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ETI
ELECTRONICS TODAY INTERNATIONAL

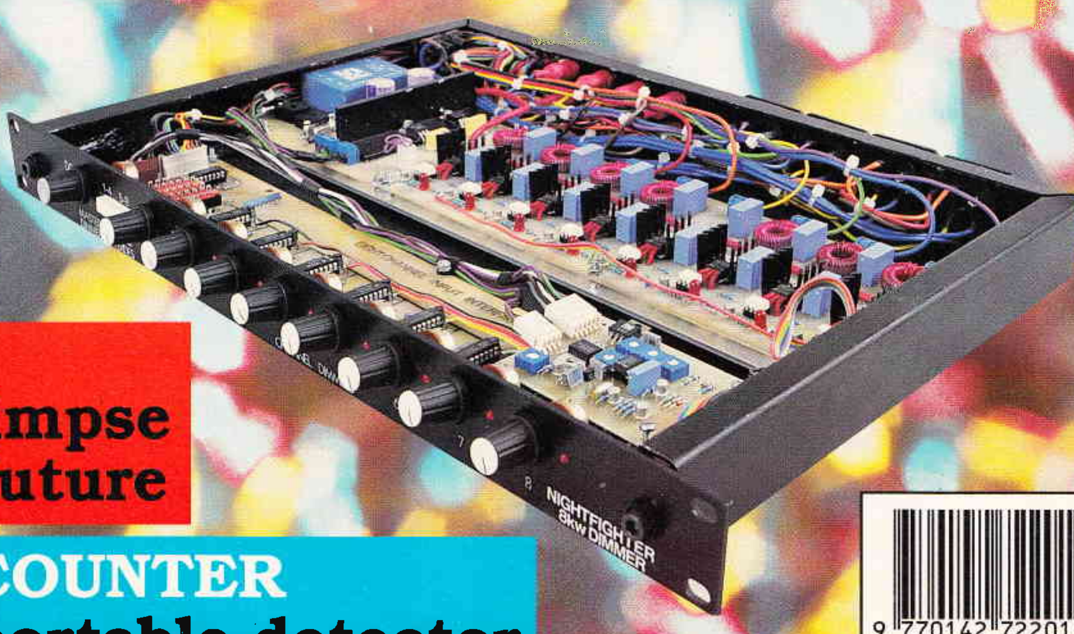
AN ARGUS SPECIALIST PUBLICATION

LIGHT, VISION, COLOUR AND PERCEPTION
How do we see the light?

THE HEMISYNC Pt2
More Construction

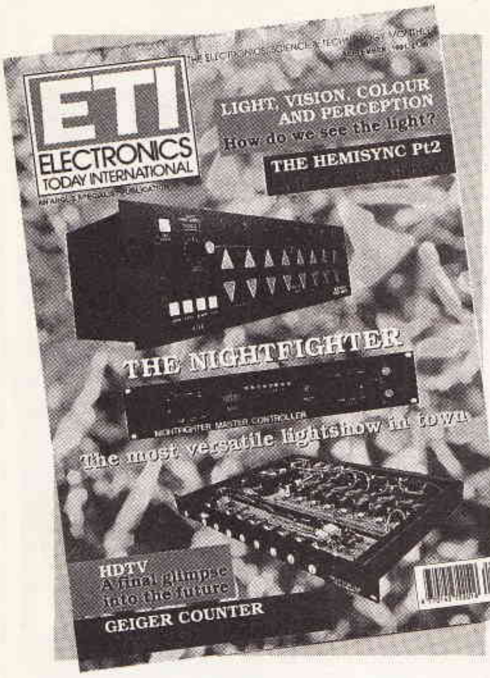
THE NIGHTFIGHTER

The most versatile lightshow in town



HDTV
A final glimpse into the future

GEIGER COUNTER
A handy portable detector



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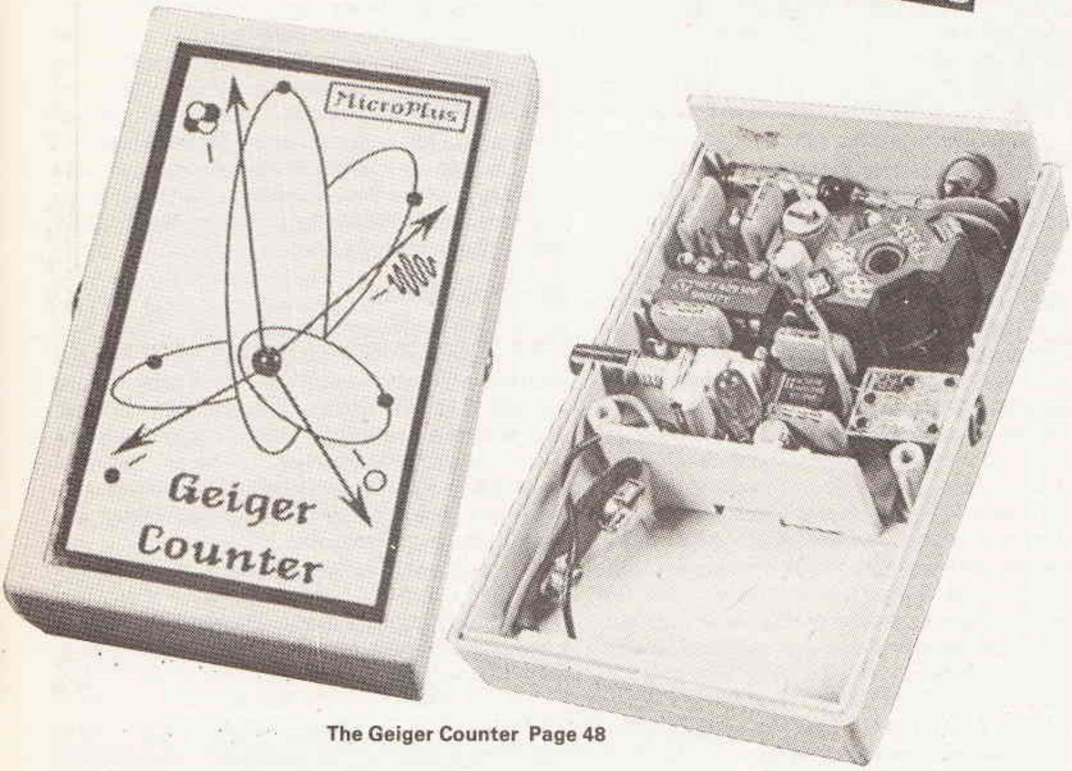

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Editorial

Radical or conservative design

It has been stated before that ETI is a testbed for any new design or idea in the field of our technology. Making the design fit your requirements is all part of that pleasurable experience to give it that certain amount of individuality.

Component parts and circuit modules like oscillators, filters, comparitors and the like are available for the designer to bring about a gadget that performs as expected. But an electronic designer, equipped with the knowledge of how the parts or modules fit together through conservative development is not there to think of the design in the first place. This is where the 'ideas person' can perform his or her part in a Lateral thinking process. After having identified the need or the approach to an answer, the electronic designer can do the rest. Most initial ideas come from an event or series of events known to be an annoyance in our routine daily lives and nearly always results in the newly designed piece of equipment performing an operation in a more efficient manner. Very often if a process is working, there is less reason to question whether another route to the same goal needs to be acheived. The sideways look could produce a risky but radical alternative to perform the same job.The rewards for such offerings are very attractive particularly to industry as in nine cases out of ten it results in the company saving money. In some cases, though not so popular, it can help the persons well-being and make their job easier within the company.

Arguably, electronics has brought about increased production speed and reliability through automation within a company but it could be at the very expense of cutting out the employee who designed it.

Mathematical aids like computers and calculators have reduced monotonuos processing time in scientific research. Electronic communication through radio, TV, telephone, fax and spy satellites has increased the disemination of knowledge to reduce misunderstandings and surprise events. It also has to be said in the wrong hands, these communication channels can supply misinformation and so supply incorrect information equally at the same speed.

On balance the benefits given to society from the electronics revolution must lead to a safer world where human races operate in harmony with each other. We have yet to live in harmony with the natural resources of the planet however.

Paul Freeman

OPEN CHANNEL

As you might expect, I have to start this month with a comment on recent happenings concerning the future ot satellite television broadcasting over Europe.

Filippo Maria Pandolfi, the European commissioner for technology, research and development has proposed that leading variant to the multiplexed analogue component (MAC) format for television transmission systems D2MAC becomes the standard for such services. Through this, high definition television services will be introduced in the future using MAC's high definftion extension known naturally enough as HDMAC. This has a number of far reaching implications on satellite television, particularly in the UK.

For instance, while he's proposing MAC is a new standard, he has not seen it fit to suggest existing broadcasters using other formats must change to a MAC service immediately. This is, perhaps, welcome news to the two million or so dish owners across Europe (three-quarters of them in the UK) and, more specifically, to broadcasters such as Brttish Sky Broadcasting which runs many existing channels.

Prior to MAC, most channels used the PAL format, in a broadly similar form to terrestrial television broadcasts in the UK. Use of PAL as a broadcast standard ensures that compatibility with current televisions is simply engineered into satellite receivers. For this reason there are still many more PAL channels broadcast from satellites than any other type. Of the 16 main television-transmitting satellites 69 channels are in PAL, 14 are in D2MAC, 9 are in DMAC, 9 are in SECAM and 2 are in BMAC. These figures put the matter of satellite television into perspective and I suspect they will surprise many casual observers.

Even now with the commissioners proposals however, this situation is unlikely to change greatly because existing non- D2MAC channels aren't immediately being forced to change. True, all new services from the beginning of next year must be in D2MAC format but that's not going to make a lot of difference - most channels which want to be up are already there; and any on the horizon with much sense will probably get their acts together before that deadline arises.

It's not that broadcasters don't see the technical advantages of D2MAC — everybody knows picture and sound quality is improved using the system — but it's not yet proven it can be a commercial success. Further, it's not yet proven users actually need or even want D2MAC.

Manufacturers like Philips and Thomson have pushed hard for the D2MAC format to be both standardised and imposed on existing broadcasters, but the commisioner has seen it necessary to do only the former, leaving existing broadcasters with the option to change as and when they want.

A second part of the proposal is to enforce that D2MAC facilities be incorporated into all new satellite television receivers from 1993. This in itself will naturalry cause the changeover from PAL transmissions to D2MAC, and it does make sure any such transition is controlled, gradual and occurs only as the user wants. Last thing anybody should desire is an instant changeover date after which two million users need to either scrap their current equipment or upgrade by buying expensive external decoder boxes.

In the end, D2MAC is still only an analogue system, only one step better than the current PAL system. It could be superseded within 10 years by a new digital HDTV system currently in early development stages. This is effectively incompatible with both PAL and D2MAC, so it's not as though D2MAC would give any advantage in the long-term except for the promotion of widescreen services. PAL itself has been shown to be capable of providing widescreen services in an extended format. For whatever reasons, Mr Pandolfi's proposals are the right ones.

Moving Data

For anyone working external to a central base, telecommunications is often vital. Originally land-line telephones were the only realistic means of communicating with the office for salesmen, delivery personnel, field service engineers and so on. True, radiophones used to be available but they can't by any stretch of anybody's imagination be called reliable. Radlopagers gave some small communications possibilities but were always pretty restrictive.

It wasn't until cellular telephone services came into being that mobile communications of any true reliability and quality were obtained. Their rapid growth over the years upto the current time gives testament to how much they are required.

But mobile voice communications is only part of the solution to business communications needs. Mobile staff need to have computing facilities too, usually in the form of laptop notebook computers. Because of this, there is a need for data communications between terminals and centralised computers. Even where data users aren't mobile, data communications at a distance is a vital area in business. Validation of credit card transactions, telemetry of remote plant and so on also require reliable data communications. A fascinating range of uses can be envisaged for comprehensive data communications networks. Electronic tagging of vehicles is just one potentially useful scenario. While no-one suggests it's necessary to monitor all vehicle positions at all times, such a system would pinpoint position of, say, a stolen vehicle instantly. It doesn't take the imagination long to come up with many more potentially useful data systems either.

Because of these data needs, a new breed of portable communications device is becoming available, comprising radio-modems or complete data terminals. In the minimum, modems can be used over existing cellular networks to allow computerised equipment to inter-communicate. At the other extreme, complete radio data terminals could have their own radio networks. It is becoming increasingly likely that the Government could legislate to allow this possibility. In effect, provision of such networks could well cut down the requirements for a cellular voice network — because many more users can communicate per channel over a similarly specified radio data network.

Keith Brindley

![ETI NEWS]

ETI NEWS

SALTMINE TEST CENTRE FOR ICL

Salt was first taken from the salt mine at Winsford in Cheshire some 150 years ago. Now it's the only salt mine still in production on the UK mainland — but that's not its only claim to fame.

ICL, one of Europe's information systems companies, has taken the innovative step of setting up a computer test centre 200 metres below ground in a worked-out region of the salt mine.

This highly automated test facility will be used by ICL to measure the electromagnetic conformance (EMC) characteristics of its range of computer systems. It will enable ICL to meet its own high standards for quality and to comply with new European Community regulations due to come into force in 1992.

Tests will be carried out on all ICL's products — including personal computers, disc files, printers and mainframe processors -to ensure that they do not cause excessive electromagnetic interference, and are immune from it.

ICL has invested over £1 million in the new underground EMC test facility which is among the most advanced in the world.

This investment includes the installation, within the subterranean cavern, of a large air-conditioned tent in which the tests are conducted; the provision of laboratory and office facilities; and the construction of a screened room housing an ICL Series 39 Level 35XP mainframe computer. This can be linked to the products being tested to simulate operational conditions.

The selection of the salt mine for this work means that much higher signal levels can be generated to test products for immunity, without creating electromagnetic pollution which could otherwise interfere with normal telecommunications.

The salt mine eliminates radio frequency signals from unwanted sources which could interfere with testing. Because of the absorption qualities of the salt walls, the need for highly expensive shielding and absorption material is greatly reduced. This means that testing can be automated and completed quickly.

As a result of establishing this underground test facility, ICL expects to be among the first European electronics companies to meet the new standards for electromagnetic conformance being established by CENELEC, the European Committee for Electrotechnical Standardization, and thus have the right to carry the 'CE' label on its products.

BREAKTHROUGH IN SOUND SPEAKER DESIGN

Canon is entering the audio market with the introduction of a new domestic loudspeaker system, called Wide Imaging Stereo.

This new system is said to offer the listener one distinct advantage — a much larger stereo area than that produced by conventional box loudspeakers.

In a conventional set-up, two speakers fire sound waves diagonally across the room in an 'X' pattern. At the centre of the 'X',the 'hot spot' — the listener is able to appreciate the stereo effect; however outside of this tightly defined area, the stereo effect is likely to disappear altogether.

The new Canon S-50 loudspeakers operate in an entirely different way. Instead of firing sound in a diagonal pattern, the sound is directed downwards from the driver onto a unique acoustic mirror, producing stereo images across a much broader listening area — ideal for group or family listening.

Wide Imaging Stereo is the result of six years intensive acoustic research, carried out by the Canon Research Centre Europe — based in Guildford, Surrey.

The concept is the brainchild of one man — Mr. Hiro Negishi — Head of Canon Research Europe. Bringing the idea to the finished product has involved a team of British acoustic engineers and the services of the Institute of Sound and Vibration Research at Southampton University.

The new S-50 loudspeakers are the very first Canon products to be both designed and manufactured outside of Japan. They are being manufactured in the UK and the sales and marketing will be handled on a global basis by newly formed company Canon Audio Ltd based in Woking, Surrey.

Canon's new S50 speaker draws on a brand new set of design rules, offering a fresh look at the design and manufacture of domestic loudspeakers; demonstrating both aesthetic and technological innovation.

The 'hot spot' has traditionally

been considered a technical priority in conventional loudspeaker design but with Wide Imaging Stereo the priorities of loudspeaker design have been reorganised. The system provides the means to control 'dispersion' — the pattern of sound radiated into the room — and the parameter, vitally important to off 'hot spot' listening. Canon has found a way of controlling dispersion by increasing the quantity, and controlling the quality, of 'early reflections' from the listening room walls. For the first time, 'true' stereo sound is able to effectively work over an extensive listening area.

In the majority of conventional loudspeaker designs, dispersion is either left unattended, or degraded, by the search for 'better' hot-spot performance. In contrast to natural sound sources such as musical instruments and voices, conventional loudspeaker dispersion often changes suddenly over the frequency range. This is thought to be the fundamental reason for the unnatural sound of many speakers. Wide Imaging Stereo however produces a smooth dispersion characteristic.

Conventional speakers use multiple forward facing drivers. The drivers physical size, mechanical characteristics and the crossover between them have been optimised to achieve 'hot-spot' performance goals.

The system controls dispersion by substantially removing it from the influence of the driver and instead uses a carefully profiled off-centre 'acoustic mirror' which has been postioned to control the way the sound is radiated into the listening room. Stereo to the left, to right and in the middle.

The S-50's full range driver, in combination with the acoustic mirror, overcomes the difficulties normally associated with such units — and removes the need for the troublesome passive crossover circuits of conventional systems.

Materials used in their construction are as radical as their design, no wood cabinets, instead zinc diecastings and modern ABS plastics.

The suggested guide price is £349.95 (inc.VAT).

SUPER VGA MONITOR

With the launch of the SV1481/82 14in Super VGA colour monitor, Southern Peripherals is introducing to the general computer market a multifrequency monitor that can support all VGA configurations up to 1024 × 768pixels with 256 colours for £240 plus VAT. All that is required is the appropriate video adaptor card, also supplied by the company.

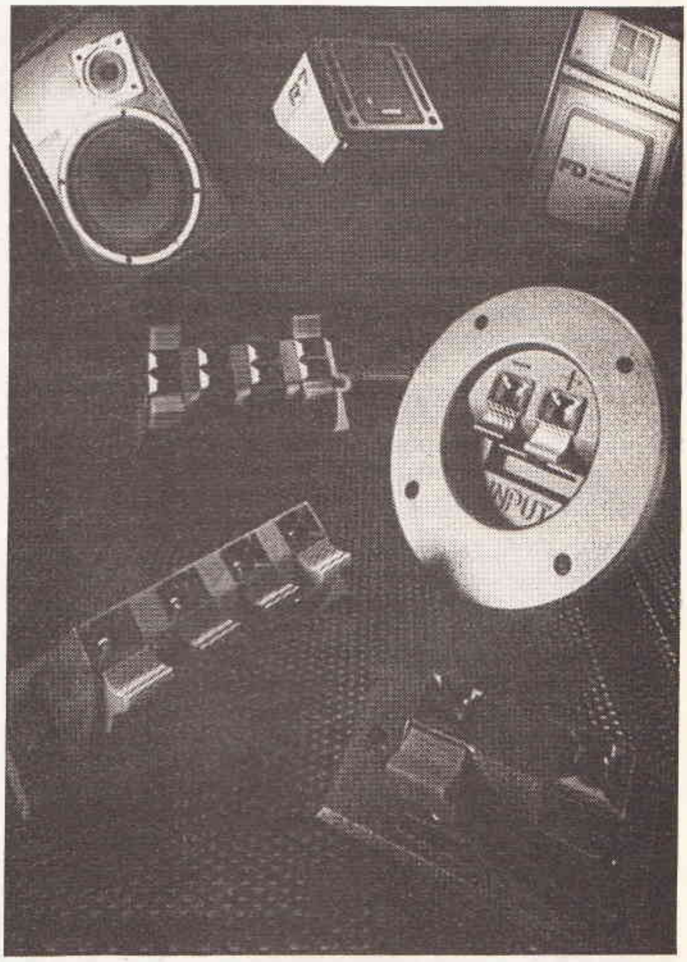
Rapid changes in technology now allow the company to offer screen resolution and colours that were once the sole domain of CAD/CAM and high technology engineering applications.

Technical specifications for the SV1481/82 include: a 14in 90° CRT with 0.28in dot pitch; horizontal frequencies of 31.467, 35.16 and 35.52kHz; vertical frequencies of 60, 70, 56 and 87Hz (interlaced); a bandwidth of 50MHz; maximum screen misconvergence of 0.3 and 0.5mm at the centre and corner, respectively; and an operating temperature range of 0° to 40°C.

The Super VGA colour monitor has been designed to be fully compatible with IBM PS/2s and PC-compatibles. offering as standard 640 × 350 resolution, which increases to 640 × 480 when used at 31.467kHz, the SV1481/82 will automatically switch modes by decoding an upgraded Super VGA video card to provide 800 × 600 and 1024 × 768 resolutions at 31.16 and 35.52kHz frequencies, respectively.

Further information, contact Derek Southern at Southern Peripherals. Telephone: 0256-819 221.

SPEAKER TERMINALS



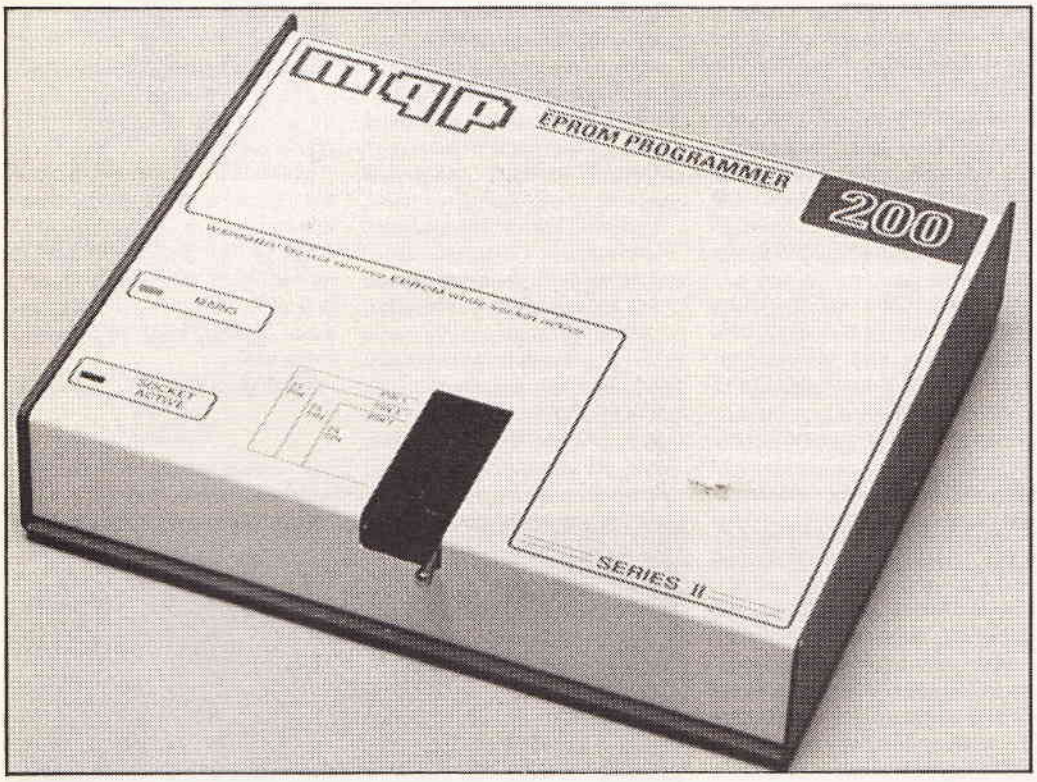
Rendar has expanded its range of high quality audio connectors with new loudspeaker terminals to suit the most demanding applications.

