THE ELECTRONICS, SCIENCE & TECHNOLOGY MONTHLY

ETI
ELECTRONICS TODAY INTERNATIONAL

OCTOBER 1991 £1.60

THE MAGNETRON
The microwave generator

HOLE-IN-THE-WALL
The cash behind the button

FREEZE ALARM

COSMIC RADIATION
High energy particles

MAINS FAILURE ALARM

THE NIGHTFIGHTER
The power behind the Triac

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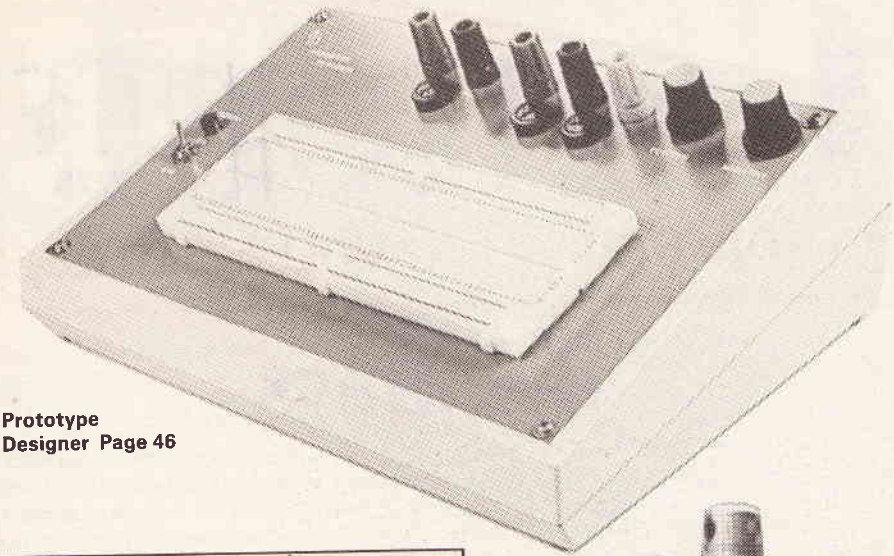

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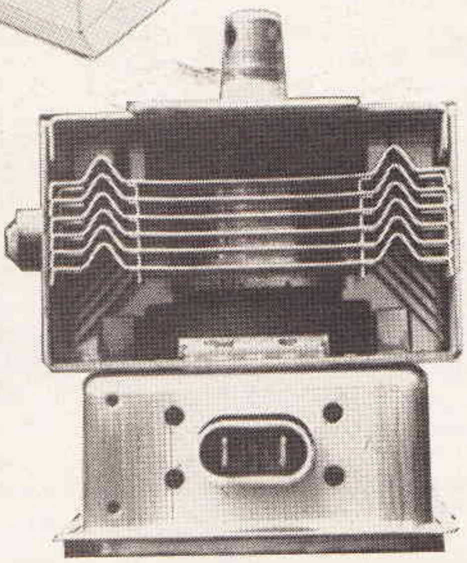

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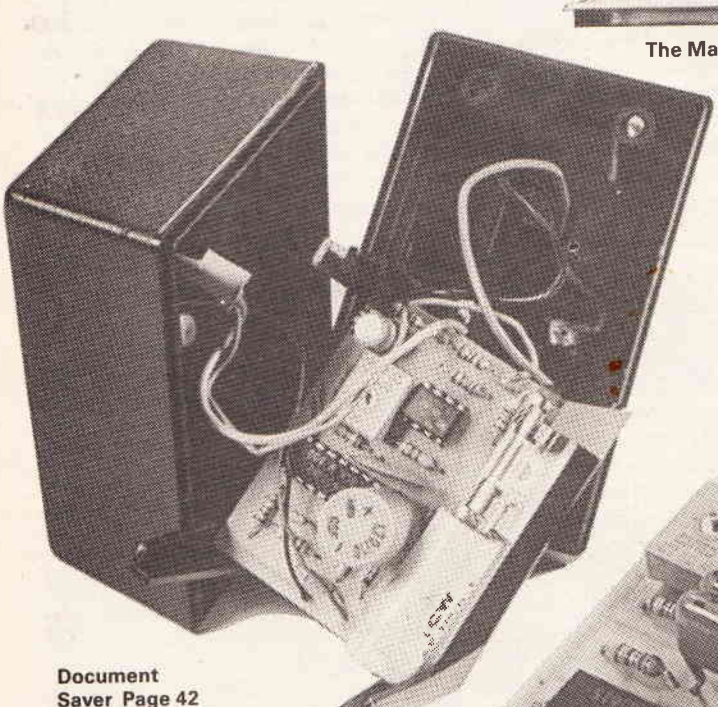

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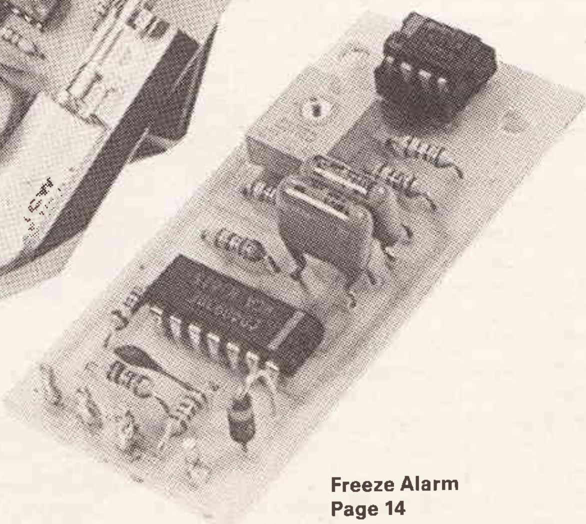

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Editorial

There has been a growing demand once again for technology to offer a helping hand in the process of bettering or maintaining ones personal welfare. I'm thinking of electronic machines to releave pain on the one hand and pocket electronics that hope to alter our state of consciousness on the other. Our recent Hemi-sync machine along with many other projects in the past are prime examples. But one thing in common with these 'specialist' machines available commercially,is their disproportionate cost to any other electronic equipment of equivalent size on the market today. As to why this is, I will leave the decision to you, but at a self-constructional level within the confines of magazines like ETI, it has to be an area of project construction that for once, is financially attractive to build.

Using electricity and magnetism to banish ailments is not radically new despite its infancy in the electro-technological age. One could call it a rediscovery in some cicumstances for Tesla,that genius ahead of his time, experimented many decades ago with high frequency currrents for the purposes of healing wounds.

It is true that Biofeedback, a technique of conscious control over ones bodily regulatory mechanisms enhanced by electronics has only emerged more recently with the use of sensitive operational amplifiers. Indeed electronics may only be a temporary helping hand in achieving total body control.

Whatever the ultimate aim, provided the demand is there and it appears that it is, the electronic forces in nature will continue to help provide a support for our well-being.

Paul Freeman

PS Twin Worlds
By the way, do let me know if you come across another human race. Last month I seem to have slipped into the plural in the editorial column.

OPEN CHANNEL

OK, I hate to say it, but I told you so, didn't I? Wasn't it yours truly who, in these very hallowed pages, prophesied doom and gloom in the personal communications sector? If you cast your minds back to the June 1990 issue of ETI, in this very column, I warned about potential problems in the cellular telephone and telepoint networks.

Well, all the chickens are starting to come home to roost now, and many of these networks are obviously having economic problems. You've only to look at what's happened over the last few months to figure that out for yourself.

First, Callpoint - one of the four licensed telepoint operators has effectively collapsed, and will be out of business by the time you read this. Callpoint had three equal shareholders: Cable and Wireless (parent company of Mercury Communications), Shaye Communications and Motorola. There had been rumblings for months before the collapse, and rumours were rife about what was going to happen to Callpoint. Indeed, Mercury's chairman had indicated back in June there was a possibility of Callpoint merging with Mercury's personal communications network operator Mercury Personal Communications. In retrospect, it would be hard for Mercury to deny it didn't know that telepoint was, and still is, a more-or-less dead duck.

Incidentally, in a not entirely unrelated move, Motorola has sold its 40% share in Mercury Personal Communications back to Cable and Wireless. I'll get back to Motorola and its current fortunes in a while.

Creditphone, the telepoint operator owned in the main by Ferranti may have closed, too, by the time ETI hits the streets. If Ferranti can find a buyer of its 68% share in Creditphone, it might have managed to save itself, but if no buyer is found; there's another one up the swanee.

That only leaves two telepoint operators currently functional. Phonepoint and Hutchison Personal Communications. Hutchison, incidentally, bought out Philips', Barclays' and Shell's share of the original license holder BYPS Rabbit. But that's not all: British Aerospace has bought a 30% stake in Hutchison Telecommunications, the parent company of Hutchison Communications. This is where the going gets hard to fathom. In the deal, British Aerospace handed over control of its personal communications operator Microtel to Hutchison. Meanwhile, Hutchison already owns Millicon; a radio-paging operation and is one of the existing cellular operators. There's got to be a message in this situation — essentially that there's probably too many communications operators across too many types of services — but whether anyone's taking any notice of this message up in the ivory towers of Whitehall is doubtful!

In the cellular sector things are getting a bit sticky, too. Recent financial interim results announced by Securicor show it's share of profits in Cellnet fell by nearly 40% from last year. Cellnet's growth in new subscribers had fallen dramatically, and the service's call rate has fallen by 10%.

Now we're all aware there's a recession and we haven't seen the worst yet, but there's got to be an underlying reason for all these problems, takeovers, buyouts and collapses.

The chips are down?

It's not unfair to say that Intel, developers and manufacturers of the microprocessor chips which have powered the majority of the world's personal computers for the last ten years or so, are about to go through one of their toughest fights ever.

Despite always championing the world over recent times with their 8080, 8086, 80286, 80386 and now 80486 personal computer microprocessors, and despite always developing 'souped up' chips, just to satisfy power hungry computer and car users and market-led computer and car manufacturers, it looks like their experience in the Garden of Eden isn't going to help them in the wilderness.

There are two reasons why this is so. First, Ford has recently adopted Motorola as its development agent for engine management microprocessors and systems. For the last eight years, Ford used Intel.

Second reason is a bit more subtle. You see, IBM, whose computers most others have to be compatible with to even stay in business, is set to form an alliance with the most unlikely partner you could ever think of; Apple.

For years, the only computer which could ever sustain significant sales while not being IBM-compatible has been the Apple Macintosh. Not only is it not directly compatible with IBM (it uses a totally different operating system to IBM's PC-DOS) but it laughed directly in IBM's face with a much friendlier yet just as powerful computer system. Consistently, Apple has never licensed its computer software to any other computer manufacture with the result that Apple computers were, and still are, unique. Even Microsoft's Windows 3, the front-end system designed to give PC-DOS computers just a hint of Apple's user-friendliness isn't a patch on the real thing.

Now though, IBM and Apple are in bed to design, develop and manufacture a totally new generation of computers based on reduced instruction set computer (RISC) chips. Apple has now licensed its software to IBM, and because Motorola has consistently backed Apple with its 68000 series of microprocessors for the Macintosh, Motorola has the exclusive licence to manufacture these RISC microprocessors.

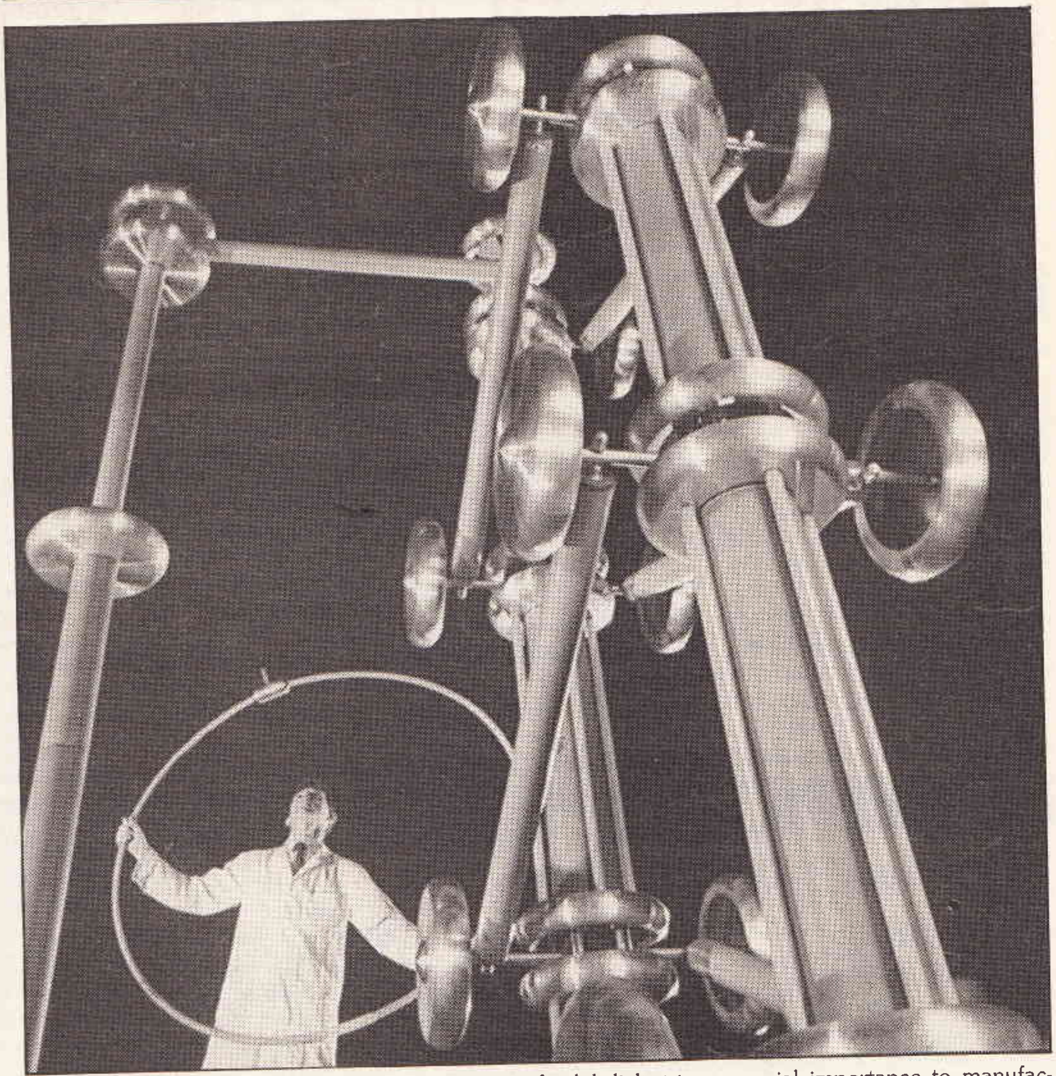
This is all rather a slap in the face for Microsoft, too. They are in the midst of legal action taken by Apple against certain features of Windows 3 which are said to infringe the Macintosh user interface so drastically that they represent a breach of copyright. Whether Apple wins or loses this legal action, they can't lose in the longer term. Microsoft is effectively being elbowed out as an operating system supplier. Committed IBM and IBM-compatible users can now look forward to an authorised Apple user interface, without all the hassles of PC-DOS.

Paraphrasing my favourite TV personality of the time, Bart Simpson; Intel, eat Motorola's shorts! Microsoft, eat Apple's.

Keith Brindley

ETI NEWS

JOINT EUROPEAN RESEARCH FACILITY



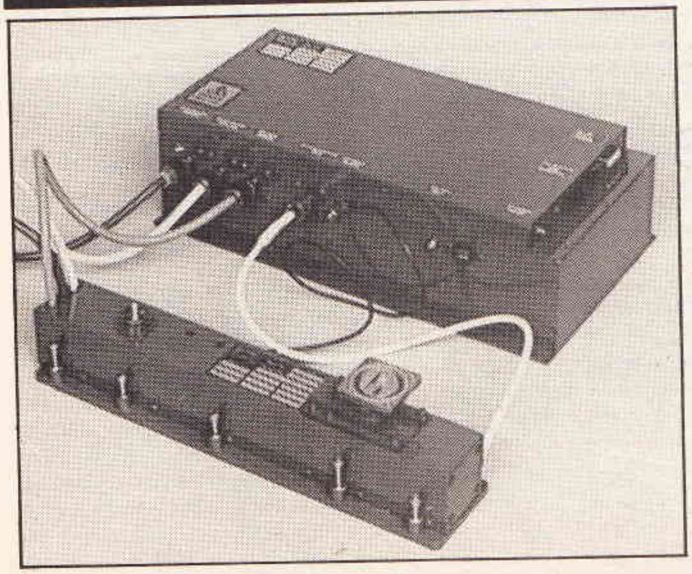
A new £250,000 high-voltage research laboratory was opened in July at Southampton University by Mr Arthur Walsh, chairman of Northern Telecom Europe Limited. The lab has been funded in full by Northern Telecom as part of its investment programme in European-based research and development.

"This new laboratory at Southampton University will be a major centre for high voltage research in the United Kingdom," Mr Walsh said. "It will offer new opportunities in the training of undergraduates while providing specialised testing facilities for the cable industry."

Northern Telecom, through its subsidiary STC Submarine Systems, has been associated with Southampton University through the department of electrical engineering for several years. Much of the collaboration has been in research programmes relating to the design and behaviour of underwater cables. A year ago, a teaching programme was developed to complement the research initiatives.

The department of electrical engineering at Southampton University has an established reputation for high voltage research, focusing primarily on the electrical properties of solid dielectrics and the long term ageing and breakdown processes in polymers. All these areas are of special importance to manufacturers of cables. STC has collaborated on a number of projects at the university.

MICROWAVE SWITCHED MODE POWER SUPPLY



Thorn Microwave Devices Limited has introduced a new range of compact, lightweight, low noise, switched mode power supplied for modern coherent radars, including multi-mode, pulse compression and doppler systems. They are also well suited to Electronic Warfare (EW), communications and instrumentation applications.

Designed for operating in a harsh airborne environment, Transpax power supplies offer high efficiency and reliability. They will drive helix, ring loop, coupled cavity travelling wave tubes (TWTs) and extended interaction klystrons (EIKs), operating from 1-60 kilowatt peak RF output power with average power up to 1.6 kilowatt.

The high efficiency of the Transpax range is achieved by the extensive use of high voltage solid state technology. A very low phase noise of only 0.1 degrees rms (−95dBC/Hz) is specified on current units; this will be improved still further on future models.

Transpax power supplies feature: a choice of modulators for operating tubes with intercepting, non-intercepting grids, or focus electrode electron guns; short pulse performance for high definition radars; and continuously variable pulse lengths up to 45 microseconds.

For applications up to 25 kilowatt peak RF output power, the HT modules are of potted construction and conduction/air cooled. Above this power, up to 60 kilowatts, liquid cooling is normally required, depending on application.

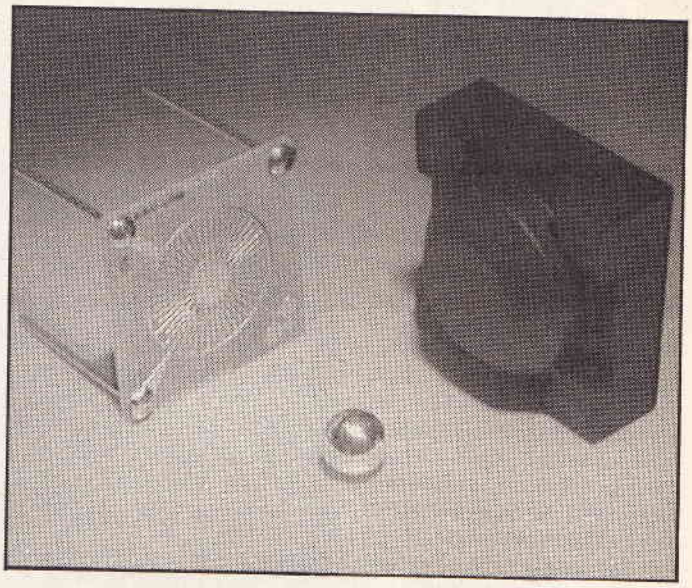
Further information contact: Tony Smart, Thorn Microwave, Tel: 081 573 5555.

NEW VEHICLE ALARM

Lucas Automotive, through its Electronics Division, have reached an agreement with Cobra Enterprises for the subsequent exploitation of a unique vehicle alarm technology. Cobra, the Toronto and Vancouver based advanced electronics company, has developed an intelligent vibration sensing system using sequential digital interpretive filtering to differentiate between specific attacks on the vehicle like a smashed window and normal interferance such as nudges and bumps or passing heavy traffic. The system has undergone rigorous tests by Lucas and found to be totally immune to vigorous rocking of the car yet able to detect the removal of a wheel or forcing of a lock.

The essence of the technology is contained within a 'golden ball sensor'. The SDI software developed over many years, has had many thousands of hours of tests in which a range of vehicles from mini cars up to station wagons and light trucks were subjected to motion and vibration analysis. This form of vibration sensing and filtering has been used for some time in the defence industry, particularly in anti-tank land mines where the technique is used to differentiate between heavy armoured fighting vehicles and light or so called soft targets. This is believed to be the only successful application of this technology to vehicle security.

The Cobra system is currently an OE fit on the SAAB range of vehicles and discussions are at a very advanced stage between Lucas and several European Vehicle manufacturers for the use of this, and other technologies in comprehensive vehicle protection systems currently under development by Automotive Electronics Division.



Vehicle security is probably the fastest growing sector within the automotive electronics market place at the moment because of the epidemic levels of car thefts and break-ins throughout Europe.

NOVICE LICENCE TRAINING SCHEME

A Novice Licence, which was proposed by the Radio Society of Great Britain, is the biggest change to UK amateur radio in 25 years. It is intended to bring more beginners into the hobby, especially young people. The Novice Licence will involve a short training course, a straightforward multi-choice examination and an optional Morse Test. It allows the world of amateur radio to be entered more easily than ever before. It is hoped and expected that most Novice Licensees will go on to study for the full Amateur Radio Licence.

The introduction of a Novice Amateur Radio Licence in the UK marks a significant step forward in the recognition of the educational value of amateur radio. The Novice Licence allows low power operation on certain designated amateur bands as a workable and pleasurabe stepping stone to a full UK Class A or B Licence.

Training for the Novice is based on the principle of 'learning through doing'. Emphasis is on practical training and the encouragement of constructional and operating skills. Training progress is continuously assessed during the course and understanding and retention checked and reinforced by means of a multiple choice examination which is taken after completion of the course.

To obtain the Novice B Amateur Radio Licence one must first successfully complete a practical training course run by the RSGB and then pass the Novice Radio Amateur Examination (NRAE — subject number 773) conducted by the City and Guilds of London Institute.

To obtain the Novice A Amateur Radio Licence, the above qualifications are required plus a pass in the Novice Morse Test (5 wpm), conducted by the Radio Society of Great Britain.

Existing full Class B radio licensees can be given access to novice frequencies below 30MHz. Full Class B licensees are also eligible to become Class A novice licensees, if they pass the 5 wpm Novice Morse Test. Such a licensee will hold both a Novice and a full Class B Licence with both Novice and full Class B call signs and pay fees for both licences.

Nevertheless, it is expected that the UK Novice Licence will attract people from all walks of life and all age groups. The Licence may well be particularly attractive to disabled people where in many cases amateur radio could be their doorway to the world.

MULTI-POINT THERMAL CONTROLLER/MONITOR

The SR630 can monitor 16 independent input channels, each separately configurable for seven different types of thermocouple. The front panel digital reading can be displayed in degrees Fahrenheit, Celsius or Kelvin as well as millivolts and volts — all with a 5-digit resolution.

Each thermocouple input is scanned 12 times per second. Built-in digital filtering reduces noise while all 16 channels can be sequentially scanned with dwell times user-variable from 0.5 to

9,999 seconds.

Audible alarm limits may be preprogrammed for each channel setting the upper/lower limits of tolerance before the alarm sounds. Additionally, a relay output is part of the alarm facitility allowing any systems or parts of a system to be instantly closed down or switched to a fail-safe mode. Isolated differential inputs have a 250V breakdown level allowing the SR630 to be used in difficult applications such a temperature profiling of electrically live equipment.

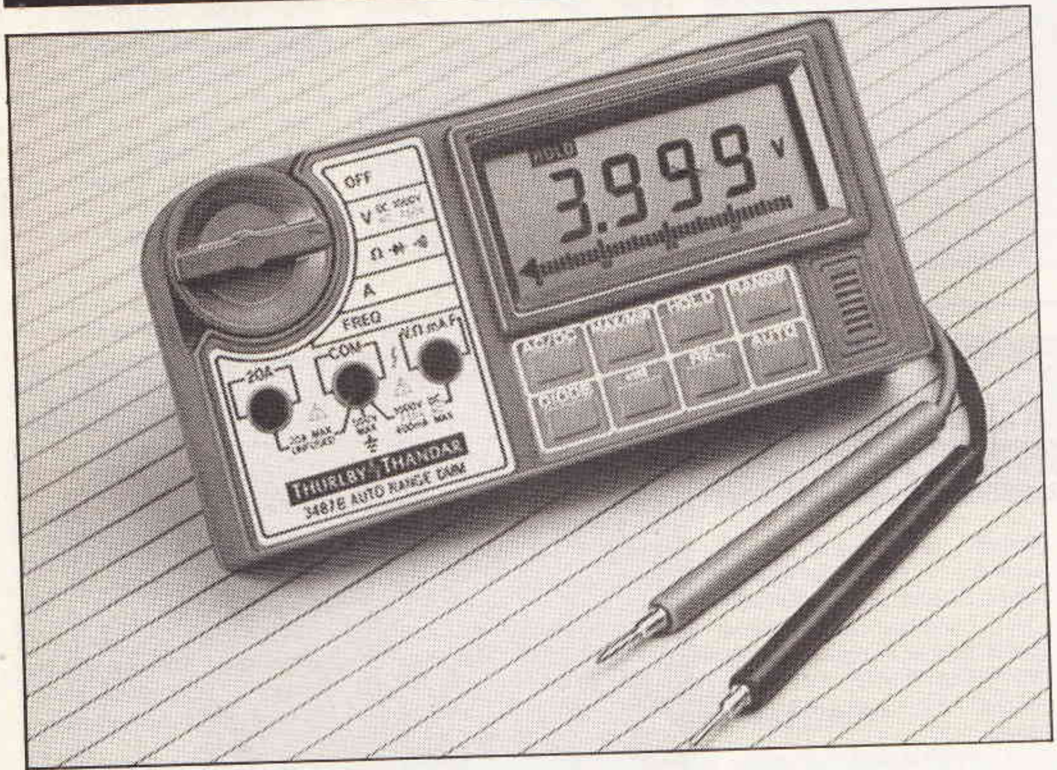
A printer output supports two forms — continuous graphic strip chart and a data printout which logs the important parameters such as time, date, temperature, voltage and channel number.

In remote stand-alone monitoring applications, the SR630 time stamps and logs 2,000 measurements in its internal non-volatile memory. Data is easily accessed by connecting a printer or computer. In addition, nine different instrument settings can be stored and recalled for convenient and accurate instrument set up offering instant and reliable repeatability.

When used in control applications or with analogue recorders, four rear panel outputs provide analogue voltages proportional to temperature of the corresponding input channel.

Contact Lambda Photometrics Ltd, Tel: 0582 764334.

HIGH PERFORMANCE DMM



The Thurlby-Thandar TM3487B is a high performance auto-ranging hand-held DMM with large display. The digits are supplemented by a 41 segment analogue bar graphs.

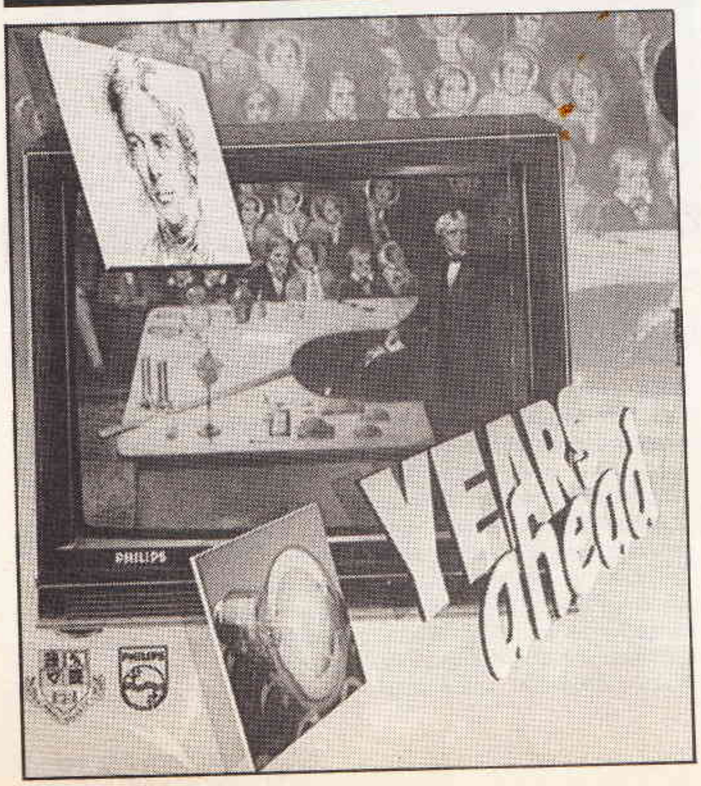
The high measurement accuracy (0.3% basic) with a 4000 count resolution is combined with a wide range of features including True RMS AC, Data Hold, Min/Max storage, Relative display and Frequency measurement. Auto or Manual ranging is selectable.

This combination of high performance in a lightweight and portable DMM (162 × 80 × 30mm and 200g approx.) is unique and the TM3487B will find applications in many different areas from field service to product development.

The TM3487B is supplied complete with probes and batteries at a price of £89.00 plus VAT.

Further details contact: Thurlby-Thandar Ltd, Tel: (0480) 412451.

LECTURE — YEARS AHEAD



What is Neuro-Computing and how can you get into Visual Reality? What is a Chladni Plate and how does a microphone work? What is an electron gun and how does it help a television work? These are just a few of the question to be answered in the 1991/92 IEE Faraday Lecture, co-presented by Philips Electronics and Imperial College, London.

Entitled 'Years Ahead' the Lecture will visit 16 towns and cities throughout the UK and be seen by an audience of over 85,000. The six month tour will begin in Brighton on 9 October and end in Sheffield on 18 March 1992.

The one hour presentation will look at the development of such high technology products as TVs, computers, stereo systems and compact discs and trace their origins back to the work of Michael Faraday, the 'father' of electrical science. The Lecture will also provide a glimpse of the future by looking at how these technologies might develop in the twenty-first century.

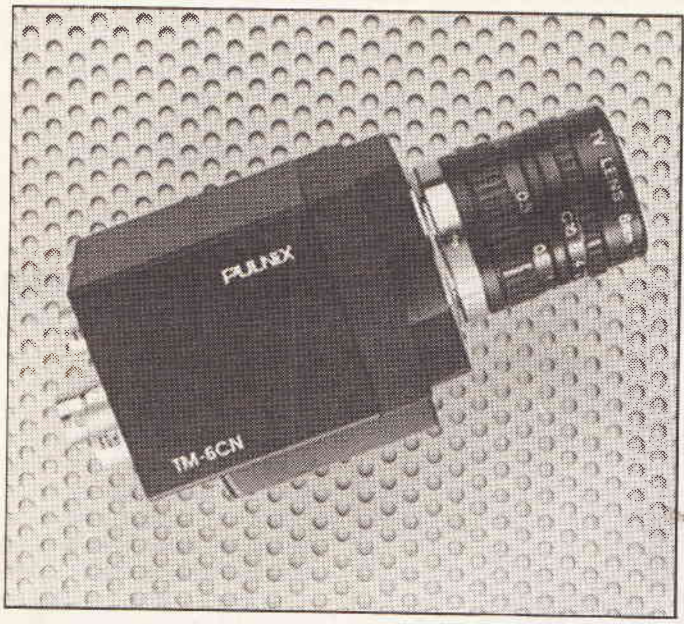
The Lecture will include stage demonstrations and film re-enactments of key experiments performed by Faraday in the 1830's and 1840's.

The Faraday Lecture was inaugurated by the Institution of Electrical Engineers (IEE) in 1924 to promote public interest in Electrical Engineering and to commemorate the life and work of Michael Faraday. In 1991, the bicentenary of Faraday's birth, the aims of the Lecture remain the same.

Admission to the Lecture is free but by ticket only. There are usually three performances at each venue, with the morning and afternoon performances being attended by local schools.

Applications for tickets should be made to: The Faraday Officer, IEE, Michael Faraday House, Six Hills Way, Stevenage, Herts SG1 2AY.

HIGH RES CAMERA



The Pulnix TM6CN series monochrome cameras offer the highest resolution interline transfer, ½" CDD imager available to date. The compact package eliminates the need for a remote imager camera in all but the most confined spaces. The camera fits both physically and functionally, into all types of machine vision, automated processing and related applications. Other uses include remotely piloted vehicles, miniature inspection devices, surveillance, microscopes and medical equipment.

The standard TM6CN includes the following features:

High resolution 570H × 460 TV lines
C-mount
1/60 to 1/10000 sec shuttering
Asynchronous reset
1 lux sensitivity (F1.4)
12 volt DC 220mA
Sync and pixel clock output

The TM6CN offers the industrial user easy access to the most commonly needed adjustments on the rear panel of the camera. They are GAMMA 1 or 045, AGC ON/OFF, and Manual gain control.

The TM6CN also allows the external selection of eight shutter speeds (1/60 to 1/10000 sec). This is achieved by attaching the SC745 shutter controller to the 6 pin connector. Auto iris outputs are also available.

Other functions including asynchronous reset, pixel clock and sync output are obtained via the 12 pin connector on the rear of the camera.

PATCHY EFFORTS TO PHASE OUT OZONE DESTROYERS

Only one in four British companies surveyed intend to phase out use of ozone depleting chemicals faster than required by EC law. Despite availability of alternatives, and new scientific evidence that ozone depletion is worsening at an alarming rate, the industry response has been patchy, concludes a survey launched by Friends of the Earth.

British companies use large quantities of two ozone depleters — CFC 113 and 1,1,1-trichloroethane — as solvents in electronics, precision and general engineering. Tough ozone protection laws have already banned used of ozone depleting chemicals in some countries, but in Britain the Government's voluntary approach leaves ozone protection decision to individual companies.

Friends of the Earth's survey of over 300 UK companies finds that while some companies are working hard to eradicate use of these chemicals, similar companies are making little or no effort. Almost half of the companies made a phase out commitment, with one in three setting a date ahead of legal requirements. Most car manufacturers are beginning to respond to pressure. Eleven of the nineteen companies contacted made a commitment to phase out in advance of the 1997 EC deadline. Volvo has already stopped using ozone-depleting solvents, as they are banned under Swedish law. Jaguar, Peugeot, Landrover, and Vauxhall failed to specify phaseout date, and Skoda (GB) Ltd alone offered no commitment whatsoever.

Companies in General Engineering lag even further behind. Fewer than one in five of companies specified an early phase out date. Almost half the companies in the General and Precision Engineering categories failed to reply to the survey. More than a quarter (28%) of Precision Engineering companies were prepared to set an early phase out date.

Recent US reports that ozone depletion is occurring twice as fast as previously predicted have fuelled calls for more decisive action to eliminate use of ozone depleters. The US Environmental Protection Agency (EPA) estimates that the new data could indicate an extra 200,000 deaths from skin cancer in the US alone over the next 50 years.

Fortunately, many EC countries have responded to public pressure for action to protect the ozone layer by adopting national strategies to phase out ozone depleters ahead of the EC deadline. The UK currently has no such plans.

NEW AUDIO AMPLIFIER FOR OEMs

The new HY60P audio amplifier module has been launched by ILP Electronics. It is particularly suitable for OEMs in applications which include sound backing systems, small public address systems and Hi-Fi equipment.

A 30 watt single channel amplifier measuring 80 × 40 × 26mm, the HY60P's input sensitivity is 500mVrms and total distortion is less than 0.015%.

The unit requires five electrical connections and the only additional components needed are a heatsink and power supply.

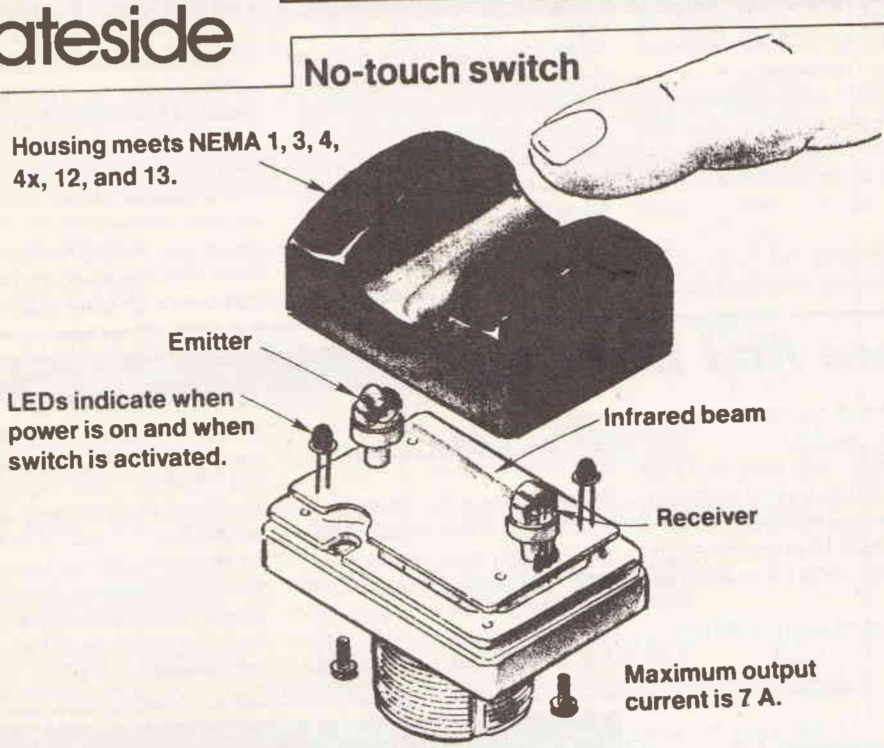
Designed and manufactured in the UK at ILP's Canterbury headquarters, the HY60P carries a two-year guarantee and is the latest addition to a wide range of audio amplifier modules available from the company.

ETI NEWS stateside

Advanced semiconductor

The National Advisory Committee on Semiconductors, a US government-industry group charged by Congress to develop a plan to keep the US competitive in semiconductor technology, has forecast that by the year 2000 advanced semiconductor factories will produce memory chips that can store more than 1 billion bits of information. But these plants will also cost about $2 billion each, and the world will have only 25 of them, with 10 in the US.

The plan, MicroTech 2000, aims to develop by the end of this decade all the technology to produce the 1-Gigabit-SRAM (static random-access memory) chip. This would require new technology capable of etching lines 0.15 micrometers wide on the chips, about one-fifth the width that is possible today.



No touch switch

An industrial illness known as carpal tunnel syndrome can result from workers repeatedly pressing push buttons on machines.

A new switch minimizes stress that causes CTS because it is energized without pressure. The housing is U-shaped, with an infrared beam passing between its sides and an operator activates the switch by breaking the IR beam.

The IR transmitter and receiver in the Opto-Touch switch are enclosed in a polysulphone and fibre-reinforced Valox housing. The housing shields the electronics from EMI/RFI as well as ambient light. It is resistant to acid, alkalis, and salts, and can be washed down.

The switch is available with alternate-action operation, where one touch energizes the internal relay and the next releases it, turning attached electronics first on, and then off.

Manufacturer is Banner Engineering, Minneapolis, Minnesota.

Optical flame detector

The incorporation of surface mount technologies into the U7652B optical flame detector enables the sensing, signal-processing and output components to be enclosed in a single housing. The unit continuously monitors both the ultraviolet and infrared sensors, activating separate LED indicators if a malfunction occurs.

Advanced signal processing gives this unit the ability to detect fires that may be partially obscured, either by other objects or their own smoke. The manufacturer claims a response time of one to five seconds with a hydrocarbon fire, and says that the sensors will ignore intense UV sources, such as arc welding. The unit's modular design allows maintenance while it is still online.

Detector Electronics Corp., Minneapolis, Minnesota.

