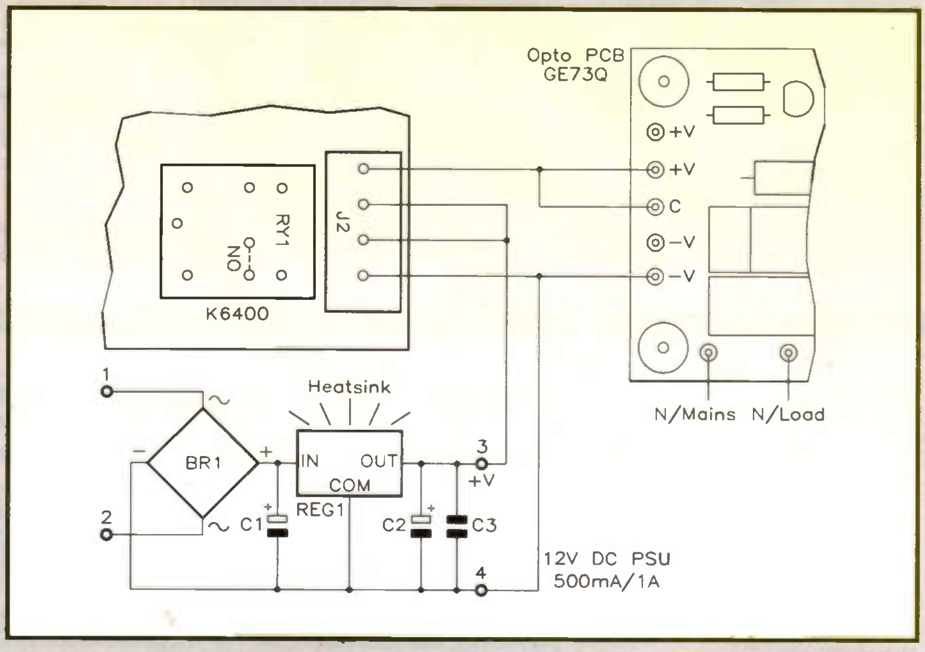


Figure 8. Zero crossing opto switch (LP55K).

Switching an External Device

Figure 7 shows the Keycode Lock operating a mains rated relay. The PCB mounted connector and track are not suitably spaced for voltages above 50V, and if mains voltages are switched then use an off-board mains rated relay. The external relay will require a diode to protect the circuit from the induced emf produced by the relay when it de-energises.

Another application is to use an optoisolated switch; Figure 8 shows the connections to the zero crossing opto switch (LP55K).

Using the optional Mains Opto Switch kit (LP55K) with the Keycode Lock enables resistive mains loads of up to 250W (maximum) to be switched. The actual details for the Mains Opto Switch are in *Electronics* Issue 41 (December 1990/January 1991).

Warning

It is imperative that every possible precaution is taken to prevent electric shock. Please take great care when using the LP55K module, as 240V AC mains CAN KILL.

KEYCODE LOCK PARTS LIST

RESISTORS			
R1	470k	1	
R2-R4	47k	3	
R5-R7	10k	3	
R8	100Ω	1	
R9,10	220Ω	2	
R11	1k5	1	
CAPACITORS			
C1	10μF 63V Electrolytic	1	
	or 22μF Electrolytic	1	
C2	470μF 25V Electrolytic	1	
SEMICONDUCTORS			
T1,T2	BC547	2	
D1-D4	1N4148	4	
D5	1N4001	1	
IC1	MC14066	1	
LD1	LED Red 3mm	1	
MISCELLANEOUS			
	Sub-miniature Tactile Switches	9	
	4-way Terminal Block	1	
RY1	5A/220V Relay	1	
	14-pin DIL IC Socket	1	
	Metal Front Plate	1	
	Plastic Membrane	1	
	M2 x 10mm Plastic Spacers	2	
	M2 x 20mm Bolt	2	
	M2 Nut	4	
	Wire Jumpers	20	
	PCB P6400B'1	1	
	PCB P6400S	1	
	Constructors' Guide		(XH79L)
OPTIONAL (Not in Kit)			
	Solenoid Lock Mechanism	1	(YR88V)
	Mains Opto Switch	1	(LP55K)