The speaker terminals are gold plated spring-loaded contacts and push-open action for convenience and speed of loading. They are designed to make good contact with all types of speaker cables, and are large enough to accommodate thick heavy-duty conductors, including high quality oxygen-free copper (OFC) cables.

Configurations are available from two to eight poles, for use on all types of equipment from consumer products to large scale professional audio systems. The terminals are available in surface mounting format for use on equipment, and recessed for use on wooden loudspeaker panels.

Further information contact Mike Gasper, Rendar Limited Tel: (0243) 866741.

EPROM PROGRAMMERS



MOP Electronics Ltd have recently introduced the Model 200A EPROM Programmer with an option available to connect the Programmer to the parallel port of a PC instead of the serial port. This combined with enhanced software gives significant increases in programming speed, for example a 1 Mbit Flash devices can be blank checked, programmed and verified in one minute.

Along with the Model 200A, a new range of adapters is now available. These allow the programming of the 8051 family derivatives from Intel and Philips in both standard and surface mount packaging.

The Model offers a comprehensive programming system supporting nearly 900 devices including EPROMs up to 4 Mbit, EEPROMs and all popular microcontrollers.

Further information phone MOP Electronics on 0666 825146.

ECHELON SELLS LONBUILDER

Echelon Corporation announced that it has sold its Lonbuilder Developer's Workbench to over 50 customers around the world. It enables companies to design and build low-cost intelligent distributed control applications into products for the first time.

Echelon introduced the concept of intelligent distributed control, along with its new Lonworks technology platform last December. With this technology, products from multiple manufacturers (such as lights, switches, security sensors and thermostats) can interoperate and communicate.

The Lonbuilder Developer's Workbench gives users the ability to- develop intelligent distributed control applications quickly with inexpensive, off-the-shelf technology. It provides developers with an integrated hardware and software environment for building the technology into products or systems. It uses object-oriented techniques and a high-level programming language to simplify the design and development of distributed control applications.

Each application contains one or more nodes. Nodes can take the form of basic elements like switches and circuit breakers, sensors or actuators, or user interface devices like keypads and liquid crystal displays. Each node contains an integrated circuit called a Neuron chip, that can be programmed to sense and monitor, count and measure time, manage switches and relays, respond to conditions reported from other nodes and report system status to other nodes.

Each node also contains a transceiver that provides the physical connection to the communication media, including electrical power lines, radio waves, optical fibre, coaxial cable, infrared and twisted pair. The technology supports communications over any combination of media with a complete seven-layer communication protocol contained in the firmware of every Neuron chip. The LONTALK protocol supplies the 'rules of the road' for linking nodes together in a network.

"By integrating programming and network management tools into a single development platform, we have significantly reduced the amount of time and money required by designers to develop their distributed applications", said Dr Michael Gilbert, Echelon's Vice President of Engineering. "In the past, people developing intelligent distributed control applications not only had to write their application in a microcontroller, but also had to create their own protocol system software and networking tools. Now with the integrated tools provided in the workbench, companies can write their application quickly and develop their network simultaneously."

The tools, run on a standard IBM PC/AT or compatible computer, combine three development products — a multi-node development system, a network manager and a protocol analyser — into a single integrated hardware and software platform.

Echelon Corporation was founded in 1988 to develop a new technology to enable implementation of the first practical, low-cost intelligent distributed control products. Echelon is a privately held company with headquarters in Palo Alto, California, with 100 employees and two subsidiaries; Echelon Europe Ltd., located in London and Echelon Japan KK in Tokyo.

LCD INVENTOR HONOURED

The man who invented liquid crystals, has been awarded the CBE.

Professor George Gray of Merck Ltd, pioneered the use of liquid crystals in state of the art technology from digital watches, calculators and computers, to all domestic appliances with electronic displays.

In cooperation with the Royal Signals Research Establishment (RSRE), George Gray and Merck Ltd are also instrumental in the production of Thermochromic inks. These incorporate heat sensitive liquid crystals which react to changes in temperature. The inks have already been successfully printed onto fabric and recently paraded on the London catwalks creating a new fashion craze.

Professor Gray spent 43 years at the University of Hull during which time he gained many awards for his work includitig a Fellowship of the Royal Society (FRS). For the last 20 years he has collaborated with Merck, contributing to their Queens Award for Technological Achievement.

HALF OF BRITAIN'S LOCAL EXCHANGES NOW DIGITAL

BT's massive programme to modernize its telephone network reached a milestone today when it hit the half-way stage in switching over its local exchanges from electromechanical to digital technology. To date, more than £15 billion has been spent on supporting, modernising and expanding mainstream services in the UK.

Last year, BT's trunk network — the backbone of Britain's telephone system — became the first in any major industrialized country to become fully digital. Now, with the modernization of half of BT's local exchanges, telephone users have access to one of the most sophisticated networks in the world. The half-way stage was reached when the BT exchange which serves the St Paul's area of the city of London became the 3,319th digital exchange to come into service.

Benefits of digital technology include:

— Features such as call diversion, call waiting, three way calling, repeat last call, call barring, charge advice, code calling and reminder call.

— Access to BT's Integrated Services Digital Network (ISDN). BT's ISDN2 and ISDN30 services allow customers to send and receive high speed, high quality voice, data, image, and text, or any combination, over the UK network and to 12 countries around the world, including France, the USA and Japan.

— A powerful high speed signalling system which enables fast call set-up.

BT's network now has more than 1.5 million kilometres of optical fibre which means that voice, image, data and text can be transmitted across the network at high speed. The current technology employed allows more than 7,600 simultaneous phonecalls to be transmitted and received over a pair of fibres.

In addition to converting more than 15 exchanges to digital operation each week (the equivalent of 6,500 new digital lines every working day), BT is continuing to extend its fibre network by more than 10,000 kilometres every single week.

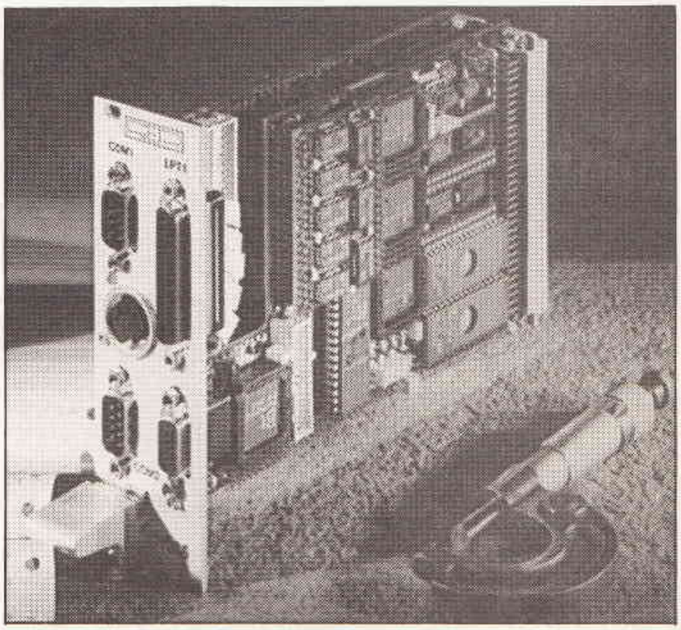
80386SX PC IN 3U

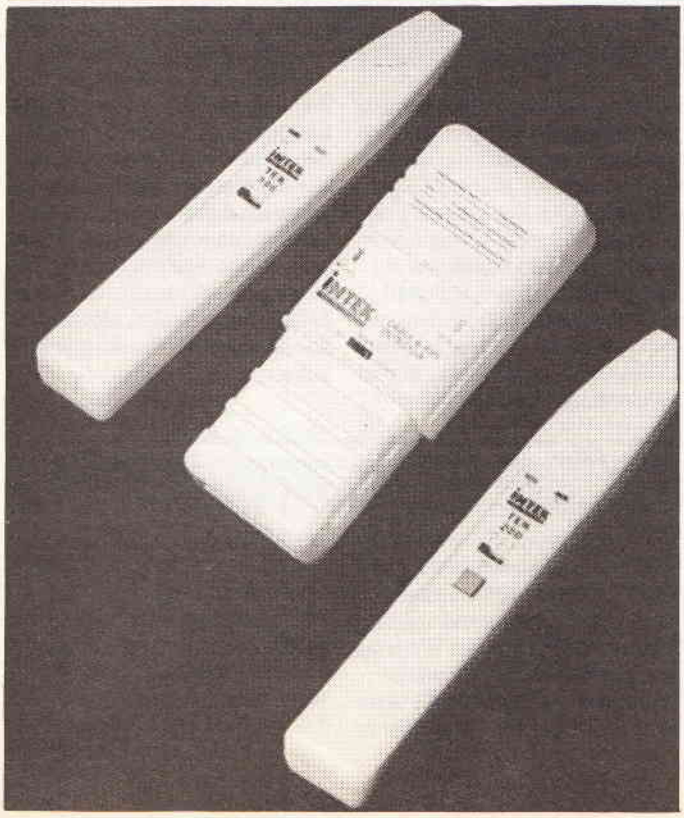
PEP Modular Computers have added the V386 to their extensive range of 3U VME boards for Industrial Automation.

The V386 hosts the popular and powerful Intel 803865X processor and costs less than F100. 1MB and 4MB DRAM versions are available with an 8MB version planned. For communication purposes 64kB of this memory is fully dual ported to the VMEbus and is supported by an OS-9 SCF driver from PEP. The on-board Cirrus VGA graphics controller also gives downward compatibility for EGA, CGA and Hercules. If flat panel displays are specified an LCD interface is also provided with 640 × 480 resolution, 64 grey scales and uses a 32kB frame buffer for flicker free operation.

For easy connection to popular PC peripherals the front panel carries standard PC compatible 'D' types and DIN connectors for VGA, keyboard, two serial ports and one centronics port. IDC headers are provided on-board for floppy and hard disks as well as the LCD interface.

Complete with battery backed real time calendar/clock and a socket for 803875X co-processor the V386 provides a cost effective solution for an easily programmable man/machine interface which is fully compatible with IBM PCAT-386SX software.





SAFE AND ALIVE WORKING

Live working is to be discouraged and the Electricity at Work Regulations 1989 make this very clear. But how do you know if the circuit is live?

Intek Instruments have designed and manufactured low cost products to overcome this problem. The use of their noncontact voltage indicators could save lives. A simple check is required to detect the presence of voltage prior to cutting a cable. Alpha Electronics have these products available to indicate and detect live or dead cables, blown fuses, breaks in conductors and the presence of magentic fields.

TEK 100 is a low cost non contact Voltage Indicator for conductors energised at voltages in the range of 100V to 600V AC. Both audible and visual warnings are given via a 3kHz tone and a red LED. Other useful features on this hand held battery operated unit, include a safe self-test facility. Model TEK 200 is similar but has the added ability to determine and display the polarity of magnetic fields found with inductors, relays, solenoids and transformers operating at both low and high AC and DC voltages. TEK 600 is a Buried Cable and Pipe Detector that reliably locates live and dead cables through a variety of building aggregate and sub-surfaces, including foil- backed plasterboard. Cables situated in close proximity to ferrous and non-ferrous metals, framework and boxes can also be located, an application not normally available with conventional methods. Prices (exc. VAT) are: TEK 100 £19.99; TEK 200 £29.99 and TEK 600 £59.95.

ETI

NEWS

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Measuring shock waves in solids

Explosive shock waves are often used to study the properties of solids. It is, however, necessary to calibrate instruments frequently when measuring waves with current 20-year-old devices.

Sandia National Laboratories of Albuquerque, says it has solved the problems encountered with older instruments by building a new set up based on optical-fibre technology. The new system is safe, more compact, and less complex than earlier systems.

The Velocity Interferometer System for Any Reflector (VISAR) measures high-pressure shock wave phenomena in solids. It gauges velocities ranging from tens to thousands of metres per second using a modified Michelson interferometer. The interferometer determines the Doppler shift of light reflected by fast-moving objects.

The VISAR consists of an intricate system of beam splitters, mirrors, and optical delay elements all mounted on a table. The 'breadboard' arrangement, which occupies about 12ft^3, allows the VISAR to be reconfigured to measure a wide range of velocities and accelerations. However, this flexibility can also be a disadvantage because the components require frequent precision adjustment to maintain alignment.

Sandia engineers have developed a VISAR with all key parts incorporated into a single unit that occupies only 1ft^3. The 'fixed-cavity' VISAR does not require frequent readjustments, and is easier to use and less expensive than the breadboard system.

In the fixed-cavity system, light beams are routed from laser to test target surfacer to interferometer through optical fibres. Besides allowing engineers to reduce the VISAR in size, it lets them locate the interferometer, photodetectors, amplifiers, recording equipment, and laser far enough away from the test target and any large electrical noise sources to prevent electromagnetic waves from interfering with measured data. In addition, the fibre- optic arrangement reduces an eye hazard by confining highpower laser beams.

Energy efficient metering pump

An electronically driven metering pump is claimed to be more energy efficient than a motor-driven one because the signals used to govern the diaphragm are easily computer controlled and counted. The pump is also powered for less than 0.1 second, using current only when a stroke is produced. Total power consumption is said to be less than that of a similar-size motor-driven pump.

Called the SysteMatic pump it is driven by a solenoid. Control circuits switch the solenoid on and off. When the solenoid is on, the magnetic field generated attracts a large steel component called a clapper. When the solenoid is switched off, springs return the clapper to its original position. The back- and-forth movement of the clapper controls the pump diaphragm through a connecting rod. Stroke length, and hence pumping volume, is adjusted by limiting clapper return.

Models in the SysteMatic Pump line vary in capacity. One has a maximum discharge pressure of 300 psi, higher than the 100-psi maximum of most other metering pumps. Another has a delivery rate that ranges to 20 gal/hr. Strokes/min on some models ranges to 100. All pumps operate with a ±1% precision.

Applications for the pump include water chlorination and pH neutralization, as well as pharmaceutical processing. By changing the diaphragm, the pump can handle reagents, solvents, and a variety of suspensions.

Luft Instruments Inc., Lincoln, Massachusetts.

Possible replacement for superconductors

A new composite of ceramic powders and polymers has magnetic- levitation properties similar to superconductors. Unlike hard superconducting ceramics, however, the material can be machined, moulded, and extruded easily. It also does not have to be fired at high temperatures. Such parts could replace superconductors in applications such as magnetic-levitation trains.

The composite, developed at the National Institute of Standards and Technology, is a mix of superconducting ceramic particles and polyvinylidene fluoride. The material itself does not conduct electric current, but when a magnetic field is applied at superconducting temperatures (below -297F), current flows around the surface of each ceramic particle embedded in the polymer. Each current creates an opposing magnetic field. The sum of all the currents produces a field large enough to levitate the composite.

According to NIST, the composite's levitation force is less than that produced by a pure superconductor of the same size. However, because the density of the polymer is much lower than that of the ceramic, parts made from the composite will be lighter and require less force to levitate.

Another benefit is the composite's thermal and mechanical properties, which permit repeated cooling and warming without physical damage.

Streamlining robotic welding

It is often necessary for process engineers to spend up to eight hours studying and designing a robotic line for welding.

A new software package promises to streamline these tasks and reduce engineering time to minutes per welding point. The package, from Technomatix, Novi, Michigan, is an extension of its Robcad robot simulation software.

To use the welding software, process engineers must have access to CAD data for the workpiece. The programme gives the engineer a means to define each weld point then automatically assigns cross sections of the welding robot to help determine how the robot gun will approach the workpiece. The programme also automatically checks for collisions between the gun and workpiece or fixtures.

Software allows users to determine robot placement in three ways. First, users can lock the gun on the welding point, and position the base. Second, users can locate the base, and the software will show each welding point that can be reached. Finally, welding points can be assigned, and the system will indicate the exact range of possible base locations.

Thin film coating process

A thin film coating process permits fully-automated deposition of precisely controlled metal or dielectric coatings at high rates. The cold process allows flat and irregular shaped substrates such as glass or plastic to be coated at or near room temperature, eliminating the need for heating and cooling cycles.

Lenses, lamps, reflectors, cylinders and even optical fibres can be coated with precise optical uniformity. Temperature-sensitive substrates, not easily coated with other processes, are suited to the MetaMode process.

Possible applications may also include the field of electronic components, high-temperature superconductors and semi-conductors.

Optical Coating Labortory Inc., Santa Rosa, California.

9 High Definition Television

James Archer takes a glimpse into the future where perhaps no HDTV standards will be required.

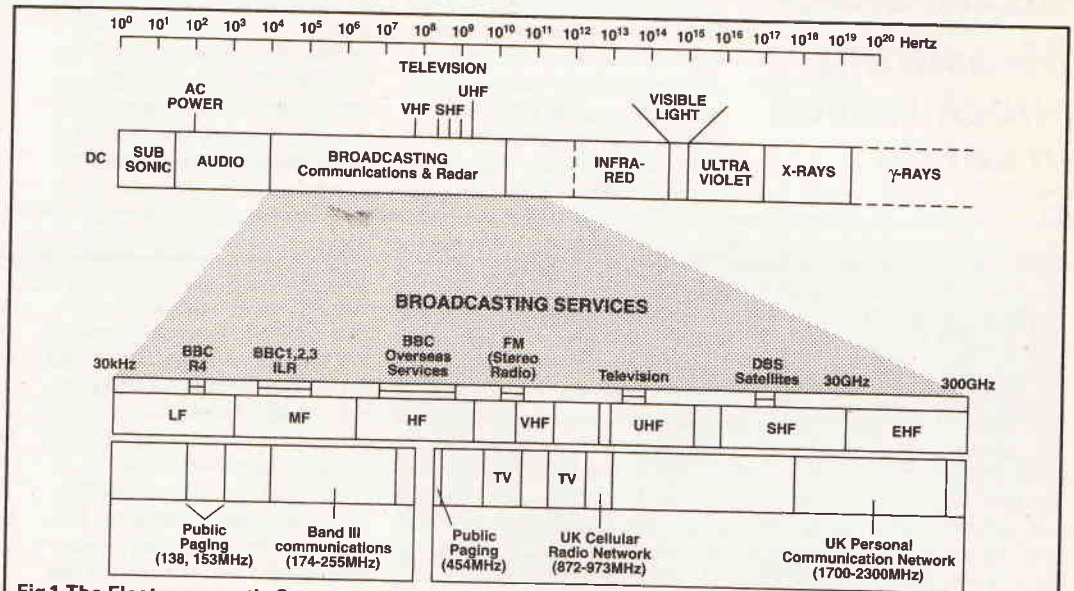


Fig.1 The Electromagnetic Spectrum

As we enter the twenty-first century, many of the problems and difficulties which are today regarded as basic to the whole subject of HDTV may well disappear or become insignificant and unimportant as changes in the various technologies surrounding electronics, computers, and broadcasting open up a whole new range of possibilities.

Spectrum Utilisation

All existing broadcasting systems have been designed to make the best use of a limited amount of frequency spectrum; whether transmitted over air, via cable, or by satellite, the limited bandwidths available in the relatively low frequency bands that are currently used have meant that it was essential to make any television signal occupy as little bandwidth as possible. During the next few years it will become possible to build consumer equipment that operates in frequency bands much higher than anything currently possible, and the advantage of using these higher frequencies is that since they are currently virtually unused it should be possible to provide much larger portions of the spectrum at these frequencies for broadcasters to use. A good example is the band of frequencies that has been allocated by the UK government for the provision of Microwave Video Distribution Systems; the band from 40-42.5GHz is 2,500MHz wide, which could allow for dozens of different conventional television signals to be transmitted, or even for the transmission of a number of wideband HDTV transmisions, each of which might take up perhaps 100MHz in its radio frequency form. The availability of such large amounts of bandwidth should also make possible the transmission of digital television pictures; we saw when considering the digital studio standard, CCIR Recommendation 601, that some 216 Mbit/s of data were required, needing over 100MHz of radio frequency spectrum if no bit rate reduction techniques were to be used, depending upon the modulation system. Digital transmission at frequencies above 40GHz would therefore be possible — there are already international frequency allocations for television use between 41 and 43GHz and between 84 and 86GHz, and as manufacturers improve their ability to produce, in quantity, equipment that works at higher and higher frequencies, at prices which appeal to the domestic consumer, digital transmission and reception could be become practicable.

Spectrum Conservation

Just because larger amounts of the spectrum will become usable, however, it does not mean that we should begin to treat the spectrum in a profligate way; our current thrifty habits of only using as much of the spectrum as absolutely necessary should be retained. The spectrum is a finite and very valuable resource, and in a world where conservation is now very much in fashion,spectrum conservation and the avoidance of 'pollution' -interference to and from other users of the spectrum — should be avoided. It is therefore important to note that although a single digital signal can take up more radio frequency channel space than its analogue equivalent, if a completely digital broadcasting network is carefully planned it is possible to interleave digital signals and to use bit rate reduction techniques which permit the overall usage of the spectrum to be extremely efficient. Other advantages of digital transmission could include an improvement in coverage and signal quality — so long as the digital signals can be received with an acceptable number of errors it is possible for the receiver to rebuild perfect pictures, even though the actual field strength of the incoming radio frequency signal is low.