Microprocessor needs only low power

A microprocessor that monitors and controls temperature is said to be a more accurate alternative to vapour-tension controllers. The chip's low 10µA power draw allows it to operate off a battery, solar cell, or external 1.5VDC supply. The controller has a -40 to 230F range, with a +/-0.5F accuracy. It also measures in degrees Celsius.

For HVAC applications, the temperature control microprocessor, slows the fan as temperature approaches the set point. It then runs the fan several minutes after the heater or cooler has been turned off, to push the remaining hot or cold air through the ducts. The chip also has a 6 or 8 minute cycle time delay, which eliminates rapid on/off switching.

Other applications include thermostats on recreational vehicles, and control on water-sourced heat pumps on boats, where low power draw is important.

PSG Industries Inc., Perkasic, Pennsylvania.

High temperature diamond transistor

A thin-film diamond transistor fabricated at Pennsylvania State University is said to be the first that operates at temperatures as high as 300°C. The transistor was built to demonstrate that it is possible to use diamond as a high-temperature semiconductor material.

It is believed that thin-film diamond semi-conductors could form the basis of integrated circuits that work at around 600°C and these could eliminate the need for bulky cooling equipment now used in high-temperature applications such as unmanned spacecraft.

The single-crystal, diamond-film transistor was fabricated on a natural diamond substrate using silicon-dioxide lithography and epitaxy. A highly-pure diamond substrate was used because crystal imperfections limit the temperature at which the transistor operates. Presently, diamond films can be grown on other materials, but single-crystal diamond films cannot.

The company is currently trying to grow single-crystal diamond films on other substrate materials. Experiments are being made with different chemical compounds and substrates to solve this problem. When a solution is found it will be a major milestone because most other substrate materials are much less expensive than high-quality natural or synthetic diamonds.

READ\WRITE

ETI LETTERS

Photo Copy PC

The Not So Easy PC on your Read/Write page, September issue, complains about the high cost of creating photopositives for PCB construction. Has anybody ever considered or tried using a conventional photocopier. The original can be drawn on paper, and then by using the copier's reducing facility, create a photopositive on an overhead projector transparency (commonly called viewfoils). Any High Street photocopying specialist should be able to provide this facility, I doubt if the local corner shop's copying service could cope.

It is probably that the thickness of the viewfoil material will not allow fine detail to be achieved due to optical diffraction, but the achievable limits could be determined by experiment. Would anybody like to try?.

Colin Long,
Chigwell, Essex.

We have used this idea in the office to obtain a quick visual reference of the reverse side of a paper foil. It is fine for graphical design work but we consider the dark areas too transparent to be used as a mask for the production of PCB's. One could of course enhance the contrast with a black marker pen — Assuming any High Street shop will allow you to put a transparent sheet through — Ed.

Life, Cash Machines And Everything

I am doing some intensive research into the meaning of life and I have come across two problems which I am unable to solve, maybe you can help.

How do those 'Hole-in-the-wall' machines know that you are putting a card in the wrong way round. Even before the card has had a chance to reach the magnetic read head, the card is refused entry into the slot.

Secondly, why does my VHS Videorecorder (and my brother's) start playing some tapes straight away, without having to press the play button whilst other tapes do not?

Help me please, I'm starting to need it.

M P Scotford, London.

Taking a guess at the first answer, I would suggest the default setting of the shutter must be closed and either using a close range magnetic proximity detector or some reflection technique, detection of the strip in the correct position will cause the shutters to open. I will leave the overall explanation to the people that build the machines. NCR, the cash register people have offered us an article on Hole-the-wall machines. (See within these pages.) Any suggestions on the second 'life' problem from any reader would be gratefully received. — Ed

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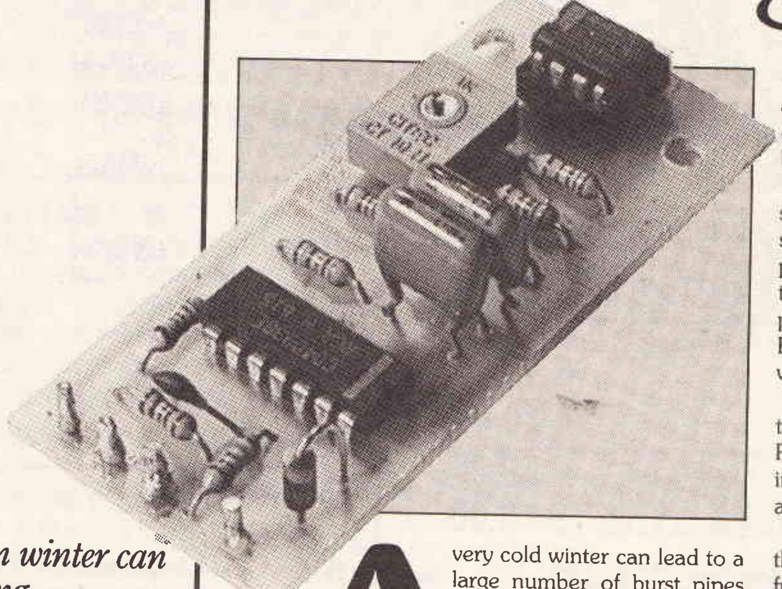
Freezing Alarm



Burst pipes in winter can be an alarming experience. Dave Bradshaw builds a circuit to warn of an impending freeze.

A very cold winter can lead to a large number of burst pipes and floods, due to the very low temperatures. The device described here should help stop your household suffering that fate in winters to come.

The device is based on an integrated circuit temperature sensor, the LM3911, which also contains a voltage regulating zener diode and an op-amp as well.

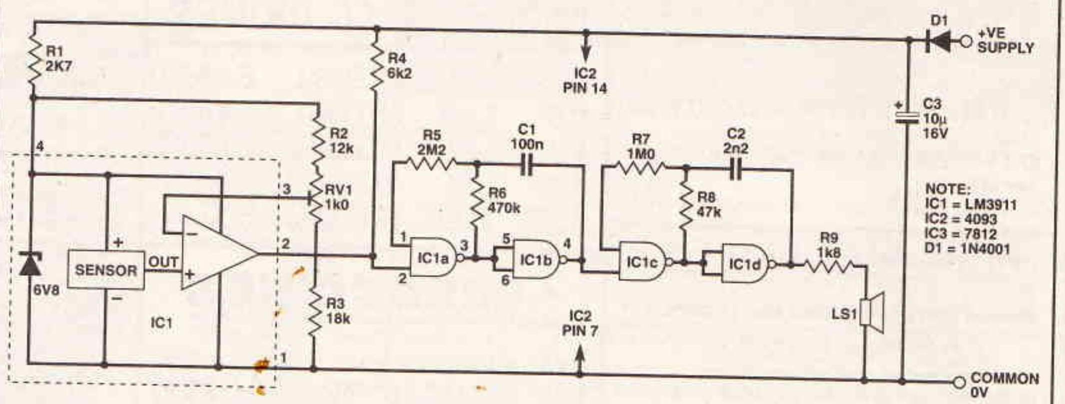


Fig. 1 Circuit diagram of Freezer Alarm.

The way this is used in the temperature alarm is shown in the circuit diagram of Figure 1. The circuit divides into three main sections: the sensor itself, a comparator which detects when the voltage from the sensor goes below a certain preset level, and the bleeper circuit which the comparator then sets off; is also a simple voltage regulator which supplies the sensor as well as the op-amp and the potentiometer circuit which is used by the comparator as a reference.

The sensor is based on a device similar to a zener diode, but is made to have a breakdown voltage which varies with temperature. In fact, the breakdown voltage is proportional to the absolute temperature the temperature scale which takes absolute zero, −273°C, as its zero. The voltage output from the sensor is 2.73 volts at zero degrees C (or 273° absolute); however, this voltage appears between the positive and out points of the sensor (*not* between the output and the common line). The + terminal is attached to the anode of another zener diode, at the extreme left of the circuit inside the IC block, but this one is made so as to be very insensitive to temperature changes.

This second zener is, as the circuit diagram shows, connected across the positive and negative supplies to the whole IC, so resistor R1 is used to supply the positive volts to the IC and the zener stabilises the voltage to 6.8 volts. Also attached across the supply connections of the IC is a potential divider circuit, R2, RV1 and R2, which is used to provide a reference voltage for the op-amp inside the IC.

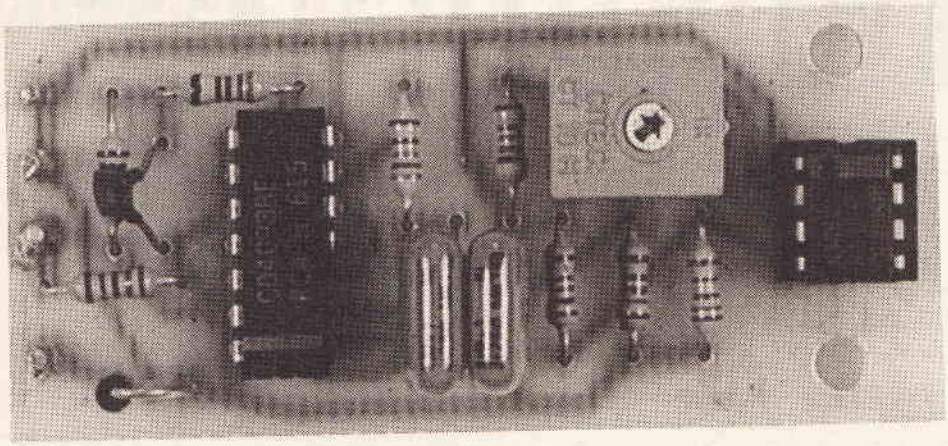
The inverting input to the op-amp is attached to the output of the potential divider, which is adjusted by RV1, and should be set to give 2.73 volts between the input of the op-amp and the top-end of R2 (the end attached to the positive supply to IC1 and R1.

When the output of the voltage sensor is greater than 2.73 volts, ie the temperature is greater than freezing point (0°C or 273° absolute), the inverting input of the op-amp (connected internally to the sensor's output) will be *lower* in voltage than the inverting input, so the output of the op-amp will be near to the common supply voltage. When the voltage from the sensor is lower than 2.73 volts, the voltage of the non-inverting input will be *above* that of the inverting input, so the output from the op-amp will be near the positive supply rail; in fact the op-amp has an 'open-collector' output, and R4 'pulls' the output voltage up to nearly the main supply voltage.

The output from the op-amp is used to turn on or off the bleeper circuit, which has already been described briefly in the 'Mains Alarm' project in this issue; this section of the circuit uses CMOS logic ICs.

This circuit needs to be powered for long periods of time, it would have be on for all of the colder months of the year. Its standing current of about 10 milliamps will use up several batteries a week. The only practical solution is to use a mains supply of some sort, and fortunately here are devices known as mains adapters or battery eliminators which are cheap to buy and which take the trouble out of building a mains power supply. However, most are not regulated, so allowance has been made on the PCB for the inclusion of a voltage regulator IC in the circuit; in most cases this will be unnecessary.

PROJECT



Construction

Making up the printed circuit board is very straightforward in general, but there is one slightly awkward point. The most sensitive part of the IC sensor, IC1, is the underneath of the IC's body, so for maximum responsiveness, it is this part of the IC that must be placed in direct contact with the pipe or whatever is to have its temperature monitored; this can be done by bending back the leads on the IC package and then soldering the IC the same way round as shown on the overlay diagram, but on the reverse copper track side of the PCB. However, at the cost of a small decrease in temperature sensitivity, the IC can be mounted on the top side of the PCB in the normal way, except that to make it easier to bring the IC into contact with the pipe or whatever, the IC should be mounted using an IC socket, so that it is above the surface of the board.

As usual, start the assembly of the components on to the board by positioning and soldering the resistors, the preset potentiometer, the capacitors and finally the two ICs. I would suggest not bothering with, the voltage regulator, IC3, unless it is found to be necessary, so leave it off for the moment and insert diode D1 between where IC3's input and output terminals would be (this prevents accidentally connecting the power supply the wrong way round doing any damage).

Finally attach wires to link the board to the power supply and the sounder; on the prototype, four-cored burglar alarm wire was used to connect the PCB in the loft attached to a pipe to the PSU and sounder in the room below. Before installing the PCB in its final position, link up the board to the mains adapter and the sounder as shown in the overlay diagram — but leave off the connection to the positive supply. Apply power to the adapter and, using your multimeter switched to a DC voltage range, check the voltage output of the adapter; it should be between 12 and 15 volts (when switched to the 9 volt range, for switchable types), but if it is slightly above this, take a 1k resistor and put this across the output to see if this brings the output down to 15 volts or under. If it does not, either the power supply must be switched to a slightly lower voltage, or some component values must be changed, or a voltage regulator IC must be used.

Continued on page 25

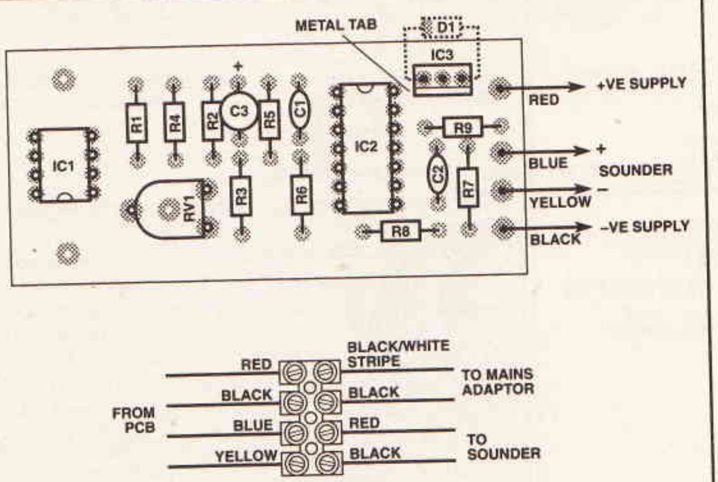


Fig. 2 Component overlay for the alarm.

Fault Finding Guide

Symptom: current drawn by the PCB is much larger or much less than expected

Check firstly that the power supply is connected the right way round (if D1 is used, check that this is the right way round too). Look for breaks in the PCB tracks, or solder bridges. Check that IC1 and 2 are the right way round — note that they are opposite ways round.

Symptom: Bleeper does not sound when IC1 cooled

Firstly, check the voltage on IC1 pin 2; if, on cooling IC1 and adjusting RV1, this voltage can be made to go to nearly the supply voltage, and the bleeper doesn't work, then there is a fault somewhere in the bleeper circuit. If IC1 pin 2 will not go to nearly the positive supply voltage, check that R4 is OK, before following the suggestions in the next paragraph.

Check the voltage at IC1 pin 3, it should be about 4.1 volts, adjustable by up to 0.2 volts by RV1(note down the exact voltage range which pin 3 can be adjusted over). If this is not then check the voltage of IC1 pin 4, which should be approximately 6.8 volts. If this is OK, look for a fault in the potential divider, R2/RV1/R3. If the voltage at IC1 pin 3 is OK, disconnect the wiper of RV1 from the PCB (you may well have to remove RV1 completely to do this) and connect together pins 2 and 3 of IC1, then reapply power. The voltage on pin 2 (or 3, which must now be the same) is the voltage output by the sensor. At room temperature, this should be approximately equal to V(pin 4) — 3.0 (where V(pin 4) is the voltage at IC1 pin 4); if it isn't, there is something wrong with IC1. If this is OK, re-cool IC1 to freezing point and re-measure the voltage on IC 1 pin 2 or 3. This should now be within the range of voltages which IC1 pin 3 could be adjusted to be RV1 before it was removed. If it is just outside this range, then adjust R2 and/or R3 until RV1 (re-inserted) can give this voltage to pin 3, now disconnected from pin 2. If the voltages are very different, then there is either some fault with IC1 or the values of resistors R2 and R3 are wrong.

Cosmic Rays

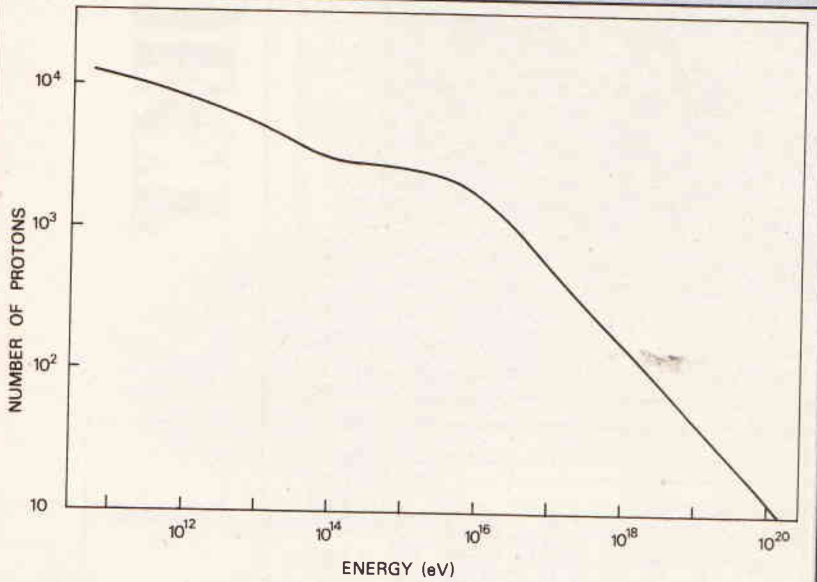


Fig.1 Typical energy spectrum of cosmic ray protons

Douglas Clarkson investigates that elusive radiation from outer space.

While life on terra firma unfolds its normal course of events, so too an age old phenomenon continues in the guise of cosmic rays bombarding the earth from outer space. Research into cosmic ray particles has been undertaken in order to provide clues about some very fundamental aspects of Astronomy. As more and more information has been obtained about these silent invaders, it has provided much valuable information, but at the same time raised other questions about the nature of the universe.

The early investigators of radioactivity were puzzled by the apparent contradiction that no matter how well they lined their ionisation chambers with lead, there was still a residual amount of activity able to be detected. It soon became apparent that the source of this radiation was not 'earth based' but came from outer space as ionisation chambers sent aloft in balloons and placed on mountain peaks detected increased amounts of radiation.

It is now known that the source of this ionising radiation is a constant stream of fast moving charged particles — atomic nuclei — which continually bombard planet earth. The patterns of ionising radiation observed by numerous cosmic ray investigators from the 1930's onwards are the result of the complex interaction of such fast moving particles with the atoms and molecules in the earth's atmosphere.

Such 'cosmic particles' provide important information about the greater universe. It is considered that the bulk of such particles originate within the Milky Way, the galaxy to which planet Earth belongs. So not only is planet Earth bombarded by photons from the electo-magnetic spectrum in the ranges of radio waves, infra red, visible light, ultra violet, X-rays and gamma rays, it is also showered by physical atoms of matter from all corners of the Milky Way and possibly beyond. Over the considerable time that planet Earth has been in existence a significant mass of such cosmic particles has fallen onto it.

Energy Spectrum

A feature of prime importance which scientists have investigated is the so called 'energy spectrum' of such particles. The bulk of cosmic ray particles are in fact hydrogen nuclei or simple protons. Figure 1 shows the typical energy spectrum of such particles incident from outer space. In general there are fewer and fewer particles at higher and higher energies. It is difficult to appreciate however, the exceedingly high energies which the fastest particles possess. Energies are typically described in electron volts where one electron volt is the energy picked up by an electron when it passes through a potential difference of one volt. Units of MeV (10^6 electron volts) and GeV (10^9)electron volts) are commonly used. The energy of 10^{20} electron volts corresponds to the energy that would raise the temperature of 1ml of water by 4° Celcius. This a single ultra fast cosmic particle can be imagined to deliver quite a 'whack' to any physical object which it encountered. In fact some impact marks made by cosmic ray particles have been detected in the space suits of the Apollo moon landing astronauts.

Understanding of cosmic ray particles and associated phenomenon have matured considerably with the advent of space research. One of the vital factors of long term exposure to outer space relates to the nature of radiation hazard which cosmic ray particles may present. Important studies have been undertaken not also to measure the relative energies of such particles but also to evaluate the type and the flux of such parti-

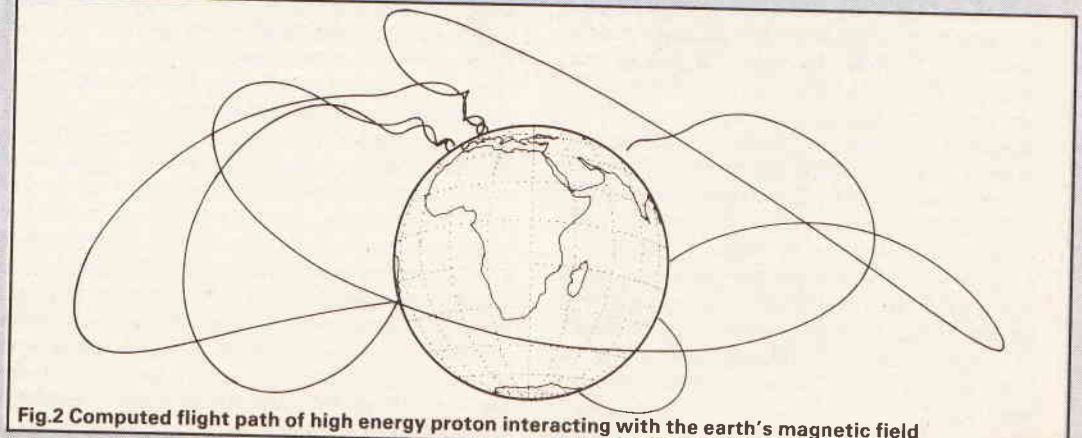


Fig.2 Computed flight path of high energy proton interacting with the earth's magnetic field

COSMIC RAYS

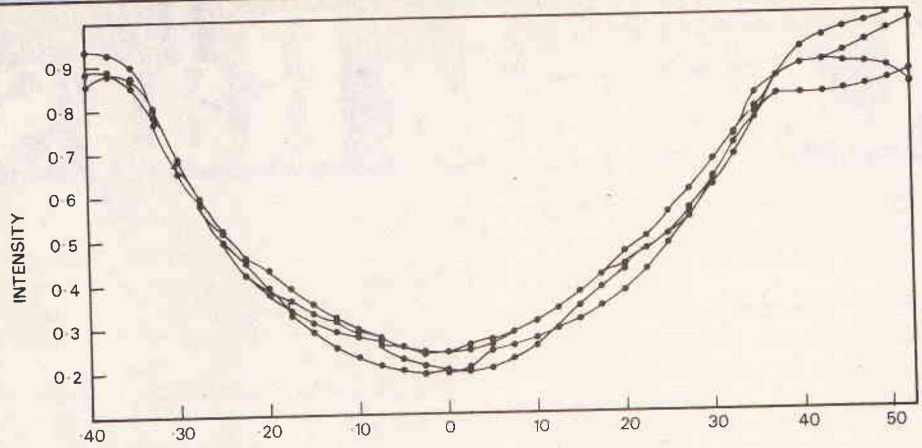


Fig.3 Variation of radioactivity levels detected at sea level as a function of geomagnetic latitude

cles bombarding the earth. Table 1 indicates values obtained for the incident flux of such particles at the top of the atmosphere for energies greater than 1.5 Ge V/n arriving from directions within 30° to the vertical.

Type of Nucleus	Flux (particles/metre²/sec)
Hydrogen	640
Helium	94
Lithium, Beryllium, Boron	1.5
Carbon, nitrogen, oxygen	6
Iron (Z=26)	0.24
Cobalt, Nickel (Z=27,28)	0.01
All nuclei with Z > 28	0.003

Table 1: Incident flux of nuclei

The total energy with which the earth is continually bombarded is around 100,000 kilojoules/sec — comparable to the total amount received in starlight.

Interaction with the Earth's Magnetic Field

Charged particles which move in a magnetic field experience a force which tends to deflect their path from a straight line. The magnitude of the force is proportional to the speed of the particle, its charge and the component of magnetic field at right angles to its path. The earth has a relatively strong magnetic field which has the property of significantly deflecting the paths of cosmic ray particles incident upon it. This magnetic field can be considered to be created by a large 'imaginary' bar magnet embedded within the earth about 200 miles from its centre. One set of field lines emerge from the earth near lattitude 79° N, 69° north of Greenland (north magnetic pole) and another set emerge at 79° south, 110° east (south magnetic pole).

This locally strong magnetic field around the earth distorts the paths of even the most energetic cosmic ray particles. The typical flight path of a cosmic ray particle passing around the earth can often be exceedingly complex as revealed by computer simulations of the flight paths of cosmic rays particles of specific types and energies approaching the earth from various directions. Figure 2 shows the computed path of a cosmic ray particle as it interacts with the earth's magnetic field. It is therefore quite difficult to predict the point of origin of a specific cosmic ray which collides with the earth. The effect of the earth's magnetic

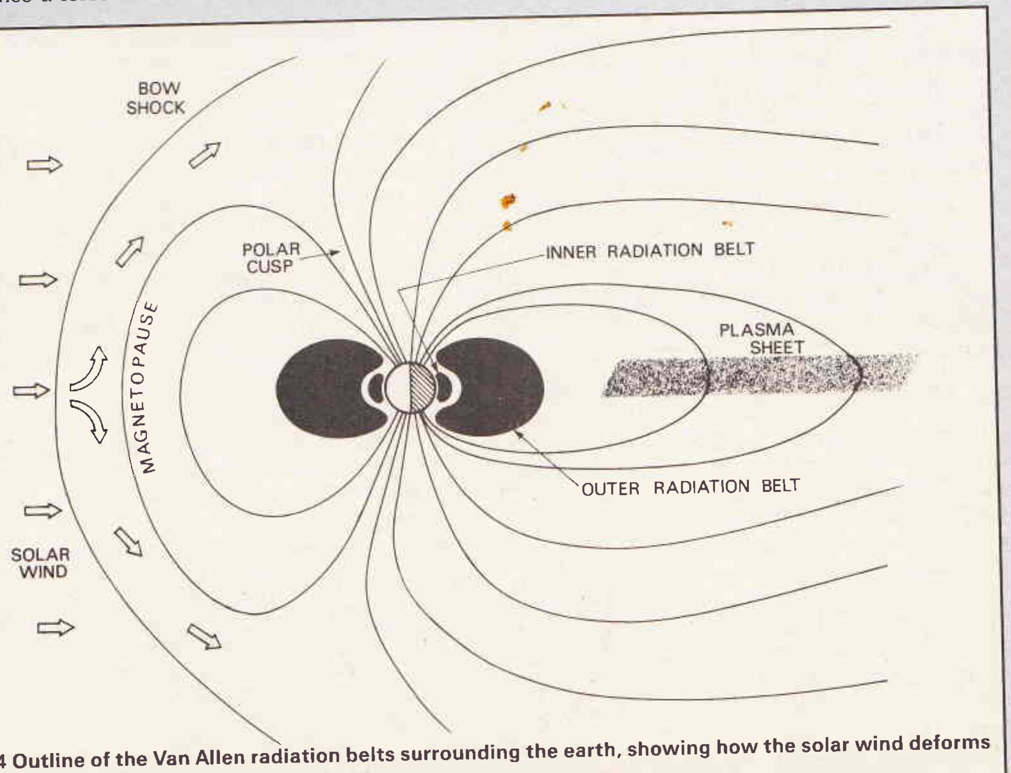


Fig.4 Outline of the Van Allen radiation belts surrounding the earth, showing how the solar wind deforms the earth's magnetic field

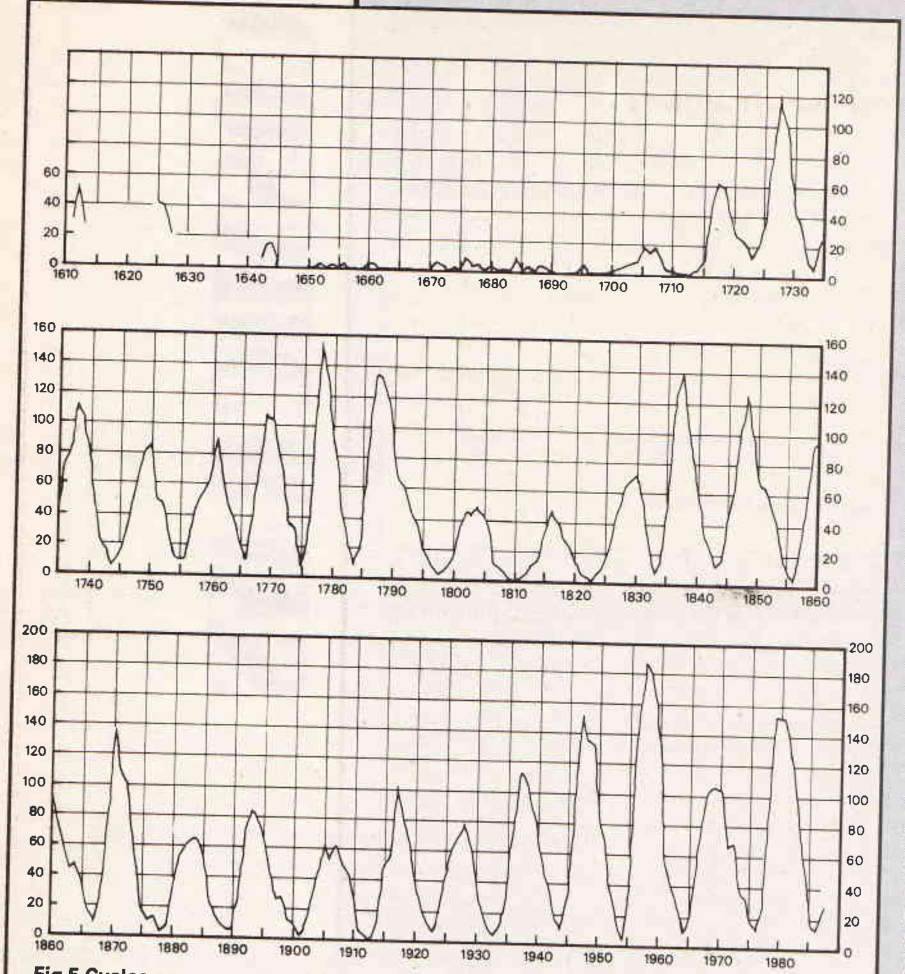


Fig.5 Cycles on sun spot activity since 1610 showing the appearance of an approximate 11-year cycle

field is to deflect particles away from the equatorial zones of the earth towards the poles. Figure 3 shows the result of a survey of cosmic ray intensity undertaken at sea level as a function of geomagnetic latitude.

The field of the earth tends to trap cosmic ray particles in zones above the earth. Such radiation belts called the Van Allan Radiation belts were discovered by the early American Explorer I and II satellites launched in 1958 in the wake of the earlier launch of Sputnik 1 by the Soviet Union. Previous high altitude rocket experiments had shown that radiation levels increased up to about 24km and then decreased to a steady value at around 150km. The early Explorer 1 mission, however, indicated that zones of considerably increased radiation existed beyond the previously mapped areas. Such radiation zones have been mapped out by numerous subsequent space probes and satellites.

Figure 4 shows the sets of radiation belts surrounding the earth. The radiation is primarily due to concentrations of high speed electrons and protons which are trapped in orbits by the earth's magnetic field. The inner belt is centred at approximately 1.5 earth radii from the earth's centre and the outer belt at 4.5 earth radii from the earth's centre. Particles travel backwards and forwards within the magnetic field of the earth acting like a magnetic mirror, bouncing the particles from one end limit point to another. In the inner belt, the typical residence time of protons is of the order of years. Typically the radiation belts contain electrons with energies of a few MeV while protons can typically have energies of a few tens of MeV up to a few hundred MeV.

The levels of radiation in the radiation belts poses a problem for satellites and space craft which have to pass through them. The maximum levels of activity detected for protons with energies above 0.5 MeV in the inner belt is about 200 million particles per second passing through a square centimetre per second. The comparable figure for protons in the inner belt with energies greater than 15 MeV is some 2000 times smaller. The maximum flux of electrons in the inner belt is about 60 per square centimetre, rising to about a maximum of 1 million per square centimetre in the outer belt. Such high energy electrons will tend to release gamma rays and 'hard' X-rays when they are suddenly decelerated by colliding with atoms in their path.

Cosmic Ray Showers

A high energy cosmic ray particle which eventually passes into the earth's atmosphere will yield up all its energy in a series of collision processes. Initially mesons (mainly pions) are produced which in turn rapidly decay to muons and neutrinos. Muons in turn produce electrons and more neutrinos. High energy electrons in turn produce ionisation and gamma rays. In this way it is possible for a cascade or shower of radiation to propagate through the atmosphere which is due to the impact of a single high energy cosmic ray particle.

The highest energy particles produce what is known as extensive air showers (EAS) which contain many millions of sub particles. Such a shower can be imagined as a disturbance which at ground level can be tens of metres 'thick' and hundreds of metres in diameter. The predicted energy spectrum would indicate that particles with energies above 10^{20} eV should be detected at the rate of about 5 per century per square kilometre. Assuming an effective area of 400 square kilometres for central London, this would indicate an extensive air shower somewhere within London once every six months. Even though this rate of incidence would seem vanishingly small, various research groups have active programmes to detect such EAS events.

The early phase of understanding the nature of the ionising radiation created by cosmic rays lasted around 50 years and during this time the radiation produced by such particles was extensively studied using ground based observation and also high altitude balloons. Space research has since revolutionised the understanding of such particles. The vast amount of work undertaken by previous sets of earth-based observers should always be appreciated.

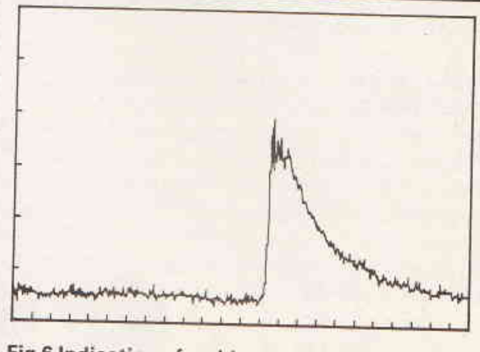


Fig.6 Indication of sudden onset of solar cosmic ray activity associated with a large solar flare. The neutron activity increase is associated with interaction of energetic solar particles in the atmosphere

The very existence of such cosmic ray particles means that electronic and computing systems can be expected in their lifetimes to be subjected to radiation triggered by cosmic ray particles. With continuing trends for miniaturisation of electronic circuits the nature of such potential risks will become more acute.

The Sun's Activity

While cosmic ray particles originate primarily from outside the solar system, the sun is a finite source of energised particles. The so called solar wind is a stream of relatively slow moving particles which escape from the sun's surface. Such activity is heightened by the emergence of so called solar flares when vast arcs of matter are ejected from the sun's surface. Such particles which escape from the sun require sufficient energy to escape from its gravitational field. It is estimated that the sun looses 300,000 tons of material (mainly hydrogen) each second though this amounts only to one part in 10^{14} of the solar mass per year.

The typical speed of the solar wind in the vicinity of the earth is 450 km/second though specific higher energy streams can reach speeds of around 1000 km/sec. The typical energy of such a solar wind proton is around 3000 eV. In terms of particle flux, this is in the region of 100 million particles per square centimetre. As shown in Figure 4, the earth's magnetic field distorts considerably the pattern of flow of the solar wind in the vicinity of the earth.

The surface activity of the sun has a cycle which lasts approximately 11 years. Sun spots on the sun's surface are associated with increased outpouring of matter into the solar wind and by their interaction with the earth's magnetic field produce perturbations in the earth's finely balanced mechanisms within the radiation belts and ionosphere. Figure 5 shows the variation of the number of visible sunspots observed since the discovery of the telescope in 1609.

The sun is also a source of cosmic ray particles. Energies associated with such particles are in the region of several MeV and such particles tend to be associated with particularly active solar flares. The sun is not identified as a source of high energy cosmic ray particles. Figure 6 shows the sudden increase in neutron activity detected at earth following the emission of a large solar flare and the interaction of such higher energy particles within the earth's atmosphere.

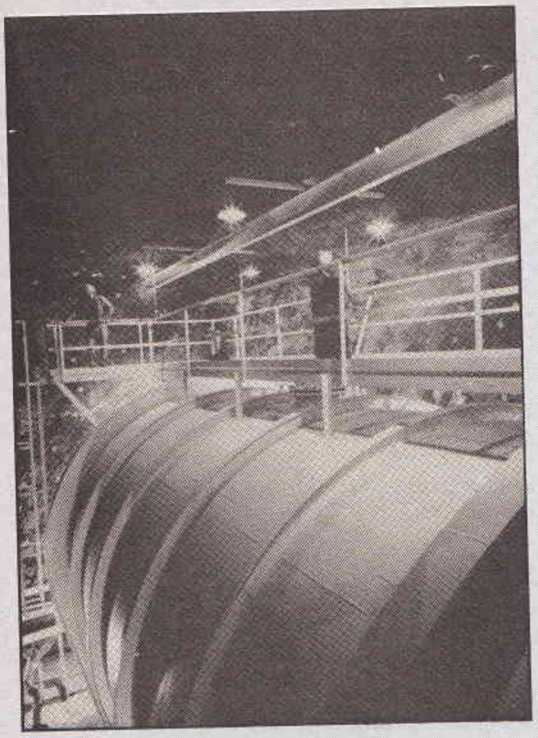


Fig.7 The large 100,000-gallon tank of perchlorethylene in the Homestake Gold Mine in South Dakota is used to detect neutrinos (courtesy Raymong Davis Jnr and Brookhaven National Laboratory)

Elusive Neutrinos

While particles such as protons and electrons are relatively easy to observe by their interaction with matter, not all cosmic particles are as easily detected. The neutrino (little neutral one) is particularly elusive. Neutrinos are created in vast numbers by the sun. At the distance of the earth's orbit the flux of neutrinos is about 10^{10} per square centimetre per second. The vast majority of neutrinos pass directly through the earth without any interaction whatsoever.

Various reseachers have developed systems to try and detect neutrinos. Information obtained from such observation systems allows comparison of predicted neutrinos flux from the sun with measured values. One system, shown in Figure 7, for detecting neutrinos is installed in the Homestake Gold mine in South Dakota and consists of a tank containing 100,000 gallons of perchlorethylene. When a neutrino interacts with an atom of chlorine in the fluid, a radioactive isotope of Argon with a half life of 35 days is created. Every 100 days the system is flushed with Helium gas and the radioactivity of the Argon atoms measured. Based on the assumed flux of neutrinos through the tank system, the expected rate of production is about three atoms a week. In practice, however, less than a third of the expected rate is observed. This result would seem to question the assumed flux of neutrinos from the sun and throws a spanner in the works of the accepted models of stellar theory.

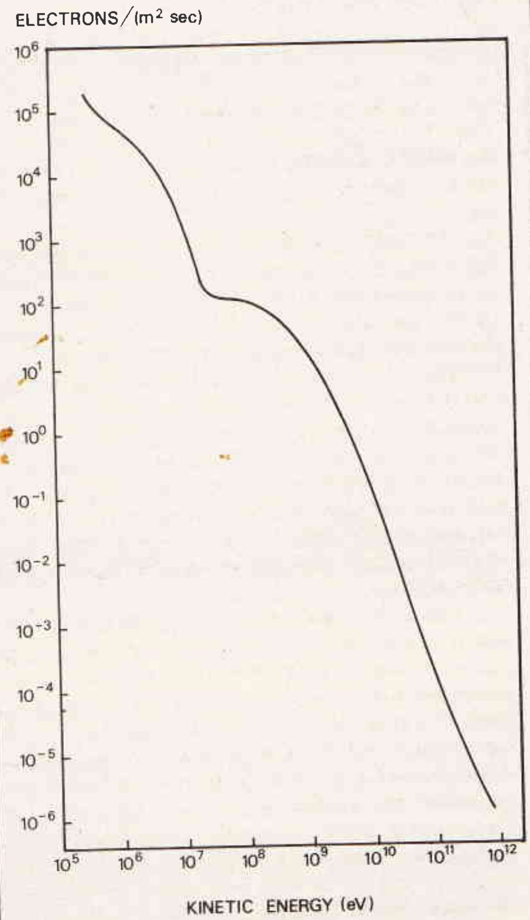


Fig.8 Energy spectrum of cosmic ray electrons

The importance of the neutrino lies in the accurate estimation of their vanishingly small mass. Although their mass is very small, they derive importance from the fact that their contribution to the mass of the universe could be significant due to their great abundance. In theories of cosmology, a key question relates to whether the universe is 'closed' ie if there is enough mass for gravitational attraction to bring about an eventual 'great crunch' or whether galaxies which continue to fly out from an initial 'big bang' will continue to do so and the universe expand for ever.