LOCK MECHANISM PSU			
	PSU Box Large	1	(YU31J)
	PSU Grommet	1	(JM16S)
	250mA Transformer 6V	1	(YN14Q)
	F50mA 20mm Fuse	1	(WR93B)
	T315mA 20mm Fuse	1	(RA07H)
	Safuseholder 20	2	(RX96E)
	Fuseholder Boot	2	(FT35Q)
	Cable 'P' Clip 3/16in.	1	(LR44X)
	Zip Wire	1Pkt	(XR39N)
	2-core 3A Mains Cable	1m	(XR47B)
+12V 500mA PSU			
C1	1000μF 63V Axial Electrolytic	1	(FB84F)
C2	10μF 63V Radial Electrolytic	1	(JL10L)
C3	100nF Disc Ceramic	1	(BX03D)
BR1	WO1	1	(QL29G)
REG1	L78M12CV	1	(QL29G)
	9V 500mA Miniature Transformer	1	(WB11M)
	0·5A/1A PSU PCB	1	(YQ40T)
	Heatsink	1	(HQ81C)
	1·3mm PCB Pin	1 Pkt	(FL21X)
	6BA x ½in. Bolt	1 Pkt	(BF06G)
	6BA Nut	1 Pkt	(BF18U)
	6BA Washer	1 Pkt	(BF22Y)

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 VE76H (Keycode Lock) Price £24.95

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

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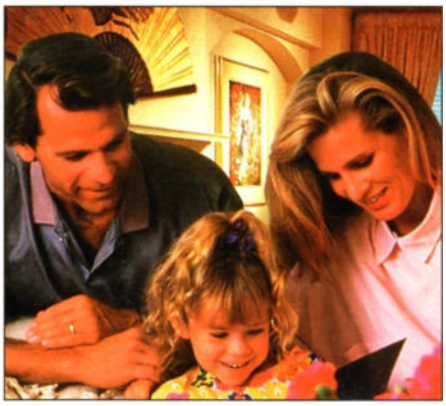

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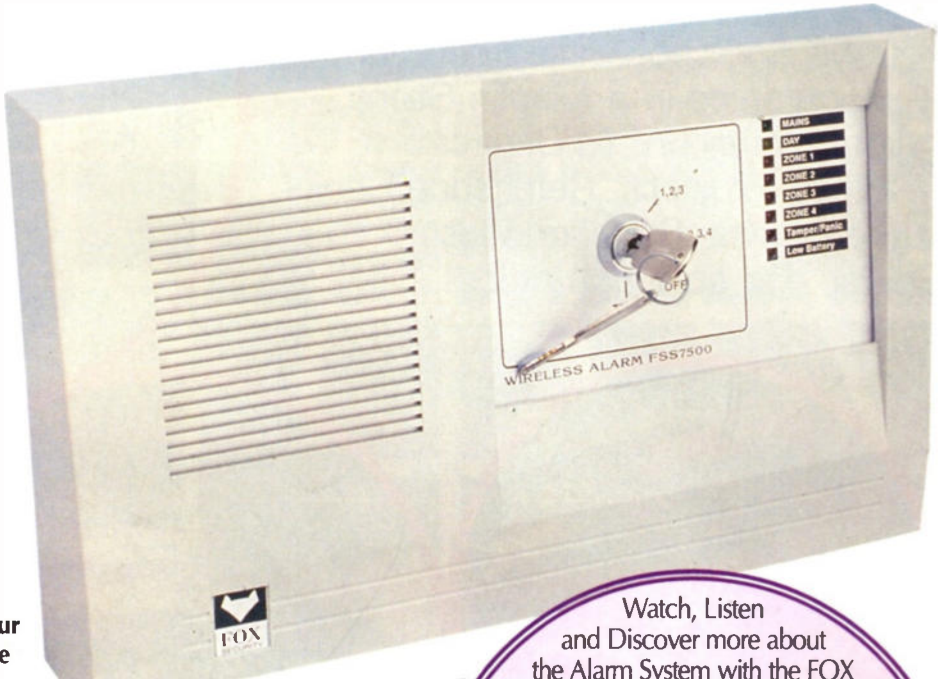

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