Once a television signal is in digital form it may be regarded as any other digital signal, merely a set of numbers appropriately placed in a large computer store, and such signals can be processed by computer circuitry which was originally intended for 'number crunching' applications. As we have seen already, the numbers to be 'crunched' when dealing with digital television are large, but modern computer chips can cope with the data rates involved. Treating digitised television pictures as numbers in a computer allows for the generation of the many special effects that seem to be indispensable to today's 'withit' programme director by the application of mathematical processes to the numbers in the field stores, but it is the wider implications of this type of treatment that are likely to affect the future of HDTV as we know it.

Digital Storage—The Frame Store

Throughout the 1980s the possibility of using complex signal processing in the receiver in order to provide improved displays was well known, but the cost of the necessary field stores proved too great to allow for their incorporation in domestic receivers. As the fabrication skills of the semiconductor manufacturers continue to improve, with line thicknesses down to 0.5 microns now feasible, the amount of digital storage that can be squeezed onto one chip continues to increase, year by year, with 1990 seeing single chips containing 16 Megabytes being developed in research laboratories, and X-ray fabrication promising line widths of less than one tenth of a micron in a year or two's time. As the amount of storage per chip rises so the cost per bit stored falls. Although the 'ten dollar frame store' has become somewhat mythical in the industry because it has been promised for so long, the early 1990s are likely to see the cost of frame stores reduced sufficiently that manufacturers can afford to incorporate them into the 'top of the range' television receivers, and already a few receivers of this type are on the market.

HDTV — Already Passe?

As we have studied the various possibilities for providing HDTV in the next few years we have seen that virtually all the different proposals are merely extensions and developments of existing methods of creating and transmitting television signals; indeed, when discussing the European EUREKA EU95 approach to HDTV and some of the American proposals, we made a positive virtue out of the fact that the systems were step by step developments of current systems. The trouble with this approach is that any new system is likely to retain some of the basic disadvantages of its predecessors. Since present day colour television systems are virtually all based on systems that first saw the light of day in the 1950s, there is a certain amount of truth in the allegation that most current HDTV plans are merely replacing the technology of the 1940s with that of the 1980s, whereas we shall be well into the nineties before HDTV reaches our homes, and probably well into the next century before HDTV becomes the norm. Every scientifically inclined schoolboy knows that the current method of sending television signals is wasteful and that the picture signal contains much redundancy; if we were starting completely from scratch we would surely not send virtually the same picture every twenty-fifth of a second, we would merely send the small amount of information needed to update the changes that occur in the picture from one frame to the next. It is this type of thinking that is leading to the adoption of computer techniques in attempts to provide the HDTV systems for the next century, and it may well turn out that the HDTV systems we are currently having such trouble in sorting out are quickly overtaken by these new techniques as we move through the next decade; if the current HDTV systems have not become well enough established by then some of them may never reach the market.

HDTV — Just Another Computer Program?

No matter how we dress up the ideas for new HDTV systems, we cannot get away from the fact that they all require computer storage and processing circuitry in the receiver if HDTV images are to be displayed, and this means that the dividing line between television engineering and computer technology is now becoming blurred. The computing power to be found inside current HDTV receivers is substantial when compared with the small amounts that have previously been required, for teletext and the like, but it is still small when compared with advanced computers. Engineers who have grown up in computing, rather than in broadcasting, are now starting to think about adopting a different approach to HDTV; why not forget the existing television receiver circuitry, which has over the last fifty years evolved from its prehistoric (well, almost!) predecessors which had glowing valves and turret tuners , and instead consider the television receiver as a powerful computer with a high quality display? We saw in an earlier article in this series that researchers from the Massachusetts Institute of Technology favoured 'smart receivers', having an 'open architecture'; they have now gone further along this road, and Nicholas Negroponte of their Media Laboratory has been quoted as saying 'the TV set will probably have 50 Megabytes of random access memory and run at 40 to 50 millions of instructions per second'. This is basically the equivalent of today's 'supercomputers', such as the Cray, and although such figures might seem incredible it is generally accepted that within the next five or six years this level of computing power will be available for image processing in receivers, and that the cost could be within the reach of many consumers.

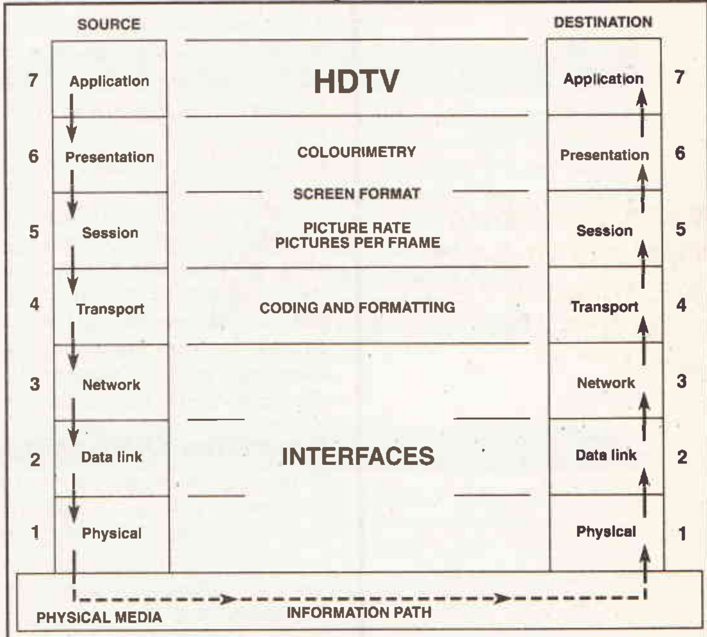


Fig.2 How a layered architecture using the ISO seven layer model may be applied to a digital HDTV system

Consider what happens if such computing power is put into the central stage of the MIT 'smart' receiver discussed in the previous article. As well as being able to deal with incoming signals from the usual sources the receiver would be able to take digital transmissions directly into its computer section, and would be able to provide sufficient processing power to synthesize a high definition picture from many different input signals. Digital compact disc video players which hold their data in a highly compressed form could again be connected directly to the digital bus, and the processor could provide cinema quality pictures on the screen. HDTV pictures could be produced from a wide range of different input sources, the appropriate computer program being used to turn the incoming signals into the best possible displayed images; the viewer selecting an HDTV programme could have his actions mirrored by the receiver automatically selecting the appropriate computer program in the processor!

Telecommunications And HDTV

We have so far considered various possible sources of digital television signals, from satellite and wideband cabled distribution networks to compact discs, but there is an even more likely contender lurking in the wings. In many parts of the world the telecommunications authorities are currently upgrading the existing analogue telephone networks to digital form, which will not only improve the quality of the received signals but will also allow for the introduction of many new services and facilities. One of the first stages is the introduction of ISDN, the Integrated Services Digital Network, which can generally provide two telephone channels and a limited amount of data transmission (typically 64 or 128 Kbit/sec) using the standard copper telephone cables to bring the services into the home or office. There is insufficient data capacity in the ISDN to transmit standard television signals, but already plans are being laid throughout the world for the eventual introduction of digital broadband networks which would be capable of carrying digital HDTV signals as well as all the telephone based services. The organisation of data for use in transmission networks such as these broadband ISDN networks has already been well documented by the International Standards Organisation OSI, and the architecture for information transfer is expressed as a seven layer model. An advantage of using a layered model is that it enables the various parts of the transmission and processing system that will be required for HDTV to be separated so that any particular difficulties may be isolated and dealt with separately.

The transmission of HDTV signals can be seen as just another application which needs data to be transmitted from one place to another, in our case, from studio to veiwer's home. Figure 2 shows the various layers as they are defined for telecommunications use, on the left and right hand arms of the diagram, whilst the ways in which each of the layers might be seen to correspond with an HDTV system are shown in the centre of the diagram. This apparently rather abstract approach allows us to deal with digital HDTV signals that may be transmitted in many different formats, and which, after processing may be turned into several different types of display, making use of the open architecture receiver techniques that were discussed earlier.

The seventh layer of the model is concerned with the use of information at application level, effectively the output from the system, or the input from the source, depending upon the point of view; it is called the 'application' layer, and this represents HDTV in our case.

The sixth layer, called the 'presentation' layer, is the layer which is concerned with the conversion and presentation of information. For our purposes this includes such things as the number and layout of the pixels which will make up the eventual display (i.e the active pixels), the number of lines in the picture, the colorimetry of the display, and its aspect ratio.

The fifth layer, known as the 'session' layer, is concerned with the selection of information and access to it; for us this means the rate at which pictures, as defined in level six, pass through the system. Since in television similar pictures will often occur one after the other, which allows some spatial/temporal processing to be carried out, it is usual in this context to consider pictures as though they were grouped in 'frames', although it is important to note that this use of the word 'frame' is subtly different from the normal usage, which can lead to confusion. In the present case a frame may be made up of any whole number of pictures, and if we take the case of a standard 2:1 interlaced picture as an example, we would consider this as having two pictures per frame, each one coded so that only every alternate line was transmitted.

The top three layers, five, six, and seven, are essentially transparent to the data, ie data transfer takes place in the same manner, whatever the type or source of the original data. Any standards conversions that may be necessary take place in the lower levels, which can be considered as interfaces which define the logical and physical ways in which the information will be carried from transmission source through the transmission path to the eventual display.

As Figure 2 indicates, the fourth layer, transport, is concerned with the identification of groups of data, which for our television application means concerned with coding and formatting the video information. It is in this area that any bandwidth reduction that is needed, for instance to convert a high bandwidth studio signal to a signal which can be transmitted over a network of lower bandwidth, is carried out; another way of looking at this layer is as the area where the matching of the video bit rate to the channel bandwidth is carried out. We mentioned in the previous paragraph the concept of pictures being transmitted in 'frames' with regard to the session layer, but it is interesting to consider that level four can be used to provide bandwidth reduction, and since the use of interface can be considered as a simple form of bandwidth reduction, vertical subsampling of a progressively scanned picture in level four could be one means of achieving an interlaced picture.

The lowest levels, three (network), two (data link), and one (physical), represent interfaces between source, transmission and display, and different interfaces can be defined for different transmission requirements, whilst the transparent nature of the higher levels means that a common studio production standard or at least a common studio interface standard could be achieved. This idea would enable different scanning formats, such as 50Hz and 60Hz television to be used, so long as the information in the sixth (presentation) layer could be agreed upon, so that appropriate data formatting could take place in level four.

This necessarily brief overview of the use of the ISO seven layer model and its possible applications to television is not meant to be anything more than an introduction to the idea that the coming of truly digital television could enable huge strides to be taken towards world standardisation.

The Ultimate Goal — HDTV Without Standards.

The basic concept of the television system of the future being all digital and utilising computer data transfer methods and receivers which are totally different from today's, should allow for the dream of a universal television system to be realised. If tomorrow's receiver is 'merely' a supercomputer on a few chips with a vast choice of separate or integrated high quality displays available to suit every living room and pocket, then no matter what type of digital data is fed into it the computer will be able to sythesize the best picture possible from the available data. Taking this scenario we are effectively letting technology carry out the work that has so far failed to be satisfactorily achieved by the world's standards committees; in a world where we have become used to allowing the computer to carry out repetitive tasks so that people can be freed for more cerebral activities, surely this computerised approach to HDTV, rather than interminable arguments about whose system is best, represents the real way forward.

READ\WRITE

ETI LETTERS

CQ-CQ 3cm Will Do

With reference to Geoff Heys' article on Amateur Microwave Equipment (ETI July 91), may I first thank him for a concise introductory article on some aspects of amateur microwave activites. A veritable 'quart in a pint pot' effort — well done, I wouldn't have attempted it.

I use *some* aspects advisedly. Accepting that it is impossible to comprehensively review such a wide radio-spectrum allocation in four pages of text and figures, there are inevitably unintentional omissions. This is particularly true at a time when amateur experimentaition is burgeoning because of new, inexpensive devices, such as surplus GaAs FETs, satellite TV dishes and LNBs, to say nothing of amateur-generated, advanced technology microstrip PCB designs.

Two questions I often get asked are: "Where can I get information on microwave designs?" and "Where can I get microwave components?". May I be permitted to answer these questions via your column?

The first is easy to answer. There is now a comprehensive three volume Microwave Handbook published by the Radio Society of Great Britain. Others are available from the American Radio Relay League and the German Amateur Radio Club. There is also a ten-issues per year informal 'Microwave Newsletter' available from the RSGB. Naturally I recommend the UK information, since there may be difficulty in obtaining some American or European parts, particularly semiconductors.

The second is reasonably easy to answer. The RSGB Microwave committee runs a limited service to resource many of its own designs and also maintains a list of other suppliers prepared to sell on a 'one-off' basis. Whilst these services are intended primarily for RSGB members, we are always willing to assist wherever we can. If any of your readers are interested, I would suggest they drop me a line (with an SAE please) and I will try to ensure that the information required is made available.

Mike Dixon G3PFR,
Chairman, RSGB,
Microwave Committee,
'Woodstock', Gaze Bank,
Norley, Warrington,
Cheshire WA6 8LL

CQ On Video Too

Being early retired but still very young at heart, it seems that people with hobbies similar to my own are somewhat thin on the ground. In fact the people that I already know, regardless of their age, have no creative hobbies or interests whatsoever; this applies whether they are in paid occupations or not. Now that I have more time to spend on hobbies, which have expanded since my retirement, it would be more satisfying and stimulating to exchange ideas and experiences with other people who have hobbies of mutual interest.

My main hobbies are radio and electronics, with particular emphasis on DX (long.distance) reception of radio and television signals; I am also very active with creative tape recording, both audio and video.

It would be nice to correspond with like-minded people, initially by letter but subsequently on C60 cassettes through the post; average inland postage for a C60 is only about 35 pence, and airmail postage to North America about £1.00. Even home videos (VHS-C) using EC30 cassettes can be exchanged in this way. If interested readers would care to write to me, initially, I would happily compile the first tape (stereo) and start the ball rolling.

Ivor Nathan,
40 Orchard Ave,
Southgate,
London N14 4ND

Not So Easy PC

Although we receive your magazine later than most being overseas, we would like to thank you for an excellent magazine.

In the advent of PC board design CAD systems it is now easy to design a PC board layout. One problem though is how do you make good quality positives cheaply? If they are made commercially they cost a fortune. How can it be made cheaply? Could you please publish an article on the topic. I would build a lot of projects if I could make the photo-positives cheaply.

A D Carstens, South Africa

A very good question Mr Carstens. There are a few suppliers of special positive making kits but alas they too tend to be expensive. The problem centres around obtaining lithographic film (the sort that develops to give completely dark and transparent areas)in small quantities. The individual does not want and cannot afford to buy a box of 100 x A3 or A4 size sheets. One or two sheets is more than adequate for proto-typing needs. If you happen to know a nearby printer or typesetter you might be able to negotiate with them for small amounts. From then on the rest is easy. The great bags of developer will last a cosiderable time. I used to cut up a piece of film, put into my 35mm SLR camera, take the shot of the paper positive, develop into the negative, put into an enlarger and enlarge up to the same size for the final positive.

Another trick but by no means anywhere near as satisfactory is by the use of thermal transparencies. The paper positive is fed into a thermal copier machine with heat sensitive celluloid and out comes a useable positive film. Combining two exposed sheets will give a greater contrast.

It has been suggested that ETI publishes the foils on acetate sheet. This is a great idea and would save a lot of work but again the cost is too high for us in production terms. — Ed

Maths — No Problem

I have in front of me, the June 1991 issue of ETI. I would just like to say that it is most refreshing to see an electronics magazine prepared to tackle the more mathematical side of the subject, when so many of your competitors are simply turning into listings of projects.

In particular, I am referring to the article regarding the design of RIAA equalisation networks. Although the article consisted of only a double page spread, it managed to cover the use of Laplace variables to solve the design of C-R networks for a given response. As a student of electronic engineering, I found this most interesting — the mythical 's' variable is useful after all!

All in all, a very well balanced magazine; not frightened off by mathematics!

M J Pomeroy, Lichfield.

PROJECT

1

The Nightfighter

Overall System And Master Controllers

Iike Meechan describes is very powerful nodular lighting control ystem

At the time of writing, there are in existence a great many mobile discotheques which boast variable-speed turntables, VCA-controlled mixing desks, digital delays and sound processing equipment which when coupled with the latest in compact disc technology and powerful but compact PA systems bring concert hall realism to the mobile roadshow.

Sadly, luminaires and lighting controllers, as far as the mobile DJ is concerned, seem in the main to be locked in the seventies era of flared trousers, platform shoes and three or four channel 'modulators' as they are sometimes pompously known. Whilst the disco industry evolves new effects on a monthly basis (albeit based on the humble PAR 36 pinspot or involving the use of waggling mirrors), the mobile DJ is offered what the author considers to be obsolete equipment in the light of current technology (if you'll pardon the pun!).

Despite this, all is not doom and despondency since this series of articles will hopefully redress the balance and bring the quality and dynamics of the lighting control equipment used in the most up-market and state-of-the-art nightclubs within the grasp of the mobile DJ for a capital outlay of little more than that necessary to buy commercially-produced, run-of-the-mill controllers.

The circuits described here are of a modular nature, catering for a multitude of different configurations and giving absolute flexibility, since it allows the system to be expanded and improved as and when this becomes desirable and/or economically viable.

Recent developments in commercial lighting control almost exclusively feature physically separate but electrically-linked control and mains switching electronics, promoting flexibility and power handling capability since extra power packs can be added at a later date and the original display supplemented without the risk of initially purchased control equipment being made redundant. The improved safety aspect cannot be too overstated either.

The featured units all embody this design philosophy and are also housed in rugged 19" rack mounting cases which should be more than able to endure the rigours of mobile work.

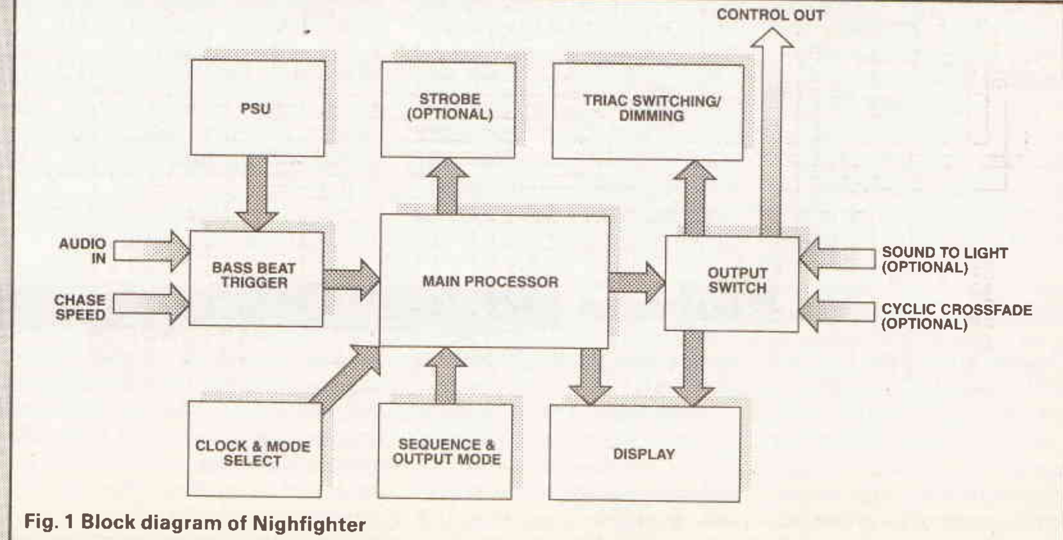


Fig. 1 Block diagram of Nighfighter

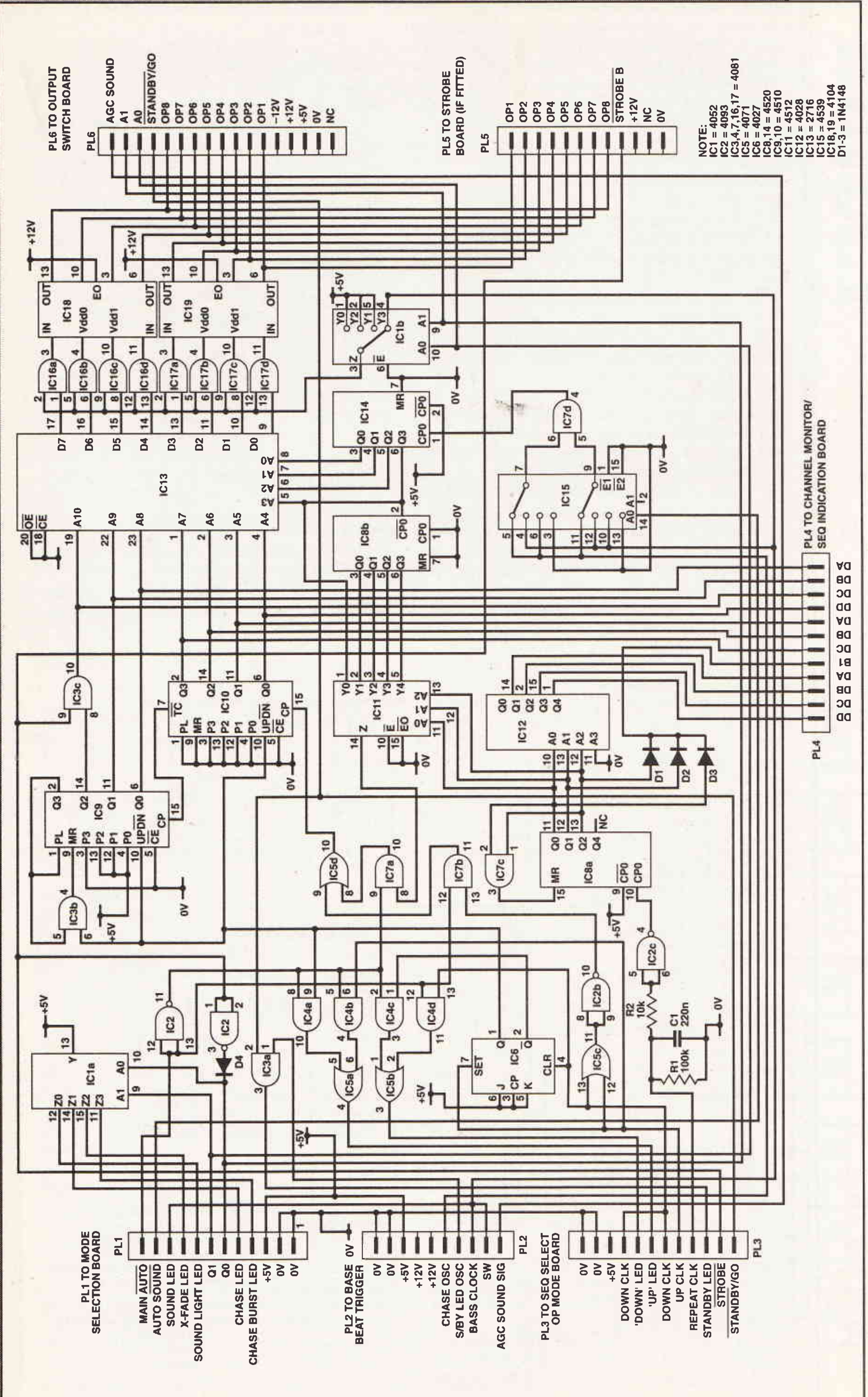


Fig. 2 Circuit diagram of main processor board

The master controller and sensor switch can also be easily interfaced with any commercial switch/dimmer packs which the reader might already possess and conversely, the dimmer packs may also be used with most low voltage commercially-produced control equipment, thus allowing the units to be integrated into an existing system with the minimum of fuss.