Supernova explosions tend to release their cataclysmic energy in a relatively short time period during which a super pulse of neutrinos is released. By observing the time period over which such supernova neutrinos can be detected on earth, astronomers can estimate the rest mass of such particles. In 1987 a total of 19 neutrinos between two sites were detected which were associated with the supernova explosion of

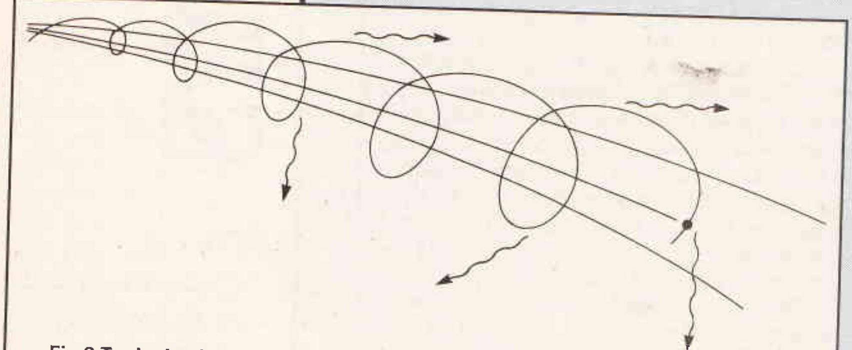


Fig.9 Typical spiral path of electrons travelling in a magnetic field, radiating electromagnetic energy

SN1987A. The time spread of detected events put a lower limit on the neutrino mass of 1/50,000 of that of an electron. Such a value of rest mass is considered not sufficient to create a 'closed' universe though the debate on the neutrino is surely far from over.

Cosmic Electrons

While high energy electrons do represent a portion of the types of particles which make up cosmic rays particles, they tend more readily to lose energy in their outward flight from their places of origin. Figure 8 shows the typical energy spectrum of cosmic electrons. The solar wind tends to alter significantly the energy distribution observed below about 10 GeV.

Because of the smaller rest mass of the electron (1/2000 of that of a proton), electrons are more subject to acceleration when interacting with other particles or spiralling in a magnetic field. When electrons are spiralling in a magnetic field, this acceleration will tend to make the electron emit photons of a frequency determined by the energy of the electron and the magnetic field through which it is passing. A 1GeV electron travelling through a galactic magnetic field of 3 microgauss would typically emit at a wavelength of 48 MHz. Figure 9 shows the typical spiral path of such an electron in a magnetic field.

It is also possible for electrons to lose a significant portion of their energy by so called 'brems-strahlung' or 'braking radiation' as they suffer sudden dramatic accelerations as they interact with physical matter. Thus interactions with hydrogen and dust particles will tend to cause significant energy losses detectable as gamma ray emission.

Origin of Cosmic Rays

It is assumed that all but the most energetic cosmic ray particles originate within the Milky Way — our home galaxy. Astronomers are fond of estimating the value of energy density per unit of volume of specific modes of energy. In the case of cosmic ray particles, the value is around 1eV per cubic centimetre. Multiplying this value by the volume of the Milky Way and assuming that this energy is replenished every 10 million years, then an energy input of 5×10^{33} Joules per second is required. This amount of energy could be transferred into the galactic system by a supernova explosion every 50 years.

While the numbers look attractive on paper, astronomers are keeping an open mind as to the origins of cosmic rays. By their very nature they must originate by means of cataclysmic scenarios. Also, the most energetic cosmic ray particles probably cannot be contained within the magnetic field of the Milky Way. The vastly improved scope for accurate observation from space of ultra violet, visible, infra red, X-ray, radio and gamma ray emissions allows theories of cosmology such as that of the origin of cosmic rays to be evaluated against much better experimental data than was available previously.

Life Cycle of Cosmic Rays

While it is always difficult to verify theories about the origin of cosmic ray particles, valuable insight can be obtained into their life cycles by examining the 'mix' of atoms detected in their streams and comparing this with the known constitution of stellar produced material such as that found on earth. The incidence of Lithium, Boron and Beryllium in cosmic ray streams is considerably higher than would be expected from the process of nucleosynthsis in stars. It is considered that these ions could be produced by interaction between cosmic ray particles of Carbon or Oxygen and interstellar Hydrogen atoms. Also, by determining the relative abundance of isotopes of Boron which are observed at Earth in the cosmic ray stream, the typical time of flight of cosmic ray particles can be estimated. Such a value is typically several millions of years.

Charged particles moving through a magnetic field tend to enter into circular orbits. Table 2 below indicates the typical sizes of orbits which cosmic ray protons of various energies will tend to experience in the weak interstellar field of 3 microgauss.

Proton Energy (eV)	Radius (km)
10^{9}	$1.1\ 10^{7}$
10^{11}	$1.1\ 10^{9}$
10^{13}	$1.1\ 10^{11}$
10^{15}	$1.1\ 10^{13}$
10^{17}	$1.1\ 10^{15}$
10^{19}	$1.1\ 10^{17}$

Table 2: Radius of paths of high energy protons in interstellar space as a function of energy.

The diameter of the Milky Way is of the order of 10^{14} km, so particles with energies greater than about 10^{16} eV cannot be held within the galaxy. It is likely that the highest energy particles come from sources outside the Milky Way.

Thus in terms of life cycles, cosmic ray particles below a given energy will typically remain within the Milky Way, and slowly interact with physical matter over periods of millions of years.

Summary

It is not surprising that cosmic ray particles have been a subject of extensive investigation. Understanding of their cycle of birth and death within the Universe provides insight into many of its fundamental laws. Is it not also interesting to consider that numerous atoms of Lithium within the human body may have originated from interactions experienced by heavy cosmic ray particles in remote corners of the Milky Way?

Back to Basics 8

Paul Coxwell investigates resonant circuits this month.

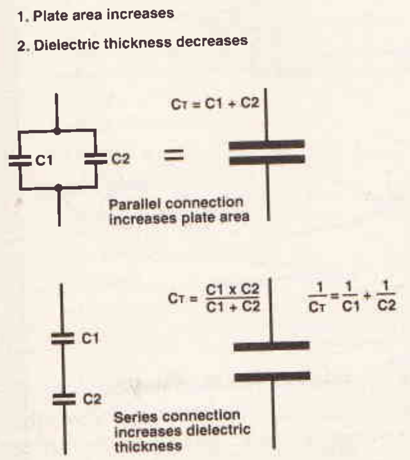


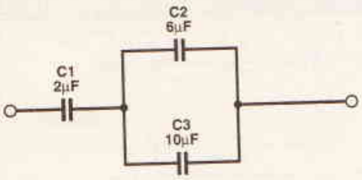
Fig.1 Series and parallel capacitance

Last month we saw the effect of capacitive reactance on an AC circuit. Just as inductors can be combined in series or parallel combinations to create higher or lower values of inductance, so capacitors can be used in combination.

Connecting inductors in series results in a higher value of inductance; parallel connection gives a lower inductance. In this respect, inductors behave in the same way as resistors. Capacitors, on the other hand, work the opposite way around. Parallel connection of capacitors gives an increase in total capacitance and series connection gives a lower capacitance.

Recall the basic laws for determining capacitance and you will see why this is so (see Figure 1). If two capacitors are connected in parallel the overall plate area has been increased, which increases total capacitance. If two capacitors are connected in series, there are two separate dielectric materials, which gives the same effect as increasing the thickness of a single dielectric.

As the formulae shows, the rules for calculating total capacitance closely resemble those for inductance and resistance, but with series and parallel formulae switched around. Parallel capacitors can simply be added together to obtain the total capacitance; for series connection you can use the product-over- sum method for two capacitors or the reciprocal method for any number of capacitors. Figure 2 shows the application of these formulae to a circuit comprising both parallel and series capacitance.



Parallel C2/C3 combination:

$C_A = C2 + C3 = 6 + 10 = 16\mu F$

Series C1/C_A combination:

$$C_T = \frac{C1 C_A}{C1 + C_A} = \frac{2 \times 16}{2 + 16} = 1.78\mu F$$

Or

$$\frac{1}{C_T} = \frac{1}{C1} + \frac{1}{C_A} = \frac{1}{2} + \frac{1}{16} = 0.5625$$

$$\therefore C_T = \frac{1}{0.5625} = 1.78\mu F$$

Fig.2 Total capacitance calculations

LC Circuits

We have seen the effects of capacitance and inductance upon an AC circuit only when one type of reactance is present. The next step is to examine the results of combining capacitors and inductors, but it is essential to understand everything presented so far before continuing. Remember the following important facts: inductance opposes changes in circuit current and causes current to lag voltage; capacitance opposes changes in circuit voltage and causes current to lead voltage; inductive reactance is directly proportional to frequency; capacitive reactance is inversely proportional to frequency.

Figure 3 shows a series circuit containing inductance and capacitance. In any series circuit the current must be the same at all points, so the current curve, I is used as a reference. In the capacitive portion of the circuit E_C lags the current by 90° and in the inductive portion E_L leads the current by 90°. Notice that these two phase shifts place E_C and E_L 180° out of phase with each other.

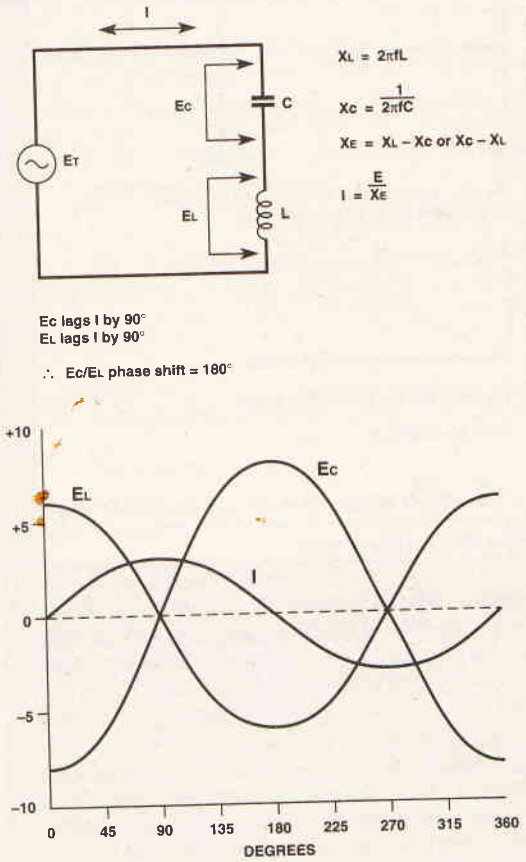


Fig.3 LC Series circuit

As can be seen from the diagram, the inductance and capacitance tend to cancel each other out, and the total reactance is the difference between X¶ and X_C. If X_L is the larger of the two reactances, the circuit will behave as an inductor; if X_C is the larger, it will behave as a capacitor.

Recall the vector diagrams we used when dealing with RC and RL series circuits and refer to Figure 4. The values of L and C are given, so their respective reactances can be calculated from the frequency of the supply. The two vector diagrams below the schematic show voltage and impedance in the circuit; notice that E_L and E_C are 180° out of phase, so X_L and X_C are drawn in the same fashion. In this particular circuit the inductive reactance is greater than the capacitive reactance, so the circuit behaves inductively. Once the effective reactance, X_E, has been calculated, the remainder of the circuit can be analyzed with the formulae you have already learned. Follow the calculations and be sure you understand them fully.

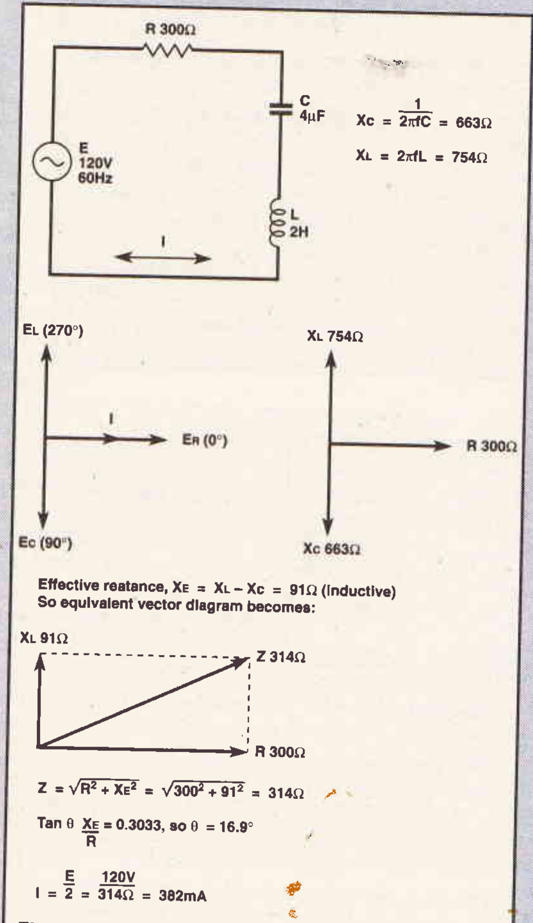


Fig.4 RLC Series circuits

Series Resonance

At first sight it may appear pointless to use a capacitor and inductor in the same circuit when one partially cancels the effect of the other. The series LC combination can be put to very good use, however, and is to be found in much electronic equipment. A capacitor and inductor together form a tuned circuit that is capable of passing some frequencies while rejecting all others. This principle is put to good use in radio and television receivers where only one station must be allowed through the set.

Refer to the series circuit shown in Figure 5. The graph shows how capacitive and inductive reactance vary with frequency. Recall that as frequency increases inductive reactance increases but capacitive reactance decreases. It should be clear from this that at some frequency the two reactances will be equal in value. Try calculating the values of reactance at the three frequencies given: 60Hz, 1,007Hz, and 8,000Hz. Notice that at 1,007Hz the values of X_L and X_C are equal, cancelling out the effective reactance completely. This is called the resonant frequency and is written as f_0. Below the resonant frequency X_C is greater than X_L and the circuit behaves capacitively; above the resonant frequency X_L is greater than X_C and the circuit behaves inductively.

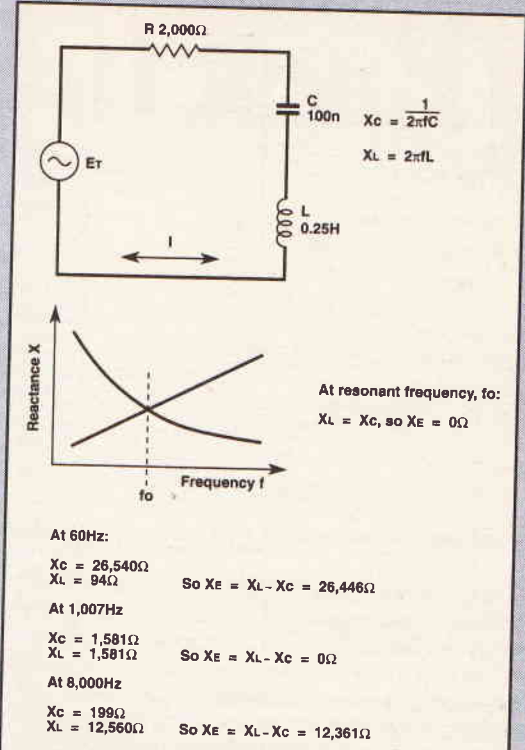


Fig.5 Series resonance

Total impedance is dependent upon both the resistance and the reactance in a circuit. Resistance remains constant with frequency, so the effective reactance determines the circuit impedance. This leads to the important conclusion that the impedance of a series LC circuit is lowest at its resonant frequency and

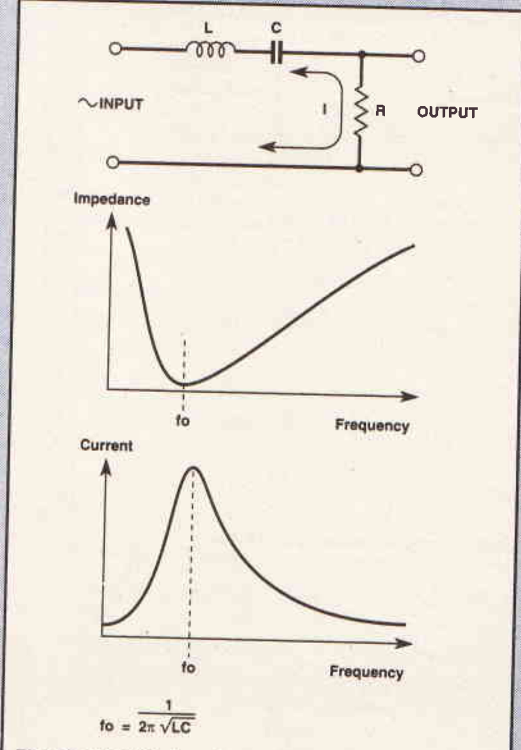
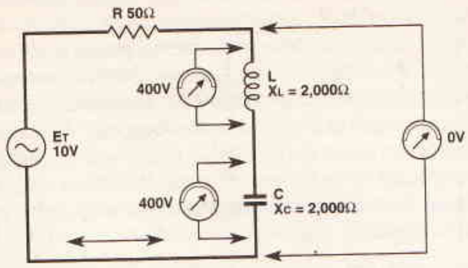


Fig.6 Series LC circuit as a filter



$X_E = X_L - X_C = 0\Omega$

So $Z = R = 50\Omega$

$I = \frac{E_T}{Z} = \frac{10V}{50\Omega} = 200mA$

$E_L = I \times X_L = 0.2 \times 2{,}000 = 400V$

$E_C = I \times X_C = 0.2 \times 2{,}000 = 400V$

Fig.7 Reactive voltages in series resonant circuit

increases above and below that frequency. Impedance determines total current flow, so it can also be said that current will be maximum at the resonant frequency.

In Figure 6 the circuit has be redrawn to represent the coupling between one part of a radio receiver and the next. We have seen that the current through the series circuit is highest at the resonant frequency, and because the voltage dropped across a resistor is directly proportional to current, we can also say that the output voltage will be highest at the resonant frequency. Input signals above or below the resonant frequency result in a reduced circuit current and a lower voltage across R. This circuit acts as a filter, allowing only a small range of frequencies around f_0 to pass. Such a circuit is called a band-pass filter. The formula for calculating the resonant frequency of a tuned circuit is shown in the diagram.

One other important aspect of the series tuned circuit is that at resonance the coil and capacitor voltages increase greatly (Figure 7). We have already seen that at resonance the total impedance of a series circuit is equal to the resistance alone. The circuit current in the example shown can be calculated as 200mA. If Ohm's Law is applied to the coil and capacitor individually, a value of 400V for each is obtained. Although these values do not seem to be consistent with a supply voltage of only 10V, they are correct.

Kirchoff's Law regarding the sum of voltage drops in a series circuit being equal to the source voltage appears to have been violated, but it should be remembered that the capacitor voltage and coil voltage are not in phase. Indeed, they are 180° out of phase, because E_C lags the current by 90° and E_L leads the current by 90°. E_C and E_L are each 400V, but the phase shift causes them to completely cancel each other. A voltmeter connected across the coil and capacitor in series would indicate zero.

Remember that in any series tuned circuit the coil and capacitor voltages increase greatly at resonance, but they are always 180° out of phase, leaving the resistance to drop the source voltage.

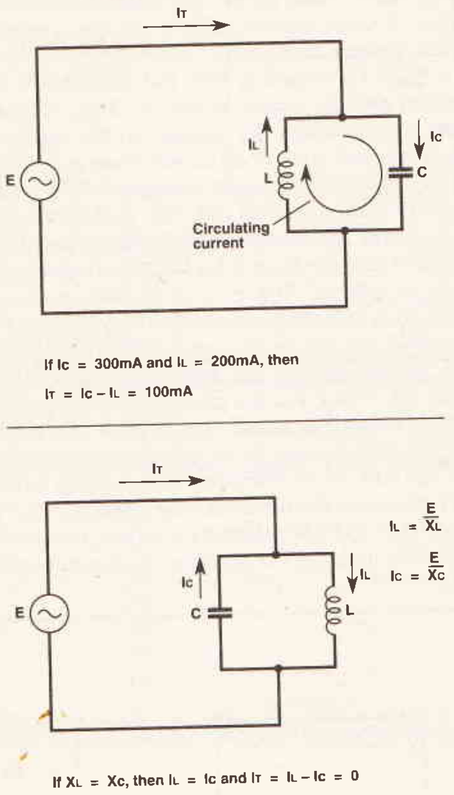


Fig.9 Circulating current in a parallel LC circuit

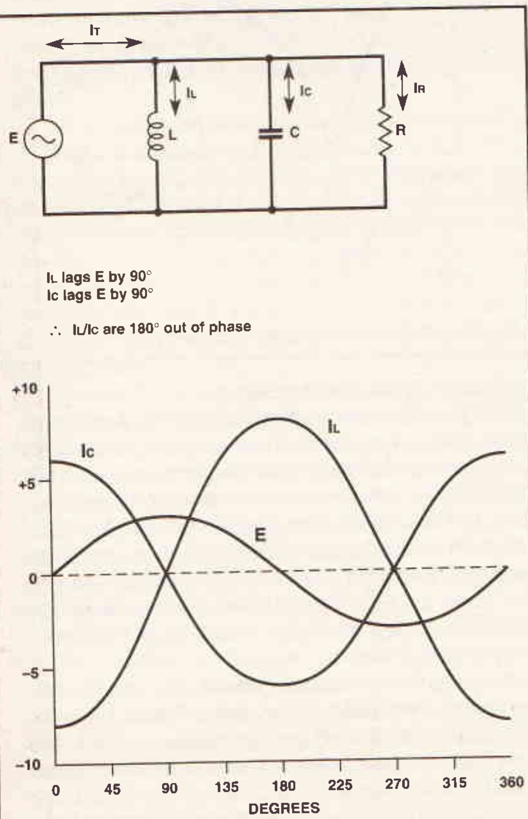


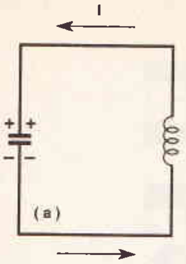
Fig.8 Parallel LC circuits

Parallel Resonance

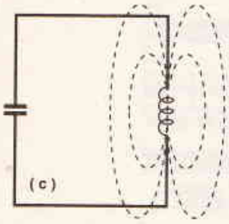
In a series circuit we think of current as the reference vector and work with voltages that vary in phase. When dealing with a parallel circuit the voltage across each component must always be in phase with the source voltage, so we must think in terms of currents varying in phase (Figure 8).

In the diagram shown, total circuit current, I_T is split between the resistive, capacitive, and inductive branches of the circuit. Although the current is alternating in nature, whenever the current is flowing up through the coil, current will be flowing down through the capacitor, and vice versa. This is because the capacitor current and inductor current are 180° out of phase. The current flowing around the coil and capacitor can, therefore, be greater than the current drawn from the supply (see Figure 9).

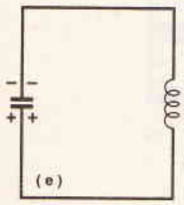
The situation is complicated somewhat by the fact that the current is alternating, so start off by



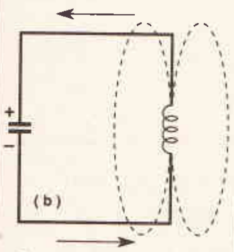
Capacitor discharges into coil



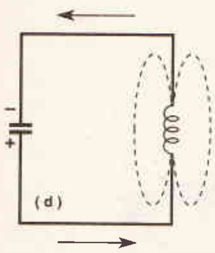
Capacitor fully discharged, so field starts to collapse



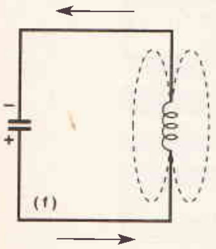
All magnetic field energy is gone, leaving capacitor fully charged



Current builds up Magnetic field



Collapsing field induces current in coil, which charges capacitor



The process repeats......

Fig.10 Mechanism of oscillating current in a resonant circuit

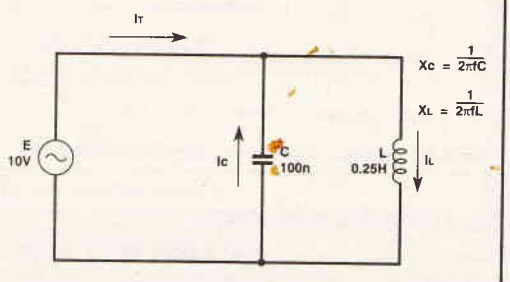
examining the circuit during one half-cycle of AC. If a current of 300mA is flowing downward through the capacitor and a current of 200mA is flowing upward through the coil, then Kirchoff's Law regarding the sum of currents at a junction tells us that 100mA must flow from the power source. During the next half-cycle the direction of all three currents will be reversed, of course.

The second circuit in Figure 9 shows what happens at the resonant frequency. Ohm's Law shows that the current through the coil or capacitor can be determined from the supply voltage and the inductive or capacitive reactance. The voltage across each component is the same, so if X_C and X_L are equal the current through each component must also be the same. The currents I_C and I_L cancel each other out at the junctions, resulting in no current being taken from the power supply. Even though I_T is zero, there is still a circulating current flowing through the parallel LC circuit.

Tank Action

The coil and capacitor combination shown is sometimes called a tank circuit, because it stores energy. Figure 10 shows the way in which the circuit operates at the resonant frequency.

Start by assuming that the capacitor is fully charged with the polarity shown (A). The coil forms a path through which the charges on the capacitor's plates can flow, so electron current flows as indicated. As the capacitor discharges, a magnetic field starts to build up around the coil (B). This field continues to expand until the capacitor is fully discharged (C). At this point, current drops to zero and the magnetic field starts to collapse. This induces an EMF in the coil, which flows to the capacitor plates (D). When the magnetic field has collapsed completely, current drops to zero once more and the capacitor is fully charged again (E). Notice that the plates are now opposite in polarity when compared to the original charge. With the capacitor charged, the process starts to repeat itself (F). The tank circuit, therefore, stores energy by passing it back and forth between the capacitor and the coil; in the capacitor it is stored as an electrostatic field and in the inductor it is stored as an electromagnetic field.



$X_C = \frac{1}{2\pi fC}$

$X_L = 2\pi fL$

At 60Hz:

$X_C = 26{,}540\Omega$ so $I_C = \frac{E}{X_C} = \frac{10V}{26{,}540\Omega} = 0.377mA$

$X_L = 94\Omega$ so $I_L = \frac{E}{X_L} = \frac{10V}{94\Omega} = 106mA$

At 1,007Hz

$X_C = 1{,}581\Omega$ so $I_C = \frac{E}{X_C} = \frac{10V}{1{,}581\Omega} = 6.325mA$

$X_L = 1{,}581\Omega$ so $I_L = \frac{E}{X_L} = \frac{10V}{1{,}581\Omega} = 6.325mA$

At 8,000Hz:

$X_C = 199\Omega$ so $I_C = \frac{E}{X_C} = \frac{10V}{199\Omega} = 50.25mA$

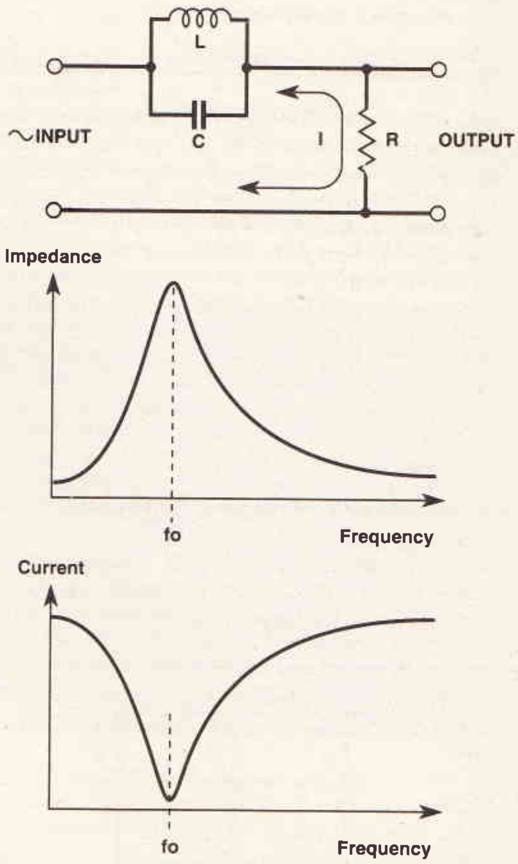
$X_L = 12{,}560\Omega$ so $I_L = \frac{E}{X_L} = \frac{10V}{12{,}560\Omega} = 0.796mA$

Fig.11 Parallel resonance

It would appear that the tank circuit provides a form of perpetual motion because it keeps circulating energy without requiring any external power source. In practice this is not the case, because there must always be a certain amount of resistance in the coil and wiring. Without a power source the resistance in the circuit would soon cause the oscillation to die out completely. The practical tank circuit, therefore, draws just enough current from the power supply to overcome the circuit's resistance.

Use Of The Parallel Tank Circuit

We have seen that when the capacitive reactance equals the inductive reactance, the coil and capacitor currents cancel. This means that, as far as the power source is concerned, the circuit draws no current and



$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

Fig.12 Parallel LC circuit as a filter

represents an infinite impedance.

Figure 11 shows how this works. The same component values have be used as were given in the series-resonance description earlier. Below the resonant frequency, most of the current flows through the coil due to its low reactance compared to the capacitor. Similarly, above the resonant frequency the capacitor's reactance is much lower than the coil's, so most current flows through the capacitor. At resonance, the reactances are equal, which results in equal (but opposite phase) currents.

Just as the series tuned circuit can be used as a filter, so can the parallel tuned circuit. Figure 12 shows one such application. At the resonant frequency, f_0, the impedance of the coil and capacitor combination rises to its highest value, which reduces circuit current to a minimum. As the voltage drop across R is directly proportional to the current, this also reduces the output voltage to a minimum. Either side of the resonant frequency the tank circuit's impedance starts to drop, giving an increase in current and a corresponding increase in voltage across the output resistor. The filter is called a band-stop filter, because it prevents any signals at the resonant frequency from being passed on to the next stage.

Note that the same formula is used to calculate the resonant frequency of any series or parallel tuned circuit. It is the method of connection that determines how the filter behaves.

Filters

Figure 13 shows some other ways in which coils and capacitors can be used to select a range of required frequencies and reject all others.

At A a series tuned circuit has been connected across the output terminals. This presents a low impedance at the resonant frequency, shunting the signal to ground, so a band-stop filter is produced. At B a parallel tuned circuit presents a high impedance across the output at resonance and a lower impedance at other frequencies. The result is a band-pass filter. This latter arrangement is commonly employed in radio and television receivers. Diagrams C and D represent a low-pass filter and a high-pass filter, respectively. The former blocks frequencies above a certain value and the latter blocks frequencies below a certain value. It will be left to the reader as an exercise to determine how these two filters operate. Start off by assuming some values for the coil and capacitor (say 0.1uF and 250mH), then work out the reactances at different frequencies.

Next month we examine transformers.

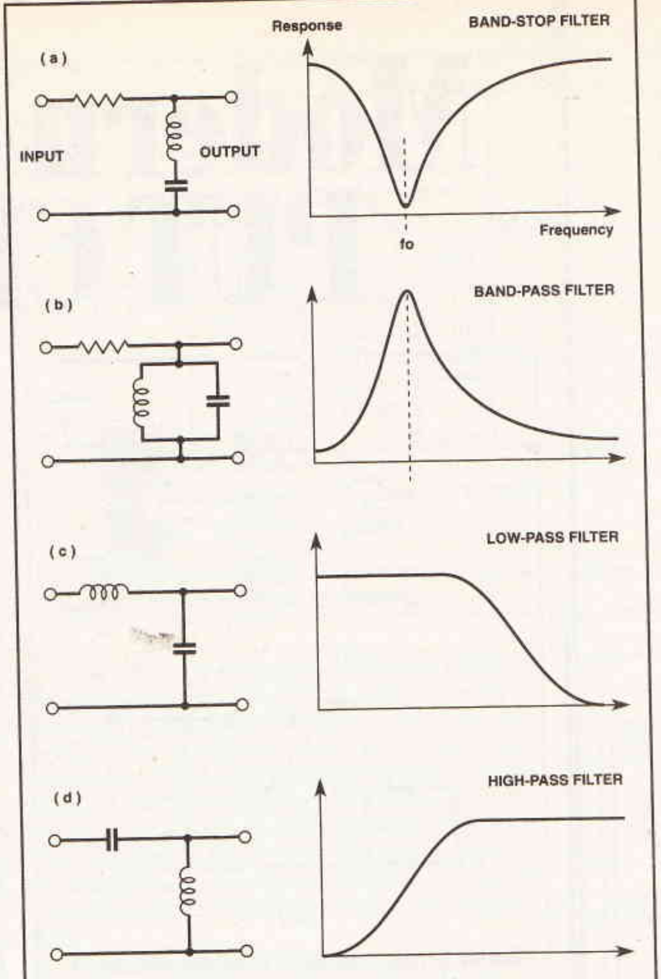


Fig.13 Other filters

Freeze Alarm continued from page 15

Once the problem of the voltage output from the adapter is solved, if is arises at all, it is time to apply power to the board itself, but via the multimeter switched to a current range. The Current drawn by the board should be around 10 milliamps; if it is very much more than this or very much less, there is something wrong, so switch off and look for an obvious fault; if none can be seen, look under the fault finding section later.

If all seems OK, test the device either by spraying IC1 with a freezing spray, if you have one, or by putting it into the freezing compartment of a refrigerator and wait a few minutes, after which it should be possible to get the bleeper to sound by adjusting RV1 (using the freezing spray, the bleeper will sound whatever the adjustment of RV1), provided IC1 is made cold enough). Warming IC1 with a finger (after removing the board from the freezer!) should make the bleeper stop quickly.

Finally, before being installed in its final position, the device must be callibrated, and this is done by placing ice and water in a metal container, and attaching IC1 to this, for example, with an elastic band round the whole circuit board. The water/ice mix will, after 15 minutes or so, be within a degree of zero Celcius in temperature, so RV1 should be adjusted so that the device just bleeps, ie moving the setting of RV1 very slightly will stop the bleeps.

The board can now be placed in position, and it can be attached to the most vulnerable pipe in the house (ie the one furthest away from the warm main part of the house) using a simple metal clip; on the prototype this was modified from a plumber's clip. Some thought needs to be given to the routing of the wire and to the placing of the adapter and the sounder, but, provided the interconnecting lead is no more than about 5 metres, there shouldn't be any problems.

PARTS LIST

RESISTORS (all ⅛W or more power dissipation, 5% or less tolerance)

R1	2k7
R2	12l
R3	18k
R4	6k6
R5	2M2
R6	470k
R7	1M0
R[	47k
R9	1k8
RV1	1k0 sub-miniature preset pot, horizontal mounting.

CAPACITORS

C1	100n, any type
C2	2n2, any type
C3	10µ electrolytic, 16V (or more), single-ended (reduce to 100µ non-polarised of IC3 is used)

SEMICONDUCTORS

IC1	LM3911
IC2	4093 CMOS quad two-input NAND with Scmitt trigger inputs
IC3	7812 (may not be necessary — see text)
D1	1N4001 (remove if IC3 used)

MISCELLANEOUS

Piezo-electric sounder (*not* the type with its own internal oscillator); mains adapter unit, 9 volt (or adjustable DC output, low current (only 10mA required, but these units will typically supply 300mA or more, which is not a problem); PCB; four core wire (eg, burglar alarm wire); solder; IC holder for IC1 if required (8 pin DIL, see text).

Modern UJT And PUT Circuits

Ray Marston looks at Unijunction Transistor and Programmable Unijunction Transistor (PUT) principles and circuits.

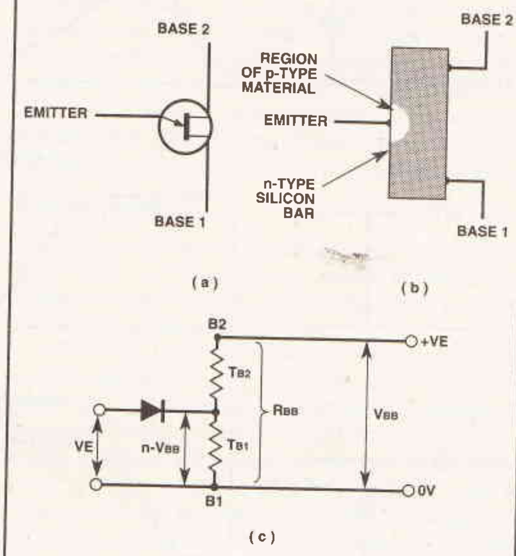


Fig.1 (a) UJT symbol, (b) UJT construction (c) UJT equivalent circuit.

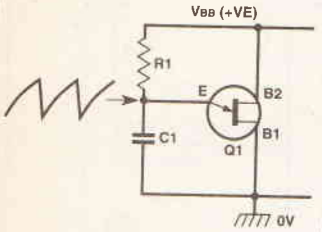


Fig.2 Basic UJT relaxation oscillator.

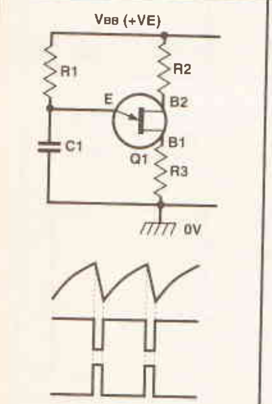


Fig.3 Alternative version of the UJT oscillator.

The Unijunction transistor (UJT) is one of the oldest and simplest of all active semiconductor devices. It first became commercially available in 1952, and for many years was widely used as a general-purpose timer, oscillator, and high-energy pulse generator. Then, in the early 1970's, many of these tasks were taken over by readily available low-cost ICs such as the 555 timer and the ubiquitous CMOS range of gates, and the UJT slowly fell out of favour, eventually being relegated to only the high-energy pulse generating role. A similar fate also fell on its hopeful replacement, the PUT (Programmable Unijunction Transistor), which is now little used. Both of these devices are still quite versatile however, and are readily available. This article describes their operating principles, and shows how to use them in practical circuits.

UJT Basics

The Unijunction transistor is a simple device that consists of a bar of n-type silicon material with a non-rectifying contact at either end (base 1 and base 2), and with a rectifying contact (emitter) alloyed into the bar part way along its length, to form the only junction within the device (hence the name 'unijunction'). Figure 1 shows the symbol, construction, and equivalent circuit of the UJT.

Base 1 and base 2 form contacts with the ends of the silicon bar, and a simple resistance appears between these two points and measures the same in either direction. This 'inter-base' resistance is given the symbol R_{bb} and has a typical value in the range 4k0 to 12k.

In use, base 2 is connected to a positive voltage and base 1 is taken to zero volts (see Figure 1c), so R_{bb} acts as a voltage divider with a division or 'intrinsic stand-off' ratio (η) that has a typical value between 0.45 and 0.8. A 'stand-off' voltage of $\eta.V_{bb}$ thus appears across the lower (r_{b1}) half of the bar under quiescent conditions. The UJT's emitter terminal is connected to this voltage via junction D1. Normally the emitter input voltage (Ve) is less than $\eta.V_{BB}$, so D1 is reverse biased and the emitter appears as the very high impedance of a reverse biased silicon diode.

If V_E is steadily increased above ηV_{BB} a point is reached where D1 becomes forward biased, and current starts to flow from the emitter to base 1. This current consists mainly of minority carriers injected into the silicon bar, and these drift to base 1 and decrease the resistance of r_{B1}. This decrease in r_{b1} lowers the ηV_{BB} voltage, so the emitter-to-base current increases and makes the r_{B1} value fall even more. A regenerative action thus takes place, and the emitter input impedance falls sharply, typically to a value of about 20R.

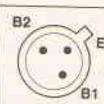
PARAMETER	2N2646	TIS43
EMITTER REVERSE VOLTS (MAX)	30V	30V
VBB (MAX)	35V	35V
PEAK EMITTER CURRENT (MAX)	2 AMPS	1.5 AMPS
POWER DISSIPATION (MAX)	300mW	300mW
INTRINSIC STANDOFF RATIO, n	0.56-0.75	0.55-0.82
RBB	4k7-9k1	4k0-9k1
Ip (MAX)	5μA	5μA
Iv (MAX)	4mA	4mA
OUTLINE	 B2 E B1 (TO-18 CASE)	 B1 B2 E (TO-92 CASE)

Fig.4 2N2646 and TIS43 UJT data.

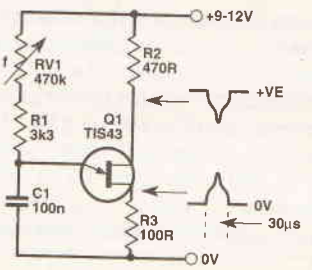


Fig.5 Wide-range pulse generator.

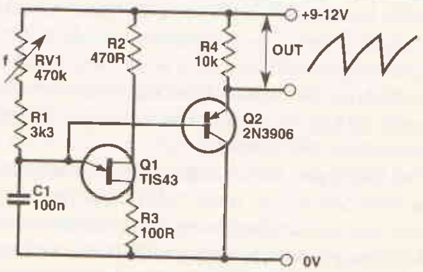


Fig.6 Wide-range non-linear sawtooth generator.

The UJT thus acts as a voltage-triggered switch that has a very high input impedance (to its emitter) when the UJT is off and a very low one when it is on.

the precise point at which triggering occurs is called the 'peak-point' voltage, Vp, and is about 600 mV above the μ,V_{BB} value.

The UJT Oscillator

The most basic application of the UJT is as simple relaxation oscillator, as shown in Figure 2. Here, C1 is fully discharged when the supply is initally connected, so the emitter is at ground potential and presents a very high impedance. C1 immediately starts to charge exponentially towards V_{BB} via R1, but as soon as the emitter reaches Vp the UJT fires and rapidly discharges C1 into the low impedance of the mitter. Once C1 is effectively discharges the UJT switches off, and C1 then starts to charge up again via R1, and the whole process repeats add infinitum and generates a non-linear sawtooth waveform across C1.

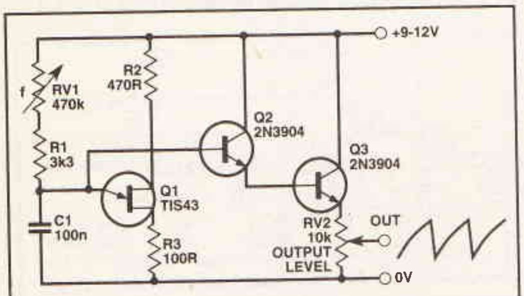


Fig.7 Wide-range non-linear sawtooth generator with variable-amplitude ground referenced output.

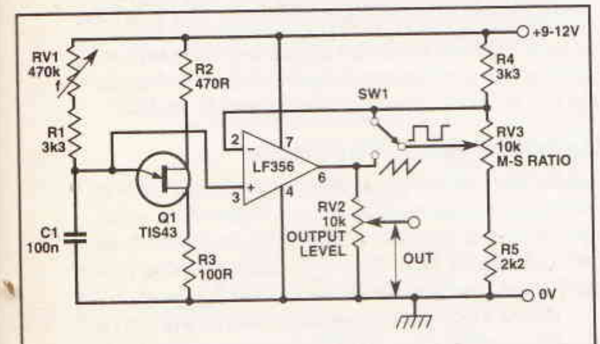


Fig.9 25Hz to 3kHz generator produces a non-linear sawtooth or a rectangular waveform with fully variable M-S ratio.

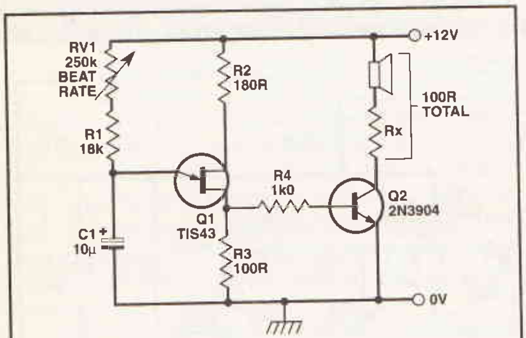


Fig.11 Metronome giving 20 to 200 beats per minute.

In this circuit the switch-off action occurs in each cycle when the total emitter current (the C1 discharge plus the R1 current) falls to a 'valley-point' value, Iv (typically several mA). A minimum 'peak-point emitter current', Ip, is needed to initiate the UJT switch-on action, and typically has a value of several μA. Thus R1's maximum usable value is limited by the Ip characteristic, and the minimum value is limited by the Iv characteristic.

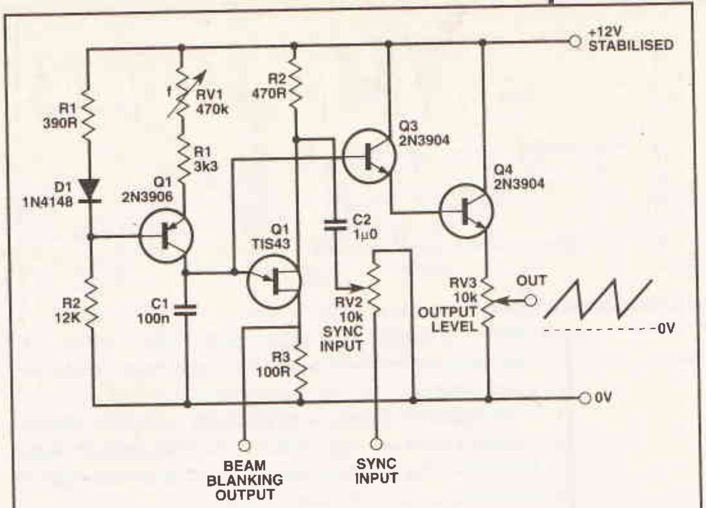


Fig.8 This linear sawtooth generator can be used as a simple oscilloscope timebase generator.

The oscillation frequency of the Figure 2 circuit is given approximately by f=1/(C.R), and is almost independent of V_{BB} (typically, a 10% change in V_{BB} causes a change of less than 1% in f). The R1 value can typically be varied from about 3k0 to 500k, enabling the circuit to span a 100:1 frequency range via a single variable resistor. The C1 value can be varied from a few hundred picofarad to hundreds of microfarad, enabling the circuit to be used over a very wide frequency range (from less than one cycle per minute to hundreds of kHz).

In most practical UJT oscillator circuits an additional resistor (R3) is wired between base 1 and ground, as shown in Figure 3, either to control the discharge time of C1 or (more usually) to give a brief high-energy positive output pulse from C1's discharge. A resistor (R2) may also be wired in series with base 2, either to enhance the oscillator's thermal stability or to enable a low-energy negative-going output pulse to be generated via C1's discharge.

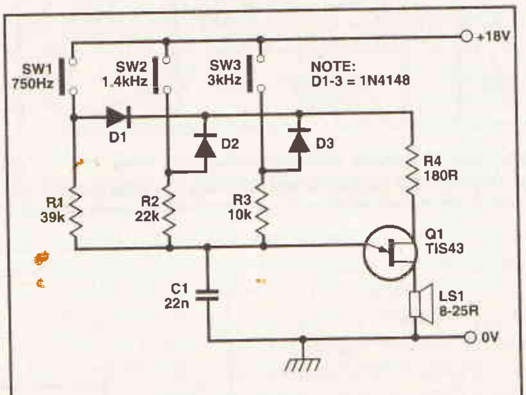


Fig.12 Simple multi-tone signalling system.

Practical UJTs

The two best known and most readily available types of UJT are the 2N2646 and the TIS43. The latter device is the most modestly priced of the two, and is used as the basis of all practical UJT circuits presented in these pages. It can be used with supplies up to a maximum of 30V, and has maximum Ip and Iv ratings of 5μA and 4mA respectively, thus allowing a wide range of timing resistor values to be used. Figure 4 lists basic details of both types of UJT.

Practical Waveform Generators

The TIS43 can be used in a variety of pulse, sawtooth, and rectangular waveform generator applications,

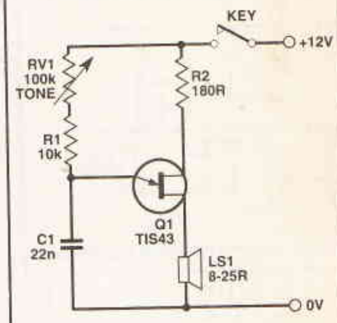


Fig.10 Simple 'code-practice' oscillator; tone is variable from 300Hz to 3kHz.

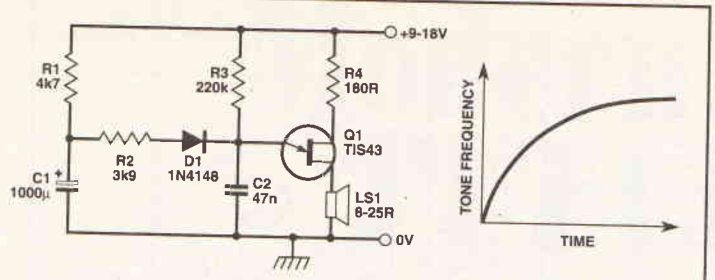


Fig.13 Simple rising-tone siren.

Figures 5 to 9 show a selection of practical circuits of these types.

Figure 5 shows a wide-range pulse generator circuit. A high-energy positive pulse is available across R3, and a low-energy negative-going one is available across R2. Both pulses are of similar form, but are in anti-phase. With the component values shown the pulse width is constant at about 30µs over the frequency range 25Hz to 3kHz (adjustable via RV1). The pulse width and frequency range can altered by changing the C1 value; reducing it by a decade reduces the pulse width and raises the operating frequency by a factor of 10; C1 can have any value from 100p to 1000µ.

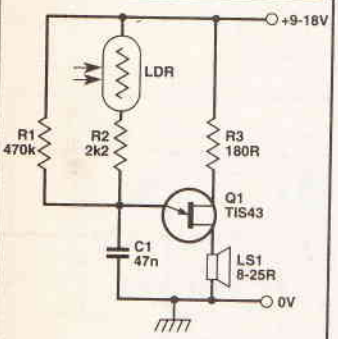


Fig.14 Light-sensitive oscillator.

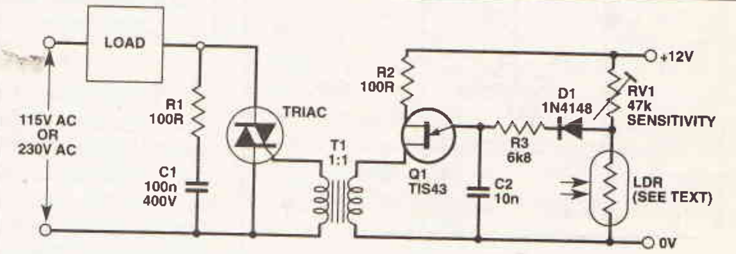


Fig.16 Light-sensitive AC power switch.

A non-linear sawtooth is generated across C1 of the Figure 5 circuit, but is at a high impedance level and is thus not readily available externally. Access can be gained to this sawtooth either by wiring a simple PNP emitter follower across the timing resistor network, as shown in Figure 6, or by wiring an NPN Darlington emitter follower across C1, as in Figure 7. Note that the Figure 6 circuit gives a fixed amplitude output that is referenced to the positive supply rail, but that the Figure 7 design gives a variable-amplitude output that is referenced to the zero volts line.

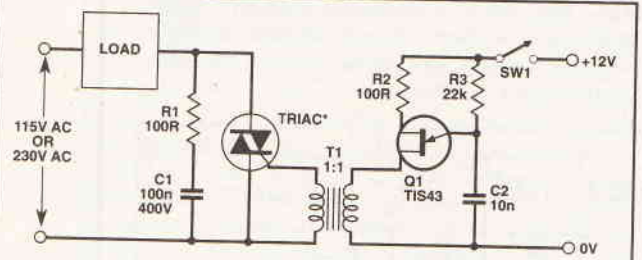


Fig.15 Isolated-input AC power switch* Select the triac voltage and current rating to suit the supply and load.

The UJT oscillator can be made to generate a linear sawtooth waveform by charging its timing capacitor via a constant-current generator rather than via a simple resistance. Figure 8 shows a practical version of such a circuit. Q1 and its associated network form the constant current generator, and the current magnitude (and thus the oscillation frequency) is variable via RV1. C1's linear sawtooth waveform is made externally available via the Q3-Q4 Darlington emitter follower network and its amplitude is variable via RV3. With the component values shown the oscillation frequency is variable from 60Hz to 700Hz via RV1; alternative frequencies can be obtained by changing the C1 value. The circuit can be used as a simple oscilloscope timebase generator by taking its sawtooth output to the 'external timebase' socket of the 'scope and using the 'positive flyback pulses' from R5 for beam blanking. The generator can be synchronised to any external signal that is fed to the SYNC INPUT terminal.

Figure 9 shows how a UJT can be used to generate either a non-linear sawtooth or a rectangular waveform with an infinitely-variable mark-space ratio. The LF356 op-amp used here is 'fast' device with a very high input impedance. When SW1 is in the SAWTOOTH position this op-amp acts as a simple voltage follower, and C1's sawtooth appears across output control RV2. When SW1 is set to the RECTANGLE position the op-amp is configured as a fast voltage comparator, with the sawtooth fed to its non-inverting input and a variable (via RV3) DC reference voltage fed to its inverting input; this simple arrangement converts the sawtooth waveform into a rectangular output that has its mark space ratio fully variable via RV3.

Gadgets And Novelties

Figures 10 to 14 show a variety of ways of using UJTs in handy gadgets and novelty circuits. Figure 10 is a simple morse-code practice oscillator; it generates a fixed tone (adjustable from 300Hz to 3kHz) directly in a small speaker whenever the morse key is closed.

Figure 11 shows a musicians metronome with a beat rate variable from 20 to 200 per minute via RV1; the UJT's output pulses are fed to the speaker via Q2, producing a distinct 'click' each time the UJT completes a timing cycle.

Figure 12 shows a multi-tone signalling system that consumes zero quiescent current and generates a tone that is unique to each one of its three push-button operating switches; each switch connects the oscillator's supply via an isolating diode, but selects a unique value of tone-generating timing resistor.

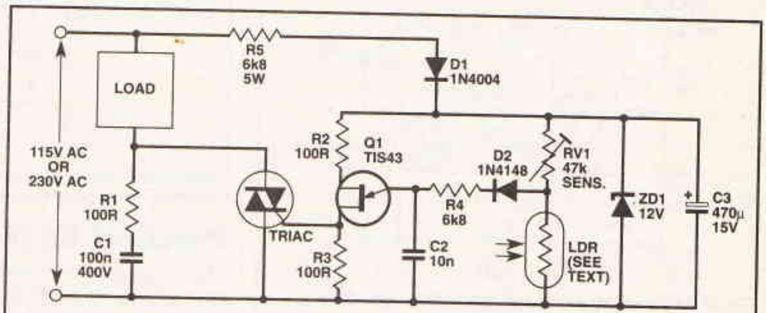


Fig.17 Alternative light-sensitive AC power switch.

Figure 13 shows a simple rising-tone siren, which operates as follows. When power is first applied C1 is fully discharged, so the UJT operates at a frequency set only by R3 and C2. As soon as power is applied, however, C1 starts to charge exponentially via R1, and its voltage causes the charge current of C2 to increase via D1 and R2, raising the UJT frequency. Thus, the UJT's oscillation frequency slowly rises as C1 charges up, as shown by the diagram's exponential graph, and the circuit generates a distinct rising tone.

Finally, Figure 14 shows the UJT used as a light-sensitive oscillator, with an LDR acting as its main timing resistor. This LDR is a cadmium sulphide photocell; under dark conditions it acts as a very high resistance, so the operating frequency is low and is determined mainly by R1; under bright condition the LDR

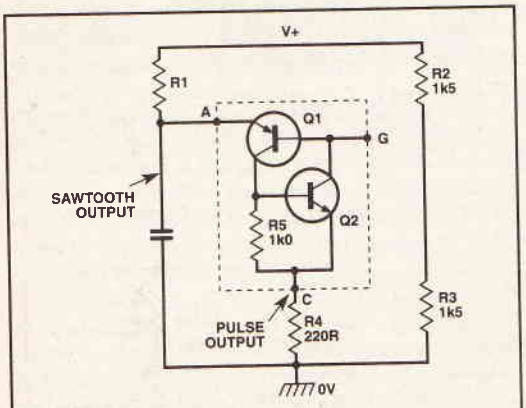


Fig.19 Transistor equivalent of the UJT oscillator.

resistance is very low, so the operating frequency is high and is determined mainly by R2. At intermediate light levels the UJT frequency is set mainly by the LDR value and thus by the light level. This circuit can thus be used as a simple musical instrument that is played by the light of a torch or by shadows cast by the hand.

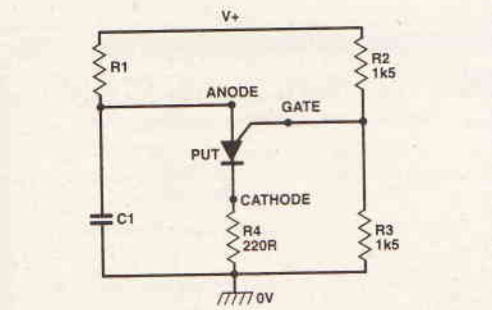


Fig.20 PUT symbol and basic oscillator circuit.

AC Power Control Circuits

The most important use of the UJT is in AC power control applications, where its high-energy time-delayed output pulses can be used to trigger SCRs or TRIACs and thus control the power feed to AC lamps, heaters, or motors. Figures 15 to 18 show four simple ways of using UJTs to control triac power switches. Note in these circuits that the triac's voltage rating must be chosen to suit the AC power line used (400V rating on 230VAC, 200V rating on 115V AC), and that its current rating is chosen to suit the load.

The Figure 15 circuit is a simple on/off unit in which the DC-powered UJT circuitry is electrically isolated from the high voltage triac system via pulse transformer T1 (this type of transformer is available from many component suppliers). When SW1 is closed the UJT oscillates and feeds high frequency (several kHz) trigger pulses to the triac gate via T1, thus switching the triac on shortly after the start of each AC powerline half-cycle and effectively applying full power to the AC load.

Figure 16 shows how the above circuit can be modified to act as a light-sensitive power switch that turns on automatically when the light level (sensed by

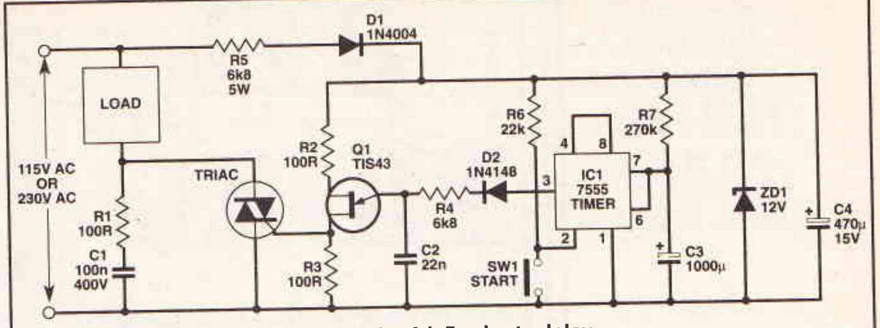


Fig.18 Auto-turn-off AC power switch with 5-minute delay.

cadmium sulphide photocell LDR) falls below a pre-set level, RV1 and the LDR form a light-sensitive potential divider which has its output taken to the VJT's timing resistor via D1. Under bright conditions the

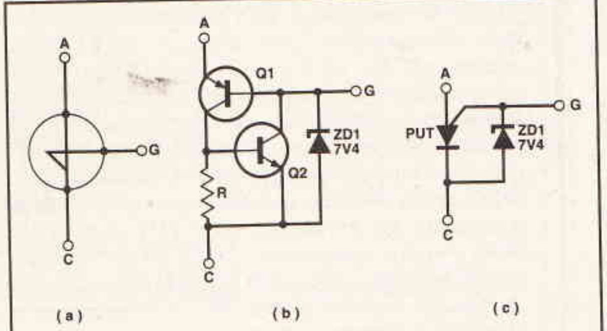


Fig.21 (a) SUS symbol and (b and c) equivalent circuits.

LDR resistance is low and the divider's output voltage is too low to enable the UJT to trigger, so the triac is off. Under dark conditions the LDR resistance is high and the divider's output voltage is high and enables the UJT to oscillate, so the triac turns on and applies power to the load. The LDR can be any type that presents a resistance in the range 2k0 to 47k at the desired 'dark' turn-on light level.

Figure 17 shows an alternative version of the above circuit in which the UJT is not electrically isolated from the triac. Here, the UJT output pulses are fed directly into the gate of the triac, and the UJT is powered from a 12V DC supply that is derived from the AC power line via the R5—D1—ZD1—C3 network.

Finally, Figure 18 shows a time-controlled variation of the above circuit. Here, the UJT and the triac are swtiched on via the IC1 555 timer as soon as SW1 is briefly closed, but turn off again automatically after a pre-set delay of about five minutes as IC1 completes its timing cycle. The circuit's timing period can be made variable by replacing R7 with a 10k resistor and a 47k variable wired in series.

Note in Figures 17 and 18 that, to generate an adequate 12V DC supply, the R5 value may have to be reduced when operating from 115V AC power lines.

PUTs And Kindred Devices

The action of a UJT oscillator can be simulated by the circuit of Figure 19, in which PNP transistor Q1 is in series with NPN transistor Q2; R1 and C1 control the circuit's timing action, and R2-R3 apply a fixed voltage

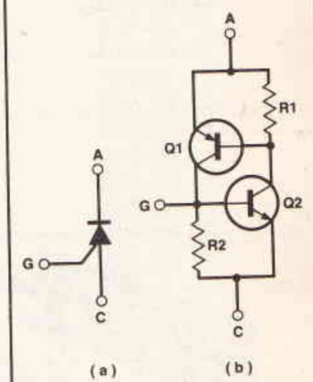
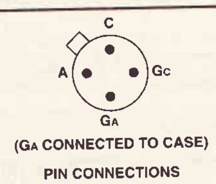


Fig.22 (a) SCS symbol and (b) transistor equivalent circuit.



ANODE TO CATHODE VOLTAGE (MAX)	= 70V
ANODE CURRENT, DC, MAX	= 250mA
ANODE CURRENT, PEAK	= 2.5A
SATURATION VOLTAGE	= 1.4V MAX

Fig.24 Basic details of the BRY39 (equivalent to the 2N6027 and D13T1) thyristor tetrode device, which can also be used as a PUT or SCS.

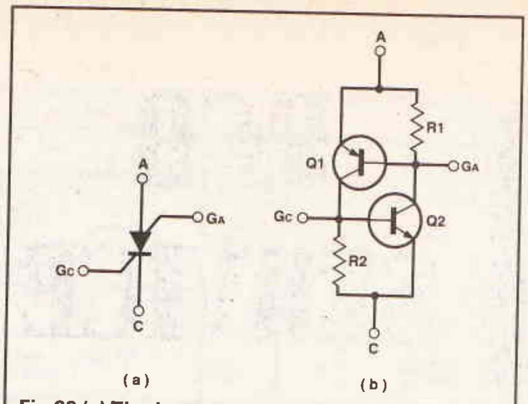


Fig.23 (a) Thyristor tetrode symbol and (b) transistor equivalent circuit.

(the equivalent of a UJT's intrinsic standoff ratio voltage) to the base of Q1; R5 shunts Q2's base-emitter junction, so that Q2 is not driven on by Q1's leakage currents. At the start of each timing cycle the R1-C1 junction voltage is low, so Q1's base-emitter junction is reverse biased and both transistors are cut off. C1 then charges via R1 until Q1's base-emitter junction becomes forward biased, at which point both transistors switch on regeneratively and rapidly discharge C1 via current-limiting resistor R4, until the discharge current flows through their base-emitter junctions. This defect can be overcome by replacing the three components within the dotted lines with a PUT, which is the direct thyristor equivalent of Q1-Q2-R5 and uses the symbol and basic application circuit of Figure 20; it is so named because it acts like a Programmable Unijunction Transistor, in which the intrinsic standoff ratio and R_{BB} values can be 'programmed' by selecting the external R2 and R3 values.

Note that the PUT symbol of Figure 20 is similar to that of an SCR (silicon controlled rectifier), except that the gate is related to the anode rather than the cathode; the PUT is in fact sometimes called an anode controlled SCR, and is one of four very closely related PNPN thyristor devices. Details of the other three members of the family are shown in Figures 21 to 23.

The SUS (Figure 21) or Silicon Unilateral Switch acts like a PUT with a built-in zener between its gate and cathode. The gate pin is normally left open, and the device acts as a voltage-triggered self-latching switch that turns on when the anode voltage rises high enough (above 8V) to make the zener start to break down via Q1's base-emitter junction. Once the SUS has latched on, it can only be turned off again by reducing its anode current below the minimum holding value.

The SCS (Figure 22) or Silicon Controlled Swtich has the same symbol as an ordinary SCR, but differs from it in one important respect; it acts as a self-latching swtich that can be triggered on by applying a positive trigger signal to its gate, but can be turned off again either by reducing its anode current below its minimum holding value or (unlike an SCR) by briefly shorting or reverse biasing its gate-cathode junction.

Finally, the most versatile of all these devices is the thyristor tetrode which, as can be seen from Figure 23, can also be used as a PUT or SCS. This device has two gate terminals (G_C and G_A), and can be turned on either by driving G_C positive to the cathode or by driving G_A negative to the anode, and can be gated off either by driving G_C negative to the cathode or by driving G_A positive to the anode.

The best known practical versions of the thyristor tetrode are the BRY39, the 2N6027, and the D13T1, which are virtually identical devices. Figure 24 shows the basic detail of the BRY39, which is housed in a TO-72 case. It can easily be used as a PUT or SCS.

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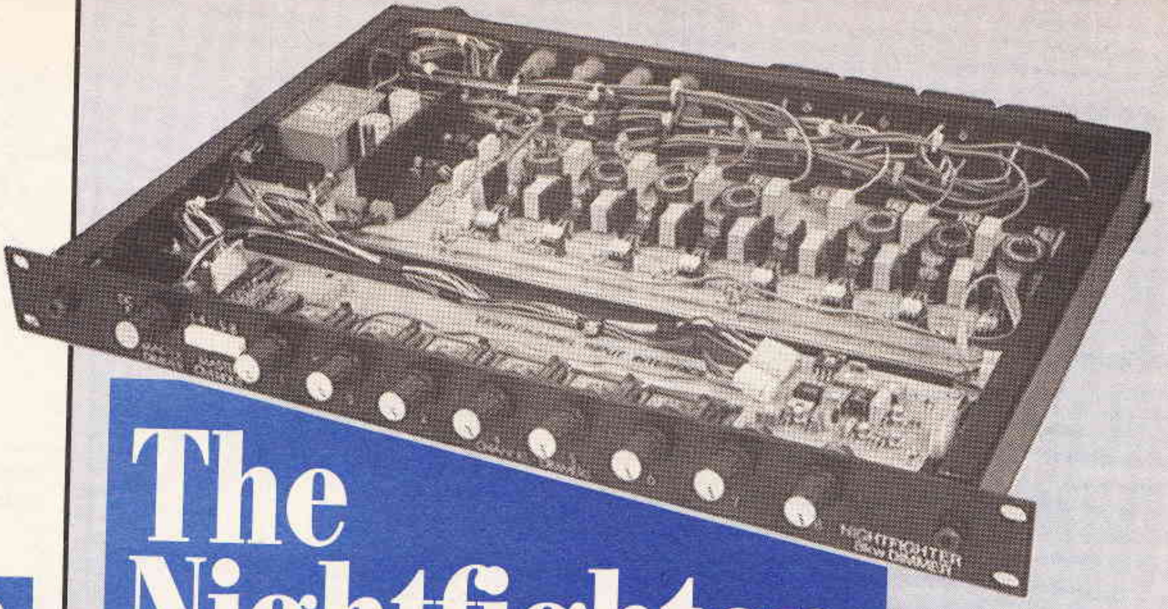


2 The Nightfighter

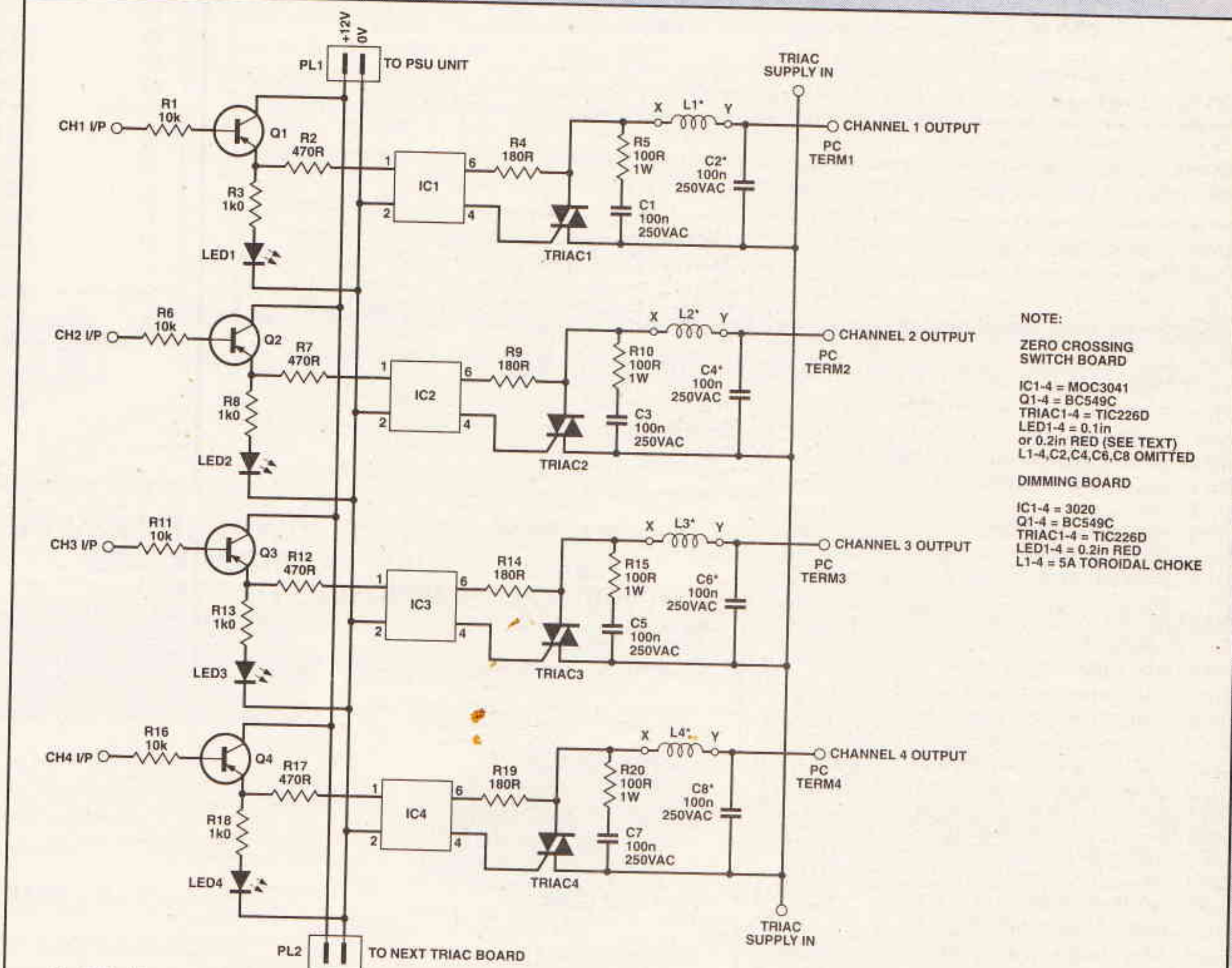


Fig.1 Basic zero crossing Triac switching circuit

This month Mike Beechan provides the high power interface for high power output.

To recap and elaborate on what we said last month, the 'Nightfighter' modular lighting control system was originally developed because at the time that the author required a control system, those available on the market seemed to fit into two distinct categories, namely the budget-priced affairs offering four or so simple sequences with distinctly suspect filtering on the sound to light and at the other end of the price scale, the all-singing, all-dancing microprocessed system which retails from about £300 upwards but yet does not offer any painless or cost-conscious method of upgrade or alteration at a later date.

Problems arise when the prospective purchaser wishes to buy at that time a controller from manufacturer X with facilities A and B. At a later date, he or she then purchases some strobes, for example, and now needs facility C, strobe control. Manufacturer X sells dedicated strobe controllers or a new controller with facilities A, B and C. The DJ now faces the problem of

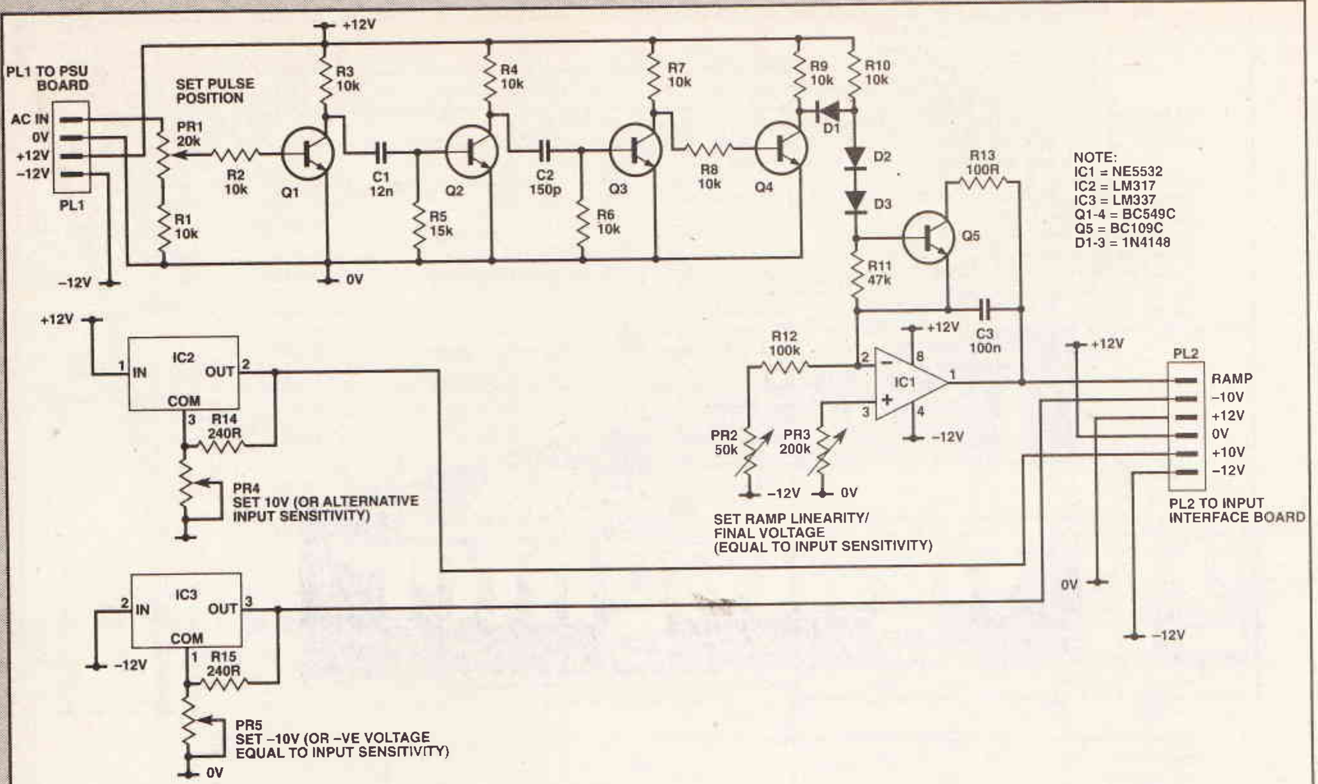


Fig.2 Zero crossing detector and ramp generator circuit

whether to buy a controller dedicated to strobe use only or to buy a new controller which will leave him/her greatly out of pocket and with a perfectly good original, rendered redundant.

Yet another dilemma occurs when we wish to interface equipment of different manufacturing origins — users of computer equipment and RS232 interfaces will be well acquainted with the problems of trying to get peripherals with supposedly internationally agreed standards to communicate intelligibly. It seems to be an unwritten rule of design that each manufacturer makes his equipment as difficult as possible to integrate/interface with equipment of another manufacturer.

The 'Nightfighter' system has no commercial 'loyalties' and so is readily compatible with all popular brands of controller. It can be purchased initially as a budget system and improved and altered when circumstances demand.

The one major snag of a system of this sort is the 'all eggs in one basket' syndrome wherein if the Master Controller fails, the whole system is rendered useless. This happen-stance can be circumvented if the operator maintains a supply of spare boards which can be plugged in quickly and easily should a failure occur.

To the best of the author's knowledge, there are no commercially-produced controllers in ANY price range which offer this instantly upgradeable feature. This philosophy also allows easy improvement of the original design — future boards presently in the pipeline include a 'Super-Audio' board which will allow automatic, pseudo-random cycling of the various options, an improved Sequence Selection which will allow the operator to pre-select the next sequence while the present one is running and a new interface board which will allow the superimposition of a background lighting level on a individual channel.

Anyway, enough of the rhetoric and future developments and back to the present design.

In Part 1 we discussed the design and construction of the heart of the system, the Master Controller.

This month we move onto the peripheral unit which enables the Nightfighter to flash, sequence, and control countless kilowatts of lights, namely the remote switch/dimmer packs.

These 'power packs' are stand-alone units which are designed to be configured in one of four ways:— as a zero-voltage switch pack contained within the Master Controller, as a self-contained remote zero-voltage switch pack, or as a self-contained full-wave phase-control dimming pack with either individual channel dimmers, a master dimmer or a combination of both. The last two options require the construction of an additional control interface board.

Low voltage control signals from the Master are daisy-chained to each of these peripheral units via 15 way D-type plug and socket assemblies and each has a separate Remote Disable Facility which overrides any control signals present.

Basic Zero Crossing Triac Switch Board

The circuit in its simple state consists of a transistor buffer/opto-triac/optional LED indicator driver circuit, triac and interference suppression circuitry. The opto-triac not only provides complete isolation of the control and power-switching circuitry but will also only switch on or off at the zero-crossing points of the mains cycle, thus almost completely eliminating any RFI.

When switching inductive loads (which in a disco environment will mean low voltage pinspot lamps, neon transformers or the motor circuits of kinetic effects), the triac must be triggered when conditions are optimum for a latching current to be established within the period of the gate pulse. To aid latching, additional (and short duration) triac load current can be provided by a parallel RC 'snubber' network comprised of R5 and C1. The snubber network also offers some protection from dV/dt triggering of the triac due to noise spikes, back EMF and the like.

The dimmable version requires the substitution of the zero-crossing opto-triac with the ordinary type and the addition of L1 toroidal choke and another capacitor, C2 which provide a measure of suppression of the RFI which is inherently generated when dimming by phase control.