There are three main component units of the system:—

- Master Controller
- Sensor Switch
- Dimmer/Switch Pack

The first of these, the master controller incorporates all of the latest features in a unit of this kind including:—

- 8 channel digital (chase) or 4 channel analogue (sound-to-light) operation.
- Test sequences of all lamps on and all lamps off.
- 78 x 16 step sequences (numerical indication of sequence in operation).
- Manual or automatic sequence select, up or down.
- Selectable sequence repeat before incrementing/decrementing to next/last sequence.
- Options of 8 channel dipless cyclic crossfade, 8 channel strobe boards.
- True low voltage, isolated control with a number of options (control and power switching boards mounted in same or separate cabinets (power switching boards may be configured for either zero-voltage switched or full phase-controlled dimming) selectable input sensitivity.
- Sophisticated bass beat detection for triggering of sequences, fully variable between one and fifteen steps per beat.
- AGC on bass beat trigger and sound to light eliminating need for continual adjustment of sensitivity for optimum effect.
- Internal auto clock.

The sensor switch is an optional unit, connected between the master controller and any switch or dimmer pack(s) to enable touch sensitive enabling of the outputs. It can also be used as a stand alone unit (when fitted with its own self-contained zero-crossing switch pack) for control of smoke machines, motorised effects or static lights such as UV tubes. It has its own inbuilt chaser with each of the 8 channels able to be switched in or out of the chase, a memory function which allows selection of the next set of outputs to be switched on (or off) whilst maintaining the present selection and a touch sensitive latch/flash keyboard.

The triac packs can be configured as zero voltage switch packs or fullwave phase control dimming packs (triac conduction angle determined by a remote DC control voltage). This unit may have individual channel dimmers, a master dimmer or a combination of both whilst the triac supply is directly accessible, allowing control of any AC voltage between 24 and 240V.

Now that your appetites are sufficiently whetted, get out of the Dark Ages and into the Light with The Nightfighter.

The Master Controller is the only indispensable item of the three and so will be covered first.

The Master Control section comprises six PCB assemblies, three for the front panel displays and push-

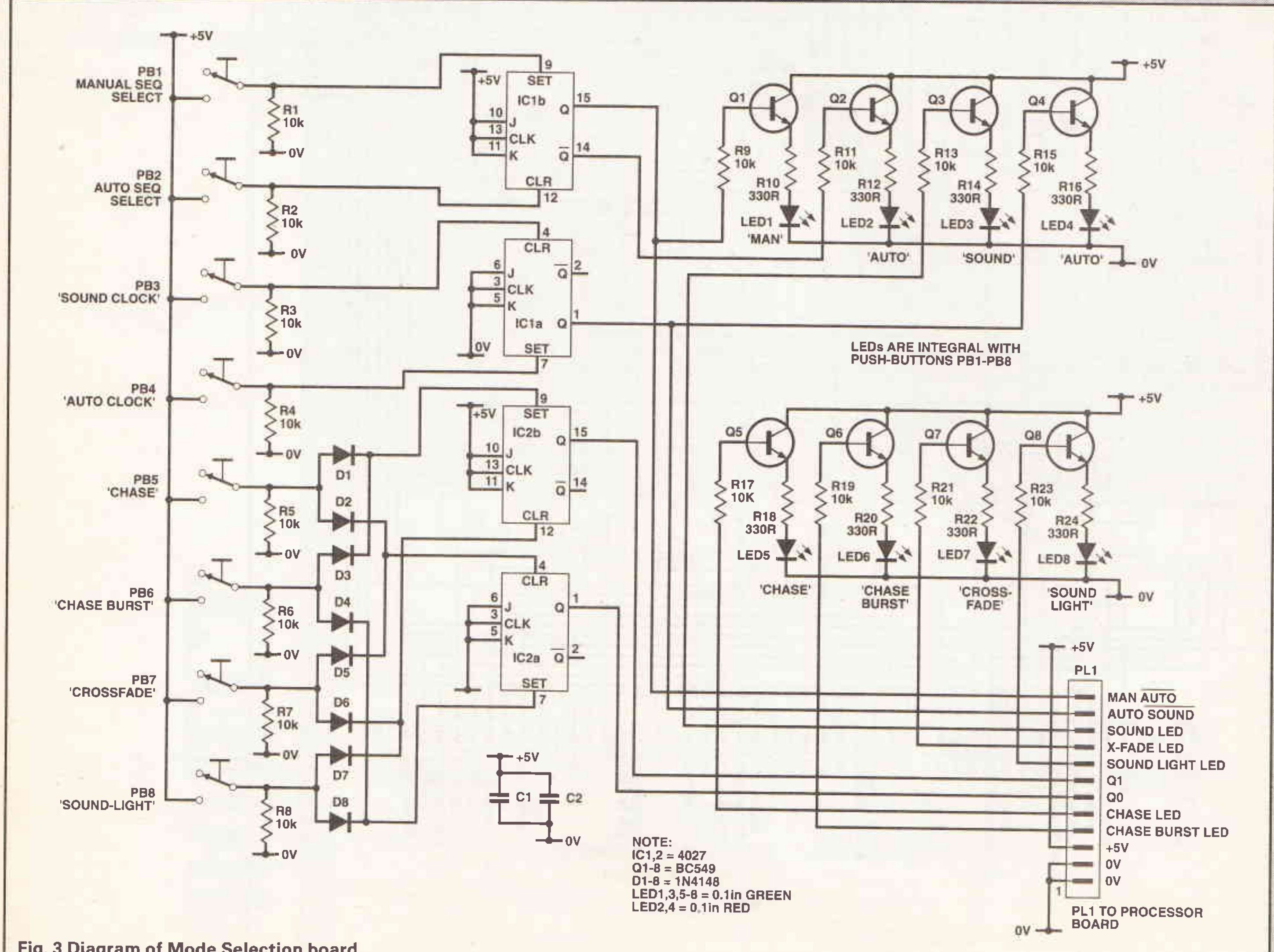


Fig. 3 Diagram of Mode Selection board

PROJECT

HOW IT WORKS

MAIN PROCESSOR (Figure 2)

The sequences are stored in IC13, a 2716 2K EPROM. Address lines A4 to A10 determine which program (sequence) is running and AO to A3 determine which if any, lights (outputs) are on at a particular part of the sequence. The EPROM is addressed on the upper address lines by IC's 9 and 10 and by IC14 on the lower address lines by IC14. IC14 is a dual binary counter clocked by the bass beat trigger output, the internal clock or by a combination of both, the bass beat enabling the oscillator. The clock mode is selected by IC15, a dual 4 input multiplexer addressed on one line by the SOUND AUTO signal and on the other by the switch incorporated into the SPEED control.

A4 to A10 are addressed by two cascaded, presettable, up/down BCD counters which are clocked either manually or automatically depending upon whether MAN. or AUTO. SEQ. SELECT is operating. In manual mode the clock signals generated by the dual timer IC1 on the MODE. SELECT board are routed via IC5c, IC5d, IC7a and IC7b to the clock input. Count up or down is determined by the Q output if IC6 bistable which is set or cleared by these same clock pulses. The pulses are inverted by IC2b so that the leading edge of the original pulse sets the flip-flop before the trailing edge clocks the counter IC10 up or down. In AUTO SEQ SELECT the Q4 output of IC14 is used to clock (on the trailing edge) another dual binary counter IC8. Q0 to Q3 of this IC are then inputted (along with the original Q4 signal) to 5 inputs of IC11, a 1 of 8 demultiplexer. The demultiplexer output is switched via IC7a and IC5d to the IC10 clock input. A0 to A2 select which of the divided-down clock signals is routed through IC11, these lines being addressed by the other half of IC8 binary counter. This is clocked by the debounced version of PB3 REPEAT key on the SEQ SELECT board. The counter is made to reset on binary 101 by IC7c. A0 to A2 are also used to address another decoder, IC12. Q0 to Q4 of this IC go high in turn as we increment the address and so provide a 1-3-4-8 code for the REPEAT RATIO BCD-7 segment decoder IC1 on the Channel Monitor board. An ORed version of these address lines is used as a blanking signal when no repeat is selected.

IC3b resets IC9 to zero after a count of 79 is detected when counting UP and parallel loads 79 after zero when counting DOWN. IC3c forces A10 low when STROBE ENABLE is low, thus restricting the available sequences to the lower 40 when STROBE is selected.

IC16 and IC17 provide the CHASE-BURST function, ANDing the bass beat with the EPROM outputs DO-D7 when CHASE-BURST is selected. At other times, these second AND inputs are held at logic one by IC1b analogue multiplexer.

Finally, IC18 and 19 provide level-shifting from +5V to +10V for inputting to the OUTPUT SWITCH board.

MODE SELECTION BOARD (Figure 3)

PB1 and PB2, and PB4 and PB3 set or clear IC1b and IC1a respectively, selecting MAN or AUTO SEQ SELECT or SOUND or AUTO CLOCK. The Q outputs of these bistables are bussed to the main processor board, while connections to these and the Q outputs provide visual indication of selection via Q1-Q4, LED1-LED4.

PB5 to PB8 inclusive are the controller OUTPUT MODE switches. Each switch controls both IC2 bistables, the combination of SET and CLEAR for each switch setting a unique 2-bit binary code on the Q outputs. This code addresses the 4-input multiplexer IC's 1 to 4 on the OUTPUT SWITCH board and selects which of the three signal sources is routed to the STANDBY/GO bilateral switches, ICs 6 and 7. A2 to 4 line decoder, IC1a (situated on the Processor Board) lights the appropriate LED (LEDs 5 to 8).

SEQUENCE SELECT/OUTPUT CONTROL BOARD (Figure 4)

PB1 and PB2 are incorporated into a dual debouncer circuit comprised of IC1, a 556 dual timer and associated components R5-R10 and C1, C2. Both debounce circuits are identical so only one will be described. PB1 is normally closed and in this standby state, holds the timer in a low output state by grounding the reset input. When PB1 is pushed, the output will immediately flip positive, since R1 pulls the reset input high, and the low input to the timer commands a high output (since reset is no longer overriding as was the case with PB1 closed). The timer then begins a monostable timing cycle which will be of conventional width, T=1.1RtC.

Should PB1 bounce during the high output state of the timer it has no influence since both the reset input and the output are now high. When the monostable period ends, the output low state resets the circuit to standby (assuming PB1 released and closed again). If PB1 is held down the circuit is a simplified astable and will repeat at a rate set by Rt and Ct such that f = 0.721Rt as in the standard astable of this type.

PB3 simply provides a pulse for the REPEAT RATIO debouncer/decoding circuitry mounted on the Main Processor Board. PB4, PB5 and PB6 work in conjunction with IC2 dual bistable to provide STROBE and STANDBY/GO signals. PB4 clears bistable 1 whilst setting bistable 2 so that the main output lights are blacked out when STROBE mode is invoked. Only by pressing PB6 'GO' can this state be released and normal operation resumed. Pressing PB5 when not in STROBE mode sets bistable 2 thus forcing the STANDBY/GO line high and enabling the STANDBY LED oscillator. The Q and Q signals of IC2a and IC2b respectively provide the drives for the STROBE and GO LED'S.

CHANNEL MONITOR AND DISPLAY BOARD (Figure 5)

The display board consists of three BCD — seven segment decoders, three seven segment displays and eight LED's and associated transistor drivers. The seven upper address lines of the EPROM are paralleled off to PL1 and then to IC1 and IC2 which convert the 1-2-4-8 BCD to a two digit SEQ. RUNNING display. The REPEAT RATIO display is fed from IC3 which is in turn fed from IC12 on the Main Processor Board.

The CHANNEL MONITOR LED's derive their drives from the OUTPUT SWITCH board prior to the STANDBY/GO bilateral switches, IC's 5 and 6 so that a valid display is always present although the main output may not be enabled. These LED's do not reflect the true state of the output channels when in CROSSFADE mode because of the simple drive techniques employed. Some indication of fading is apparent.

OUTPUT SWITCH BOARD (Figure 6)

The output switch is basically a three pole, eight way switch in series with an eight pole on/off switch. IC's 1 to 4 are dual 4-input analogue multiplexers which route one of four inputs to the output depending on what 2 bit address is presented to A0 and A1. This 2 bit address is generated by the MODE SELECTION board and determines which of the three sources, CHASE, CROSSFADE, or SOUND TO LIGHT is selected as the output. (The EPROM data lines occupy inputs two and four, crossfade is on input one and sound to light is on input three). The address lines and output enable lines from the Master Control Board are level converted from 0-5VDC to 0-10VDC by IC5 low to high translator before application to the address lines of each multiplexer IC. The outputs of these IC's are used to drive the CHANNEL MONITOR LED's. These signals are also applied to IC6 and 7 switches which are enabled by the STANDBY/GO control line. This control line is sent off-board and returns via JK2 REMOTE DISABLE jack socket. Inserting a jack-plug into JK2 breaks this signal away from the contacts and releases control of the switching action of IC's 6 and 7 to an external control voltage (the Sensor Switch touch panel).

BASS BEAT TRIGGER (Figure 7)

The stereo input signal from the rear panel AUDIO INPUT jack socket JK1 is applied to IC1a, a virtual earth summing amplifier with a gain of 3. IC1b is a Sallen and Key low pass filter which derives the bass content of the signal and passes it to an AGC amplifier IC1c (constant current source Q2 charges capacitor C5 to a DC voltage proportional to the magnitude of the output signal. This voltage alters the drain/source resistance of Q1 MOSFET and thus the gain of the amplifier).

This gain-controlled bass component of the music signal is then full wave rectified by IC2a and IC2b before passing through the time constant network/shaping circuit of R18, C7, R30 and C8 and hence to IC2d, a Schmitt trigger/comparator whose threshold level is set by PR1. R35, 36, and 37 provide positive feedback and so a measure of hysteresis. The signal then charges C9 and is used to trigger monostable IC5 and produce a pulse of approximately 0.25s long which can now be used as a clock for the digital system and less importantly to drive the SOUND LED on the MODE SELECTION board. The Trigger board also provides a gain-controlled, precision-rectified version of the wideband music signal via IC1d, Q3, Q4 and IC3a and b which is used to provide a drive signal for the optional sound to light board. IC4 quad Schmitt NAND is used to provide two independent oscillator outputs for use as the STANDBY LED oscillator and the internal CHASE oscillator respectively.

buttons and three (Bass Beat Trigger, Main Processor and Output Switch) for the main control electronics. Interconnections between the various assemblies are made using ribbon wire and Maplin minicon connectors. The optional boards (crossfade, sound to light and strobe modules) plug into the output switch board and processor board respectively.

Construction

The Master Controller requires that a minimum of seven boards to be constructed — Bass Beat Trigger, Processor Board, Output Switch Board, Display Board, Mode and Sequence Select Boards and the PSU. (This supposes that the unit will not have any mains switching capability — if a mains switching unit is required then you'll need to wait until next month for full constructional details!). Interconnections between the various boards are made using ribbon wire and the Minicon latch style of low power connectors.

project, it is as well to wait until all the monthly parts have been published and then decide on what parts you want to build and what method you go about constructing it. Full parts lists are presented here for the seven master controller boards to give the reader an idea of the quantities involved.

When constructing boards solder all links and through-board pins and IC sockets first, not forgetting D1-8 on the NMode Selection board which are mounted on the foil/pushbutton side.

The switches as supplied do not have any LED's fitted. There are two possible mounting patterns i.e. four holes through which the LED legs may be pushed. For this application the two outer holes are used, the LED legs being bent. Because of this it is necessary to use LED's with long legs so that enough of the leg protrudes through the PCB to allow a good solder joint to be made. As the design uses around 60 LED's, it is as well to learn at an early stage which is the anode and

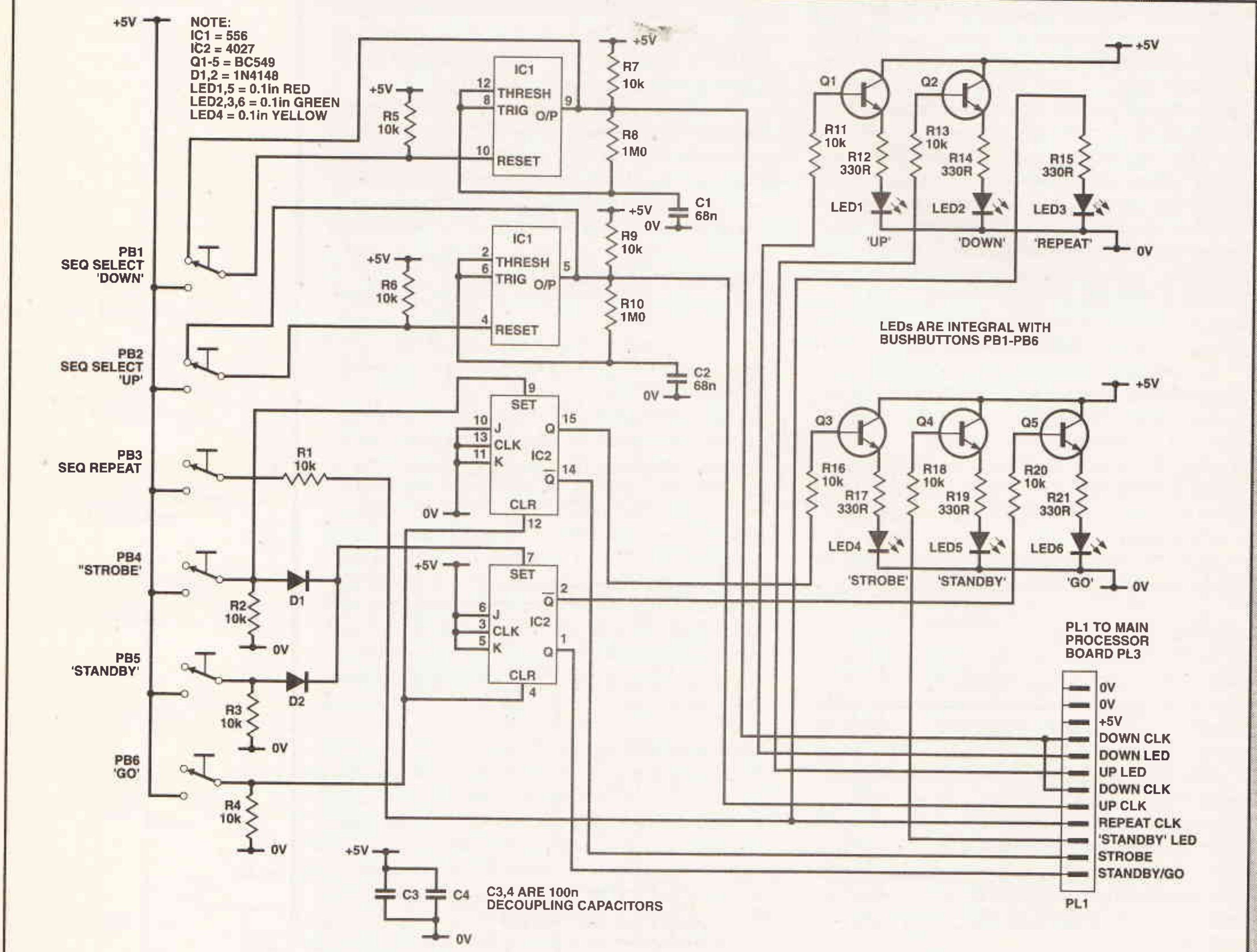


Fig. 4 Sequence select output control board

All the circuit diagrams for the master controller are featured here this month. Owing to space, only the component overlay for the main prcessor board is shown in Figure 9, all the other overlays will be featured next month. All funtional operation of the seven boards is detailed under the 'How it works' section.

When constructing projects, most people build the boards first, test them, then the cabinet and associated metalwork is cut out, drilled and assembled, followed by placing the boards and controls. The last aspect is usually the interwiring.

Before committing yourself to such a sizeable

which is the cathode of the LED.

Only one leg of each LED on the CHANNEL MONITOR BOARD should be soldered at this point. The board should then be offered up to the front panel at which point the LED's are free to move and accommodate any slight discrepancies between front panel holes and the LED positions. Once all of the LED's line up, the other leg can be soldered. The PCB's are mounted on 1/2" × 1/8" aluminium bar secured at each end of the front panel to the inside of the case. M3 screws, nuts and spacers secure the PCB's to the aluminium bar. This method of construction is adopted in each unit featured in the series since it provides a neat and secure method of fixing and furthermore means that no ugly mounting hardware is visible either on the front panel or on any exterior surfaces of the case. The four remaining boards can now be constructed following the standard construction procedures outlined above, noting that on the Processor Board, the three diodes are soldered on both sides of the PCB.