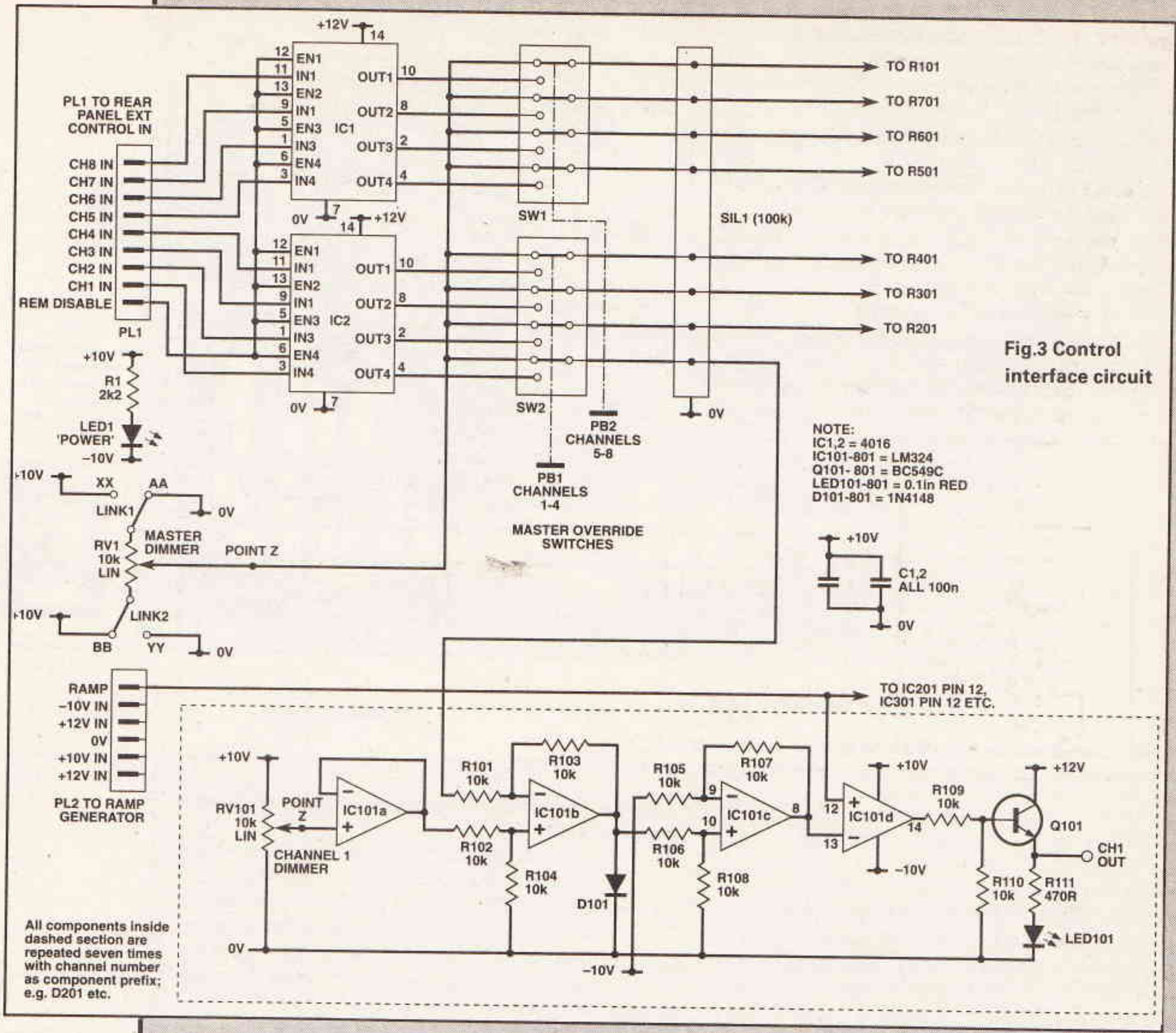


Fig.3 Control interface circuit

Diodes D1 and D2 control the charge and discharge paths of the timing capacitor C1 and so PR2 sets the width of the positive pulse — 'mark' — used to trigger the strobe units and RV1 alters the space between marks and hence the frequency.

Construction

The Switch/Dimmer units are again housed in the ubiquitous 19" rack casings, 1U high in this instance. The nearness of the dimensions of the height of the rear panel of a 1U high case and the cut-out holes required for the Bulgin sockets means that depending on the nature of the construction of the casing, the exercise may prove impossible.

If this is the case (another awful pun!), the two options are to either use different, less disco-industry standard mains multipole sockets (or terminal block) or to use 2U high cases.

Construction of the actual electronics of this section should present few problems, the guidelines given in Part 1 applying equally to the boards just described qv IC sockets, through-board pins, links and resistors mounted first before moving on to more height-conscious components.

A PSU will need to be constructed for the dimmer version. This PSU is identical in all respects to that constructed in Part 1 with the exception of the transformer which is a 6VA rated type, and the 5V regulator, IC1, which is omitted.

The PCB for the triac board has been designed in such a way that it can either be constructed as a 4 or 8 way board, the 4 way option possibly being most useful for installation in a Sensor Switch with mains switching capability — Part 4 will make this a bit clearer. Boards should be bought/made with this in mind. All resistors (and LK1, 2 if the 8 channel version is to be constructed) should be soldered first. Six pin DIL sockets are not easily attainable so the author used some SIL strips cut to length.

The legs of the triacs should be insulated with fine bore silicon sleeving and mounted on the heatsinks using mica washers, insulating bushes and M3 nuts and bolts, the nut being on the component side. Unfortunately, the type of triacs employed do not have isolated tabs and so these are at mains potential but if the techniques outlined above are utilised, these tabs are the only points on the component side of the board where potentially lethal voltages are readily accessible.

The author has always been highly sceptical of the practise of PCB tracks being used to carry heavy currents, especially at mains voltages. The triac boards here use heavy-gauge, 2.5mm stranded wire links to distribute mains to each triac channel so the PCB track carries only a maximum of 5A for that channel. Seven pieces of $2.5mm^2$ insulated wire, 100mm in length should be cut and the ends bared 10mm from the ends. These should then be soldered into positions LK1 to LK7. For total loads in excess of 13A, a ringmain style of connection is employed with a 2.5mm tail from each end of the board terminating at the Mains input terminal block.

The Bulgin 8 way mains socket is regarded universally within the installation business as the industry standard for mains multipole connectors and all commercial controllers feature this connector or terminal block, there seeming to be no other connector regarded as satisfactory although stage dimmer units do use McMurdo or similar connectors.

The pinout for these connectors is as follows:—

Pin 1	Earth
Pins 2,3,4,5	Switched Live Outputs
Pins 7,8	Neutral

Each Neutral and Earth connection to the Bulgin sockets should be made individually with each set of eight wires being brought together at the terminal block end, NOT one or two wires distributing earth and neutral to all of the sockets.

The cables should be tie-wrapped together into neat looms and the loom containing wires from the Bulgin channel outputs looped to the right hand side of the case. Each wire should then be terminated at its respective triac board PC screw terminal. The loop

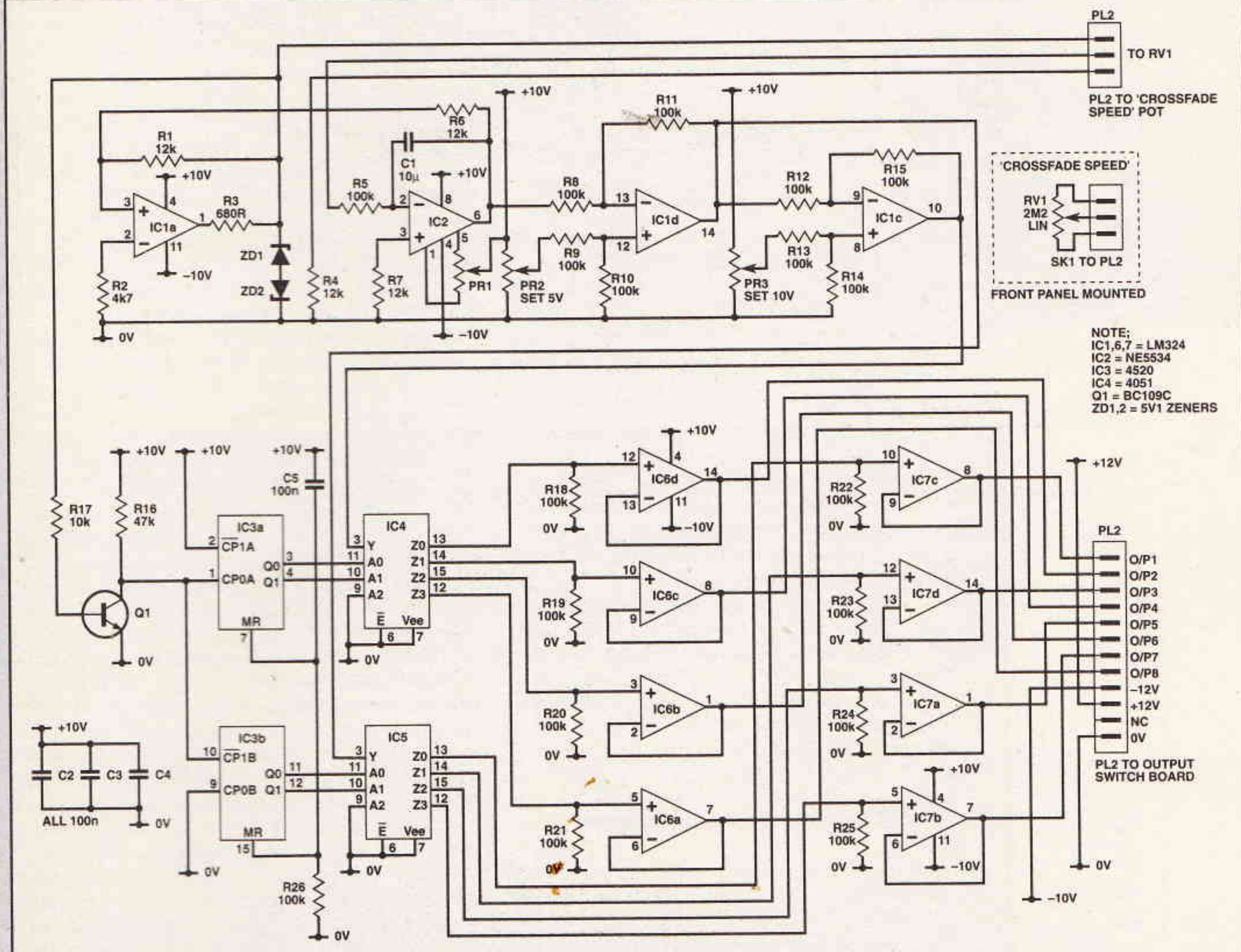


Fig.4 Cyclic crossfade circuit

enables facilitates removal of the board from its fixings without straining any connections and provides a neat and professional looking internal layout.

The wiring of the unit is the main bugbear of the construction process principally because there are so many interconnections between rear panel connectors, fuseholders and the triac boards, and the mains voltages involved mean that any mistakes are both expensive and potentially dangerous! The most methodical way of making the connections is to adopt the resistor colour code for Channel 1 to Channel 8 wiring, black for all connections relating to channel 1, brown for channel 2 etc. The cable should be suitably rated for the load to be controlled-maximum of 5A per channel. The solder tags of the Bulgin sockets should all be sleeved and the fuseholders sheathed with insulated rubber boots.

The PCB's are again mounted on ½"×⅛" aluminium bar and once the front panel has been drilled in places appropriate for the unit constructed (the only holes common to all three variations being the eight Channel Monitor LED holes).

It should be noted that the guidelines given here apply equally to the housing and wiring of a Switch Pack inside the Master Controller casing.

Each variation necessitates a slightly different approach in construction. The differences for each are outlined as follows.

Zero Voltage Switch Pack

This variation requires one triac board and one connector board (fitted with Remote Disable transistors Q1, Q2) to be constructed. Zero-crossing opto-triacs are used and interference suppression components L1-8 and C2,4,6,8,10,12,14,16 are omitted. Each of the eight LED's is mounted at right-angles to the PCB so that it can protrude through the appropriate front panel hole. The connector board is mounted adjacent to the triac board on the left-hand side of the casing and power is derived from the rear-panel mounted EXT. CONTROL IN 15-way D-type socket. The two way power supply plug PL1 on the triac board mates with the plug on the connector board.

Full Facility Dimming Pack (Master and Channel Dimmers c/w Standby/Remote switches

For this version, an 8-way, fully suppressed triac board, PSU, input interface board, ramp generator board and connector board need to be constructed. The input

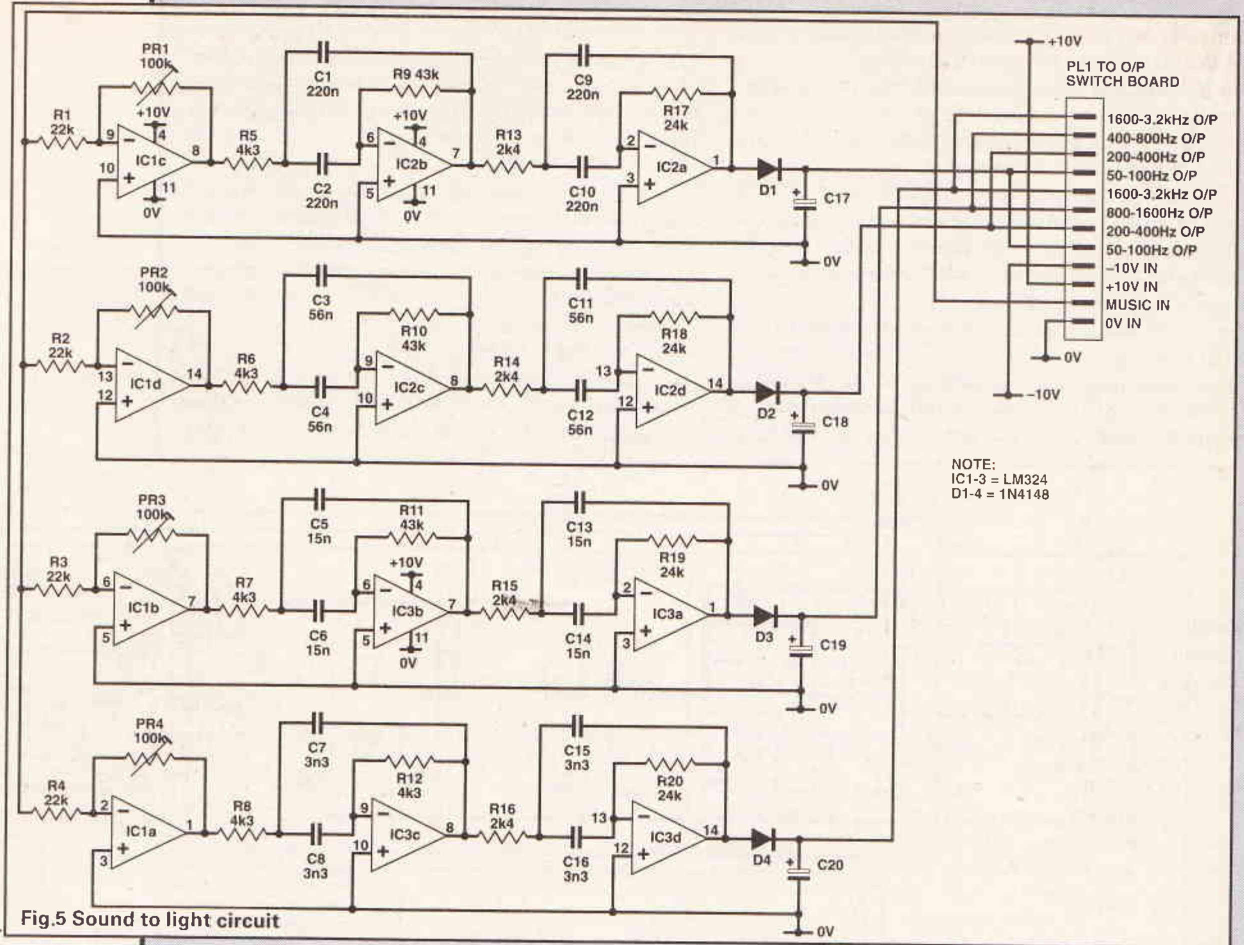


Fig.5 Sound to light circuit

interface board is fitted with 8 channel dimmer pots, two override switches and a master dimmer pot. The ramp generator board is mounted piggy-back fashion on the right-hand side of the interface board. Care should be taken that the through-board pins marked Z and Z' on the component overlay are NOT inserted in this version as they will short together the control voltages from the master dimmer and channel dimmer pots with the consequent destruction of one or more pots and possibly some PCB tracks. PL1 on the triac board plugs into the PSU board. Also RV1 derives its power from pins AA to AA' and from BB to BB' NOT through XX and YY.

Master Controller Optional Plug-in Boards

The plug-in boards can now be tested in the Master Controller. Ensure that each board occupies its correct slot on the board as although the signal pins are common to each unit, some power rails are omitted and replaced with, for example, an audio input signal.

Limited Facility Dimming Pack (Master Dimmer only)

This requires all of the above boards to be constructed, omitting only the 8 channel dimmer pots and the two override switches. The through-board pins at Z, Z' and XX and YY are inserted on this version. There are also links to be inserted in place of the override switches. These will be shown on the component overlay next month.

Setting Up

The PR1 bias preset control on the crossfade board should be set about mid-position — the setting isn't critical — but extreme adjustment affects the low frequency linearity of the triangle wave — a 'scope or an analogue voltmeter are the best instruments to have to hand for this adjustment. PR2 should be set for 5V and PR3 for 10V — again if the waveform is viewed on a 'scope it should fall to 0V and rise to 10V. Any marked deviation from these two extremes obviously affects the smoothness of the fading action between lamps.

Strobe Board

The adjustments on this board are PR2 which set the Mark time of the oscillator waveform and PR1 which sets the maximum strobe flash rate. PR2 should be set using a 'scope according to the strobe manufacturer's specification. If this is not readily available, RV2 should be set for a long space and PR2 for a short mark. Should the strobes fail to trigger, increase the mark length until they do so. PR1 should be set according to personal preference and with reference to the maximum flash rate attainable at maximum light output from the strobe units to be used — most strobe units trade-off light output against flash rate. It should also not be forgotten what was mentioned earlier about flash rate and the incidence of dis-orientation and epilepsy.

Sound to Light

PR1-4 are the only adjustments to be made on this board. The best way to adjust these is by using an audio frequency generator to 'squeak' through the normal audio frequency range, adjusting each preset so that there is equal response from each associated filter within its passband. Failing this, each filter should be adjusted for reasonable response with normal programme material.

Ramp Generator

A dual trace 'scope is a most useful instrument to have to hand for precise adjustment of the Ramp Generator so that the mains input waveform and the output of the zero-crossing detector can be viewed simultaneously although PR1 can be set reasonably accurately using a DMM. PR1 should be set for 3.5V on an AC range or for an narrow a 12V pulse as possible. PR2 sets the ramp linearity and its final voltage — for use with the circuitry in these articles and for most dimming equipment in the commercial world, it will be set for 10V although one manufacturer does use a 0-6V DC control signal. PR3 is set such that the resistance which it presents to IC1 pin 3 is equivalent to the combined resistance of R12 and PR2. PR4 should be set such that IC2 output voltage is equal to the ramp final voltage and PR5 for an equal and negative voltage at IC3 output.

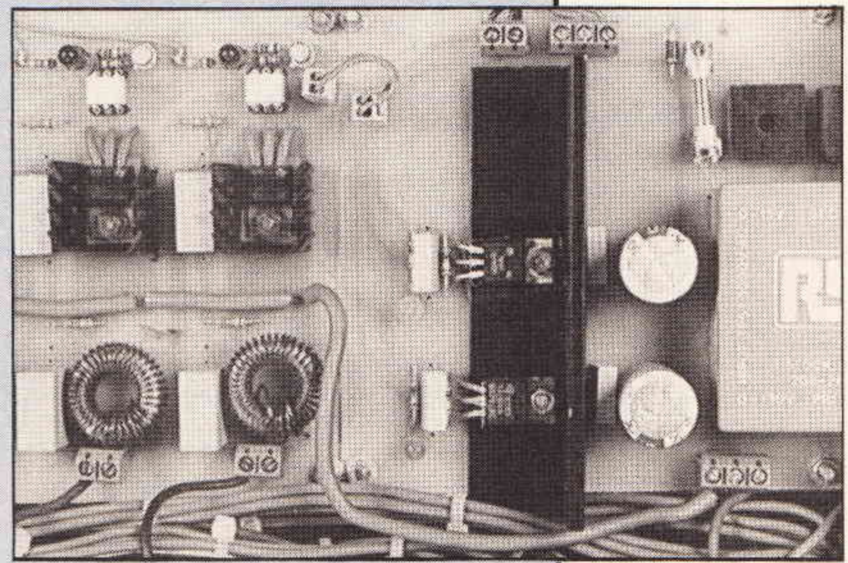
There are no adjustments to be made on the Input Interface board. All that is now needed is to plug all of the previously set-up boards and the External Control In socket into the board, leaving the connection to the triac board for the present. With power applied and the two Standby/Remote switches (if fitted) in the Out ie Remote position there should be no front panel LED's lit. Advance all of the pots fully clockwise and press SW1 and SW2 in turn. LED's 1 to 4 and then 5 to 8 should come on at full brightness. Turning the Master Dimmer anticlockwise should smoothly dim all eight LED's simultaneously while turning a Channel Dimmer down should smoothly dim that channel only.

Disconnect power and connect a 15" piece of insulated wire bared at both ends to the +12v terminal on the PSU. Reapply power and touch the bared end in turn to each channel input pin on the triac board — this should cause each LED to light in turn. If this is the case, connect the interface output plug to the Connector board — the LED's on the triac board should now mirror exactly the front panel Monitor LED's.

Switch off again and connect the triac supply wire(s) to the Live terminal in the terminal block. Beg, borrow or steal a 100W light-bulb, holder and some connecting wire and connect one tail to the Neutral terminal and the other to the PC screw terminal of channel 1. Reapply power and the lamp should be glowing if none of the front panel controls had been touched in the meantime. It should be possible to smoothly alter the brightness of the lamp from off to fully on using the front panel pots. Any flicker means that the gain of the opto-triac is low and necessitates lowering the value of R2 drive resistor.

This routine should be followed for each channel. The switch board should be tested in a similar manner, powering PL1 temporarily from the Master PSU and using a +10V feed from the PSU output terminal to fire the triacs. Once the triac board is verified as completely working, it should be installed in either the Master Controller or Dimmer cabinet as appropriate.

All that now remains is to make up an 18" 15-way



HOW IT WORKS

ZERO CROSSING DETECTOR & RAMP GENERATOR

A fullwave rectified but unsmoothed version of the AC secondary waveform is applied via PR1 and R2 to Q1. Every time the input from the bridge drops below about 1V, Q1 is biased off and the collector swings to +10V. When the collector goes negative again, Q2 is biased hard off for a very short period defined by the C1/R5 combination. This pulse is applied to the leading edge detector comprised of C2, R6 and Q3. The output waveform at Q3 collector is a narrow, negative-going pulse which is exactly coincident with the zero crossings of the 50Hz waveform. It is inverted by Q4 and applied to the trigger input of the sawtooth generator of IC1 and associated components. IC1 is basically an integrator with a clamping transistor Q5 added, this resetting the capacitor to zero volts at the end of each timing cycle. When the trigger input is high, the circuit is in hold mode, R11 holding Q5 in saturation with R13 in parallel with C3 causing the output to be essentially zero volts. When the trigger pulse goes low, D1 steers the current in R11 away from Q5 by reverse biasing D2 and D3, turning Q5 off and preventing any "sneak path" current flow from the summing point (which would alter it).

The circuit then integrates at It/C3 V/s until the trigger voltage swings high again. PR2 and the R12/C3 combination are chosen to allow the output to ramp to 10V in the required 10ms (half mains cycle). PR2 thus sets the output voltage at the top of the ramp, and unless the reader is interfacing the dimmer with commercial control equipment with control sensitivities different from 10V, it will normally be set for +10V output.

IC2 and IC3 generate plus and minus 10V supplies from the plus and minus 12V rails of the PSU, as the op-amps on the interface board operate on different supply rails from the rest of the boards in the series.

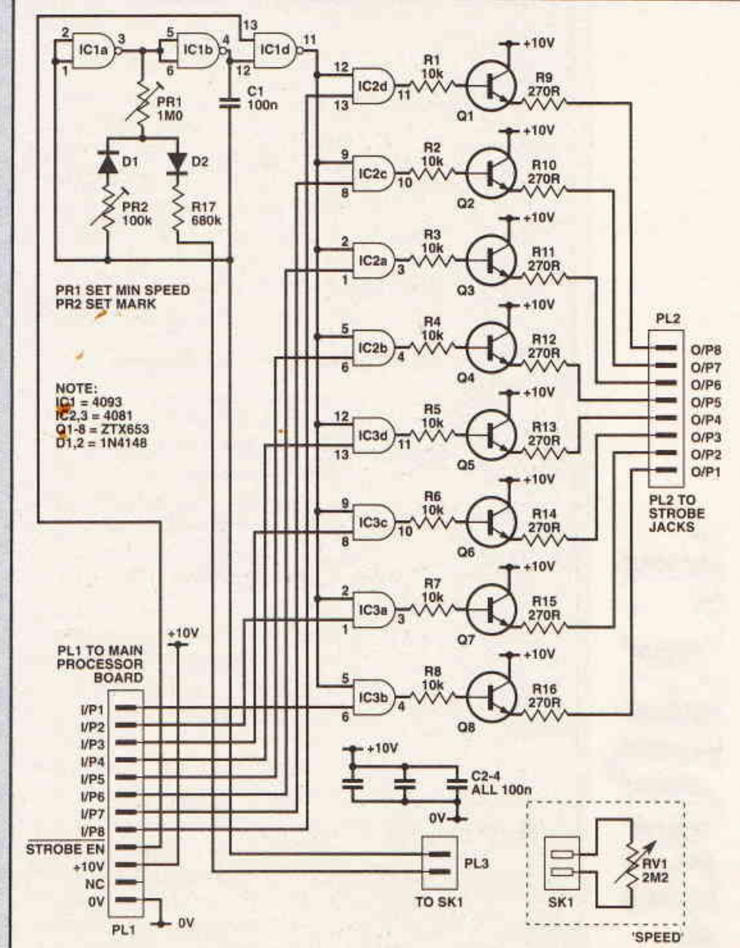


Fig.6 Strobe circuit

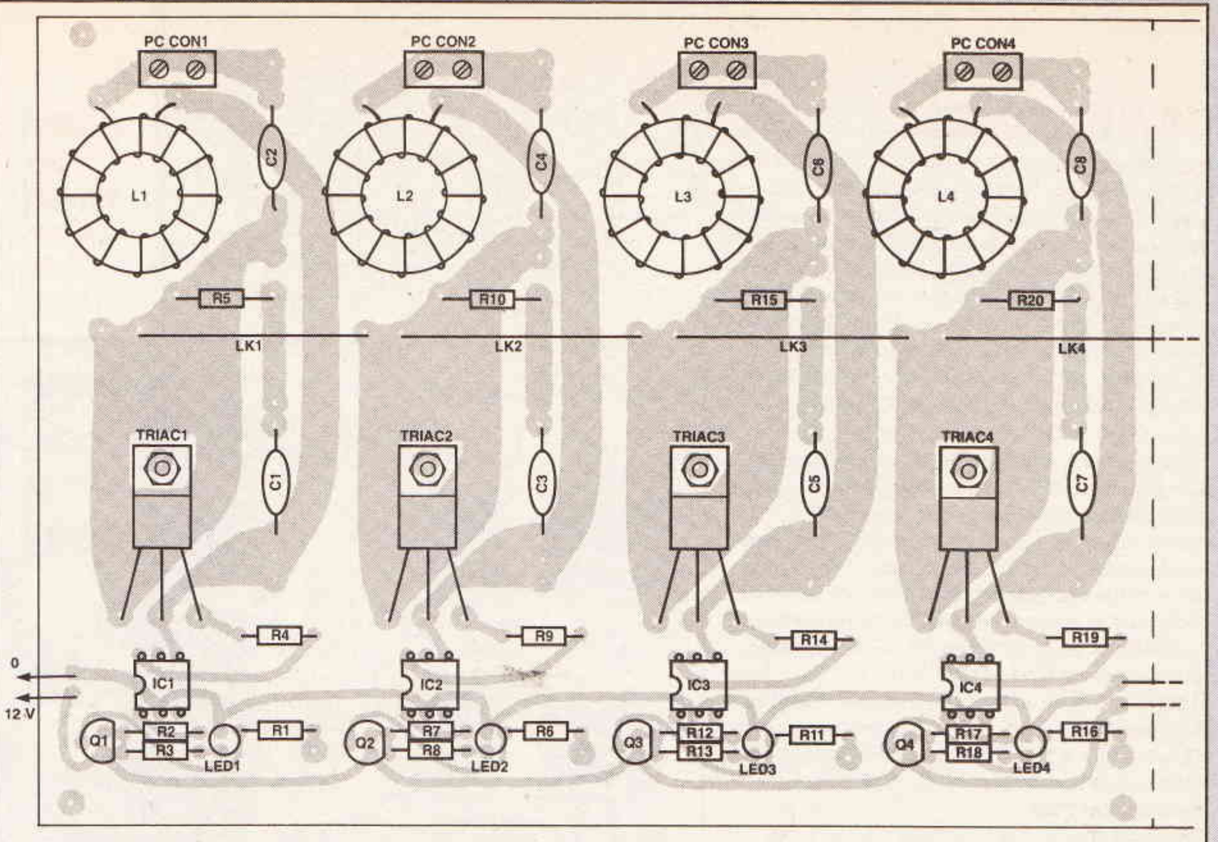


Fig.7 Triac switching board overlay

HOW IT WORKS

CONTROL INTERFACE

The ramp from the zero crossing detector is applied to the non-inverting terminals of eight identical comparator circuits, IC101d-801d. The reference voltage for these comparators is derived (in remote control mode) from the external control voltage for that channel and from the voltage output from the channel dimmer pot if fitted. In STANDBY mode, the control voltage is derived from the MASTER DIMMER pot, RV1, and from the channel dimmer pots if fitted.

Each channel consists of 4 op-amps contained within IC101 to IC801 which are used to buffer, add, subtract and compare the various control voltage sources available to dim the channel.

To understand the operation of the circuit, we shall assume that the unit is fitted with both MASTER and CHANNEL DIMMER controls, that the EXTERNAL control voltage for the channel under scrutiny is 10V, ie channel fully ON, that the STANDBY/REMOTE switch is in the REMOTE position and that the CHANNEL DIMMER is set for 50% brightness level. The external control passes through bilateral switch IC1 (no disable signal present), through the STANDBY/REMOTE switch SW1a to the inverting input of IC1b. The non-inverting input is derived from RV101 and is presently +5V. (IC1a voltage follower is used simply to ensure that both + and - inputs of the differential amplifier are of the same essentially very high impedance). The output of IC101b is V2-V1 where V2=5V and V1 = 10V. The -5V is passed to IC101c, another differential amplifier. (D101 is reverse-biased and so of no consequence). The inverting input is permanently connected to -10V, so V2-V1 = -5--10V = +5V. This is the reference voltage for the comparator, which will flip positive half way up the ramp, firing the triac 90° into each mains half cycle.

Were the CHANNEL DIMMER is set to off ie 10V at its wiper and a 5V signal present from the EXT. CONTROL, we can see IC101b output will be V2-V1 = +5V. This is shunted to earth by D101 which is now forward biased and the + input of IC101c is 0V. IC101c output will be +10V. The comparator will then never change states, ie always 0V and the triac will remain off.

The STANDBY/REMOTE pushbuttons switch the input voltages to RV101, RV201 etc from the EXTERNAL control to a voltage derived from RV1 MASTER DIMMER which controls all channels simultaneously.

The CHANNEL DIMMERS and the STANDBY/REMOTE pushbuttons may be omitted and the RV1 wiper voltage at Z connected to point Z, the input to the voltage followers on each channel. The MASTER DIMMER becomes a display brightness control used in conjunction with the EXT. CONTROL VOLTAGES. So the pot operates in its correct sense ie fully clockwise is 'fully on', the 0V and +10V connections to RV1 are reversed by connecting it through pins XX and YY.

JK1 is the REMOTE DISABLE jack which opens or closes the bilateral switch IC's and allows the EXT. CONTROL signals through to the STANDBY/REMOTE switch when the signal on the 'tip' contacts is +10V.

The CONNECTOR BOARD was used on the Master Controller to parallel together the CHANNEL MONITOR LED drives and the low voltage CONTROL OUTPUTS. It is used in the 'Power Packs' to connect the triac board channel inputs and the Input Interface board outputs together and also to mount two transistors Q1, Q2 and associated components which provide the REMOTE DISABLE function for the zero-voltage switch pack by controlling when the +10V is switched to the triac board, +10V is provided via PL1 from the PSU. The darlington transistor configuration, Q1, Q2 is powered from the 15 way EXT. CONTROL IN socket on the rear panel and controlled by the voltage on the REMOTE DISABLE jack, providing drive only when unit is enabled.

There are three optional lighting effect boards which plug into the Master Controller, namely a 4 Channel Sound to Light board, an 8 Channel Cyclic Crossfade board and an 8 Channel Strobe board. These mount piggy-back fashion over the three principal control boards and plug into the output switch board and main processor board respectively.

The Sound to Light board takes the gain-controlled music signal from the Bass Beat Trigger board and splits it into four octave-spaced frequency bands, the signal from each band being rectified and used to charge a capacitor to the mean DC level of the signal at that frequency. The octave-wide 'holes' in the spectral spacing of the filters mean that dropouts occur when an instrument hits the guard bands between filters, adding considerably to the liveliness of the display. It also means the harmonic content of music doesn't turn all the lamps on at the same time.

The Crossfade board provides a dipless crossfade, dimming one lamp whilst dimming up the adjacent lamp, the sequence repeating in a cycle. The speed is adjustable via the front panel SPEED control. It can only successfully be used with an external dimming pack.

The Strobe board uses the lower 40 of the 80 patterns available from the Processor EPROM, none of these 40 containing fill or empty routines which lose effect when used with strobe lighting.

It is unlikely the reader will wish to construct all three of the bolt-on goodies, rather that he or she build those which best apply to the display to be controlled.

HOW IT WORKS

CYCLIC CROSSFADE

The Crossfade board consists of two main sections — a very low frequency function generator which provides the square and triangular waveforms and a CMOS analogue multipexer which route the waveforms to the appropriate channel outputs at the correct time.

The function generator comprises IC1a and IC2, IC1a forming a comparator with hysteresis and IC2 an 'ideal' integrator which simultaneously generates ultra-linear triangle waveforms and symmetrical square waves. The timing components, R5 and C1 set the integration and hence positive and negative ramp rate and the two zener diodes set the positive and negative voltage limits of the waveform. There is also b network, R4 and RV1. The problem in our application of a circuit of this type is in the very long time constants involved which would normally involve impracticably large non-polarised capacitors (for long fade rates) and very hard-to-find (impossible?) high value variable resistors. The B network placed between the clamping diodes and the timing resistor R5 varies the fraction of ± Vz that is fed to R5, and thus the input current to IC2 which consequently increases the dynamic range very easily to 1000:1. With the components values shown, the ramp rate is variable from about 2Hz to 0.01Hz.

IC1d and IC1c are both differential amplifiers used to shift the bipolar output to the 0-10V DC swing required by the dimmer circuits and IC1c providing an inverting function of the triangle wave whilst preserving the 0-10V DC swing.

The square wave is used to clock the two binary counters of IC3, IC3a advancing on the rising edge of the clock and IC3b on the trailing edge. C4, R26 combination reset both binary counters on power up. The Q outputs of each counter address IC's 4 and 5 eight input analogue multiplexers, IC4 input being the inverted ramp and IC5 input the original. IC4 outputs comprise channels 2 to 8 (even) and IC5's are the odd channels, 1 to 7.

We shall consider the case where both sets of address lines are 00 and the ramp voltage outputted to channel 1 is almost 10V, ie lamp almost full brightness. At the instant that the ramp voltage reaches 10V, the clock alters state and the rising edge clocks IC3a changing the address lines of IC4 to 01. The ramp input, now connected to output channel 2 on IC4 is at 0V and ramping up while IC5 ramp input is falling. At the instant that IC5 input reaches 0V, a falling edge clock is generated, IC3b clocks and the now-rising ramp input of IC5 is outputted to channel 3. This sequence of events continues ad infinitum. IC6 and IC7 simply buffer the multiplexer outputs.

SOUND TO LIGHT

The Sound to Light board consists of four octave-wide two pole filters covering the ranges 50 to 100Hz, 200Hz to 400Hz, 800Hz to 1600Hz and 3.2kHz to 6.4kHz. Each filter has a 1dB passband dip. The filter is implemented using a multiple-feedback section for each of the two poles and the filter has a Q of 3.2. The centre frequency of each filter is determined by (f2 x f1) (f1 x f2) where f2 and f1 are the upper and lower frequencies respectively.

Each filter input is first amplified by IC1a to IC1d, the gain of the amplifiers being set by PR1-4. The four filter outputs charge capacitors C17 — C20 via diodes D1-4 and so a DC voltage representative of the mean level of signal at that frequency is outputted to the Output Switch board.

STROBE BOARD

The Strobe Board is an optional extra which plugs into the Main Processor Board and from which it derives its power and control signals. It consists of an oscillator whose frequency is user-variable from about 1 — 17Hz via the front panel STROBE/CROSSFADE SPEED pot, a series of AND gates enabled on one input by the data lines of the EPROM (O/P 1 to O/P 8) and on the other by the LFO.

The oscillator itself is enabled by the STROBE/ENABLE line which is switched by the STROBE pushbutton on the Output Mode board and which also limits the sequences available to those held in the lower 1K of the EPROM.

The outputs are buffered by transistors Q1-8 before connection to strobe jacks JK3-10 on the rear panel. PR1 sets the max. flash rate attainable as it has been proven that prolonged exposure to strobe light in the frequency range 15Hz causes break-up of vision, or more seriously, fits in those who suffer from epilepsy.

female D-type to 15-way male for testing of the remote driving facilities of the Master Controller. Pinout connections given in Table 1 will be later. The lead should be connected to CONTROL OUT on the Master and to EXT. CONTROL IN on the remote unit. The remote unit should mimic exactly the Channel Monitor display (if no override buttons are depressed and no Remote Disable jack is inserted).

Inserting a 1/4" jack plug into the Remote Disable socket will disable the remote unit.

Next month we will present more constructional aspects of the two units described so far including the case, front panel and board interconnections. The six overlays for the master controller will also be presented.

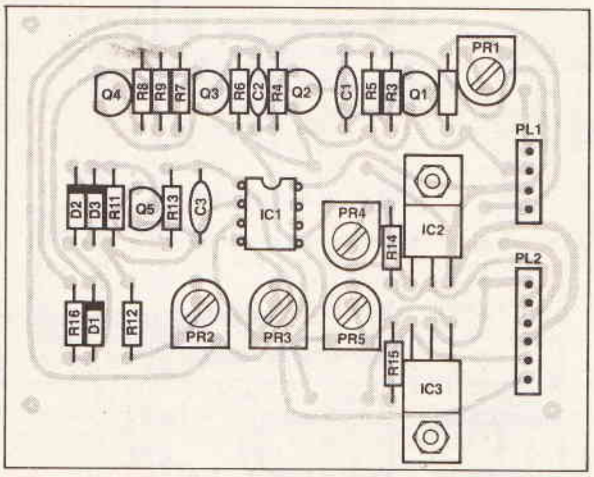


Fig.8 Zero crossing detector and ramp generator overlay

PARTS LIST

TRIAC BOARD

RESISTORS	
R1,6,11,16	10k
R2,7,12,17	470R
R3,8,13,18	1k
R4,9,14,19	180R
R5,10,15,20	100R, 1W
CAPACITORS	
C1,3,5,7	100n 250VAC WORKING Interference Suppression Capacitors
C2,4,6,8	*(same as above, fitted only to dimming version)
SEMICONDUCTORS	
Tr1-4	TIC226D 8A Triacs
IC1-4	MOC 3041 Zero crossing opto-triac *MOC 3020 opto triac
Q1-4	BC549C
LED1-4	0.1" or 0.2" red LED (SEE TEXT)
MISCELLANEOUS	
L1-4	*150µH 5A Toroidal Choke
PL1,2	2-way Minicon latch plugs
PC TERM1-4	2-way PC screw terminal (Maplin FT38R)

4 off high power vaned heatsinks (Maplin FL58N), SIL socket strip (see text), Triac PCB, Heatsink mounting hardware, Quantity of 2.5mm^2 stranded insulated wire (see text), Insulating sleeving, SK1, 8 way Minicon Socket-lead assy

SK2, 2 way Minicon Socket-Socket assy

Parts list above is for four channel version-double the quantities of components shown for an eight channel version.

Parts denoted thus (*Toroidal Choke) are fitted to the dimmer version only.

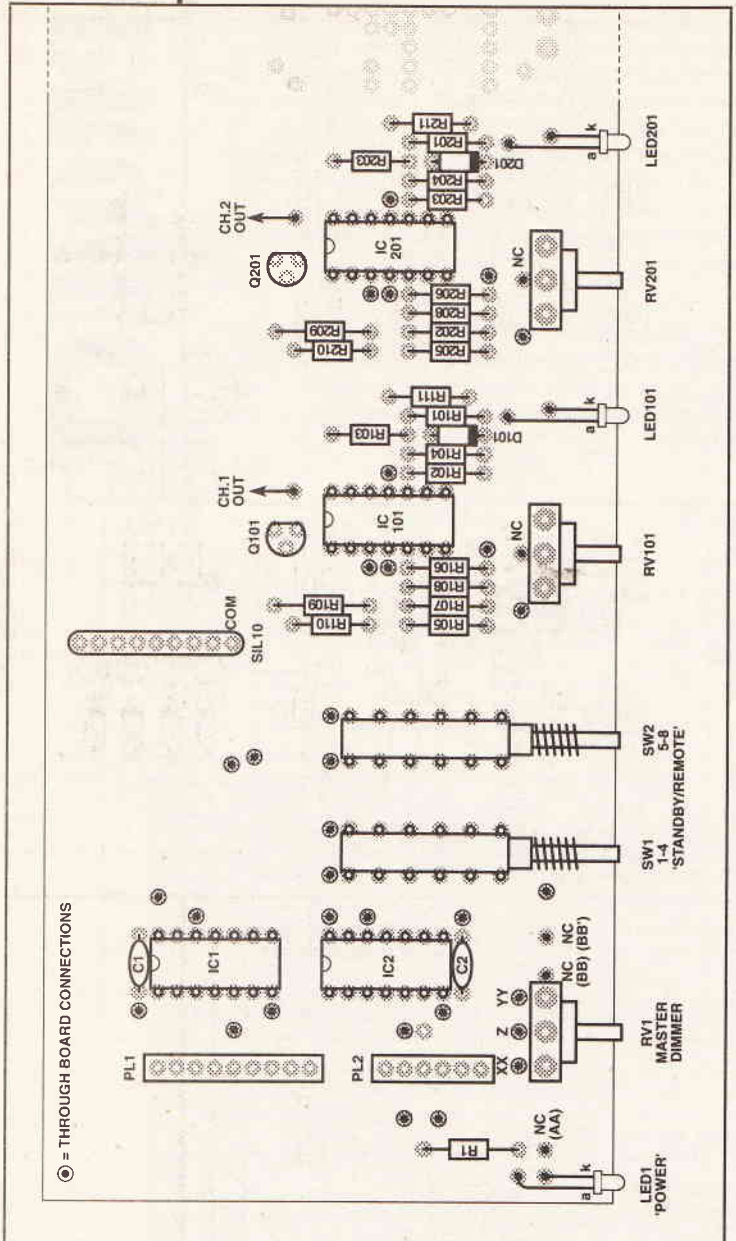


Fig.9 Control Interface overlay showing only two channels

PARTS LIST

RAMP GENERATOR

RESISTORS

R1-4,6-10	10k
R5	15k
R11	47k
R12	100k
R13	100R
R14,15	240R
PR1	20k horizontal preset
PR2	50k horizontal preset
PR3	200k horizontal preset
PR4,5	5k horizontal preset

CAPACITORS

C1	12n polyester
C2	750p polystyrene

SEMICONDUCTORS

IC1	NE5532
IC2	LM317T
IC3	LM337T
Q1-4	BC549C
Q5	BC109C
D1-3	IN4148

MISCELLANEOUS

PL1,	4 way Minicon latch plug
PL2,	6 way Minicon latch plug
SK1,	4 way Minicon latch socket-assy
SK2,	6 way Minicon socket-socket assy

IC socket to suit, PCB, veropins

CYCLIC CROSSFADE

RESISTORS

R1,4,6,7	12k
R2	4k7
R3	680R
R5,8-15,18-25,26	100k
R16	47k
R17	10k
PR1,2,3	10k horizontal preset
RV1	2M2 linear pot

CAPACITORS

C1	10µ non-polarised electrolytic
C2,3,4	100n disc ceramic
C5	100n polyester

SEMICONDUCTORS

IC1,6,7	LM324
IC2	NE5534
IC3	4520
IC4,5	4051
Q1	BC549C
ZD1,2	5V1 300mW zener

MISCELLANEOUS

PL1,	3 way Minicon latch plug
SK1,	3 way Minicon Socket lead assy

IC sockets to suit, PCB, veropins

4 CHANNEL SOUND TO LIGHT

RESISTORS

R1-4	22k
R5-8	4k3
R9-12	43k
R13-16	2k4
R17-20	24k
PR1-4	100k horizontal miniature preset

CAPACITORS

C1,2,9,10	220n Polyester
C3,4,11,12	56n Polyester
C5,6,13,14	15n Polyester
C7,8,15,16	3n6 Polystyrene
C17-20	4µ7 16V Radial Electrolytic

SEMICONDUCTORS

IC1,2,3	LM324
D1-4	1N4148

MISCELLANEOUS

IC Sockets to suit, PCB, Veropins, 12 way Minicon plug

STROBE BOARD

RESISTORS

R1-18	10k
R9-16	270R
R17	680k
PR2	100k miniature horizontal preset
PR1	1M miniature horizontal
RV1	2M2 linear pot

CAPACITORS

C1	100n polyester
C2-4	100n disc ceramic

MISCELLANEOUS

PL1	3-way Minicon plug
PL2	12-way Minicon plug
SK1	3-way Minicon socket-lead assy

IC sockets to suit, PCB, veropins

JK1-8	1/4" mono jack sockets-panel mounting

MISCELLANEOUS TO COMPLETE SWITCH/DIMMER PACK

SK1	15-way D-type socket
SK2	15-way D-type socket
JK1	1/4" mono switched jack socket
FH1-8	5x20mm panel mounting fuseholder
BULGIN1-4	Bulgin octal socket

1U black anodised front panel, case to suit (see text), 20mm gland, 30A terminal block, 6A connecting wire 6VA PSU.

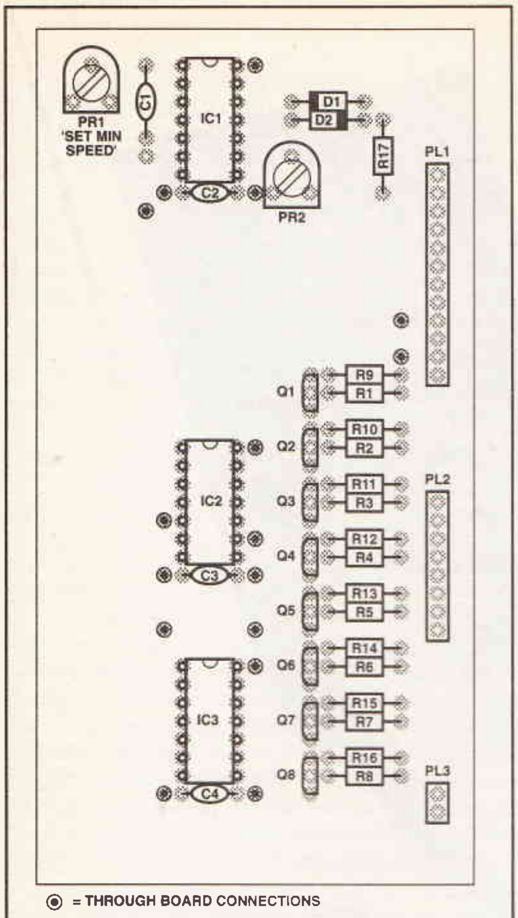


Fig.12 Strobe board overlay

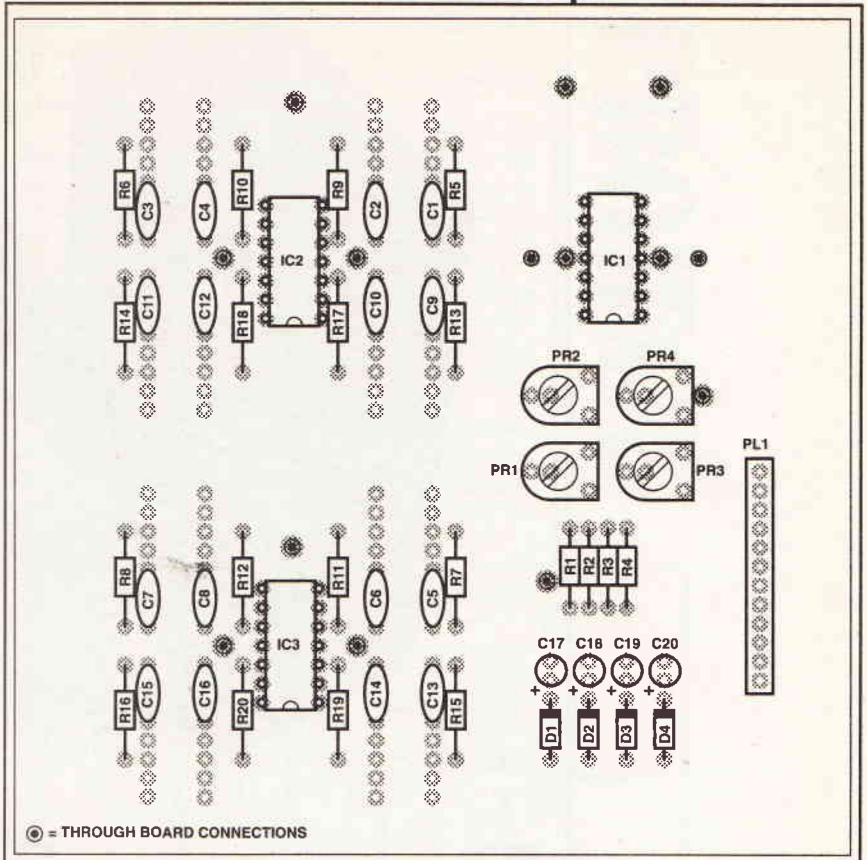


Fig.11 Sound to light overlay

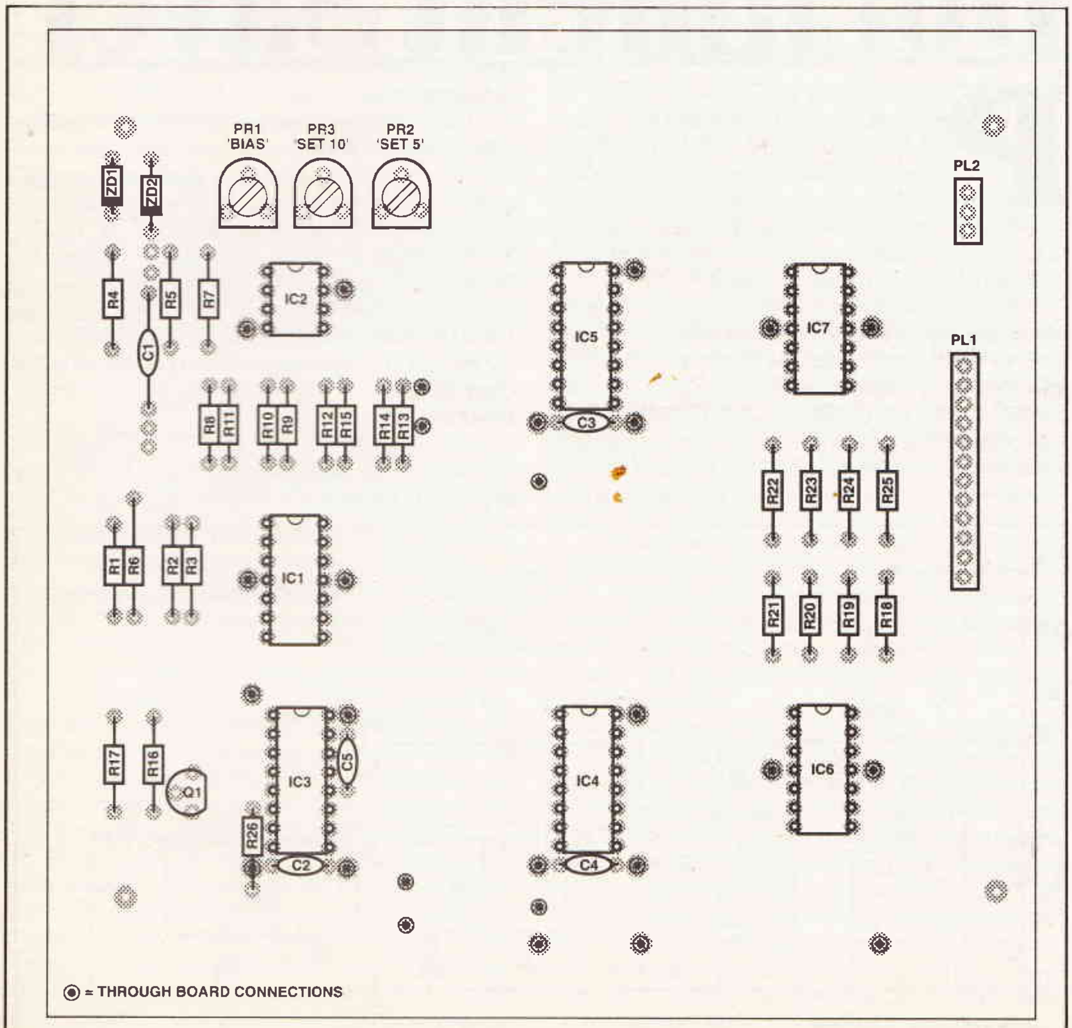
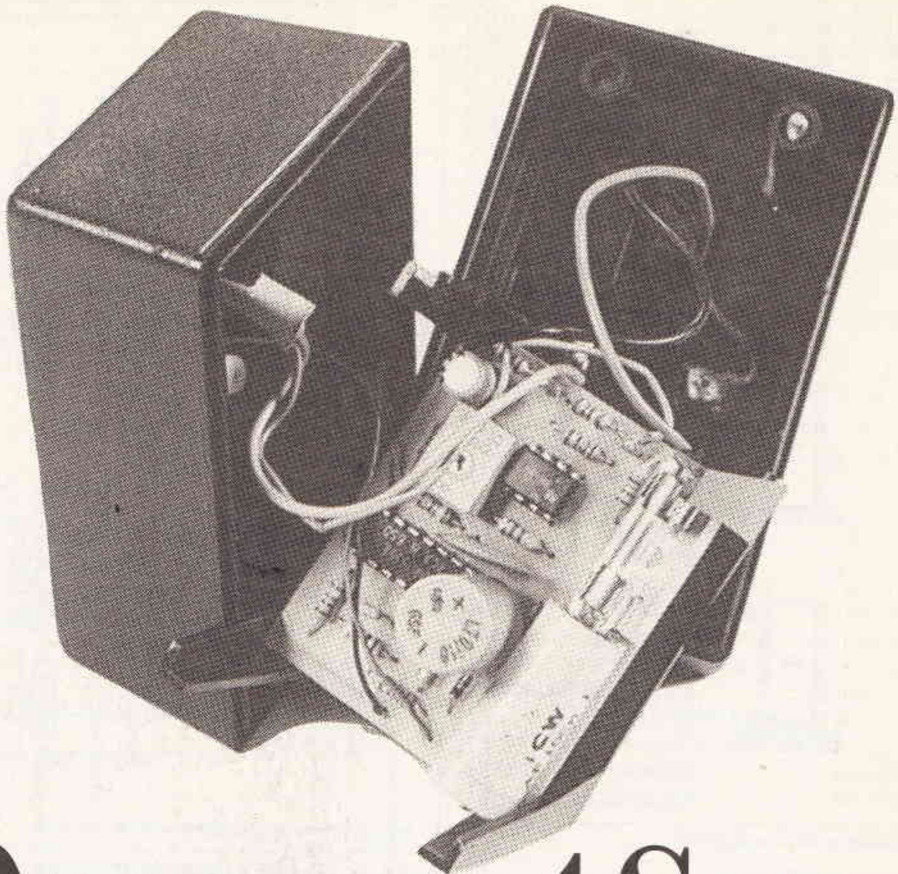


Fig.10 Cyclic crossfade overlay



Document Saver

David Bradshaw builds a mains failure alarm to warn of possible data loss.

Power cuts are frequently preceeded by mains voltage reductions, so a device that lets you know when the mains voltage drops significantly below its normal level can be an invaluable 'early warning'. This is particularly important to computer users, who may loose a lot of valuable work, but many others would find warning of any power cut useful.

The heart of this device is a voltage comparator, which uses an op-amp with no feedback. Other sections of the circuit include the power supply, which also is used to provide a reference voltage to the comparator, a potential divider which reduces the mains voltage down to a level which the comparator can deal with and rectifies and smooths it into DC, and finally a bleeper which using a piezo-electric sounder produces the warning tone.

The power supply uses a capacitor to reduce the mains voltage; because capacitors have pure reactance and no resistance, the capacitor C1 does not dissipate any heat, but still acts as a 'voltage dropper'. ZD1 limits the positive voltage at point A to 10 volts, and the diode D1 limits the negative voltage to-0.6volts. So C1 and ZD1/D1 can be thought of as acting as a sort of potential divider. D2 allows the voltage at point A to charge up capacitor C2 while A is at a positive voltage, but disconnects A from C2 while A is at a negative voltage (or any voltage less than that on the capacitor).

The potential divider uses D3 to rectify the incoming voltage, then resistors R1 and R2 form the upper arm of the potential divider and R3 and R4 form

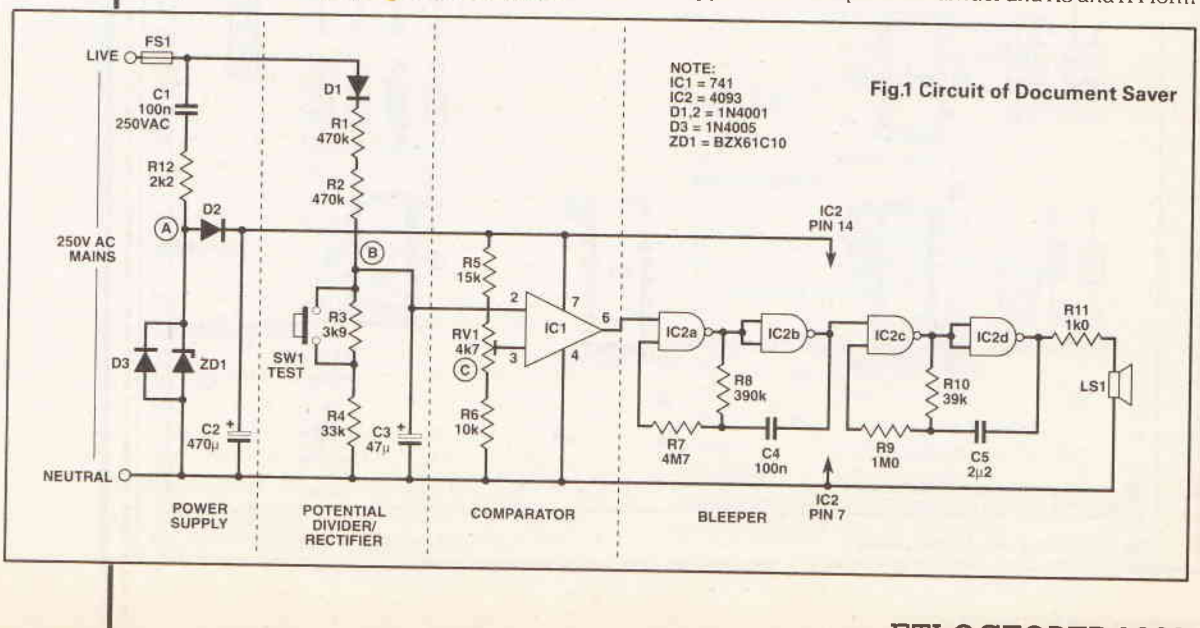


Fig.1 Circuit of Document Saver

the lower arm. The reason why two resistors are used for the upper arm is so that if one resistor fails, there is still the other to prevent a dangerously large current from flowing (which could lead to a fire). The lower arm is divided so that the smaller resistor, R3, can be shorted out by a switch to simulate a drop in the mains voltage. The voltage given by the voltage divided is not a simple function of the two resistance arms, because the input is AC but the output is DC. If the mains voltage in your area is different to those for which component values are given in the Parts List, you can calculate the required value of R1+R2 needed from the formula:

$$R1+R2 = 4.05 \times V_{in} - 21.2\ (k\Omega)$$

where V_{in} is the RMS mains voltage (the figure usually quoted). Choose two resistor values for R1 and R2 that when added together get fairly close to the required value, say within 25k, using an E12 value. Try to make the two resistor values fairly similar, if this isn't possible then do keep them both above 100k.

The comparator is a simple open-loop op-amp, with one voltage coming from the potential divider/rectifier and the other from a simple resistive potential divider between the positive supply and the common line. This uses a preset potentiometer so that the voltage from it may be adjusted. Because the voltage from the potential divider/rectifier goes to the inverting input, the output of the op-amp will be low as long as the mains voltage is above a certain value determined by the resistor values in both potential dividers.

The final stage is the bleeper which uses some CMOS logic gates. There are in fact two oscillators, one around IC2a/IC2b which is a slow oscillator, (frequency approximately 3 Hz), is off until the output of IC1 goes high, and a fast oscillator around IC2c/IC2d, (frequency about 3 kHz) which drives the sounder via R11. It can only operate when the output of IC2b is high. The result is that the tone output is interupted several times a second.

Construction

Because this circuit is live to the mains, there are a number of important points which must be observed with the design of the case for the unit and during construction. The most important points are:

- Make sure that nothing live can be touched with the box closed
- Never operate the unit without a suitably rated fuse
- Use components as specified for C1, D3 and SW1
- Where available, use a special 'plug in' case.

As this project is connected to the mains, I would strongly recommend using the PCB shown in Figure 2. Start by positioning the fuse holder and capacitor C1 to check that they will fit. Then fit the PCB pins for the off-board connections to the switch. Then fit and solder all the resistors, all the capacitors except C2 (making sure you get C3 the right way round), then preset potentiometer and the fuse holder. Fit the diodes D1-3 and the zener diode, ZD1, taking great care to get them the right way round. The ICs can be inserted and soldered at this point, and then C2, which may have to sit a bit above the board because of its width. Solder wires for the connections to the mains supply and to the switch, and also connect the wire to the piezo-sounder. Note the polarity on the connections to this.

Borrow a 9 volt battery, and using your multimeter check that its voltage is not much over 9 volts (sometimes very new batteries can have voltages quite a bit above their nominal voltage). With the battery negative terminal to common connect the positive terminal to point A. This should make the unit start bleeping. The wire soldered to point B (for the connection to SW1) should be tacked to the battery positive and this should silence the bleeper. Switch the multimeter to the current range, connect it between the battery positive and point A and measure the current the unit draws-it should be a milliamp or so with or without the bleeper going.

The next step is to fit out the case: if possible, use the type of case the prototype was built in, which has the plug connections built in; make sure there is enough room inside to fit all the components. The case the author used, from Maplin Electronic Supplies, has an internal plastic frame which the PCB fits into. The sounder has to be fixed and a hole drilled to let out the actual sound. The hole must be very small so that even a child's finger cannot touch the sounder itself. In the prototype, the sounder was glued to the case behind the hole using epoxy resin adhesive.

If you cannot use a case with built-in plug connections, then you will have to use a twin-core mains cable, and provide some way of clamping the cable in the box so that even a strong pull will not loosen it; there are special cable clamps available.

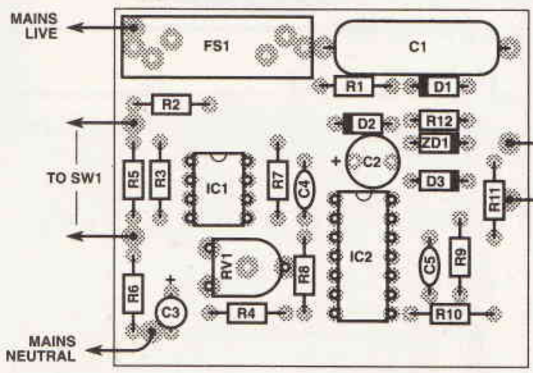
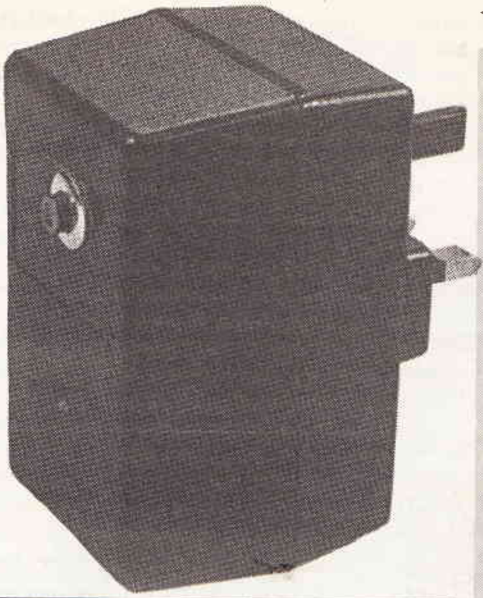


Fig.2 Component overlay for the Document Saver

A hole will be needed for the test switch SW1; this should be mounted in such a way as to prevent the back of the switch coming into contact with the components on the PCB. On the prototype, this was achieved by pushing a short length of heat-shrink sleeving over the back of the switch once it was mounted with the leads attached to it, then using a hair-drier to get the heat shrink sleeving to actually shrink on to the switch, to cover the contacts completely. (A soldering iron can also be used to shrink the sleeving, but this tends to be quite tricky as touching the sleeving scorches it, so you have to place the bit right next to the sleeving without touching.) The connections for the mains should be made next, if the special case is used it will probably be better to remove the plug pins to solder the connecting wires to them.

The time has now come to try out the unit by connecting it to the mains. Close up the case and plug it in. The unit should start to bleep immediately, possibly falling silent after a ten to twenty seconds. If the unit doesn't bleep at all, there is something wrong so unplug it and try to discover what is wrong from the fault-finding chart.

If this test is OK, disconnect the unit and open the case. Now find some way of adjusting the potentiometer RV1 without risking an electric shock. If the potentiometer has a plastic case and a plastic adjustment point, then you can use any screwdriver with a plastic handle to adjust it. If, on the other hand, the adjustment tool is metal, it will be connected to the mains via the circuitry and you must use a screwdriver with an insulated shaft as well as an insulated body (a mains tester screwdriver would be suitable or you could improvise a suitable screwdriver by covering the shaft up to nearly the tip with heat-shrink sleeving). Alternatively, there are plastic trimming tools which you can buy for very modest cost.



PARTS LIST

RESISTORS (all 1/4W 5% or lower tolerance R1 and R2 must be of types which have a maximum working voltage of at least 250 volts AC)

R1,2	470k
R3	3k9
R4	33k
R5	15k
R6	10k
R7	4M7
R8	390k
R9	1M0
R10	39k
R11	1k0
R12	2k2
RV1	4k7 subminiature preset potentiometer, horizontal mounting

CAPACITORS (capacitors must be at least the minimum voltage stated; there is no harm in having a larger rated voltage but this usually increases size)

C1	100n 250 V AC (or 750 V DC)
C2	470µ/16V electrolytic
C3	47µ/16V electrolytic
C4	100n 16V
C5	2n2 16V

SEMICONDUCTORS

IC1	µA741
IC2	4093 (quad CMOS NAND gates with Schmitt trigger inputs)
D1,2	1N4001 (low-voltage rectifier diodes, 50 PIV)
D3	1N4005 (high-voltage rectifier diode, 600 PIV)
ZD1	BZX61C10 (10 V zener diode, 1·3 W max dissipation)

MISCELLANEOUS

FS1	80-100 mA fuse, 20mm length, and holder
SW1	Pusbutton switch, rated for 250 V AC, push to make
LS1	Piezo-electric sounder (without built-in oscillator)

Printed circuit board; case; wire; heat-shrink sleeving.

FOR 220 V OPERATION
R1 should be made 390k
all other values stay the same

FOR 110 V OPERATION
R1 should be made 270k
R2 should be made 150k
C1 should become 220n 110 V (min) AC or 500V DC
SW1 can be rated at 100 V AC
all other values stay the same

FAULT FINDING GUIDE

If a fault develops, look first for a simple mistake - it's surprising how often a very obvious error can be the problem. Check particularly for reversed diodes, capacitors, ICs, and any connecting leads wired wrongly. Check also for solder bridges or damaged tracks on the PCB.

Symptom: No bleeps when battery connected between A and common
Check voltage on IC1 pin 6; if this is high (ie nearly battery voltage) then there is a fault in IC2 or associated circuitry; if the problem is not due to wrongly positioned components, then IC2 is probably damaged and needs to be replaced. If IC1 pin 6 is low (nearly zero volts), check input voltages on pins 2 (which should be 0) and 3 (which should be 3-5 volts); if these are OK, the fault is in IC1 itself so replace.

Symptom: Bleeps do not stop when point B is connected to battery + terminal
Check voltage on IC1 pin 6; if low, then fault is in IC2; if high, check IC1 pin 2 voltage which should be equal to the battery voltage; if it is IC1 is faulty.

Symptom: Unit doesn't bleep when first connected to the mains
This is almost certainly due to a fault in the power supply. Open the unit and connect a multimeter switched to a 10 VDC (or slightly higher) voltage range between the + and - terminals of C2 (soldering extra pieces of wire to the underneath of the board if necessary. Then, with the unit well away from you and one hand behind your back, apply the mains to it. The meter should read between 8.5 and 10 volts. If not, disconnect the mains and check the fuse, the correct orientation of the diodes and the zener diode and the correct orientation of C2.

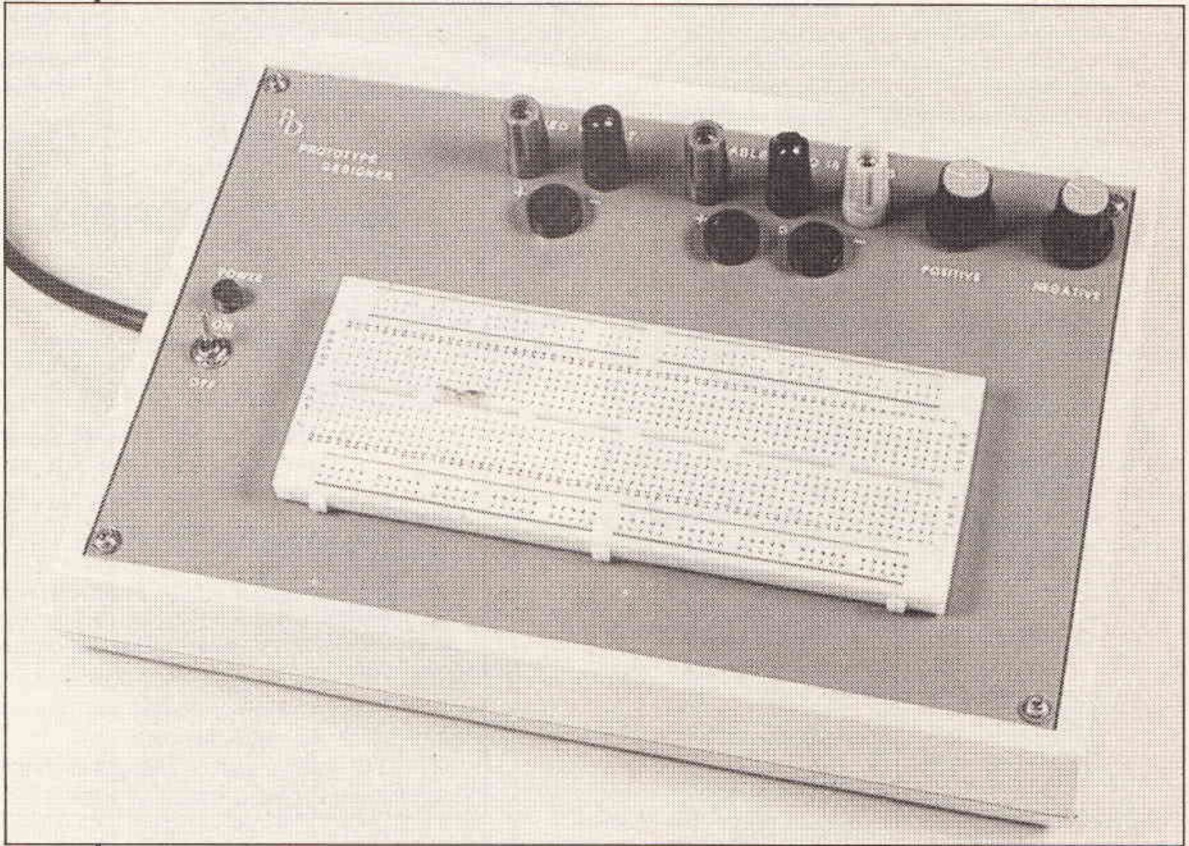
Symptom: Unit cannot be adjusted to stop bleeping
Attach multimeter leads between point B and common, soldering on small lengths of wire if necessary, switch multimeter to 10 VDC range and connect unit to the mains, with one hand behind back. The voltage should be 4.1 volts (3.7 volts with SW1 closed). If it is much less, check you are using the correct value components for the two potential dividers and that D3 is the correct way round. If voltage at B is OK, perform the same check for the voltage at IC1 pin 3, which should be adjusted by RV1 from about 3 to 4.5volts.

Symptom: Unit cannot be adjusted to start bleeping
As above, but this time the voltage at B will be too high. Disconnect immediately if over 16 volts. As above, look for a fault in the potential dividers.

Now for the bit that requires a great deal of care to avoid getting a shock. Find some way of connecting the unit to the mains whilst still open. If there is a separate mains plug, this is not a problem. If the plug is part of the case, use an extension lead and plug in the extension lead plug when required. Check that you can adjust the potentiometer using the screwdriver with just one hand, then put your other hand behind your back and keep it there (this is a precaution to stop an accidental shock being a serious shock). Using your one free hand, plug in the unit and then adjust the potentiometer until you find the point at which the bleeper begins to go all the time (if this isn't possible, disconnect the unit then go to the fault-finding table). Disconnect the unit from the mains, then find some way of keeping SW1 pushed in (you could use some masking tape, for example; you can use both hands for this bit!). Reconnect the unit (with your other hand behind your back) and now the bleeper should be on all the time; readjust RV1 so that the bleeper just stays on, ie adjusting it slightly clockwise will take the bleeper off. Disconnect the unit from the mains and re-close the case.

The unit is now set-up and ready to use. Plug it in where you will hear it should the alarm go off. Pushing in SW1 periodically will check simulates a 10% reduction in the mains voltage and will make the bleeper start making its noise if the unit is working correctly.

Prototype Designer



Bill Alexander builds a unit as a test bed for experimental circuits

PROJECT

A Prototype Designer is a must for all newcomers to electronics and practising design engineers. This simple piece of equipment will enable the designer to experiment and design different circuits with the aid of an easy plug in component board and three power supplies. The component board has approx 880 sockets which are on a 0.1in pitch set in rows that the components can be plugged into. This size of board was found to be large enough for the design of even quite large circuit modules. The power supplies consist of a +5 volt 500mA fixed, +5 volts to 15 volts at 500mA adjustable, and −5 volts to −15 volts at 500mA adjustable making it convenient for the use of op-amps and other components that require plus and minus supply rails. The power supply is not only simple but reliable and is enclosed in an attractive grey sloping case, which makes it easier to view the circuit as you are working.

The chosen supply voltages are taken to the plug board with the aid of single strain wires which are plugged into the appropriate sockets. Each supply has

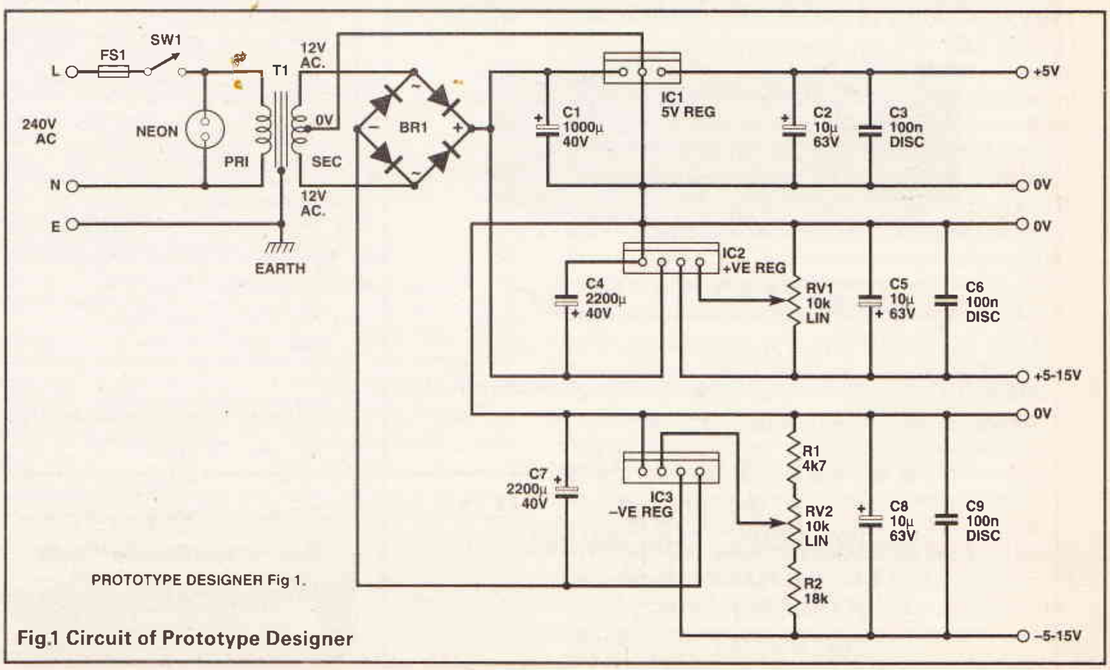


Fig.1 Circuit of Prototype Designer

short circuit protection along with output fuses appropriately rated at 500mA.

Construction

Once the front sloping panel has been drilled as in the photograph the panel components can be fixed in place. The mains switch shank is a good place to fit a large solder tag which will be in good contact with the front panel and switch housing. This is the point where the earth wire is to be secured. The mains neon indicator should be fitted above the power switch to observe the internal space requirements. Once the 4mm sockets and fuse holders have been bolted in place the connections can be made, these connections should be made so that the fuses are wired in line with the two plus rails and the negative rail. The two pots can have their shafts cut to the right length to take the knobs and can also be secured to the front panel. The plug board should be aligned carefully to the required position and then fixed in place with a good quality double sided tape.

The transformer should be positioned into the top left hand corner of the case to allow room for the circuit board. Once the correct position has been found the fixing holes can be drilled into the case and the transformer bolted into position. The mains input path. Once all the components are soldered to the PCB the interconnections to the pots, sockets and transformer can be made.

Testing

When the unit has been completed, check every connection and component orientation at least twice, then go have a cup of tea and return to the unit later. You may think this is strange but is derived from experience. You may have overlooked an error in the excitement of getting to the final test stage. Now check the whole unit again.

With the power switch in the off position, plug the unit in, then switch the power switch on and if all is OK the neon will come on and the DC voltage of the 5volt supply can be checked with a meter. If this is correct check the other supplies. However if the 5 volt supply is not present switch off, unplug, and recheck the unit. NOTE when dealing with mains operated equipment and switching on for the first time it would be wise to try the following. Place one hand behind your back, this is done so if you were to receive a mains electric shock the shock path can only run down one side of your body. If the shock runs from one hand to the other hand it would run across your heart and you could be in trouble.

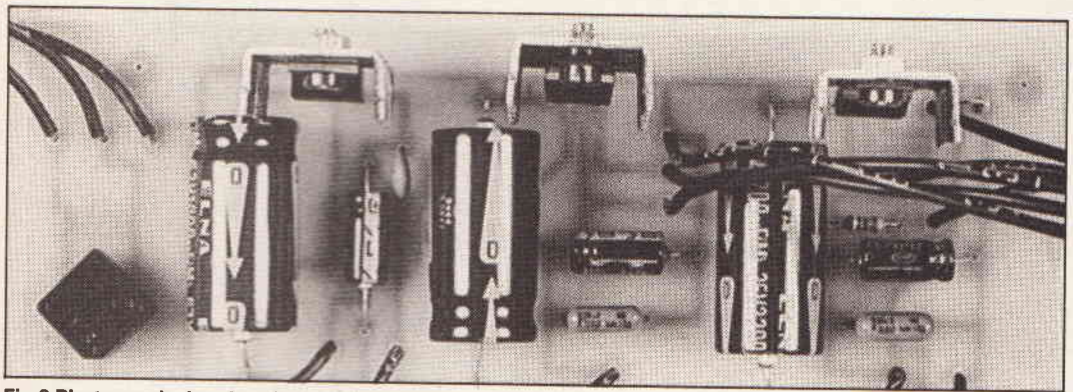


Fig.2 Photograph showing the position of the parts

fuse can then be fitted to the case. This is best done once the transformer is fitted as some transformers of the correct rating may vary insize, and this will avoid placing the fuse hole in the wrong position. If all this has been done correctly the circuit board will fit neatly into the case fixings

The transformer must be so configured as to take 240 volt AC in and 24 volts AC out with a centre tap (12-0-12). Extreme care must be taken to ensure that interconnections on the transformer are correct and if in doubt consult another engineer. Remember we are dealing with mains voltages.