Construction of these boards is fairly straight-forward, the only point to note being the link on the PSU board which has to be mounted early in construction as the smoothing capacitor C1 obscures the link mounting holes once soldered to the board. Also note that the heatsink for the three regulators is created from a 3.5" long piece of 1" angle aluminium drilled according to Figure 2. Each of the regulators must be mounted using mica washers and insulating bushes. The PSU board layout is such that it will accommodate both 6VA and 18VA transformers. The Master Controller PSU requires an 18VA power supply.

These four boards are again mounted on flat aluminium bar secured on either side of the casing with M3 countersink screws. The connector board is mounted vertically on the right hand inside of the case and has the capability to provide up to four parallel outputs of the LED drives/external control voltages — normally only two will be used, one for the LED drives and one for the rear panel EXT. CONTROL OUT socket.

The interconnecting leads can now be made up. The ribbon wire should be cut to length and bends made in the leads in the places shown in the diagram-coloured ribbon wire makes the interconnections much easier to check.

Once completed, the leads should be plugged into the appropriate outlets on the boards, ensuring that none of the socket pins become dislodged from their housings. The only lead left unplugged should be the power supply/audio input lead to the Bass Beat Trigger.

Operation And Setting Up

The unit is now ready to be tested. Set each of the presets on the PSU board to halfway and connect a mains supply (preferably isolated) to the mains input PC terminals. The terminal nearest the regulators is the Live input terminal. Upon switch on each of the three LED's should be glowing and inspire confidence. Using a multimeter, check the +5V rail and the bipolar supplies — these should lie somewhere in the region of plus and minus 9V. It is assumed at this stage that the Master Controller is to be used with either a Switch Pack/Dimmer from the Nightfighter range or with a commercial unit with an input sensitivity of 10V — if this is the case, the appropriate presets should be adjusted to give output voltages of plus and minus 10.5V. For input sensitivities of voltages other than this, the presets should be set for voltages +0.5V more than sensitivity voltage on the positive rail (6.5V for an input sensitivity of 6V) and for an equal and opposite voltage on the negative rail. Once this is done, switch off and connect the final plug to the Trigger board. Now reapply power and if there are no ominous wisps of smoke from any of the boards, and all of the supply

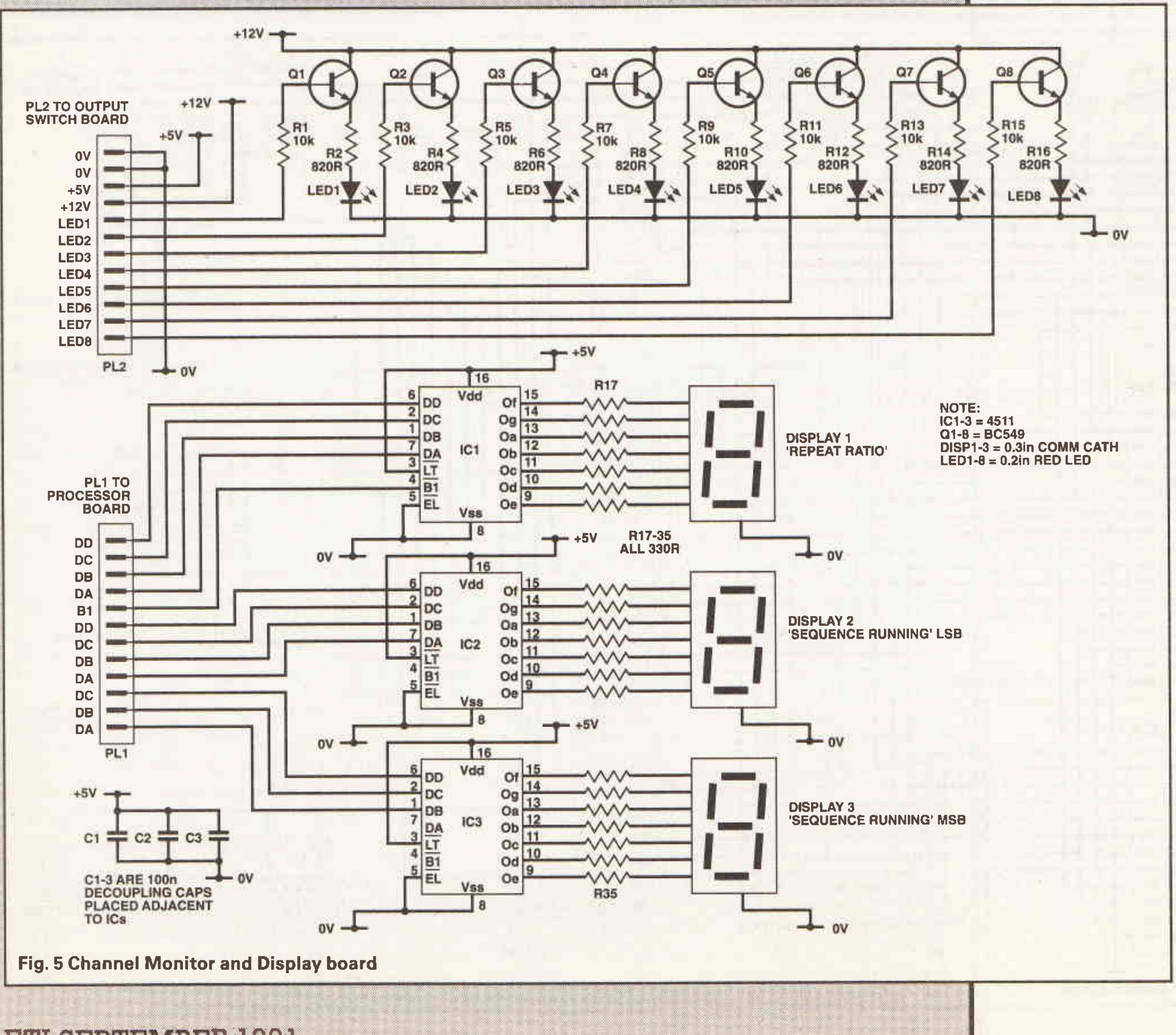


Fig. 5 Channel Monitor and Display board

rail monitor LED's are still illuminated, the front panel should be awash with glowing or flashing LED's.

Press each pushbutton in turn, except the CLOCK 'SOUND' and check that the associated LED lights or flashes. Select MAN.SEQ SELECT on the MODE SELECTION board, CHASE and AUTO CLOCK. Now press the UP or DOWN SEQ.SELECT buttons on the right hand panel until the SEQUENCE RUNNING display shows 00 (there is no reset-on-switch-on circuitry). All eight LED channel monitors should be on. Pressing UP or DOWN SEQ.SELECT pushbuttons should advance the SEQ.RUNNING display one step if the button is released and at a rate of about 4Hz if the button is held down for more than about a second. The LED should flash for the duration of the keypress. Select one of the lower sequences (1-10) and advance the SPEED control ensuring that the sequence steps correctly at all speeds. Turning the speed control fully anticlockwise should halt the display. Check that pressing the STROBE button forces a sequence between 00 and 39 and that the output is in STANDBY mode. Select AUTO SEQ.SELECT and the UP or DOWN LED will be constantly on. The SEQ.RUNNING display will alter in this direction. Pressing the REPEAT SEQUENCE button will enable the REPEAT display which will show 1,2,4,8 and blank on consecutive keypresses whilst causing the present sequence running to repeat the same number of times.

Pressing CROSSFADE or SOUND TO LIGHT will cause the display to blank. Finally connect an audio signal source of nominal line level to AUDIO INPUT jack socket JK1 and adjust the multi-turn trimmer on the Trigger board for a voltage of approximately 2.5V on pin 13 of IC2 on this board. The SOUND CLOCK LED should be pulsing to the beat of the music – if this is not the case, PR1 should be carefully adjusted for a satisfactory response.

Now, with the speed control turned fully anticlockwise until the switching click is heard, select SOUND CLOCK on a sequence between 01 and 10. Now adjust PR3 on the trigger board until the sequence advances neatly (on the bass beat) one step at a time with no tendency to double-step.

The final trim is for the flash rate of the STANDBY LED, PR2 being adjusted according to personal preference. The unit is now fully set up.

Next month we shall deal with the front and rear panel details, interconnections and with the Triac Switching Board which enables us to improve the pres-

HOW IT WORKS

PSU (Figure 8)
The PSU is a very simple affair using the standard series of 317/337 series of monolithic variable voltage IC regulators to generate the + and – 10V supplies required by the op-amp and high level logic circuits, and the 78 series 5V regulator to generate the supply rail for the majority of the processor logic. The only point of note is in the use of a dual secondary transformer and two bridge rectifiers – this is so that we can derive a positive, fullwave rectified but unsmoothed version of the AC 50Hz waveform for use in the zero crossing detector/ramp generator to be described at a later point.

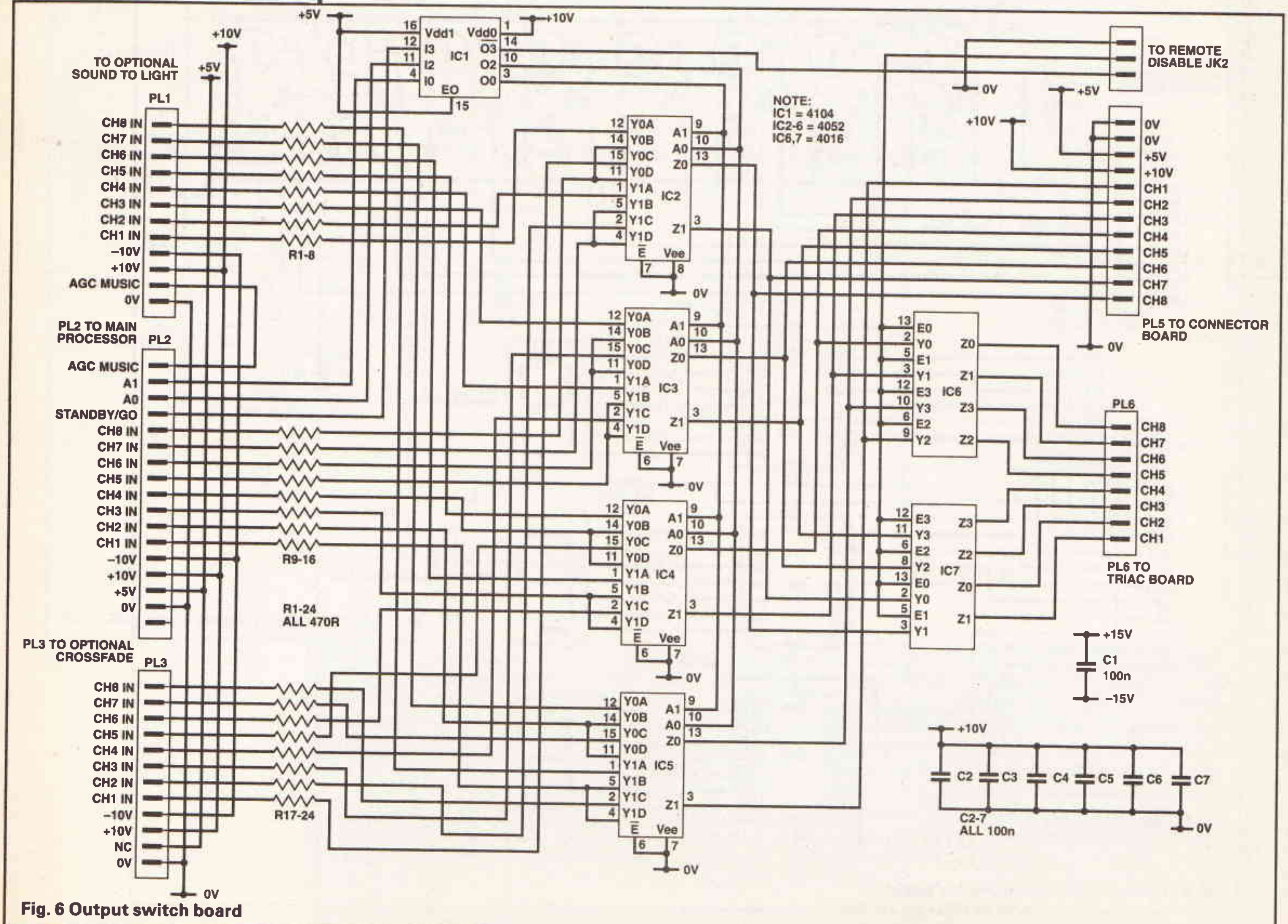


Fig. 6 Output switch board

ent power-handling capability of the unit from 8LED's to 6kW of mains powered lighting. We shall also look at the bolt-on goodies for the Master Controller, namely the Sound to Light board and the Cyclic Crossfade. The final part of the article will feature the Sensor Switch touch panel and a few hints on how to configure the separate units as a working system.

The author has let it be known that patents have been applied for on the Nightfighter system.

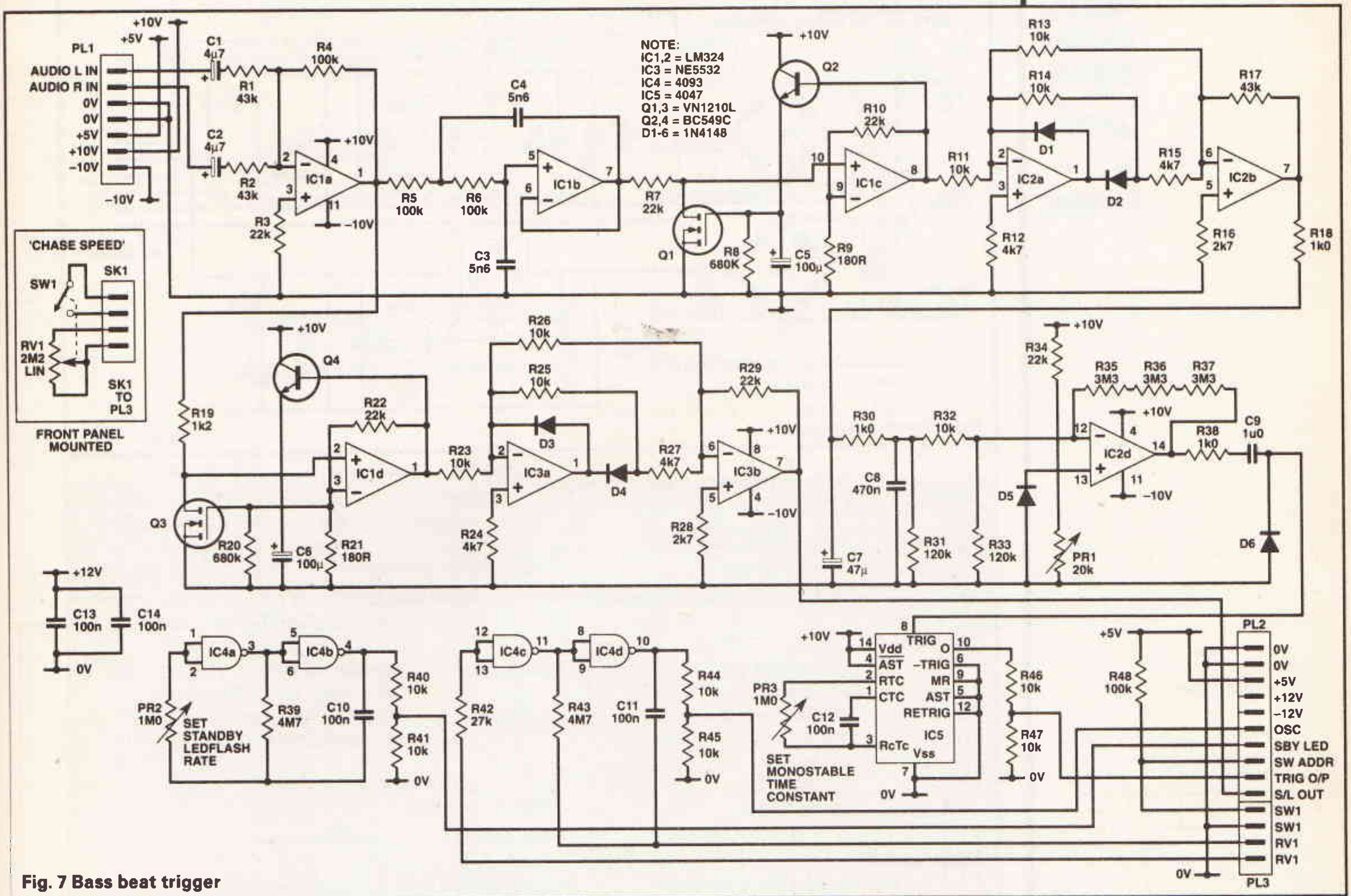


Fig. 7 Bass beat trigger

PARTS LIST

PSU BOARD

RESISTORS

R1,2	240R
R3,4,5	1k
R6	330R
R7,8	1k
PR1,2	5k

CAPACITORS

C1,2,3	2200µ 16V axial electrolytic
C4,5,6	220n polyester
C7,8,9	100n polyester

SEMICONDUCTORS

IC1	7805
IC2	LM317T
IC3	LM337T
D1	1N4002
BR1,2	40V, 2A Bridge Rectifier

MISCELLANEOUS

T1	18VA 12-0-12-0 PCB mounting Transformer (see text for transformer applicable to this section)
FUS1,2	5x20mm PCB chassis mounting fuseholders
PL1	2-way Minicon latch plug Heatsink (see text) 3 off 3-way PC screw terminals 1 off 2-way PC screw terminal PCB Mica washers, insulating bushes for regulators.

BASS BEAT TRIGGER

SEMICONDUCTORS

IC1,2	LM324
IC3	NE5532
IC4	4093
IC5	4047
Q1,3	VN1210L
Q2,4	BC549C
D1-6	1N4148

RESISTORS

R1,2,17	43k
R3,7,10,22,29,34	22k
R4,5,6,48	100k
R8,20	680k
R9,21	180R
R11,13,14,23,25,26,32,40,41,44,45,46,47	10k
R12,15,24,27	4k7
R16,28	2k7
R18,30,38	1k
R19	1k2
R31,33	120k
R35-37	3M3

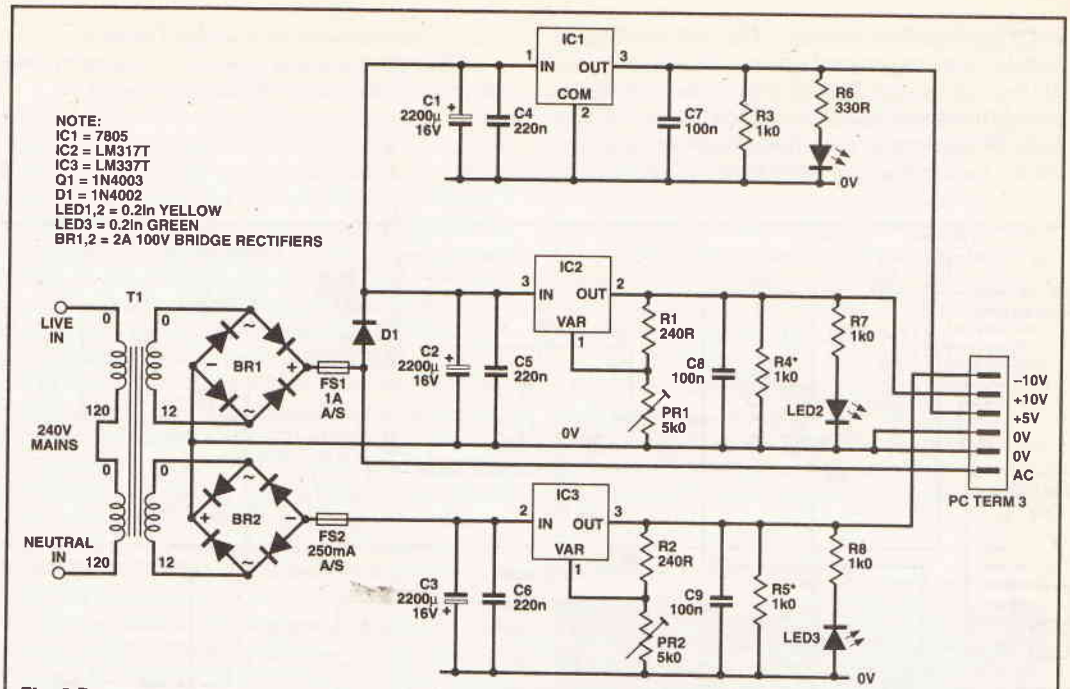


Fig. 8 Power supply unit

R39,43	4M7
R42	27k
PR1	20k Vertical Multiturn Preset
PR2,3	1M Horizontal Preset
RV1	2M2 Chassis Mounting Linear Pot with D.P. Switch

CAPACITORS

C1,2	4µ7 Axial Electrolytic
C3,4	5n6 Polystyrene
C,6	100µ Radial Electrolytic
C7,10,11,12	100n Polyester
C8	470n Polyester
C9	1µ Polyester
C13,14	100n Disc Ceramic

MISCELLANEOUS

PL1	8 way Minicon plug
PL2	10 way Minicon plug
PL3	4 way Minicon plug
SK1	8 way Minicon latch socket, lead assy
SK2	4 way Minicon latch socket, lead assy
SK3	10 way Minicon latch socket – socket assy

IC Sockets to suit, Bass Beat Trigger PCB, Veropins

MAIN PROCESSOR
RESISTORS

R1	100k
R2	10k

CAPACITORS

C1	220n Polyester
C2-17	100n Disc Ceramic

SEMICONDUCTORS

IC1	4052
IC2	4093
IC3,4,7,16,17	4081
IC5	4071
IC6	4027
IC8,14	4520
IC9,10	4510
IC11	4512
IC12	4028
IC13	2716
IC15	4539
IC18,19	4104
D1,2,3	1N4148

MISCELLANEOUS

PL1,3,4,5	12 Way Minicon Latch Plug
PL2	10 Way Minicon Latch Plug
PL6	17 Way Minicon Latch Plug
SK1-3	12 Way Minicon latch socket – socket assy
SK4	17 Way Minicon latch socket – socket assy