An earth wire must be connected to one of the transformer bolting lugs and the front metal panel solder tag.

Once all the connections to and from the transformer are complete they should be covered up with a plastic shield, no access to these connections should be possible. It is important that the layout shown is followed to enable everything to fit properly inside the case.

The circuit board is nice and simple and no problem should develop as long as the correct orientation of the capacitors, regulators and rectifier are observed. You should start by soldering the smallest components in first and work upwards. The regulators should be soldered in place with their leads at their full extent to enable the heat sinks to be raised away from the PCB. The regulator ICs require a heat sink to dissipate heat which will be generated under short circuit and high load conditions. Thermal heat transfer paste should be used on all heat sinks to ensure a good thermal

PARTS LIST

RESISTORS

R1	4k7
R2	18k
RV1	10k lin

CAPACITORS

C1	1000µ/40v
C2,5,8	10µ/63v
C3,6,9	100n disc ceramic
C4,7	2200µ/40v

SEMICONDUCTORS

BR1	Diode Bridge 3A
IC1	7805CT
IC2	LM78GCP
IC3	LM79GCP

MISCELLANEOUS

TR1 Transformer 25VA 12-0-12v
FS1 Panel mount fuse holder
Breadboard, console style case, knobs, toggle switch, mains neon, red, black and yellow terminals

BUYLINES

A complete kit of parts or ready built and tested is available from the author. The price built and tested is £85+£4.50p&p. Schools and Colleges £78+£4.50p&p. Send remittance to 26 Levishaw Close, Buxton, Norwich NR10 5HQ.

The Magnetron

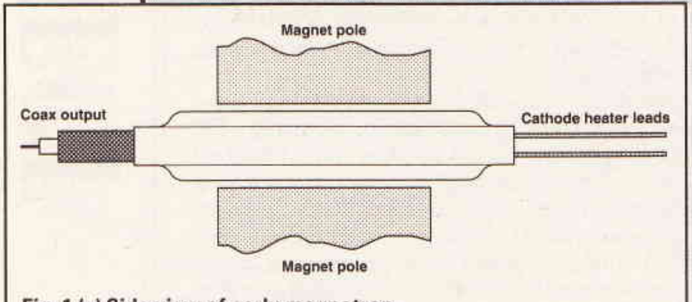
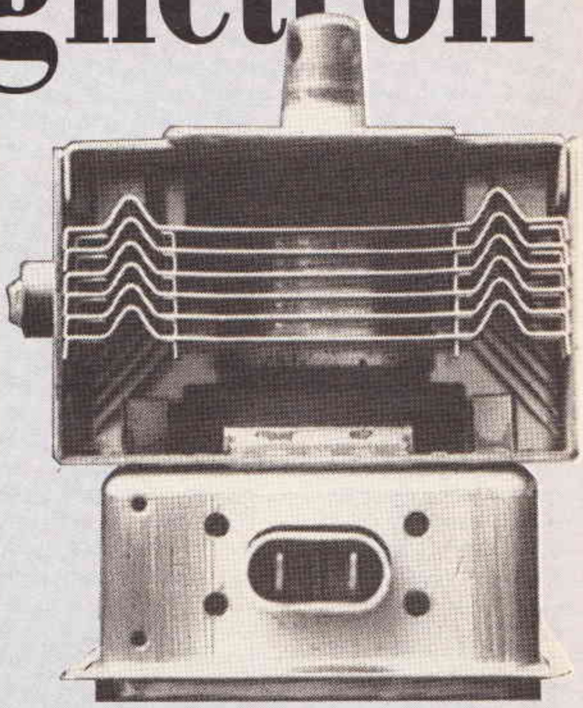
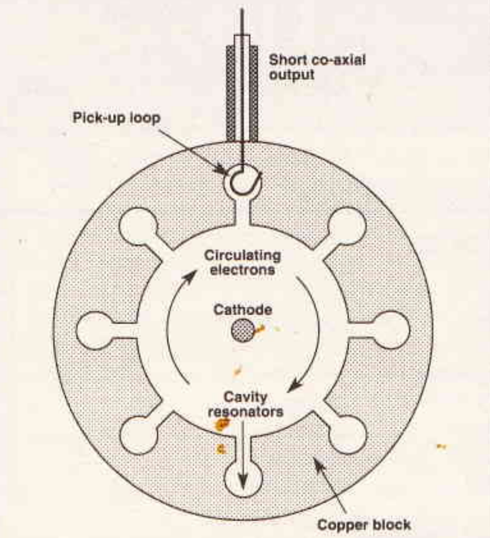


Fig. 1 (a) Side view of early magnetron.



The resonant cavity magnetron has been widely used for many years. A P Stephenson looks into the operation of this very successful device.

Although the Spitfire and the Hurricane were the dominant factors in winning the Battle of Britain during World War II, it should not be forgotten that without the help of our superior radar techniques the outcome might have been quite different. That superiority was due in no small measure to the introduction in late 1939 of a strange looking object consisting of a block of copper with two glass tubes sticking out of it. It was the brain child of two scientists, Dr Randall and Dr Boot. The gadget, which revolutionised radar, was the Resonant Cavity Magnetron — 'magnetron' for short.



(b) Cross-sectional view.

The Chiefs of Staff at the time were concerned that the secret of its design might fall into enemy hands so they decided that aircraft using the new radar must be equipped with an incendiary system to destroy the magnetron should the aircraft crash in enemy territory.

It is sad in a way that the magnetron, which once enjoyed such a privileged position, should now find itself relegated to the ignominious task of agitating the molecules of junk food in microwave cookers.

Although radar systems were in operation many years before the magnetron arrived (first experiments began in 1922), they were crude and bulky and could only operate at relatively low frequencies in the order of a few hundred MHz. At such frequencies the resulting wide radar beam, even with the largest possible practical scanning mirror, could not achieve the accuracy demanded for good target discrimination. The available technology at the time was capable of generating frequencies in the GHz region but only of relatively low power. What was needed was a reliable, non-bulky device which was easy to manufacture but capable of generating powerful bursts of microwave energy.

The magnetron provided all these features. It was small. It was rugged. It was disarmingly simple and easy to manufacture. It could generate peak powers in excess of 20 kilowatts at wavelengths as low as 3cm (10GHz frequency). In short, it answered the prayers of the British Military Establishment and put a smile on the face of Sir Hugh Dowding and 'Bomber' Harris.

The Lure Of The Black-Box

There is an increasing tendency for lecturers and technical writers, when faced with some difficult theoretical concept, to fall back on the 'black box' treatment. The intestines of any component or sub-system which cannot be taken apart is now considered fair game for the 'you don't need to know this' excuse. Admittedly, in some fields such as the internal design of complex logic chips, it may be justifiable for even the most conscientious lecturer to clutch at the black-box straw. The trouble starts if this tendency is allowed to get out of hand and in which case there is a danger of reaching a position when even the humble discrete transistor is considered too complex for the average technician to grasp above black box level.

In the case of the magnetron, there is no reason whatever why the internal operation should remain a mystery just because it can't be repaired. A thyristor or transistor cannot be repaired but, mercifully, the theory behind their design is still taught! The magnetron is an extremely straightforward device, understandable with the minimum of mathematics and is an excellent guinea pig for a refresher course in basic electro-magnetic principles.

Construction

Figure 1a shows the general appearence while Figure 1b shows a cut-away cross-sectional view of a typical magnetron in the early years which, from the DC point

SHF

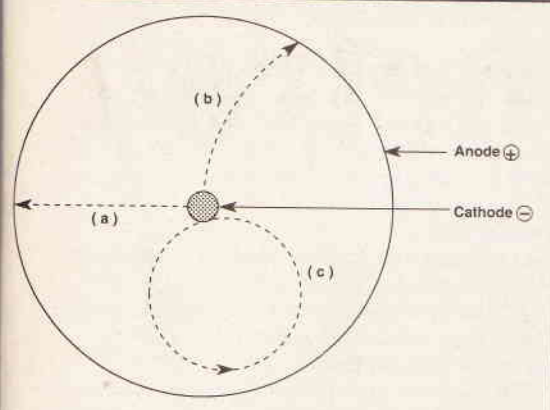


Fig. 2 Electron paths under influence of magnetic field.

of view, behaves as a simple diode. The copper block itself is the anode and the heated cathode sits in the centre busily sending out a copious supply of electrons. The flux lines from a powerful magnet are directed downwards through the block. The queer shaped holes near the outside edge of the block, called 'cavity resonators', are the places where high power centimetric oscillations are produced. The copper block must be held several kilovolts positive to the cathode but it is more convenient – and less hazardous for humans – if the block is grounded and the cathode is held several kilovolts negative with respect to ground. The design of the heated cathode was not easy! It was required to emit amps rather than milliamps of current and had to be insulated to withstand a potential difference of many kV between itself and the copper block.

Outline operation

When first switched on, the cavities, which behave as high Q tuned circuits, are shock excited into oscillation but without some additional help, such oscillations would rapidly die away. This help is provided by the shower of electrons which, under the influence of the permanent magnet, circulate in curved paths, almost in free orbit. Under certain conditions, some of the electrons' kinetic energy is transfered to the cavities, thereby sustaining oscillations.

The Cavity Resonators

A coil of wire with a capacitance across it is quite satisfactory at 'normal' frequencies because it would posses a reasonable circuit amplification – the Q factor. The ability of a tuned circuit to oscillate depends on the magnitude of Q. The higher the Q factor, the easier it is to sustain oscillations. There are several equations for Q factor but the following is particularly relevant:

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

indicating that a low value of R and a high value for the inductance (L) is required. The resistance of a coil depends on the number of turns but the inductance depends on the square of the turns so when reducing inductance in order to increase frequency, the Q factor is reduced at a greater rate than the resistance is reduced. This means that in conventional tuned circuits the Q factor tends to deteriorate with frequency. Other factors which cause trouble at very high frequencies are losses due to direct radiation and coil skin resistance.

A tuned circuit doesn't have to be a coil of wire and a separate capacitor. The inside surface of a hole in a block of copper can have inductance – not much, it is agreed but, to operate at several GHz, not much is required! The hole is constricted at the mouth to form 'lips', as shown in Figure 1b, in order to maximise the electric field strength, thus forming the 'capacitance' of the tuned circuit.

The Q factor of a cavity resonator can be very high because the resistance of the copper walls are very low and there is no radiation loss if the cavity is closed at both ends.

Details Of The Electron Orbits

Under the influence of a positive anode voltage (V) an electron would normally accelerate in a straight line path from cathode to anode as shown in Figure 2a. However, if a weak magnetic field is applied at right angles, the electron would be deflected as shown in Figure 2b. The magnetic flux density and the anode voltage causes the electron to rotate in a closed orbital path as shown in Figure 2c. The mathematics for establishing the correct relationship is not difficult.

An electron of mass (m) and charge (q) moving with velocity (u), entering a magnetic field at right angles to its direction of motion, is deflected by a force proportional to the magnetic flux density B: Deflection

$$\text{Force} = Bqu \text{ Newtons}$$

To maintain an orbital path, this deflection force must be balanced by a centripetal force acting towards the centre of orbital radius (r):

$$\text{Centripetal force} = mu^2/r \text{ Newtons}$$

By equating the two forces, we obtain the necessary condition:

$$Bqu = mu^2/r$$

or

$$Bq = mu/r$$

The electron velocity (u) is the only awkward term. However, we know that an electron at the cathode has potential energy and that, under the accelerating force of the anode potential (V), this energy is converted into kinetic form, reaching its highest value just prior to impact at the anode.

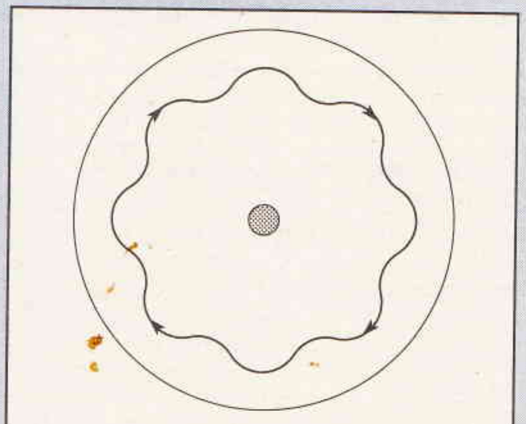


Fig. 3 Equivalent outer orbit.

By the conservation of energy law:

$$\text{Potential energy} = \text{kinetic energy}$$

$$\text{or } qV = mu^2/2$$

and by re-arranging, we obtain:

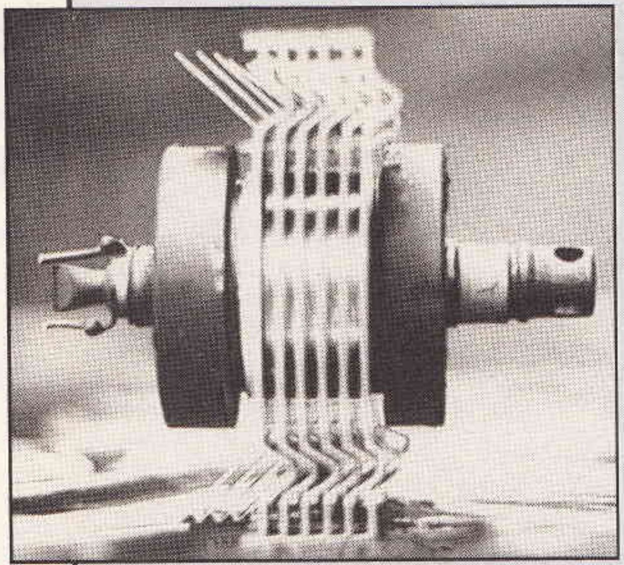
$$u = \sqrt{2qV/m}$$

Substituting this expression for u in equation 1 and simplifying gives:

$$B = \frac{\sqrt{2Vm/q}}{r}$$

It is more convenient to use R, the full radius between the cathode and the anode rather than r. Since r = R/2, the above equation can be rearranged into the form:

$$B = \frac{\sqrt{8Vm/q}}{R}$$



The electron mass (m) is a standard physical constant equal to approximately 9.1×10^{-31} kg.

The charge (q) is also a standard physical constant equal to 1.6×10^{-19} coulomb.

Substituting these values in the above equation and evaluating yields a final simple formula which relates the value of flux density to anode voltage necessary for maintaining orbital conditions:

$$B = 6.75 \times 10^{-6}\sqrt{\frac{V}{R}} \ldots \text{Eqn 2}$$

Example 1: A 1cm magnetron, operating with an anode voltage of 10kV requires a magnetic flux density of about 0.07 Tesla.

Example 2: A 2cm magnetron operating at 5kV requires a flux density of 0.024 Tesla.

It is important to note from Equation 2 that the required flux density of the magnet depends only on the square root of the anode voltage.

This means the orbital conditions are not too critical of variations in anode voltage, a property which is fortunate from the designer's viewpoint.

Sustaining Oscillations In The Cavities

We now have to explain the mechanism behind sustained microwave oscillation within the cavities.

The single equivalent orbit

The above treatment showed that, under certain conditions, an electron could be forced into a free orbital path whose radius was midway between the cathode and the inner wall of the anode block. So ideally, we can visualise millions of these electrons each buzzing around endlessly in their own separate orbits. To explain the operation of the magnetron, it is convenient to ignore the individual electron orbits and consider their integrated effect close to the anode wall. Since all the electrons are rotating in the same direction the overall effect is equivalent to a single large orbit having the cathode as centre. (See Figure 3).

If we ignore the presence of the cavities, the anode current would be zero because no electrons would ever hit the anode wall. The device would be operating under current cut-off conditions!

Velocity modulation

When the magnetron is first switched on, the cavities are shock-excited into oscillation at their natural frequency. In the absence of some driving force, such oscillations would eventually die away at a rate inversely proportional to the resonant Q factor of the cavities.

The mechanism for sustaining these oscillations is known as 'velocity modulation'. The orbiting electrons, as they pass across the lips of a cavity, can have their velocity altered by the extra kick they receive from the oscillating electric field — hence the term velocity modulation. Whether this extra kick is beneficial for the purpose of sustaining oscillations depends entirely on the phase relationship at the instant the electron crosses the cavity lip. There are three possibilities:

(i) The electron is speeded up, in which case, oscillatory energy is robbed from the cavity and transfered to the electron. Such an electron is a bad electron!

(ii) The electron is slowed down, in which case the kinetic energy of the electron is transfered to the cavity. Such an electron is a good electron!

(iii) The electron is unaffected because it encounters a zero point in the oscillatory cycle. An electron in this case is neither good or bad — just a non paying passenger!

The statistical advantage

The above description of velocity modulation may lead to the conclusion that just as many electrons would be bad as good so the overall advantage to the cavities would be zero. However, when the effect of the change in electron velocities is taken into consideration, it will be seen from Figure 5 and the following that there is indeed an overall advantage:

(i) An electron which is speeded up suffers a greater deflection force from the magnet and so tends to spiral inwards towards the cathode where it can do no damage.

(ii) An electron which is slowed down is less effected by the magnet and so is still maintained in orbit, although of slightly larger radius. This means it has a second (or even a third or more chance) of doing good at the next cavity. There is thus a statistical probability that the good electrons have the advantage as far as sustaining oscillations is concerned.

How The Cavities Are Coupled

The microwave output is normally taken (via a ring probe into a short stub of coax) from one of the cavities and on into a waveguide. This cavity is not different in any way from the others, apart from the fact that its uniquness has been chosen by the whim of the designer. To ensure all other cavities contribute to the final output, the lid of the magnetron (which is necessary to preserve the internal vacuum) is raised slightly above the top of the cavity block so as to leave a 'reaction space' which allows the electric and magnetic lines from each oscillating cavity to link with its neighbour on either side. Electrically, this means that all cavities are coupled in parallel, a condition which may help to explain why it was sufficient to take the output from any one of them.

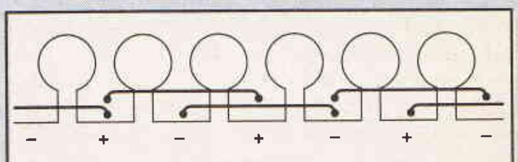


Fig. 4 Rolled out view showing pi-made straps.

Establishing Correct Phasing Between Cavities

It is important to realise that each cavity is an entirely independant oscillator in its own right. To prevent the resulting chaos, some additional persuasion is essential in order to maintain some form of phase discipline. There are recognised ways of imposing such a discipline, such as:

Pi mode strapping

Thin copper conductors are welded into the block as shown in Figure 4. Note that they strap altern-

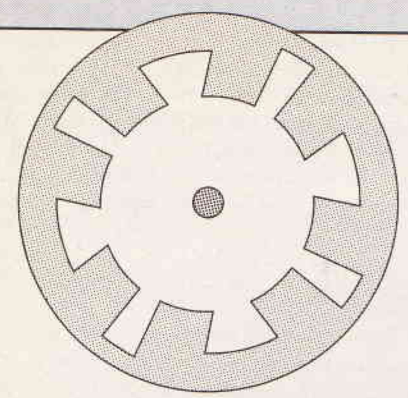


Fig. 5 Rising sun cavities.

ate cavities together. At first sight, their presence would seem to border on the ridiculous — why add copper wires in parallel with a large block of copper? However, it must be realised that at microwave frequencies, a thin wire can have appreciable inductive reactance — much higher than the copper block. (For those who still remember their basic theory, the inductance of a wire is dependant on its length but inversely proportional to its diameter).

Now, if adjacent cavities can be persuaded to oscillate with a phase different of 180° it follows that alternate cavities must be in phase and must always be at the same instantaneous potential. Since each strap connects alternate cavities, each end will be at the same potential so inductive currents cannot flow through it!

If the phasing is not correct, inductive currents would flow down the straps and dissipate energy which would tend to damp out the cavity oscillations. This means that oscillations will only be sustained if the magnetron behaves itself by maintaining 180° phase difference between adjacent cavities.

It seems to be a law of physics that potential oscillatory systems have an inbuilt urge to oscillate — rather similar to the reproductive urge in biological species. If a loophole exists for allowing this, the system will find it. A strapped magnetron has this one loophole and is said to operate in the 'Pi Mode' — presumably because Pi radians is 180°.

Rising sun magnetrons

Shaping the cavities, as shown in Figure 5, is an alternative to pi-mode strapping. Long narrow cavities, alternating with short fat ones which, for some reason never fully understood by the writer, ensures, pi-mode operation. We are reliably informed that this useful property is inherent in the geometry and, because such geometry faintly resembles the Japanese flag, it has achieved the faintly glamorous title of a 'Rising Sun' magnetron.

Operating Conditions

A magnetron, although physically small, operates in the kilowatt region — even the first specimens operated at a peak power of 20kW with a DC/AC conversion efficiency in excess of 50%. It should be self evident that continuous operation at that kind of power level would quickly turn the magnetron into a molten mass. Fortunately, radar makes comparatively modest demands on average power because, by its very nature, it is pulse operated. The transmitter (the magnetron) is switched on for microseconds and then off again for milliseconds while it waits for an 'echo' to return. Thus the average power is only a small fraction of the peak power. (See Figure 6).

The terms used in the operating cycle are as follows:

(a) Pulse recurrence frequency (PRF) is the number of times the magnetron is switched on per second.

(b) Pulse width (PW) is the time the magnetron is on during a cycle.

(c) The duty cycle is the product of PRF and pulse width, representing the proportion of total time in one cycle that the magnetron is operating.

(d) Average power = Peak power × duty cycle.

Example: Assume a magnetron with a peak power of 20kW operates with a pulse width of 10µs and a PRF of 1000 pulses per second. Duty cycle = $10^3 \times 10^{-2} = 1/100$. Average power = Peak power × duty cycle = 20 kilowatts × 1/100 = 200 watts. It should be

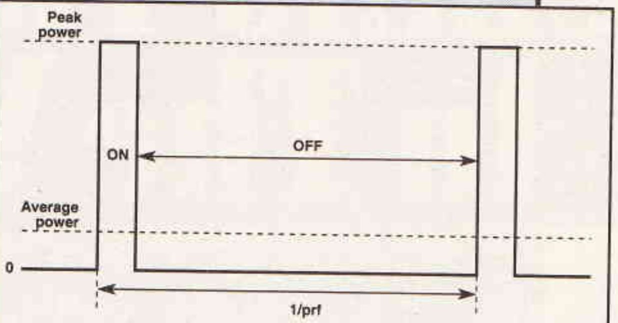


Fig. 6 Pulse modulated magnetron (not to scale).

note that magnetrons used in fields other than radar must still use the pulsed operating system to control power. It is clear from the earlier discussion on electron orbiting conditions, that any attempt to control power by reducing the magnetron voltage is doomed to failure. Once a permanent magnet of a particular flux density is installed, there is only one narrow band of magnetron voltage which will sustain oscillations. In the microwave cooker, the average power is still controlled by varying the on/off time of the magnetron.

Behind The Hole In The Wall

Paul Shlackman from NCR reveals some of the operations behind a modern cash dispenser.

Nowadays, we take easy access to money for granted. Whenever we are in need of some ready cash, we simply pop down to the nearest 'hole-in-the-wall' machine and draw out a wad of crisp new notes.

This has become such a part of everyday life for millions of people that we never give it a second thought. Yet if you stop for a moment to consider the size of the task involved, it becomes clear that the achievement is an astonishing one.

At any time of the day or night, and from almost any town or city in the UK — not to mention airports, service stations and out-of-town shopping malls - you can have instant access to *the money* in your personal banking and savings accounts. You can deposit money, check your account balance or conduct any number of other special transactions.

Every transaction is conducted with speed, yet with security and integrity guaranteed. Even though a machine may perform hundreds of transactions in any one day, each one is conducted quickly, neatly and correctly.

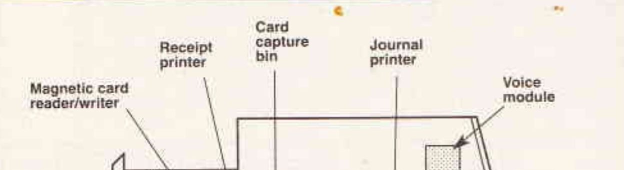


Fig.1 Layout of basic automated teller machine (ATM)

From the customers point of view, withdrawing money is a simple and convenient process. But making it easy for the customer is a complex task indeed. Behind the wall is a massive array of electronic, mechanical and computer wizardry, all playing a vital role in the making of the modern automated teller machine (ATM).

The first ATM was introduced in America in 1969. At first, customers were a little hesitant about the new technology, unwilling to be convinced that a machine could be trusted to handle their finances. However, as the advantages they offered became clear, and people realised that they were very secure, enthusiasm grew rapidly, so that by the end of the 1980s there are around 400,000 machines installed world-wide.

Today there are a number of different types of ATM machines in use throughout the UK, supplied by various manufacturers. One of the most important of these is NCR, which supplies machines to all the 'Big Five' UK banks, as well as many other banks and building societies. In this article, we will examine an NCR machine as a typical example of the technology employed in the construction and operation of the modern ATM.

The success of these devices depends upon the efficient interaction of various engineering technologies. This interaction is an activity that has become known as 'mechatronics'.

Let's consider what happens from the moment when the customer arrives at the machine. We are all familiar with the CRT (cathode ray tube) display which invites us to insert our magnetically-coded card. But what happens after the card is swallowed by the machine remains a mystery to most people.

The card is actually drawn into a special reader/writer unit, which reads the user' card number and the encryption of his personal identification number (PIN). The next stage is to ask the customer to enter the PIN via the keyboard.

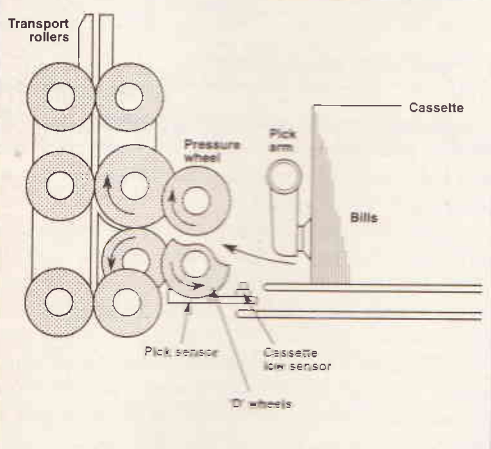


Fig.3 Pick module transport section-pick mode

What happens then depends on whether the machine is on-line to the bank branch where the customer's account is held. If it is, further checks can be made. The host computer will check that the PIN entered is correct. Once the customer has requested the sum required, the host computer will check that sufficient funds are available in the account.

If the ATM is not on line to the bank, or for some reason fails to communicate, local checks are made. The number entered is checked against the information on the card, and a nominal limit is placed on the sum that the customer can withdraw.

The next stage of the operation is the selection and delivery of the money requested. Bank notes, or bills, are held in special cassettes, each capable of holding up to 3000 notes. Each cassette is able to accommodate any currency in use in the world today, with the size of the cassette being adjusted to suit the notes to be dispensed.

The notes are picked from the cassette by a special vacuum device. This extracts them one by one from the front of the cassette. They are then carried via a series of wheels and belts to the presenter module which actually dispenses the money. Another device stacks the notes as they arrive in the presenter module, and pushes them through a security shutter to the customer.

In theory, this sounds reasonably straight forward. But in practice, the need for absolute security and integrity in every transaction necessitates some very sophisticated techniques and controls. In this area, interaction between the electronics, mechanics and software elements of the system become absolutely crucial to successful operation. And as ATMs become more sophisticated, electronics technology plays an increasingly important role. Currently, for example, the vacuum pick-up mechanism which extracts the notes from the cassette is driven by mechanically operated pumps. These are operated via a chain of gear wheels at the appropriate point in each cycle.

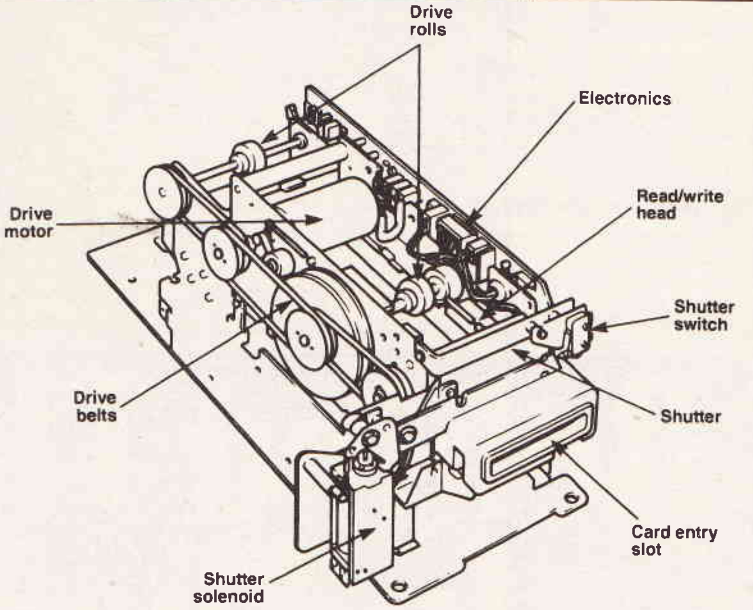


Fig.2 Reader/Writer unit

Future mechanisms will be able to implement a system that uses electronically controlled valves (not the devices before transistors came along). A single vacuum source can be piped to each pick module, with the electronic valves controlling the timing.

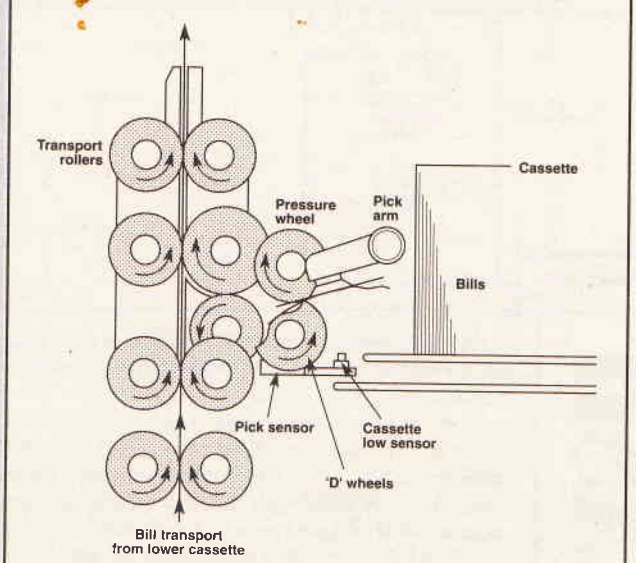


Fig.4 Pick module-transport mode

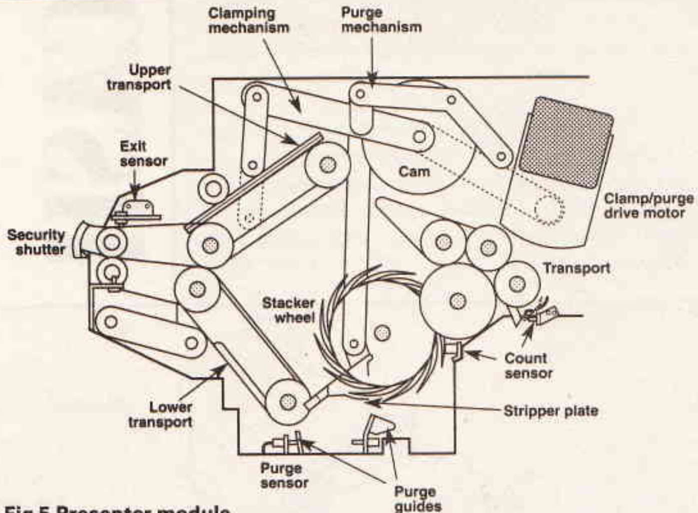


Fig.5 Presenter module

The use of electronics allows much greater control to be achieved. The use of solid state relays in place of mechanical alternatives will offer better reliability and more accurate control. In addition, low voltages and the absence of arcing make them electrically quiet.

One of the most important tasks of the ATM is ensuring that exactly the right amount of money is delivered. Naturally, if even one note is accidentally omitted, the customer is going to become very irate indeed. Conversely, the bank cannot afford to have more than the required amount of money dispensed.

For this reason, very tight controls are used to ensure that the right number and denomination of notes are delivered. One of the most important operations in this respect is the detection of double or folded notes.

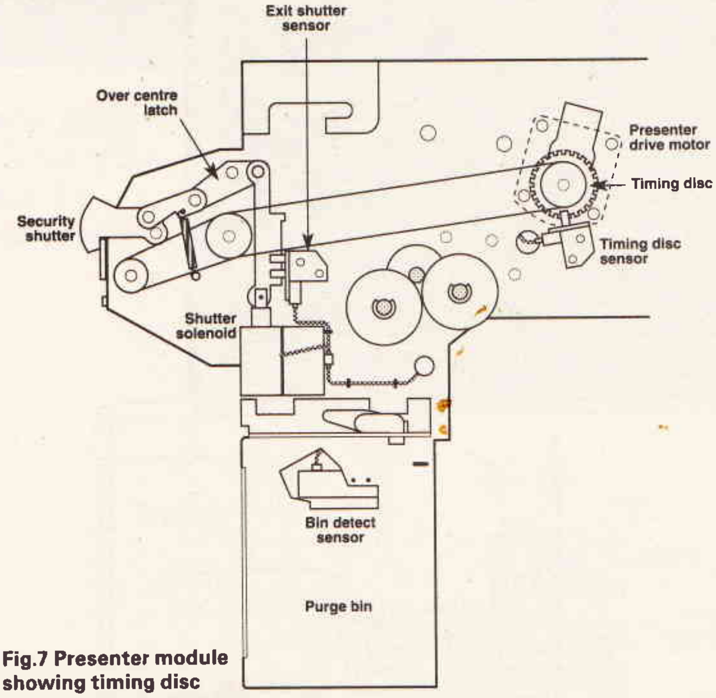


Fig.7 Presenter module showing timing disc

ATMs use an optical technique to identify times when two or more notes have been picked up by mistake, or when a note has become folded in the mechanism. A bright light is shone through the note onto a special detector behind. Double or folded bills can then be detected by a reduction in the light intensity that reaches the detector.

An improvement in differentiating between double pick or a folded note is provided by passing the notes through a pair of rollers. One of these is fixed, while the other is capable of radial movement. This second roller is designed so that its circumference equals the length of the note.

A linear variable differential transformer (LDVT) is used to calculate the small increase in the distance between the rollers as the note passes between them. A larger than expected increase indicates that one or more notes have been picked, or that the note is folded.

At the same time, the length of the bill is calculated by measuring how far the second roller turns. If this is shorter than expected, then the note has clearly become folded during the pick up.

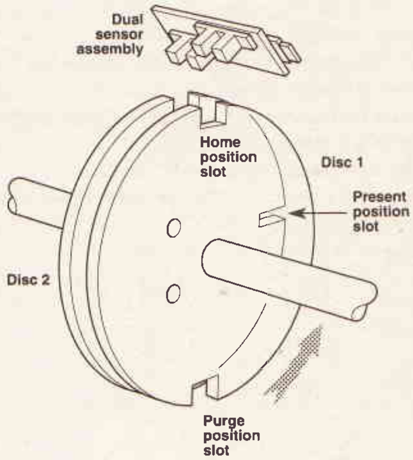
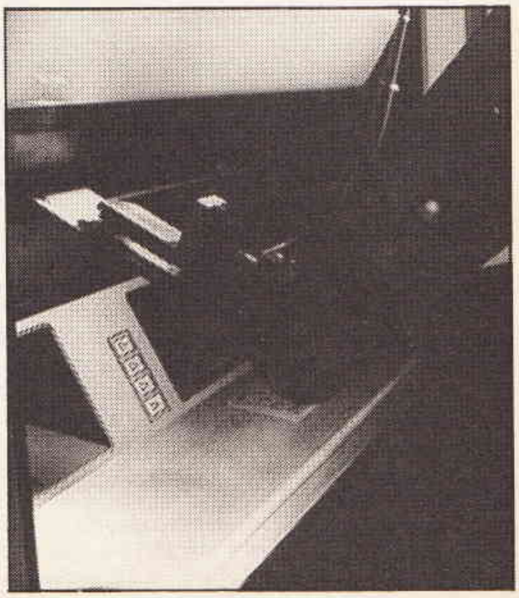


Fig.6 Optical position sensor

Other developments include advances in the switching sensors used to sense the presence of cards and bank notes, and to detect the position of moving parts within the machine.

Infrared position sensors are arranged as a transmitter/receiver pair, together with opaque elements which interrupt the infrared beam. As well as being more reliable than micro-switches, these offer more accurate timing and do not require any adjustment.

These have proved useful for a number of applications. For example, infrared sensors are used in conjunction with rotating discs which have a series of holes around their edge. The disc interrupts the beam as it rotates, except at those points where the beam passes through the holes.



The result is a signal that is exactly proportional to the speed of rotation of the disc and, therefore, the shaft on which the disc is mounted. Being digital in nature, these signals are ideal for interfacing to the digital processor controlling the ATM, frequently being used as an interrupt command.

A number of other sensors are also used in ATMs. These include semiconductor optical coupling elements, which can be used to preserve total electrical isolation while transferring digital signals from one circuit to another.

Digital electronics have also had a major impact on the motors that drive the mechanical parts of the machine. Conventional electric motors proved less than ideal as they were noisy and difficult to control. They required regular servicing and maintenance, and introduced high voltages into the ATM itself.

Consequently, these have been superseded by stepping motors which are much quieter, more dependable and do not require gearboxes or clutches. Because they are digital in nature, they are ideally suited for use as output transducers for the digital processor which controls the ATM.

In the twenty two years since the first ATM appeared, technology has advanced considerably. Thanks to the improvements that these advances have made possible, today's machines are much more sophisticated than their counterparts of two decades ago.

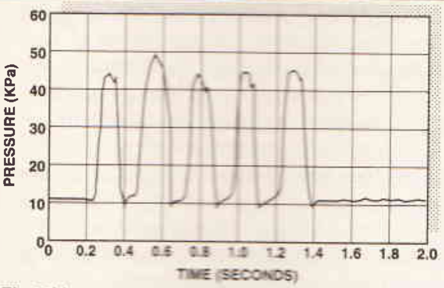


Fig.8 Vacuum waveform-local mechanically operated pump

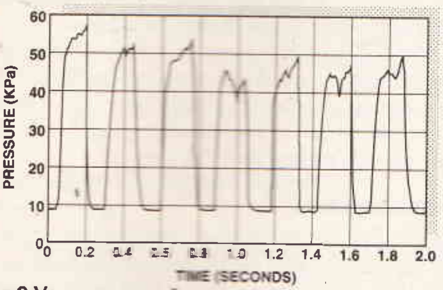


Fig.9 Vacuum waveform-central pump with local electrically operated control valve

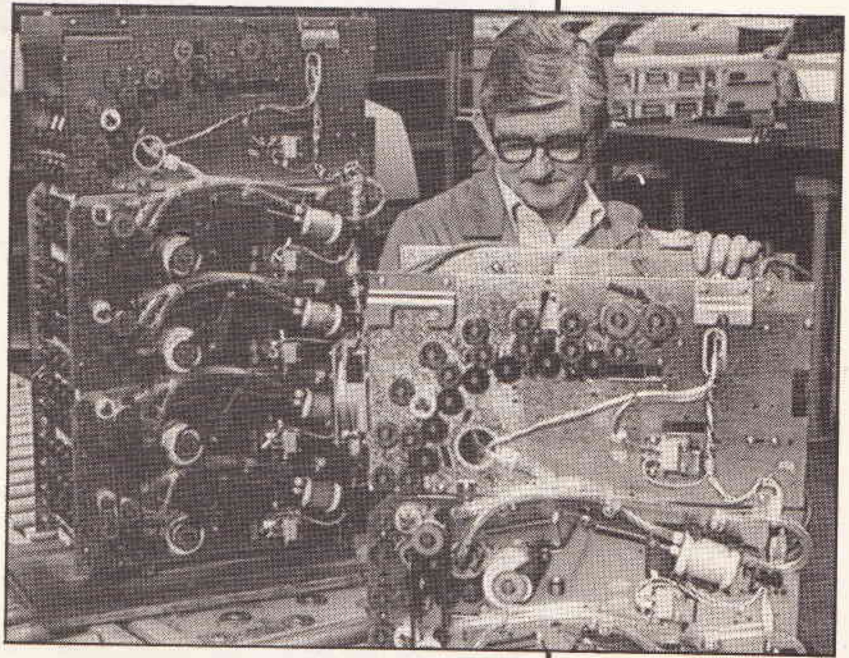
Whereas early machines dispensed only cash, usually in pre-filled envelopes, today's ATMs can handle everything from bill payments to cheque cashing to passbook updates and ticket issuing. Many machines can now issue coins as well as notes.

Performance has improved greatly, too. The percentage of time that machines are available for use has moved forward from 88 per cent to over 99.5 per cent. Greater reliability has been achieved, with the number of service calls falling from an average of 35 a year to five or fewer.

The number of transactions between replenishments has grown substantially too, rising from several hundred to about 5000. At the same time, the time required for a typical withdrawal has fallen from 30 seconds to just 12 seconds.

These are substantial improvements that have helped to make the modern ATM such an integral part of our everyday lives. But of course, technology does not stand still. Already we are seeing the next generation of ATMs emerging, bringing a much greater convergence between electronics and computing technologies.

NCR, for example, is now producing self-service devices based on PC architecture to increase flexibility and to make the most of the very sophisticated PC technology that is now available. As a result, we are now beginning to see devices that offer full- colour graphics with touch-screen and animation, together with digital sound.



Dual processor configurations speed up processing and support extra functions such as networking and communications. Other new features include increased security to control fraudulent use of cards.

Thanks to these developments, ATMs will soon be playing an even more important role in our lives. As the interface becomes easier and more attractive to use, and the range of facilities offered continues to increase, we will begin to wonder how we ever managed before the ATM came along.

We have already reached the stage where many people never go through the doors of the bank that holds their account. Thanks to the ATM, we are now entering a new era of convenience in the management of personal finances.

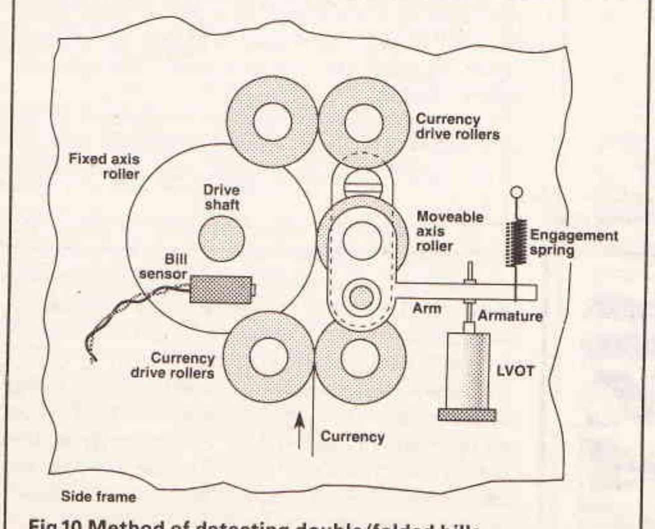


Fig.10 Method of detecting double/folded bills

4

Fire Detection Systems

Testing and Maintenance

Vivian Capel presents the final part in his series.

Having installed the system, the final step is to test it, and for a large installation this can be rather tedious. However, it is essential to do so and not to cut corners.

Most detectors are easily removed from their wired bases, so they can be taken down without disconnecting the wiring. All should be removed and the circuit of each zone should be meggered for leaks. Any leak should be investigated and cleared before the next step. A high resistance leak, though having little effect if any, on the operation of the system could shunt monitoring currents and thereby allow future faults to pass without indication. Also leaks themselves are a sign of a fault condition that could get worse.

Next, after replacing all the detectors, the standby battery is connected, but the mains is not switched on. There should be a fault indication on the panel showing that there is no mains supply. The mains are now connected, and the output of the panel switched from the bells to the test buzzer.

Now comes the tedious part — testing every detector. Most will probably be smoke detectors and these can be checked by holding a piece of smouldering cord near the device and blowing the smoke gently into the vents. Chemically generated 'smoke' from aerosols is not recommended as it can be corrosive, and can also leave deposits inside the smoke chamber. Smouldering cord gives the minimum of undesirable side effects and is also kind to the decor.

The test buzzer should sound for each one, and the system must be re-set for the next. For a large installation it needs a two-man team with radio communicators, one testing the detectors, and the other reporting at the control panel and re-setting.

For heat detectors, a portable hair dryer is the most practical method for testing. Not all dryers get to the 135°F at which heat sensors trigger, so the dryer should be tested with a thermometer. This may take several minutes.

Any heater merely raises the temperature of the surrounding air, so a hair dryer that attained the temperature in mild or warm weather, may not do so when it is cold.

In the case of a rate-of-rise heat detector, the rapid increase in temperature when a hair dryer is directed into it should produce a quick result, well before the 135° stage is reached. This incidentally demonstrates the faster response of this type of detector compared to the fixed heat sensor.

Manual call points can be tested by breaking the glass — but it is not the recommended method! Some can be opened from the front thereby releasing the pressure on the button, while others have a special key which moves the glass relative to the button. Spare glasses are available from the makers if one is broken.

When all the call points and detectors have been tested, the final detector in each chain should be removed again. A fault indication should appear on the panel for that zone, showing that the monitoring system is working properly.

Finally, the bell should be switched in place of the test buzzer, and a manual call point actuated. A check should be made to determine that all bells are sounding. If a sound level meter is available, (professional installers should certainly be so equipped), readings should be taken at the furthest points from the bells to ensure that the minimum 65 dB is produced, or 75 dB at the bedheads of residential establishments.

If all is in order, the resistor across the final bell should be disconnected so producing a fault indication on the panel. Reconnection of the resistor ends the installation test. A record book should be kept for all except small domestic systems. This contains details of test results such as sound levels, zoning, and records each maintenance and what was checked. Any activation of the system by a fire, by accident, or by a false alarm of unknown cause should be entered.

Any cases of the latter should be thoroughly investigated to try to find the cause, but unlike intruder alarms fire systems rarely suffer from false alarms. Most of the common causes of such with intruder alarms are not present with fire systems.

Maintenance

Faults can occur in any system, either due to component failure of external conditions such as damage to wiring. With a fire alarm system, such faults must be identified quickly and repaired as soon as possible. To this end, a routine of regular checks and maintenance is suggested by the BS 5839 and should be followed. Detectors should never be painted as this could modify their thermal characteristics.

Daily Someone should be appointed to check the control panel at the start of each day and preferably at the end of the day too. All that is required is to make a visual examination of the fault indicators. If any show a fault, a record should be made in the record book and the matter immediately reported to the management. If the fault has not been cleared by the next working day, a further record should be made, until rectified.

Weekly Each week one detector or call point should be actuated as described in the installation test and the result and the identity of the device should be recorded in the book with the date. A different detector should be chosen each week, so that in time all are tested. The bells should be sounded briefly to ascertain whether all are operating. Any fault should be reported immediately. The standby battery terminals should be checked for corrosion and cleaned if necessary.

Quarterly The mains should be disconnected or switched off, and the current tests for that week and the others here stipulated should be made using the standby battery. Its voltage should be checked when all

ALARMS

the sounders are operating, and recorded. Check that the 'no mains' indicator is signalling. Faults should be simulated by removing the last detector in each zone to check the detector circuit monitoring. Likewise disconnect the bell terminating resistor to ensure that the bell circuit monitor is functioning, then re-connect.

Performing these tests using the standby battery not only tests it, but keeps it healthy. All batteries, like humans, need at least occasional use; prolonged inactivity accelerates deterioration.

BS 5839 suggests that a certificate be issued for each quarterly test.

Annually In addition to the current quarterly test, every smoke detector should be cleaned and tested. A visual examination of all fittings and accessible wiring should also be made.

Cleaning Ionizing Smoke Detectors

Although the amount of radioactivity generated by these is small, care should be taken to avoid unnecessary exposure. The following is recommended.

Three brushes should be used, a stiff one and two soft nylon brushes. One of the soft ones should be designated the 'wet' one and kept for applying methylated spirit, and the other one should be kept dry.

First clean the casing and the anti-insect mesh with the stiff brush. Any grease will need to be removed with spirit and the wet brush.

Next, dismantle the device and clean the inside of the chamber first with the wet brush thereafter removing deposits with the dry one. When cleaning around the radioactive element, hold the brushes at their ends so that the fingers do not get closer than 2 inches (50 mm) to the element. Do not let the eyes approach to less than 6 inches (150 mm) to it. Avoid inhaling any vapour from spirit contaminated by the cleaning operation. Use the minimum of spirit, and throw away any left over into which the brush has been dipped. Clean the wet brush with fresh spirit, and the dry one with soapy water. Allow it to dry thoroughly before re-use. It obviously saves time to clean all the ionizing smoke detectors at the same time.

Cleaning Optical Smoke Detectors

The exterior and insect mesh of the optical detector is cleaned in the same way as the ionizing detector. The chamber interior, lenses and optical units can be cleaned with a puffer brush such as used to clean camera lenses. In particular, light-coloured dust deposits on the chamber walls must be removed because it could cause reflections and generate false alarms. Do not polish or buff up the chamber walls as they must be matt to avoid spurious reflections.

In general, the ionizer type of detector needs more cleaning than the optical ones. Ions attract dust and dirt, as owners of room air ionizers will be aware. Optical ones usually need only a dust-out unless in a greasy environment. Heat detectors need little cleaning at all, but should be given a dust over and check to see that there is no build-up of dirt, once in a while.

It can be seen then that although installing and maintaining a fire alarm system is usually considered a specialized job, there is no reason why it cannot be done by anyone using basic installation skills, following the principles outlined in this series.

Auxiliary Equipment

Although out of the scope of these articles, we will mention some of the equipment which can be linked to the fire alarm system, and is worth considering especially for larger premises or where circumstances could make added protection desirable.

The first of these are the auto-diallers. These can be either analogue or digital. With the former, the 999 number is recorded in pulse form on an endless tape followed by a message. When activated, the number is dialled and the message given. Several numbers and messages can be recorded so that responsible staff members can also be alerted. The dialling and message is not repeated, so if the device fails to get through the first time it does not try again. The tapes have to be specially recorded by the makers otherwise the numbers could not be recorded.

These are used mostly with intruder alarm systems, but dual-purpose ones are available that can be linked to both an intruder and fire alarm system, and give the appropriate message when activated.

The digital dialler has the 999 number contained in a memory store instead of on tape, although the message is on tape. It will only dial 999 so messages to other numbers are not possible.

An alternative to the diallers is the digital communicator. These do not use tape at all and so are more reliable and are also cheaper. They have to be used in conjunction with a central receiving station which sends back a handshake signal when called. If this signal is not received the communicator keeps dialling. When it does get through, it sends a coded identification and then a message in digital code. On completion, the receiving station sends an acknowledgement. If not received, it re-dials and repeats the message.

Communicators are usually used with intruder alarms, but can be used with fire alarm systems. Most are single message types, but some can send different codes actuated by different triggers, so could be linked to both an intruder and fire alarm.

The receiving stations are commercially operated by private security firms for a subscription plus a charge each time the system is used. When a message is received from a subscriber, they telephone the appropriate authority. The subscription and use charges must thus be set against the lower initial cost of a communicator compared with a dialler.

In addition, due to the possibility of false alarms in the case of intruder systems, most receiving stations will not accept an installation unless it has been carried out by an approved installer. DIY systems are thus ruled out leaving the 999 dialler as the only choice.

Another item which is often used in conjunction with the fire alarm system is the overhead sprinkler. These sprinkle water over the affected area when activated by the alarm system. They do little to extinguish a fire, but can confine it and prevent it spreading or at least control it until the fire services arrive. They really need to be self-contained and operated by sensors in the same area, as the results could be disastrous if sprinklers all over the building were activated by a small fire in one part.

Fire doors are another safeguard. If doors are closed in the affected area, draughts on which a fire feeds can be prevented and also the fire itself can be contained within its fire compartment at least for a while. The door must be fitted with a return spring that closes it firmly, and the back of the door is fitted with a catch that engages with a magnetically operated holding device on the wall behind it, which is wired to the alarm system. This normally retains the door in the open position, but an alarm signal causes the device to release the door so that it springs shut. The door can be pulled shut manually from its catch if required and of course can be opened by anyone seeking to escape. It is not held shut by anything other than its spring.

Finally, all premises should be provided with fire extinguishers. The correct type should be chosen for the type of material likely to be involved in the fire. The following table is a guide to the correct types.

Type of Fire	Type of Extinguisher
Electrical, computers	CO_2, BCF
Paper, wood, straw, textiles, furnishings	Water, CO_2, soda acid, foam, powder
Oil, petrol, paint, tar, spirits, inflammable liquid	Foam, powder, BCF, CO_2
Gas, calor, propane	Powder, BCF
Metal: sodium, calcium uranium plutonium, phosphorus	Special metal fire powders

CO_2 = carbon dioxide gas.
BCF = bromochlorodifluoromethane, a vaporizing non-toxic liquid giving a clean vapour free from deposits and is therefore ideal for electronic equipment fires.

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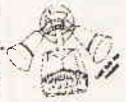

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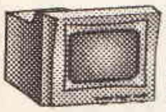

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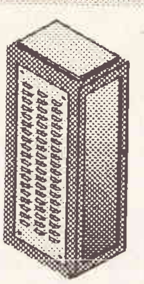

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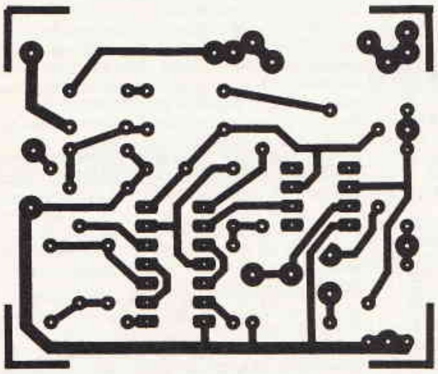

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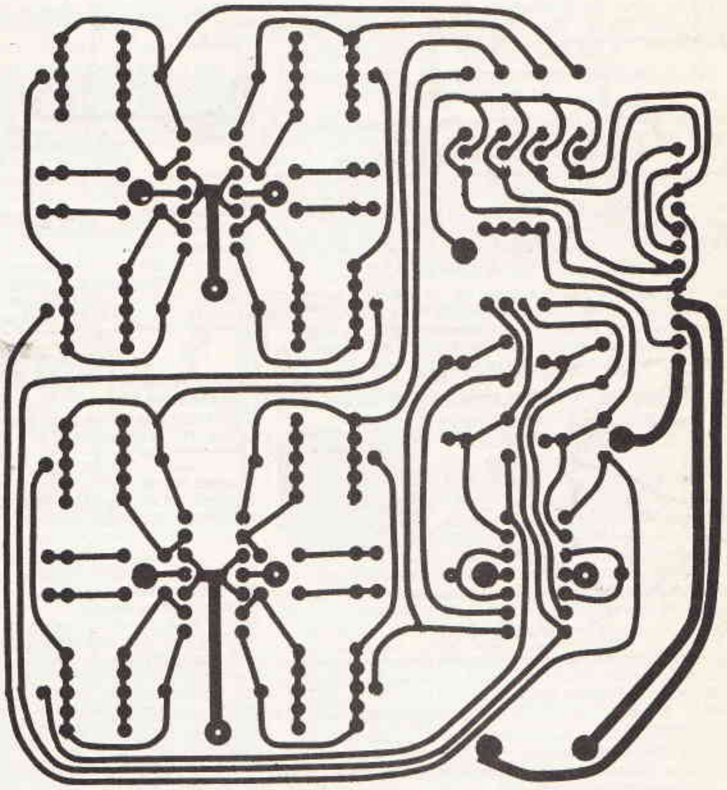


Nightfighter Sound to Light solder side

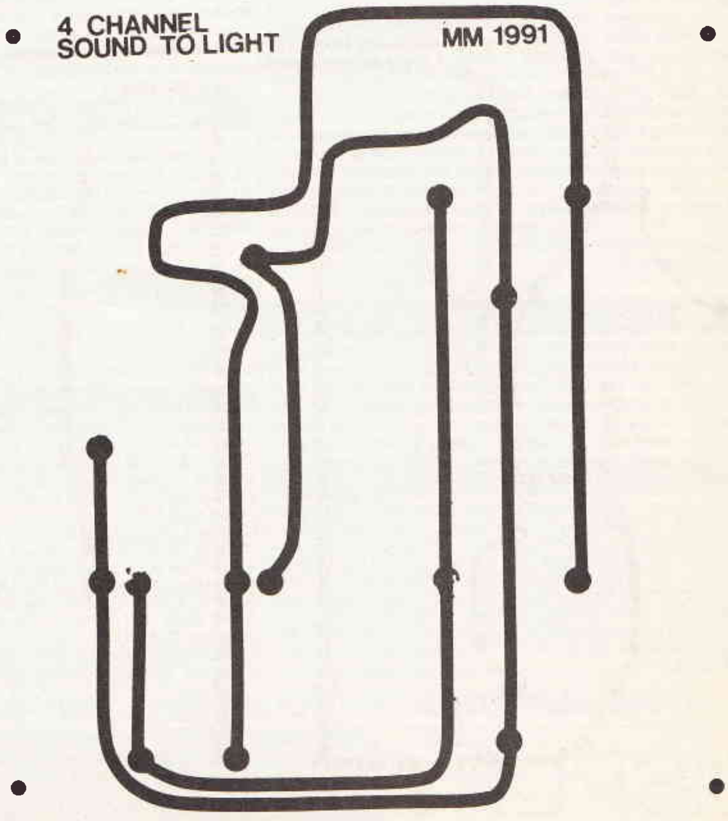
Fault-finding 2 (September 91)
In Figure 15, C403 and C404 should be 8200u not 8200p and R402, a 5R6 resistor should appear in the line adjoining the 47V rail and R408, R612 and R713. The caption in Figure 16 should refer to Figure 15 not Figure 17. The fault-finding exercise, option 18B should direct you back to paragraph 1 and option 11B should read . . . A to C and A to D.

Pocket Geiger Counter (September 91)
Diodes D1/D2 should be 1N4006 and D3/D4 should be 1N4002.

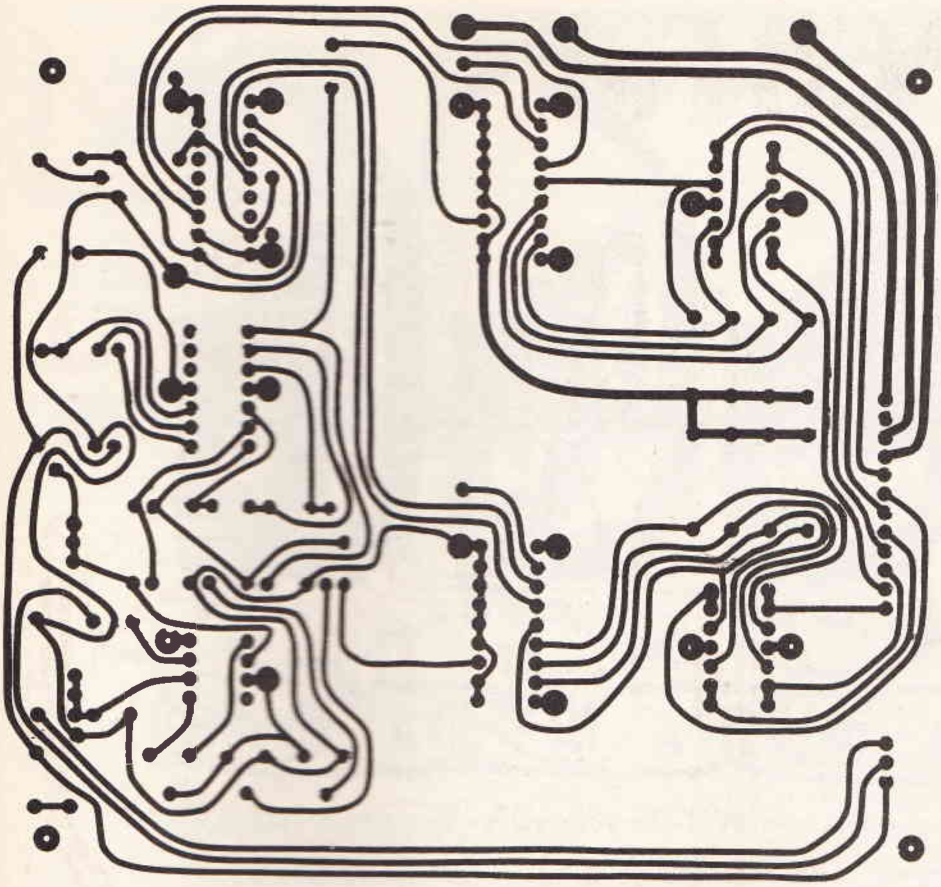
Model railway speed controller (Aug 91)
In Figure 3 D7, D3 and D4 are shown orientated the wrong way and the 1k0 R27 should be R37. Fuse 1 should be to the right of the connection from te lower winding of T1.

Radio Calibrator (April 91)
IC1 is a Hex invertor and should be labelled in the parts list as 74HC14.

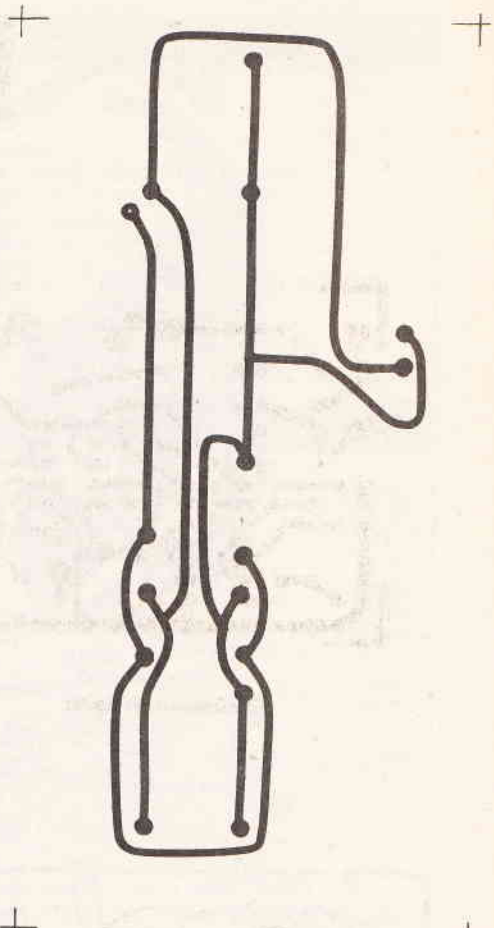
Consort Speaker (July 91)
In Figure 4, R8 should be 180k, C7 should be 100n. IC1 output should not be shorted to ground. Mains input should be applied to 2×120V windings. The formula for the reduction in Q should read 1/Q(required)=. . . In How It Works all resistor and capacitor component identities have been transposed by one. R10 should read R9 etc. In Parts List R2,4,. . . should all read 39k. In Figure 7, the WO output lead goes to the red woofer terminal. To avoid a slight DC offset problem on the woofer output, instead of linking points B and C on the PCB, point C should be linked to the junction of R15 and C16 by an insulated wire.



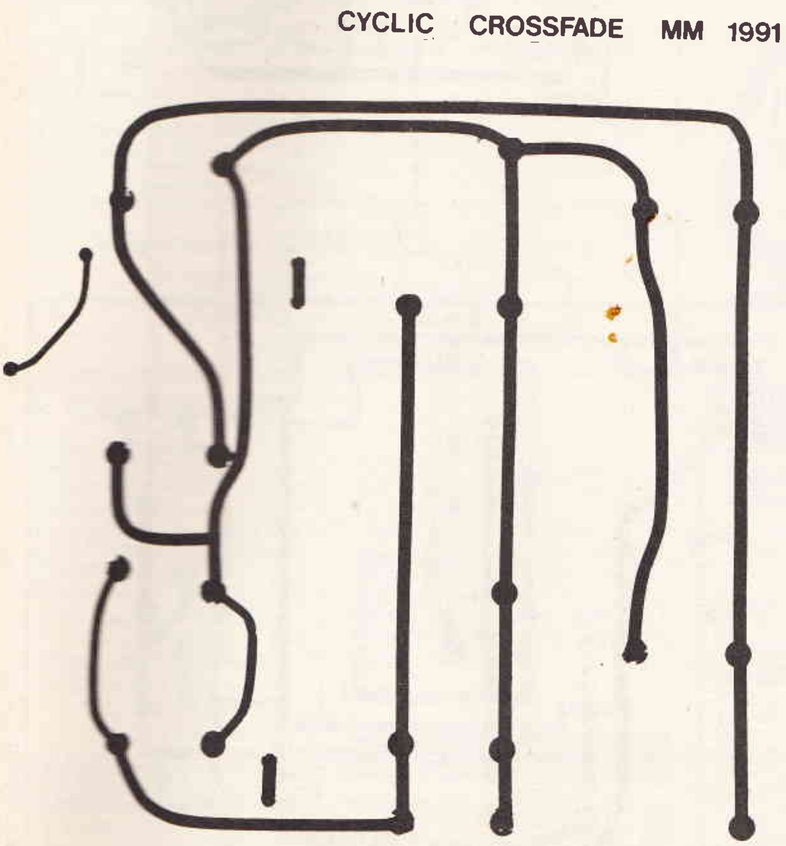
Sound to Light top side



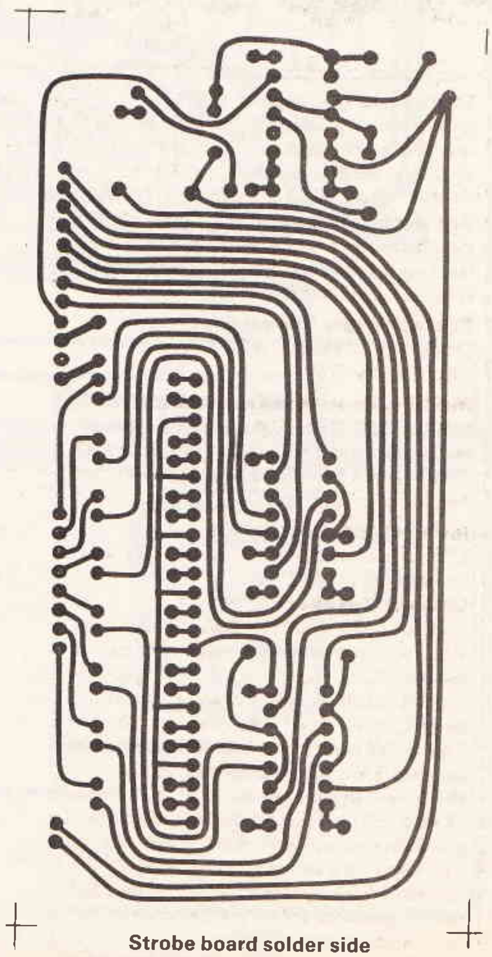
Nightfighter cyclic crossfade solder side



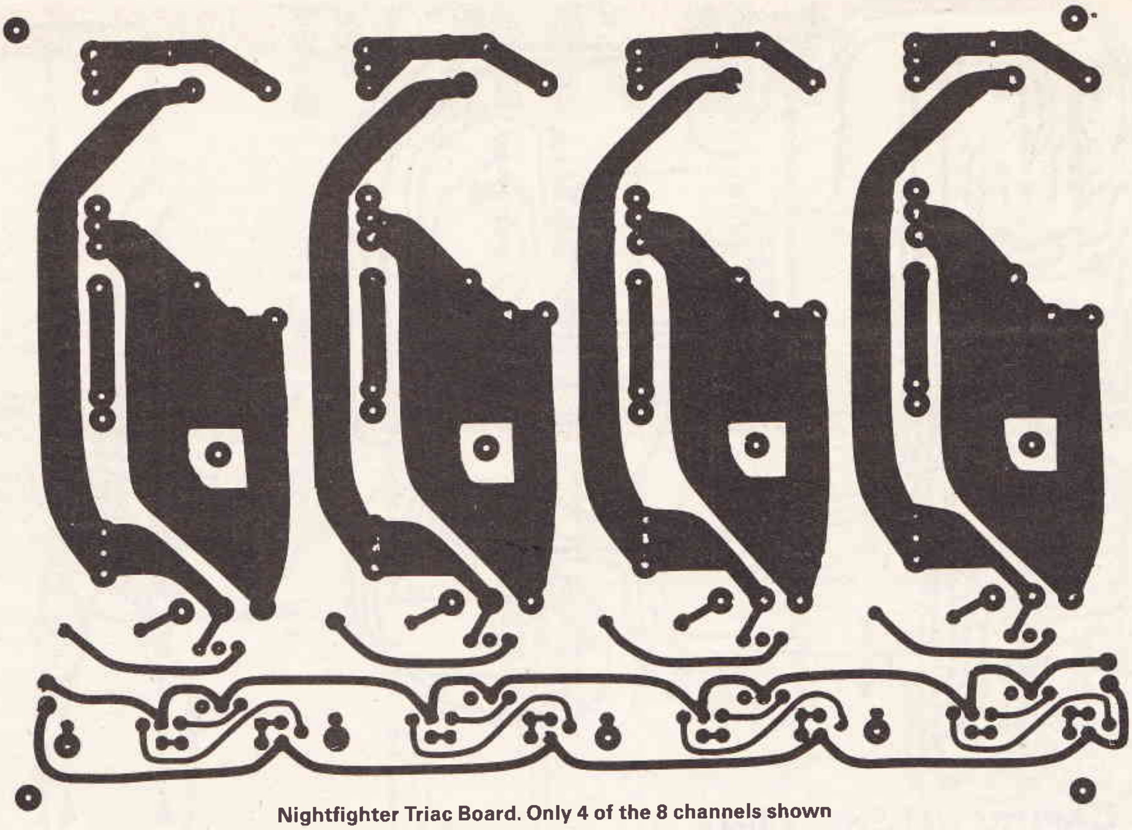
Strobe board top side



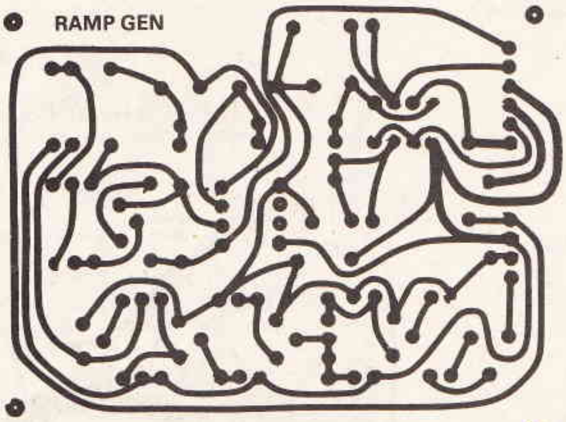
Cyclic crossfade top side



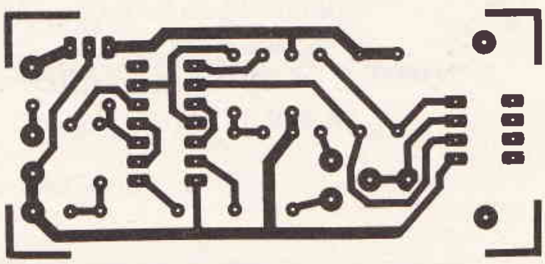
Strobe board solder side



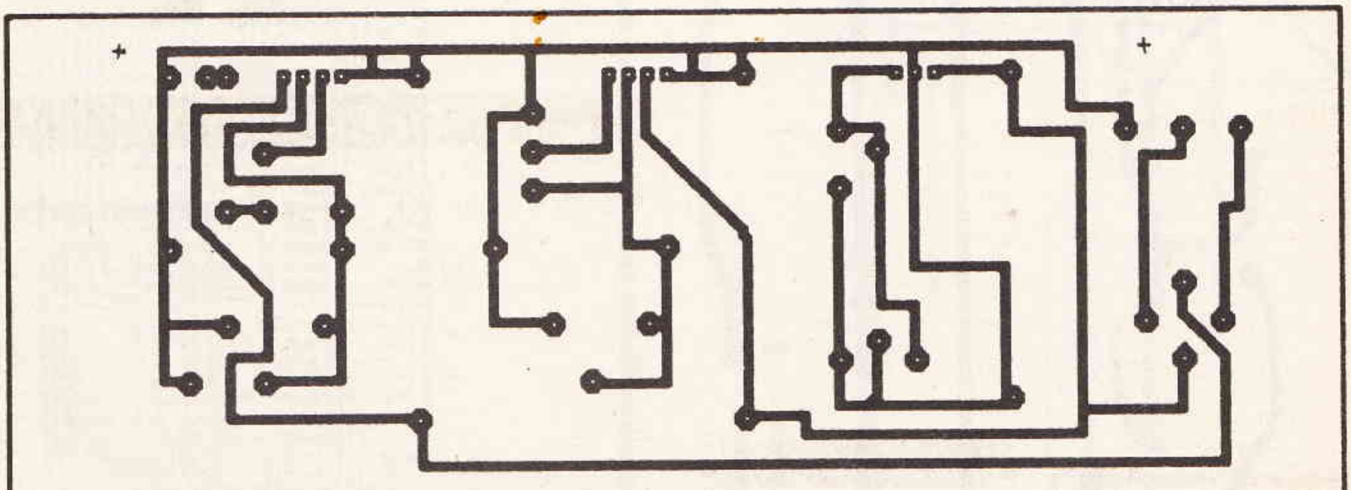
Nightfighter Triac Board. Only 4 of the 8 channels shown



Nightfighter Ramp Generator



Freeze Alarm



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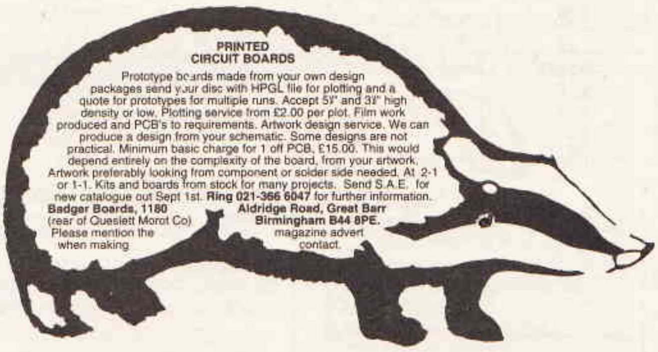

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NEXT MONTH

In the November issue we have a feature article on electromagnetic waves. Are they really waves or are they particles? Or are they particles with the characteristics of a wave? Find out also about the techniques of Digital pulse transmission as most of our communications down wires or fibres are by this method.

We start a new mini series from Ray Marston on Test-gear basics and instrumentation and Back To Basics looks at inductance and transformers.

On the construction side, we continue with the Nightfighter lamp controller, including the board overlay circuits from the master controller which could not be included in this issue owing to lack of space.

A switched mode power supply is always useful to have around on a bench along with a digital code lock to give a whole variety of containers or rooms greater security.

These are just some of the articles appearing in the November issue of ETI. Order your copy now from your newsagent, out on 4th October.

The above articles are in preparation but circumstances may prevent publication

LAST MONTH

Items featured in the September issue were:
Light, vision colour and perception — the science of vision · Fault-finding in the electronic equipment · Pocket Geiger counter · The Hemisync machine Part 2. A machine to encourage brainwaves · The Sony Minidisc — The storey of the next generation recorders · HDTV 9 The last part in the series on High definition TV

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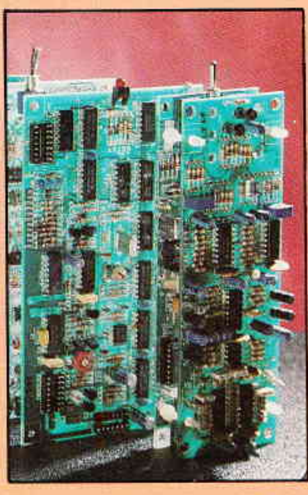

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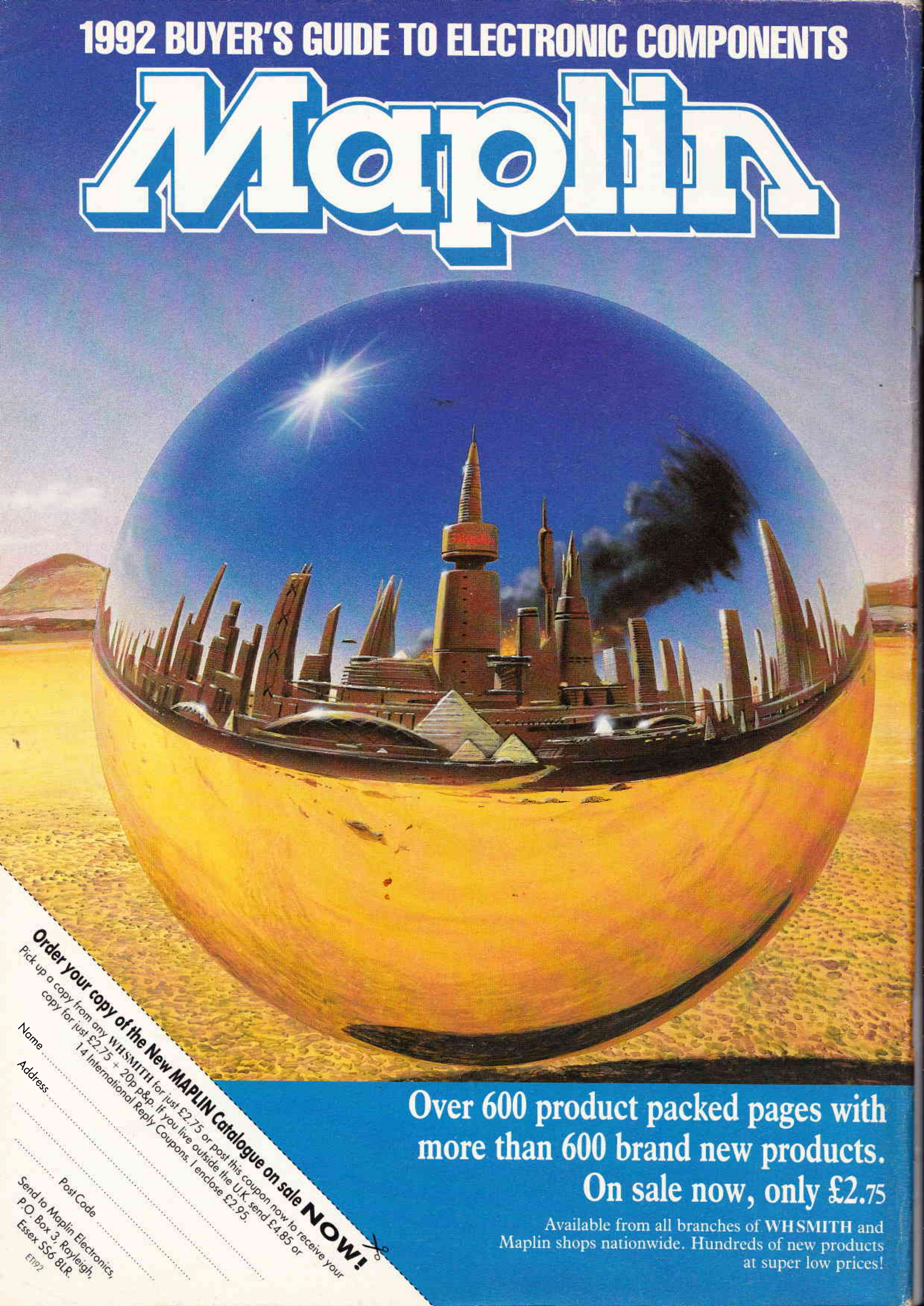
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