IC Sockets to suit, Master Controller PCB, veropins

OUTPUT SWITCH
RESISTORS

R1-24	470R

CAPACITORS

C1-7	100n Disc Ceramic

SEMICONDUCTORS

IC1	4104
IC2-6	4052
IC6,7	4016

MISCELLANEOUS

PL1,3,5	12 way Minicon Plug
PL2	17 way Minicon Plug
PL4	3 way Minicon Plug
PL6	8 way Minicon Plug
SK1,2,6	12 way Minicon Socket – Socket assy
SK3	8 way Minicon Socket – lead assy

IC Sockets to suit, Output Switch PCB, veropins

MODE SELECTION BOARD
RESISTORS

R1-9,11,13,15,17,19,21,23	10k
R10,12,14,16,18,20,22,24	330R

CAPACITORS

C1,2	100n Disc Ceramic

SEMICONDUCTORS

IC1,2	4027
Q1-8	BC549C
D1-8	1N4148

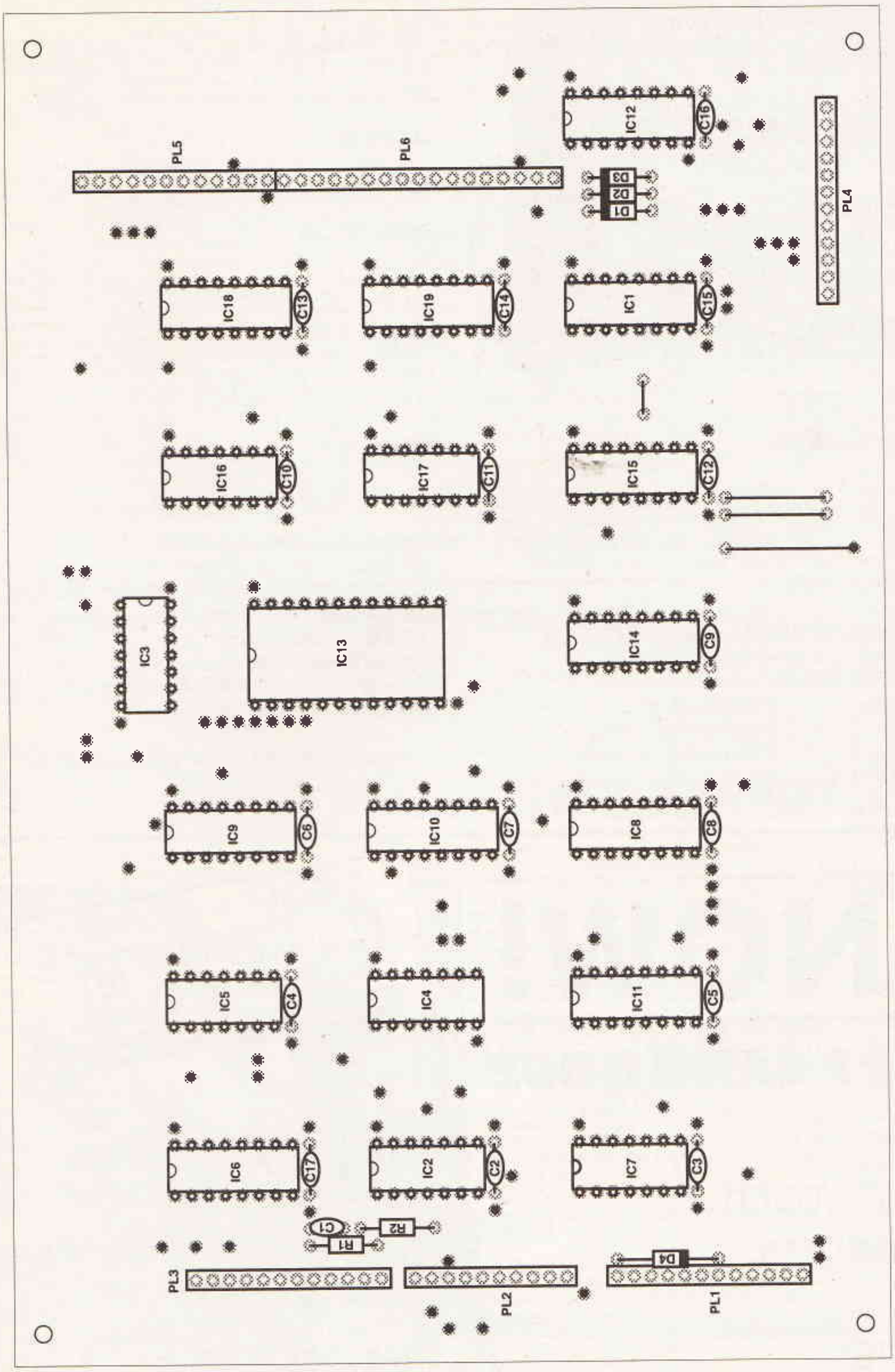


Fig. 9 Component overlay of main processor board showing connecting through points

LED1,3,5-8	0.1" Green LED
LED2,4	0.1" Red LED

MISCELLANEOUS

PB1-8	Alpha-style Keyswitch (see Buylines)
PL1	12 way Minicon Plug
Veropins, Mode Selection PCB	

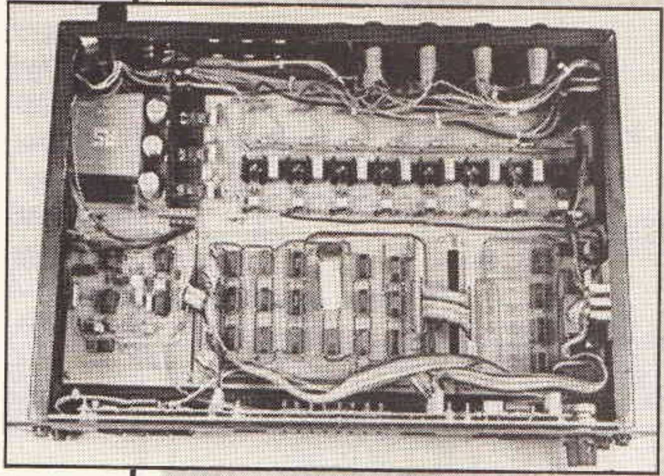
CHANNEL MONITOR/SEQ. INDICATION

RESISTORS

R1,3,5,7,9,11,13,15	10k
R2,4,6,8,10,12,14,16	820R
R17-35	330R

CAPACITORS

C1,2,3	100n Disc Ceramic



SEMICONDUCTORS

IC1,2,3	4511
Q1-8	BC549C
LED1-8	0.2" Red LED
DISP 1-3	0.3" Red Common Cathode 7-Seg Display

MISCELLANEOUS

PL1,2	12 way Minicon Plug

Sockets to suit, Veropins, Channel Monitor PCB

CONNECTOR BOARD

PL1,2	12 way Minicon Plug
PL3	8 way Minicon Plug
SK1	12 way Minicon Socket – Socket assy
SK2	8 way Minicon Socket – lead assy

SEQ SELECT/OUTPUT CONTROL

RESISTORS

R1-7,9,11,13,16,18,20	10k
R12,14,15,17,19,21	330R
R8,10	1M

CAPACITORS

C1,2	68nF
C3,4	100nF Disc Ceramic

SEMICONDUCTORS

IC1	556
IC2	4027
Q1-5	BC549C
D1,2	1N4148
LED1,2,6	0.1" Green LED
LED3,5	0.1" Red LED
LED4	0.1" Yellow LED

MISCELLANEOUS

PL1	12 way Minicon Plug

IC Sockets to suit, Veropins, Output mode PCB

MISCELLANEOUS (MASTER CONTROLLER)

JK1, 1/4" stereo socket with break contacts
JK2 – 9, 1/4" mono jack sockets (if unit to be fitted with Strobe board)
* 8 off 5x20mm panel mounting fuseholders & insulating boots
* 4 off Bulgin P551 octal sockets
Selection of M3 nuts, bolts and washers and threaded spacers
20mm cable gland, 5A connecting wire, various colours, 2U Rack Mounting Case and Front Panel

Components marked thus (*) are required only for a unit with mains switching capability.

Light, Vision, Colour and Perception

he Physics of how we ee by Douglas Clarkson.

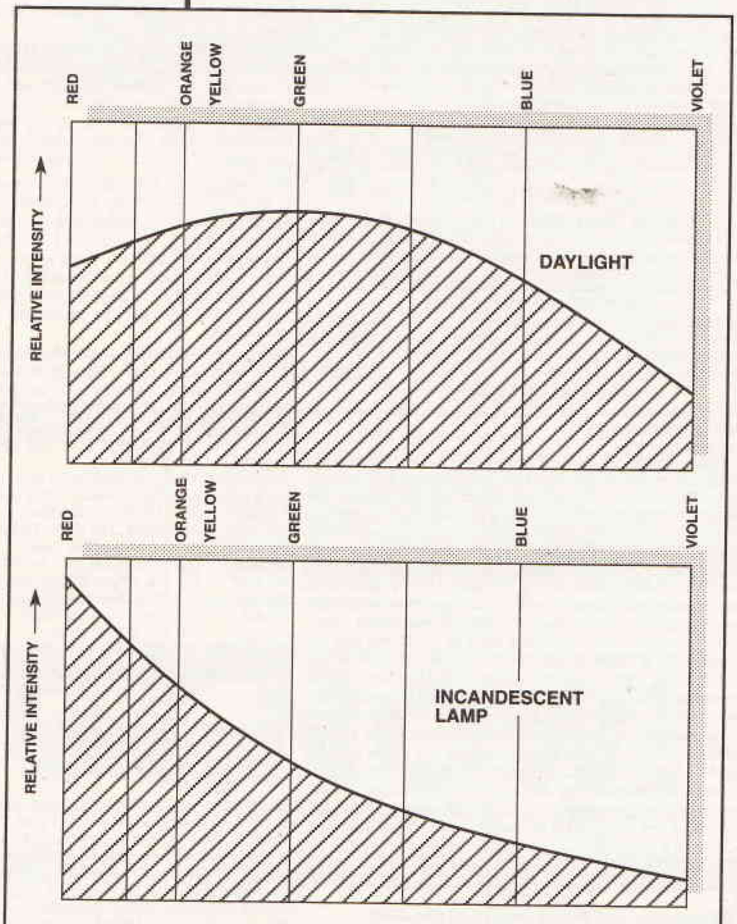


Fig.1 Typical spectrum of daylight and incandescent lamp

Without light from the sun the world's agriculture would fail. Light provides appreciation of colour and form. Light is therefore very important to life but is so often taken for granted. This article reviews a broad range of topics related to light and vision generally and looks at current so called 'artificial retinas' to get a flavour of where current research in this field is heading. The subject matter, covers a range of disciplines including those of physics, optics, biology and neurobiology to name but a few. No single branch of science has a monopoly of interest in this specialty.

About Light

Light is made up of small bundles or packets of energy called photons. While the light from some sources is mainly of one colour, such as in neon signs or in sodium street lights, light from the sun or from a light bulb contains photons of all colours, although in normal conditions the light appears white.

In the rainbow or by the action of a prism, 'white light' is revealed to be a spectrum or spread of colours ranging from blue to red. The blue photons are associated with more energy (shorter wavelength), and the red photons with less energy (longer wavelength). We cannot see the photons with slightly more energy than the blue photons (ultra violet radiation), though our skin is sensitive to them as those who sunbathe will know. Neither can we see the photons with slightly less energy than the red photons (infra red radiation), though these rays give the feeling of heat. Light radiation therefore represents only a very small portion of the so called 'electromagnetic spectrum. Table 1 describes typical data of the visible spectrum.

colour	wavelength (nm)	photon energy (eV)
red (limit)	700	1.77
red	650	1.91
orange	600	2.06
yellow	580	2.14
green	550	2.25
cyan	500	2.48
blue	450	2.75
violet (limit)	400	3.10

Table 1: Typical Data of the visible spectrum

The visible spectrum is, as it were, sandwiched in a very small space within the electro-magnetic spectrum. While the terms wavelength and photon energy are essentially equally valid for describing the characteristics of light, it tends to be the wavelength which is used to describe its features.

Towards the high energy end of the photon range, photons exist with energies in excess of millions of electron volts (gamma rays) while towards the lower energy range, photons have energies of millionths of electron volts (ultra long wavelength radio waves).

Figure 1 shows the typical spectra of daylight and an incandescent lamp. The spectrum of daylight, however is not itself entirely constant or static. The exact spectrum will be influenced by the time of day and direction of light, eg if from the north or south. This is why sensitive colour differentiation, for example of textiles, requires to be undertaken in association with careful reference lighting conditions. Traditionally daylight from a north facing window has been a preferred option. The spectrum of daylight is essentially the output spectrum of the sun plus absorption by some elements of the earth's atmosphere. The spectrum changes around sunset, for example, as refraction or bending of shorter wavelengths takes place and the light has a greater dominance of red.

Light reflected from surfaces produces a modified spectrum of light where for a given broad range of incident wavelengths, a specific pattern of wavelengths is reflected, so that while the eye sees the colours of reflected surfaces, the 'mix' of light photons in any environment is likely to be influenced considerably by the 'decor'. The eye's sense of colour shows a remarkable degree of colour constancy, where colour appreciation is relatively independent of the spectral content of incident light.

The blue of the sky is caused by scattering of light by molecules of the atmosphere. This scattering effect is greater for shorter wavelengths of light such as the blue. In fact if an observer looks at the blue sky, all the blue light that he sees is scattered light. An observer on the moon which has no atmosphere, looking up would only see a black 'sky' and the bright disc of the sun. There is a broad range of subjective feeling about the psychological effect of colour on the individual. Most of this is not given very much in the way of scientific importance. Some investigators have claimed to have determined a direct link between a lighting environment and physiological factors such as blood levels of calcium. There is an indication, for example, that too much artificial fluorescent light is not healthy. No doubt a lot more work still needs to be done in this area.

Perhaps in the future, colour schemes will be selected not purely on the basis of social fashion but according to some as yet undetermined colour therapy code. This is an area where such research has still to become respectable. It is a curious point of view however, to allow pre-judging of areas of scientific investigation. In the past this has consistently been shown to slow the process of the development of a broad scientific understanding of the world around us.

It is quite true to say that people see colours because the eye detects the different mixes and concentrations of colours reflected from objects. The actual mechanisms which bring this about are still poorly understood but this area of research is one of the most interesting since it is providing clues about the way in which the brain itself is functioning. This topic will be explored in a later section in more detail.

Rods and Cones

The eye as shown in Figure 2a is very much like a camera where the retina is the light sensitive 'film'. Figure 2b shows the structure of the retina. Light has in fact to travel through the outer layer of cells before it reaches the photosensive area. Nature has designed these cells to be transparent.

The retina consists of up to ten layers of which the first three, photoreceptor (rods and cones), horizontal and bipolar cells (in inner nuclear layer) are better understood. The function of the amacrine cell (in inner nuclear layer) and ganglion cells layers are as yet something of a mystery.

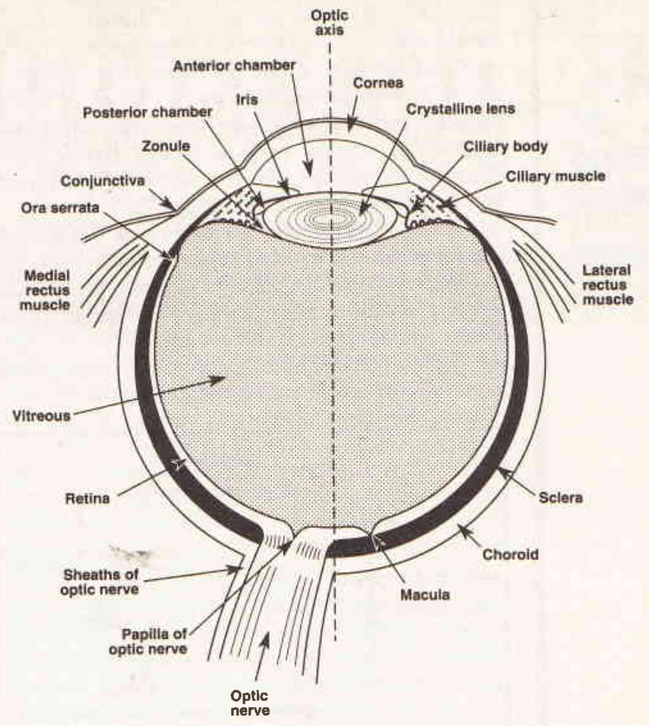
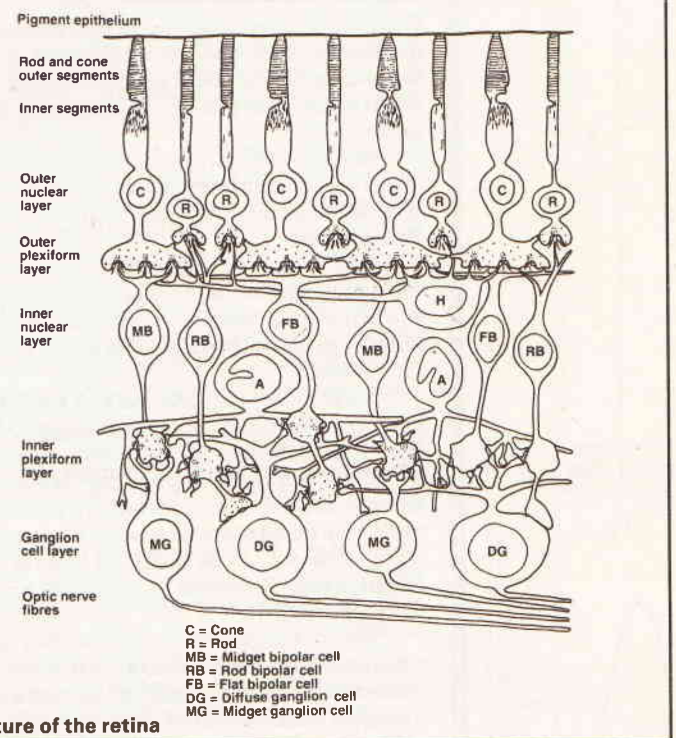


Fig.2 a) Diagram of the eye



b) Structure of the retina

The photoreceptor cells are of two distinct types — rods and cones. The rods are used for low level vision (night vision) and have no perception of colour. The cones are less sensitive than rods but provide the sensation of colour.

Figure 3 shows the relative response of the rods and cones as a function of wavelength of light. The daylight sensing (photopic) cones have a maximum sensitivity at around 555nm and the night vision (sctopic) rods a maximum sensitivity at around 512nm. The rod cells are approximately 2.5 times as sensitive as the cone cells at their respective peak

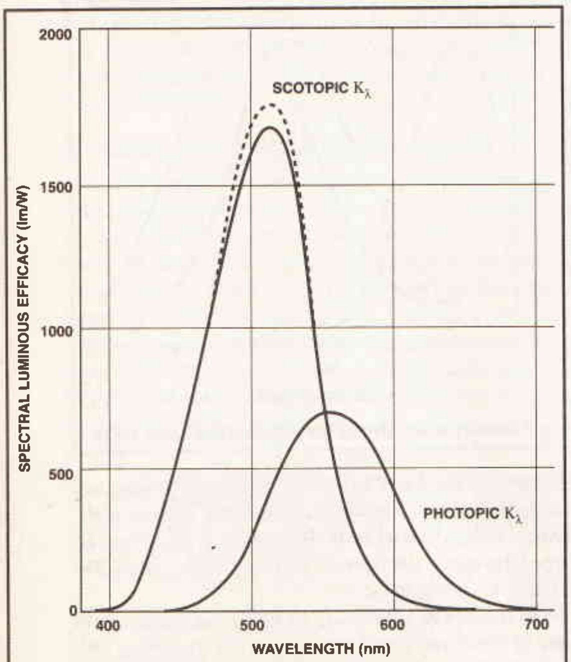


Fig.3 Relative response of rod and cone cells to wavelengths of light

sensitive wavelengths. This shift in sensitivity of the eye can be detected under conditions of fading light and is termed the Purkinje effect after it was first reported by the Czechslovakian physiologist Johannes Purkinje in the early 19th century. Under conditions of fading light, the red objects appear less bright while blue objects can appear brighter as rod based vision becomes dominant. Green colours often appear bright under conditions of fading light.

Lighting designers can often use the distinct visual functions of rods and cones to advantage. On the control bridge of a ship, for example, a saturated red light can be used to illuminate the bridge instruments. Since only the cones are adapted by this light, the rods can readily adapt to the task of generalised night time vision, for example scanning the horizon.

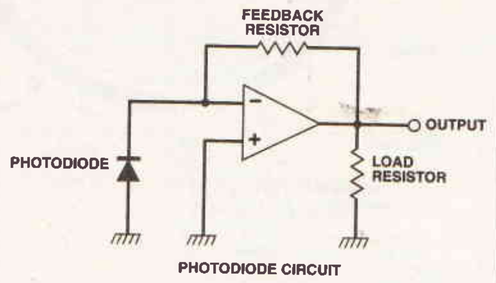


Fig.4 Typical circuit of photodetector

Light Measurement

There are two main divisions of light measurement — radiometric measurements which relate to absolute values of energy or power and photometric measurements which relate to perceived brightness and illumination.

Attention will be directed primarily to the photometric quantities since these are most often involved in light measurement in the human environment.

The Lumen

The Lumen is basically a definition of an 'amount' of light. In 1979 the Lumen was redefined as 'the amount of light of monochromatic radiation whose frequency is 540 x 1012Hz and whose power is 1/683 watt'.

It can probably be inferred that the definition of the Lumen has undergone may changes in its history. The initial definition of the Lumen related to the amount of light incident upon a one square metre surface at a distance of one metre from a standard candle made from the oil of the sperm whale. In very simplistic terms, a candle can be imagined to be a source of approximately 12 lumens (surface area of sphere at one metre = 4π).

Thus if a single point source can be imagined to radiate out light of this frequency and power, then the amount of light is one Lumen. When such a definition is adapted to air, one watt of monochromatic radiation of 555nm is equivalent to 683 Lumens.

Recalling the data of Table 1, the energy associated with a green photon is approximately 2.25eV or $2.25 \times 1.6 \times 10^{-19}$ Joules. In one second, therefore such a source of one lumen would radiate approximately 5×10^{15} photons. (This calculation is just the total energy radiated in one second divided by the energy of a single photon.) The human eye, however, has sensation of brightness which is wavelength dependent according to the curves indicated in Figure 3 where both the cone cell sensitivities and rod cell sensitivities are indicated.

Measurements of the relative brightness of light sources need to involve consideration of the relative spectral sensitivity of the eye. Normally the cone response (photopic response) for day vision is used. Thus measurements of say the total power output of light source in watts between the wavelengths of 400nm and 700nm will not necessarily provide an indication of the relative brightness of the source.

Table 2 outlines some relative values of the so called spectral luminous efficacy curve where each curve has been 'normalised' to give maximum value of 1 at the most sensitive wavelength.

Wavelength (nm)	Cone Daylight response	Rod Night vision response
400	0.0004	0.0093
420	0.0040	0.0966
440	0.0230	0.3281
460	0.0600	0.5670
480	0.1390	0.8390
500	0.3230	0.9820
520	0.7100	0.9350
540	0.9540	0.6500
560	0.9950	0.3288
580	0.8700	0.1212
600	0.6310	0.0312
620	0.3810	0.0074
640	0.1750	0.0015
660	0.0610	0.0003
680	0.0320	0.0001
700	0.0041	0.0000

Table 2: Spectral luminous efficacy values of normalised rod and cone responses

Luminous Efficacy

Where the light output of a source spans a range of wavelengths, which is typically the case, then the effective output of the source has to be modified by the response curve,specific values of which are indicated in Table 2. For daylight vision, the cone response curve is used. Even for a 'flat' source of light of equal radiometric output per unit of wavelength, the average luminous efficacy or 'efficiency' is only 187 lumens per watt compared with 683 lumens per watt for a perfect light source at 555nm. A 100 Watt incandescent bulb has a typical luminous efficacy of 17 lumen per watt due to the large amount of energy dissipated as heat in wavelengths greater than 700nm.

In fluorescent light sources, short ultra violet

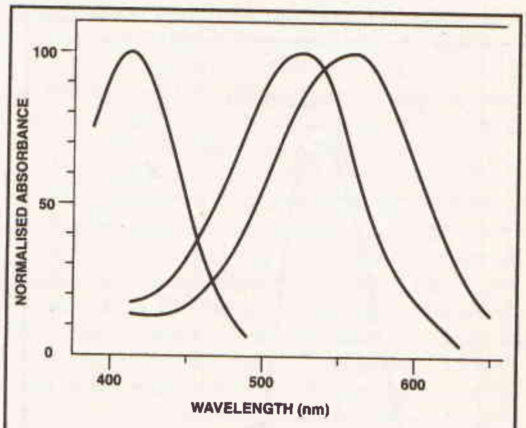


Fig.5 Absorption curves for pigmented cone cells

wavelengths released by the gas discharge process stimulate emission of longer wavelengths due to excitation of special phosphors. Radiation in the infra red part of the spectrum cannot, however, be converted in this way to visible light.

In the era of awareness of the greenhouse effect there is increased drive to improve the luminous efficacy of light sources. It also improves the domestic budget.

The Lux

While the lumen is a useful measure of the total amount of light output of a light source, most local measurements of light refer to the illuminance where this is expressed in lumens per square metre — a unit called the lux. Taking the example of a point source of light of strength 1000 lumens, if this is distributed over a surface area of 10 square metres, then the average illuminance will be 100 lux. The lux therefore refers to levels of perceived brightness through linkage to the Lumen.

Table 3 outlines typical values of illuminance currently recommended in the UK.

Visual Task	Lux value
little difficulty (eg stores)	200
ordinary tasks (eg general offices)	400
some difficulty (eg business machines)	600
fine detail (eg tailoring)	900
very fine detail (eg gem cutting)	up to 3000

Table 3: Typical values of illuminance currently recommended in the UK

The human eye can adapt over a broad range of values of illuminance. Values of illuminance as high as 60,000 lux can be experienced in direct sunlight. Even an overcast but bright sky can have a value as high as 10,000 lux. Even the rods begin to fail when light levels fall to around one lux.

A range of instruments can be used to measure light levels. Light sensitive materials such as cadmium sulphide and selenium have been extensively used. It is important that such devices have an appropriate wavelength response to match that of the cone receptors.

Photodiodes are finding increasing application in the measurement of light. So called 'eye response' diodes are now available which provide the required wavelength sensitivity. This is implemented by use of a specific filter in association with a standard characteristic photodiode. A typical circuit is shown in Figure 4. When light photons are incident on the detector, current is induced in the diode. In the circuit shown, the non-inverting input of the operational amplifier is grounded and this ties the inverting input to ground. A trimming element is usually required in order to cancel the 'dark current' flowing in the diode. Current generated in the photodiode passes to ground and after passing through the gain resistor the voltage at the output rises. A range of gains would be necessary to cover the typical ranges required for light measurement. Photodiodes are very linear over a broad range of output intensity levels.

Colour Perception Theories

The trichromatic theory of colour perception was first expounded by Thomas Young in 1801 and developed by the German scientist Hermann von Helmholtz some 50 years later. Young proposed that the perception of colour arose from the eye having three basic types of colour receptor — blue, green and red. The theory has been essentially proved experimentally by direct observation of retinal function although it is understood that the eye can also show sensitivity to colour opposites like green and not red or red and not green.

The magnificent ability of the eye to detect colour should, however, never be underestimated. It is considered, for example, that the eye can discern over 10,000,000 separate colours.

Colour vision is principally derived from the fact that cones have certain wavelength specific pigment filters. Figure 5 shows what is considered to be the typical wavelength absorption of three sets of cones. There is a blue type absorption (peak 445nm), a green type absorption (peak 535nm) and a red type absorption (peak 565nm) which has also a strong contribution in yellow. These are described also as the S, M and L sets for their sensitivity to short, medium and long wavelengths. On the basis of these curves, the eye would appear to be better at resolving say blue from green than green from red.

This selective absorption is determined from pigments within the cone cell. The absorption curves indicate how much light is being absorbed by the cone. The response of the cone to any absorbed light is not specified but can be expected to be proportional to amount of light absorbed. By contrast, the rods which come into play in conditions of low light, have no different pigment filters and provide no colour sensitivity.

The process of establishing that there are cones with specific spectral sensitivities does not immediately solve all problems of colour vision. For a specific individual cone being struck by a particular photon, in terms of the excited signal, the cone does not know if it has detected a weak signal in a sensitive part of its spectrum or a strong signal in a less sensitive part of its spectrum. The sensation of colour must be about relative perception of signal among groups of cones with different colour sensitivities. This perception must also take place independent of overall changes in intensity over such specific areas. The distribution and neural linkage between the cones must therefore a key element in colour perception.

The problem of colour blindness is related to the nature of the cone pigmentations. About 8% of the population, mostly male, is colour blind to some extent. This is caused by variations in the spectral responses of the cone pigments. In some cases the M or L set of cones may be missing altogether. Such individuals are said to have dichromatic vision. Loss of the S cones is quite rare.

It is often stated that an individual with normal trichromatic vision is discarding a great deal of perceptual information. The world of colour as perceived; while rich and varied, may in fact be much richer than it appears. Some species in nature, for example, have quadchromatic vision where four separate colour responses are used to encode colour information.

The analogy is often made that while in auditory perception, sensory detection allows discrimination of individual frequencies of sound, in colour perception a great deal of information is being lost. Is this a result of some economy of scale where it is more important to be aware of the approach of a predator than become dazzled with a true appreciation of its luxuriant striped coat?

Modern instruments such as the spectrophotometer can undertake an accurate analysis of the spectral output of, for example, an artist's pigment as shown in Figure 6. This is as it were a fingerprint of the photons emerging from the source. The trace, however, does not give a subjective appreciation of colour.

The German physiologist Ewald Hering;proposed what is termed the opponent theory of colour in 1878. This theory anticipated that colours were also specifically sensed as opposites such as light-dark, red-green and blue-yellow. It is generally accepted that while the majority of colour perception is determined by the trichromatic theory, the opponent theory also plays a part in determining colour perception where neural connection in the retina are sensitive to specific colour differences.

Verification of this mode of visual sensing has in fact been observed experimentally. The lateral geniculate nucleus (LGN) is a small region in the brain where the optic nerve terminates before information is transmitted into the visual cortex. Using animal studies, it has been possible to determine the response to

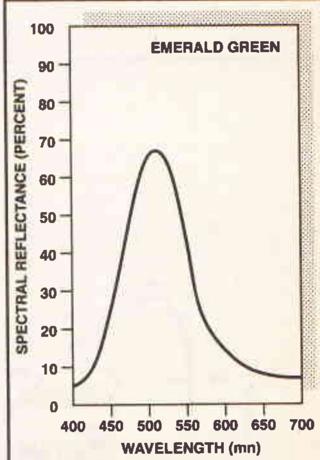


Fig.6 Spectra of coloured pigment

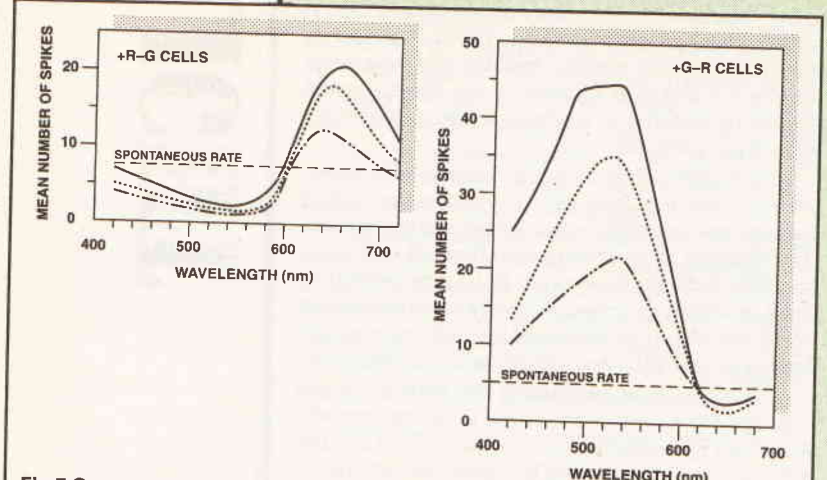


Fig.7 Opponent response of +R-G and +G-R cells

individual cells in this structure as a function of the wavelength of light. For this work an extremely fine probe (diameter about 0.0001 cm) is required. While there are a range of cells which can be observed — those for example which have a broad spectral sensitivity — a class of so called spectrally opponent cells can also be identified.

Figure 7 shows the typical responses of so called +R−G and +G−R cells where the +R−G is excited in red light and inhibited in green light and the +G−R cell is as it were a mirror image of this activity. The +Y−B and the +B−Y cells show similar characteristics for yellow and green. The mechanism whereby the responses of the three photoreceptors are translated into such a four colour system are the subject of considerable on-going research. It is likely that the answer lies in the complex patterns of connection between the neural cell of the retina.

The Chromaticity Diagram

In the many varied divisions of commerce and industry there has always been considerable need to be specific about colour and colour matchings. In 1931 in Paris the International Commission on Illumination drew up a system for classification of colours. Central to its approach was the construction of the Chromaticity diagram. This took place before the finer details of the possible functioning of colour perception were identified. The Chromaticity diagram relates to additive colours from direct light components. It does not apply to mixing of colour pigments.

In accordance with the trichromatic theory of colour, it was assumed that any colour could be formed by a combination of the primary colours such as red, green and blue. A given colour can be described as a combination of fractional components $x + y + z$ where $x + y + z = 1$ and x is the red contribution, y is the green contribution and z is the blue contribution. The z contribution is not used in the Chromaticity diagram since its value can be deduced if x and y are known.

A typical Chromaticity diagram is shown in Figure 8. Its form is that of a horse shoe with white in the middle, green at the top blue in the lower left and red in the lower right. The diagram also allows estimations of the purity of a given colour to be determined. The point E for example, in the figure which is distance n from the central white point and distance m from the periphery of the curve is said to have a purity value of :—

$$100n/(m+n)$$

The purer colours lie therefore towards the periphery of the curve.

The white or achromatic point is conventionally located at co-ordinate $x=1/3$; $y=1/3$.

The Chromaticity diagram is of direct use in determining the various colours which lie between specific end points on the diagram. In the case of moving from red to green, for example, as the mixture of colours changes from saturated red to saturated green along a specific line, a desaturated yellow will be created at an intermediate point.

The Chromaticity diagram can also be used to determine so called complementary colours. For a specific colour on the periphery of the diagram, if a line can be drawn through the achromic point, this will intersect at the periphery of the diagram to indicate the so called complementary colour — that colour which if mixed with the original will in the correct proportions produce white.

While it is stated that all colours can be created by mixing three primary colours, when specific points of a triangle are drawn into the Chromaticity diagram to represent these colours, not all hues can be created. Certainly all those within the triangle can but some colours outside the triangle cannot. A suitable choice of yellow/green primary can vary the degree of saturation of key colours required. With the base of the triangle fixed along the purple red axis as shown in Figure 9, the locus of an infinite number of triangles can be imagined to be swept round the diagram, so that all colours can be created with specific starting points for their respective colour triangles.

It is very important to appreciate that the Chromaticity diagram is a process of addition of light. It would be of value, for example, in determining the range of possible colours which could be achieved by exciting red, green and blue pixels on a colour television tube or independent beams of light projected onto a surface.

The processes of colour mixing in painting is mostly a subtractive process where pigments which absorb light are mixed together. A red pigment, for example, will absorb all colours in white light except red. Similarly a green pigment will absorb all colours in white light except green. When the two pigments are mixed, little light will be reflected back — a brown will be produced and not the yellow as predicted from the Chromaticity diagram.

The Chromaticity diagram does not therefore apply to such subtractive methods of achieving different colours. It is possible to predict the colour mixing of pigments on the basis of their superimposed absorption spectra. It is probably more convenient to make up colour mixing charts at first hand. A lot of confusion

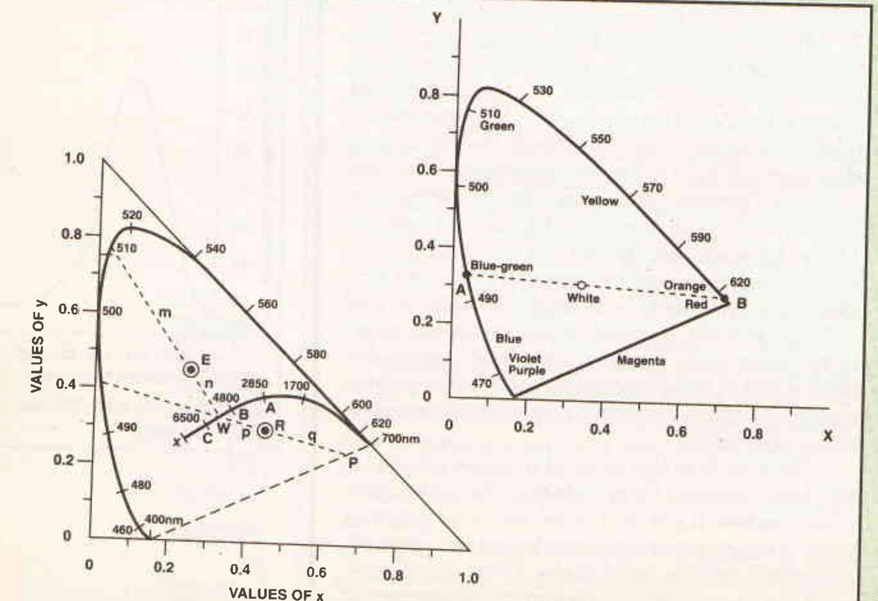


Fig.8 Chromaticity diagram

has been caused by imprecise references to the separate processes of additive and subtractive mixing of colours.

Understanding the Retina: Silicon Models

While systems for classification of colour have been established for some time, there is still a long way to go before a complete understanding of vision is obtained. In particular, it is the degree of local processing which takes place 'within the various layers of the retina which is considered to hold the key to understanding vision. The retina has special processes for enhancing edges of structures, for determining local contrast so that features can be discerned both within shadows

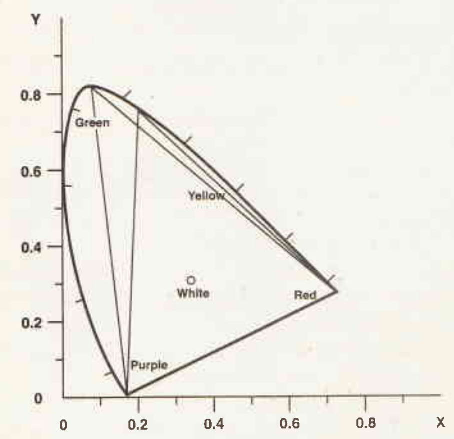


Fig.9 Colour generation using three primary colours

and brightly lit areas in the same field of view. Also, it has mechanisms for highlighting moving edges.

Many of these features have been developed to a high degree within the natural world for both the hunter and the hunted as the excellent BBC book 'Supersense' superbly describes. These mechanisms cannot be understood within the context of individual cell types operating independently. These functions are derived from complex interaction between retinal cells within specific layers — and across layers. The essential first levels of signal processing are therefore undertaken close to where the signals are initially detected.

While the general principles of natural neural connected systems had been appreciated for some time, the very considerable complexity of such systems had distanced practical modelling of such systems even on a much humbler man-made scale. During the 1980's the study of artificial neural networks has made considerable progress — so much so that there has arisen a new feeling of confidence about developing artificial systems to mimic (ever so crudely) the superb designs of natural systems.

This confidence has given encouragement to various researchers to mimic natural neural networks using VLSI circuits. The development of such hardware based systems is, however, in its infancy.

The work of Carver Mead in the USA in the field of vision research has succeeded in simulating in a crude man-made silicon neural network the basics of vision. This approach gives a more satisfactory approach than modelling of such artificial networks using even the most powerful computers. For the class of networks investigated, the 'training' of the network is as it were 'fixed' - learning is not taking place.

A range of different photodetector arrays has been developed using techniques of VLSI integration. A specific array of 50 by 50 photoreceptor elements has been constructed using a basic hexagonal local structure where the value sensed by a single photoreceptor is compared with the weighted average of six nearest neighbour sensor elements. This gives the function of local adaption where the relative brightness of a signal is referenced to the local average value of brightness. Also, the system has been designed to respond to changes in signal level. Thus a static signal area will eventually fade out as the signals in a specific area become uniform. Increased information content will therefore be associated with changing structures.

The typical design of the photoreceptor, which has a logarithmic response, is shown in Figure 10. This function allows large variations in input light level to be translated to a much smaller range in output.

When an initial image, is presented to the array, the elements will initially reflect the maximum contrast across the static picture. In time and according to the time constant of the amplifiers, the differences between the individual photoreceptor elements will decrease as the process of adaption is undergone. Eventually the picture will fade. A favourite trick is to display an image of Abraham Lincoln to the array. An initial sharp image progressively fades. When this image is replaced with a uniform white background, a negative image is produced where the greatest signal corresponds to areas of previous low illumination.

Another party trick is to present the image of a rotating windmill. The greatest contrast is presented at the leading moving edge of the rotating blades.

It is interesting to note that one common form of optical illusion can be observed with the crude silicon retina. Where a lattice of black squares is observed against a white background, grey spots can be observed in the white 'cross roads' area of the array. This is because the retina estimates relative brightness of an area as a function of the brightness of its background. This illusion is in fact also picked up by the artificial retina.

It is estimated that before any practical use can be made of such technology, the number of pixels would have to be increased by a factor of about 100 — equivalent to an array of 500 by 500. Also, these results with an artificial retina of this type are only demonstrating specific attributes of the real retina — that of adaption

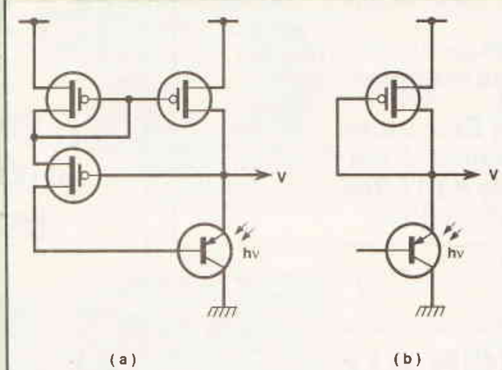


Fig.10 Photoreceptor circuit

of vision and accentuation of moving objects. The real retina has many surprises still in store. The various theories of colour perception are, for example, still have to be resolved in terms of neuron connection and interaction. It is likely that for some time to come, even the most advanced artificial retinas will not implement colour vision, although models of how attributes of colour vision may be implemented will be constructed.

The economy of energy which Nature is able to bring to bear on the function of the retina is remarkable. Modern electronic technology has reduced the energy required to implement a single digital operation to about 10^{-9} of a Joule. A single operation in a neuron within the retina will typically only expend about 10^{-16} Joule.

There is at present considerable activity in developing artificial neural networks 'in silicon'. These implement either analogue circuitry, digital circuitry or a combination of both. Nature does not use binary circuits for its complex computations which is something that conventional digital electronics engineers find runs contrary to their training in exact representation of data. The natural solutions are eminently successful and considerable research is being undertaken to implement new technologies which will allow more effective copy of Nature's designs to be undertaken.

What the development with the silicon retina demonstrates is that processing of images is best undertaken at the direct interface where the photodetection is taking place. In this way edge enhancement, local adaption, can be undertaken without the need for massively powerful digital computers.

The initial 50 x 50 element photosensor array with local signal processing can be considered to the first step in the development of smart vision systems of the future where chip fabrication methods incorporate the functionality such as photodetection,independent local adaption and moving edge detection.

A significant part of the brain is understood to provide a connectivity function — the cabling as it were between message processing centres in the cortex. The cortex can be mapped out according to specific functions, but it is difficult to anticipate mechanisms of linkage of neurons of the higher sensory regions. This is why the study of the retina which is in effect a very sophisticated visual pre-processing system, is valuable to achieve insight into the problem. The actual process which allows individuals to see, is poorly understood. In many ways the solution is like a jigsaw puzzle where all the pieces have been identified ,but where putting the pieces together is a very complex task.

Summary

The sense of re-discovery of natural sensory systems such as vision has helped refocus thinking on how to tackle some very basic problems in information processing. Instead of building increasingly powerful serial computers and developing yet more complex computer software, the emphasis is now changed to processing at the point of data creation as demonstrated by the work of Carver Mead and his associates.

While so much has been found out about light and perception, no doubt many more surprises await discovery.

Further Reading:

Seeing and the eye: an introduction to vision; Hugh Begbie.

Light and colour: a brief survey, Francis A. Jenkins and Harvey F. White.

Light and colour in nature and art, S. J. Williamson and Herman Z. Cummins.

The Sony Mini Disc

MINIDISC

A New Proposal for Digital Music Entertainment

A technology overview by Eric Kingdon

As co-inventor of the Compact Disc (CD), Sony has been the driving force behind a music medium that, for the first time, provided consumers with high-quality digital sound reproduction in a wear-resistent, fast-access, convenient format. Since its introduction in 1982, in less than a decade, the CD has grown to become the preferred format for the home music enthusiast.

Moreover, as the needs of home music enthusiasts continue to evolve, the CD format has the capability of evolving to meet those needs. For example, the industry has already seen dramatic improvements in digital encoding, which have resulted in higher-resolution CD master tapes. Additional enhancements to the CD format are also being realized, as witnessed by expansion of the medium from a pure audio format into a multimedia product like CD-ROM and CD-I.

But in today's highly segmented music market, no single audio format can meet every consumer's needs. Hence, since 1986, Sony Corporation has been working on a new digital format designed to meet the needs of the personal audio marketplace, The result of this research and development effort is the new digital Mini Disc (MD). Targeted for market introduction in late 1992, the MD offers consumers the sound quality, quick random access, and durability of optical media, such as CD. At the same time, it offers the portability, recordability, and shock resistance associated with the analogue cassette.

In short, the MD format has been created to meet the needs of personal music entertainment in the future. Based on an array of new technologies, the digital Mini Disc is poised to become an important new product.

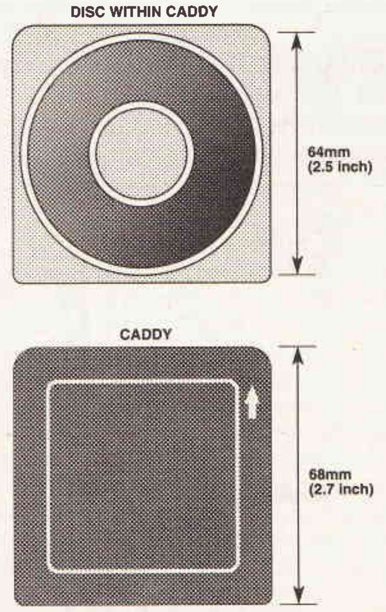


Fig.1 Disc within Caddy

A New personal Music Format

The Sony MD system is the result of efforts to synergize the appeal of the CD with those features traditionally required in successful personal music formats. There-

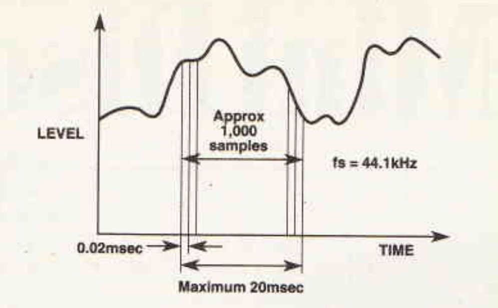


Fig.2 ATRAC Waveform and Sampling analysis

fore, the MD system will provide the following features and benefits:

- The MD system is based on a 2.5-inch optical disc that utilizes adaptive data compression technology to store up to 74 minutes of digital music, with sound quality approaching that of CD.
- The disc is housed in a caddy that protects it from physical damage. Together, both caddy and disc are approximately half the weight of an analogue cassette.
- The MD system offers both record and playback capability for maximum versatility.
- The MD system uses separate operations for recording and playback functions: magneto-optical heads for recording needs; CD-type optical playback head for prerecorded software.
- The MD system provides random access to any music selection in less than 1 second.
- It is resistant to shock and vibration under both record and playback conditions and uses a Serial Copy Management System (SCMS).

The Technological Foundations of the MD System

The prodigious capabilities of the Sony Mini Disc format can be attributed to the successful development of four new technologies, they are: 'ATRAC' Digital Audio, Magneto-Optical 'Over-Write',Dual-Function Laser Pickup and 'Shock-Proof' Memory.

ATRAC Digital Audio Compression Technology

The 2.5-inch disc used in the MD format is capable of storing virtually the same amount of music as the standard 4.72-inch CD as a result of a newly developed digital audio compression technology called 'ATRAC' (Adaptive Transform Acoustic Coding). With ATRAC, signal encoding efficiency is 5 times greater than with the non-compressed 16-bit linear technique currently used in the CD and DAT formats.

In 16-bit linear encoding with a sampling frequency of 44.1 kHz, the analogue signal is sampled approximately once every 0.02 milliseconds. Each sample is quantized at 16-bit resolution into one of 65,536 (216 possible values). Therefore, with CD and DAT, when the analogue signal is converted to digital data in real time, 16 bits of data are used every 0.02 milliseconds regardless of the amplitude of the signal and whether or not signal is even present.

ATRAC starts with the same 16-bit digital data but analyses segments of the data for waveform content. Based on this analysis, ATRAC extracts and encodes only those frequency components that are actually audible to the human ear. This method of encoding is far more efficient than the linear coding technique used for CD and DAT, yet sound quality remains comparable.

The actual record/playback sequence of events using the MD system can be described as follows:

During the recording process, the analogue signal is quantized at a sampling frequency of 44.1kHz and converted into digital data in the usual manner via a 16-bit A/D converter.

The ATRAC encoder divides this data into segments in intervals of up to 20 milliseconds (approximately one thousand samples). After applying Fourier transform analysis to the digital waveform in each segment, approximately one thousand changes in amplitude are analysed as single frequency (sinusoidal) components.

During this analysis, each frequency is assigned bits by amplitude (sound level), using psychoacoustic principles such as threshold of hearing and masking effect, to identify only those components in the segment that are audible to the human ear. As a result, overall coding efficiency is greatly increased (by a factor of approximately 5). This data is then format encoded with additional EFM and CIRC (error correction) data, then recorded onto the disc.

During the playback process, the numerous frequency components recorded on the disc are recomposed by the ATRAC decoder, and the 20 millisecond segments are reconstructed into digital waveform

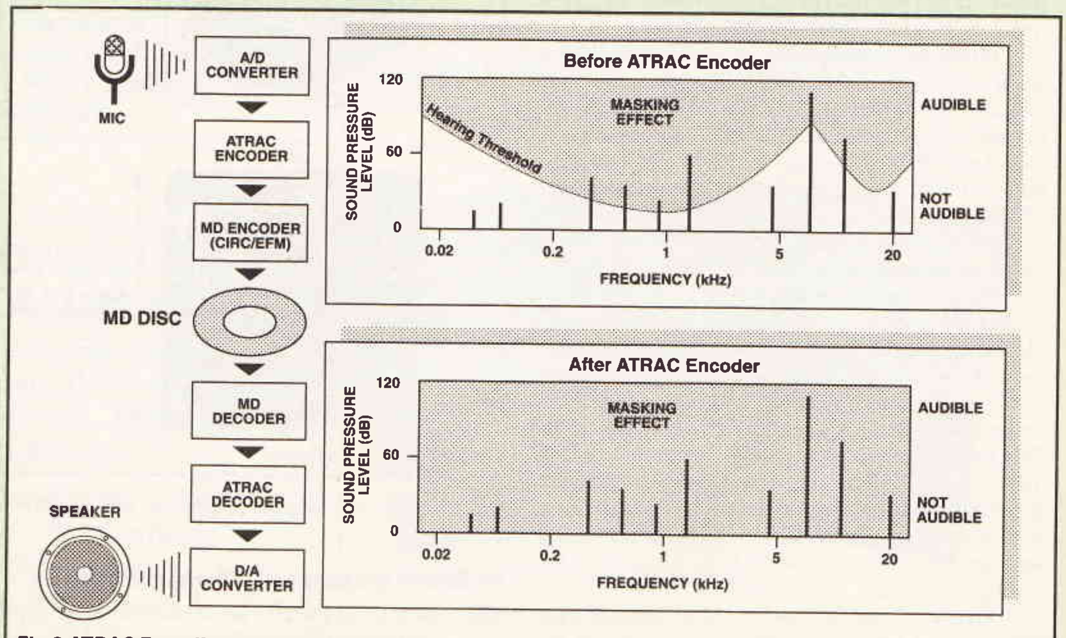


Fig.3 ATRAC Encoding/Decoding Process

MINIDISC

data. This data can then be processed by a 16-bit D/A converter in the conventional manner.

ATRAC The Underlying Psychoacoustic Principles

Threshold of Hearing

As sound level diminishes, there is a level below which the human ear cannot detect its presence. This threshold varies with frequency. The threshold of audibility is lowest for sounds with a frequency of approximately 4kHz; that is, sounds close to this frequency are most easily detected by the ear. By analysing the frequency components of an audio signal, it is possible to identify those components that lie below the threshold of hearing.' Such components can be removed from the original signal without affecting perceived sound quality.

Masking Effect

If two sounds, one loud and the other soft, are produced simultaneously and they are close to one another in frequency, the softer sound becomes difficult or impossible to hear. Therefore, when an audio signal has a high-level component and a low-level component at neighbouring frequencies, the latter can be removed without affecting perceived sound quality. Moreover, with increasing overall signal amplitude, it becomes possible to remove a greater number of components without audible effect.

Magneto-Optical Over-Write Technology

In order to meet the requirements of a compact, lightweight, record/playback system for personal audio applications, the MD system employs a newly developed Sony magneto-optical (MO) disc that uses magnetic field modulation with direct 'over-write' capability.

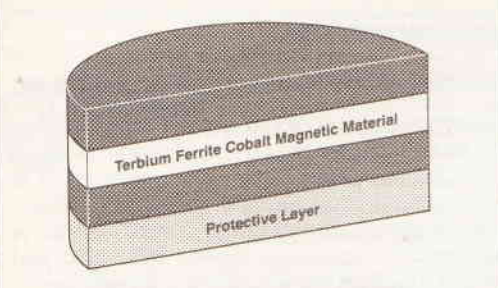


Fig.5 Cross section of MD magneto Optical disc

With MO disc technology, the recording of data requires the use of a laser and a polarizing magnetic field. When the magnetic layer in the disc is heated by the laser to a temperature of approximately 400°F, it temporarily loses its coercive force. As the disc rotates and the irradiated domain returns to normal temperature, its magnetic orientation is determined by an externally applied magnetic field. Polarities of 'N' and 'S' can thus be recorded, corresponding to digital data '1' and '0'.

In order to record new data on an MO disc, the previously recorded signals must first be erased. This is done by irradiating the track with a laser in a magnetic field to change all domains to a uniform '0' polarity.

In practice, two different methods have been developed for rewriting.

The first method uses two lasers, one for erasing and another for recording. Approximately one-half disc rotation after the signal is erased with the first laser, the second laser records the new signal. A single laser is used for both erasing and recording, but in two separate steps. Erasure takes place during the first rotation, and recording takes place during the second.

The first method is costly because two lasers are required. The second method results in excessive

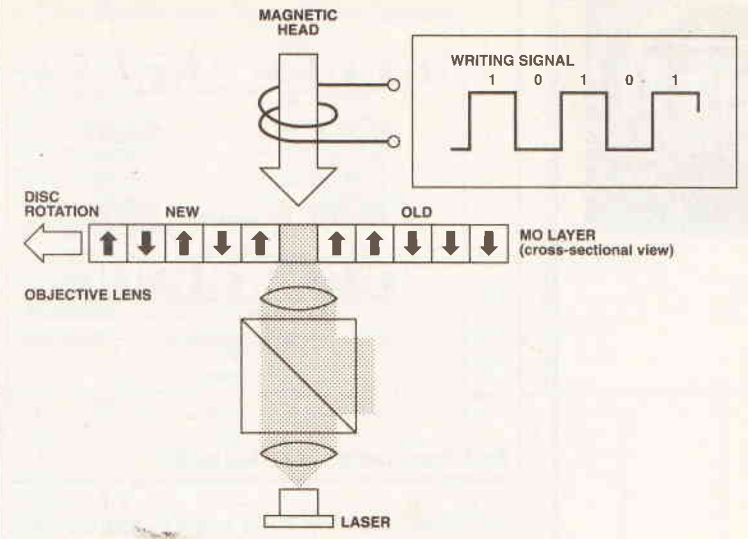


Fig.4 Overwriting technique

recording time and requires a complex servo mechanism.

The over-write system developed by Sony for the MD system adopts a new magnetic field modulation technique for recording signals. This technology has vastly reduced the size and complexity of MO disc recording. Fast data recording is accomplished by modulating the magnetic field at high speed in response to an input signal.

Unlike conventional MO rewrite mechanisms, the Sony MD over- write system positions a magnetic head directly across from the laser source on the opposite side of the disc. A magnetic field corresponding to the input signal is generated over the laser spot. The rotation of the disc then displaces the area to be recorded, allowing the temperature at the spot to drop back below the Curie point. At that point, the domain takes on the polarity of the applied magnetic field regardless of the polarity that previously existed.

The size of the spot recorded on the magnetic layer is controlled by the reversal cycle of the applied magnetic field, which permits accurate shortwave recording. This is in contrast to conventional methods where the laser beam is repeatedly turned on and off to record the magnetic signal; shortwave recording is difficult to achieve because of heat dispersion.

Moreover, since the Sony over-write method permits the laser to be continuously on during record and playback, the structure of the optical head can be greatly simplified. This enables the design of highly compact and lightweight MD hardware.

A major barrier to the successful implementation of the MD system over-write technique was the fact that the MO disc is a non-contact medium. A certain amount of space is required between the disc and the head surfaces to accomodate undulation as the disc rotates. Thus, a powerful magnetic field must be generated by the head to produce the desired polarity reversals on the disc. The high power consumption and heat generation associated with producing such a strong field were prohibitive factors.

Sony has solved this problem through two breakthrough developments. The first of these is where the Mini Disc uses a newly developed magnetic layer of Terbium Ferrite Cobalt that changes polarity with a coercive force as low as 80 Oersteds. This is approximately 1/3 the coercivity required for conventional MO discs. This enables stable polarity reversal using a relatively weak magnetic field.

The second is that the MD recording system uses a new highly power-efficient magnetic head that can

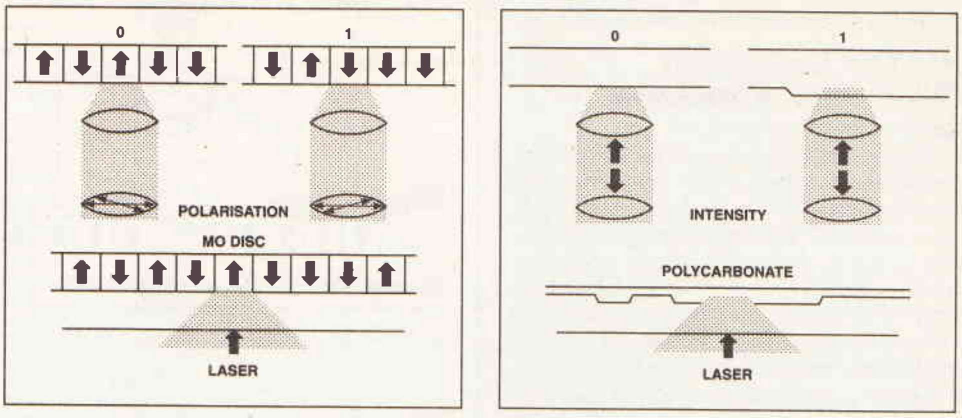


Fig.6 Cross section of optical media

perform polarity reversals at a rate of approximately 100 nanoseconds per reversal. The low power consumption of this head has solved the problem of overheating and has made it possible to design a practical battery operated recorder.

Dual-Function Laser Pickup Technology

The optical pickup developed for the MD system has the remarkable ability to read both MO and prerecorded optical discs. For MO discs, the pickup reads the polarity of the disc. For polycarbonate optical discs, the pickup reads the amount of reflected light. The MD pickup system is based on the design of the standard CD pickup with the addition of a MO signal readout analyser and two photodiodes.

During the playback of MO discs, a 0.5mW laser is focused onto the magnetic layer. The magnetic signal on the disc affects the polarization of the light. The direction of polarization is converted into light intensity by the MO signal readout analyser.

Depending on the direction of polarization, one of the two photodiodes will detect more light. The electrical signal from the photodiodes are subtracted, and depending on whether the difference is positive or negative a '1' or '0' signal is read. The same 0.5mW laser is used for the playback of prerecorded optical discs. The amount of light reflected depends on whether or not a pit exists on the surface of the disc. If no pit exists, a high proportion of the light is reflected back through the beam splitter and analyzer into the photodiodes. If a pit does exist, some of the light is diffracted, and less light reaches the photodiodes. The electrical signals from the photodiodes are summed in this case; and depending on the sum, a '1' or '0' is read.

Shock-proof Memory Technology

Conventional optical pickup systems can easily mistrack when subjected to shock or vibration. In digital audio CDs, this causes 'skipping' or muting, and CD player manufacturers typically go to great lengths, using mechanical suspensions and servo systems, to minimize such occurrences. Resistence to shock and vibration is a virtual pre-requisite for true portable personal audio applications. And in the MD system, Sony has solved this problem with a unique shock-proof memory.

While the MD pickup can read information off the disc at a rate of 1.4Mbit per second, the ATRAC decoder requires a data rate of only 0.3Mbit per second for real-time playback. This difference in processing speed enables the use of a read-ahead buffer, placed between the pickup and the decoder. If a 1Mbit memory chip is used for the buffer, it can store up to 3 seconds of digital information. Should the pickup be jarred out of position, the correct information continues to be supplied to the ATRAC decoder from the buffer memory. As long as the pickup returns to the correct position within 3 seconds, the listener never experiences mistracking or muting.

Since signals enter the buffer memory faster than they leave it, the buffer will eventually become full. At that point, the MD pickup momentarily stops reading information from the disc; it resumes reading as soon as there is again room in the memory chip.

Using a concept called sector repositioning, the MD pickup has the ability to quickly resume reading from the correct point after being displaced. When signals are recorded on the Mini Disc (either record/play MO or prerecorded optical media), address information is assigned every 13 milliseconds. When a pickup

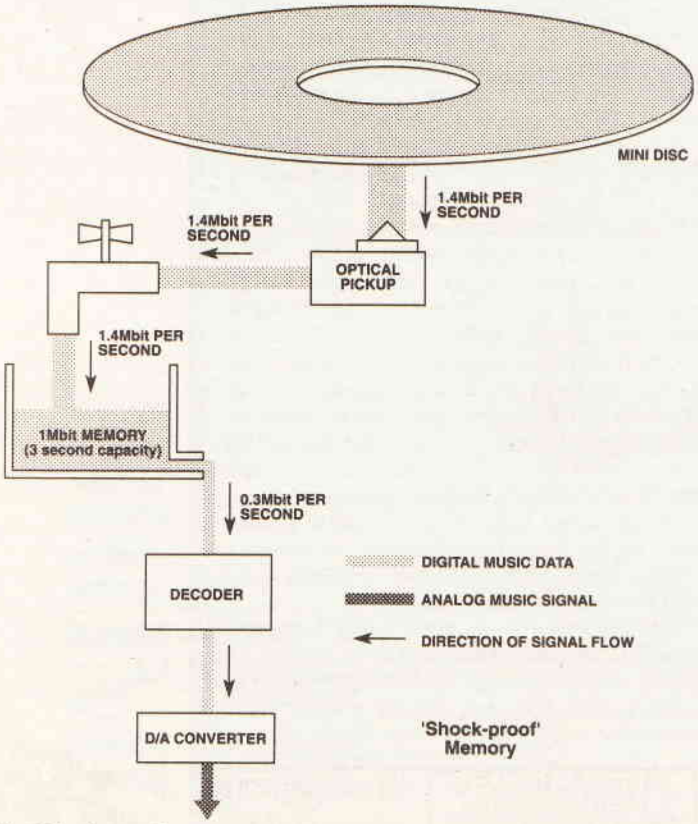


Fig.7 Shock-proof memory

is shifted out of place, the MD player quickly recognizes the disruption, identifies the wrong address, and instantly returns the pickup to the correct position.

The Next Step in Personal Audio

The MD system, a new digital audio format based on an advanced miniature optical disc, is being proposed by Sony for personal music entertainment application in the consumer market. The Mini Disc offers many of the advantages of the current CD, including high-quality digital audio reproduction, resistance to wear, and fast random access, but also is uniquely adapted to the needs of the personal audio enthusiast. Among the MD system's chief attributes are an extremely small, easy-to-handle, cartridge-loaded disc; up to 74 minutes of record/playback time; record, playback, and over-write capabilities; exceptional resistance to shock and vibration; and affordable hardware and software costs. In addition, the ability of MD players to read both MO discs and readily mass-produced pre-recorded optical discs makes the format a practical music software medium.

Sony does not view the MD format as an eventual replacement for CD. It is expected, rather, that the CD and the MD will peacefully co- exist in much the same way as the LP and the analog cassette have for so many years. Modern digital audio and optical disc technologies have pushed the CD ahead of the LP as the medium of choice for home music entertainment systems. These same technologies can now be harnessed to meet the needs of the personal music entertainment market, now being served by the analogue cassette. The Sony Mini Disc system is a format whose time has come.

Sony Mini Disc System – Preliminary Specifications

Channels:	2 (stereo)
Frequency Response:	5-20,000Hz
Dynamic Range:	105dB
Wow-and-Flutter:	Unmeasurable
Sampling Frequency:	44.1kHz
Coding System:	ATRAC system
Modulation System:	EFM
Error Correction System:	CIRC
Disc Speed:	1.2-1.4msec (CLV)
Record/Playback Time:	Up to 74 minutes
Cartridge Size:	72 x 68 x 5 mm
Disc Diameter:	64mm

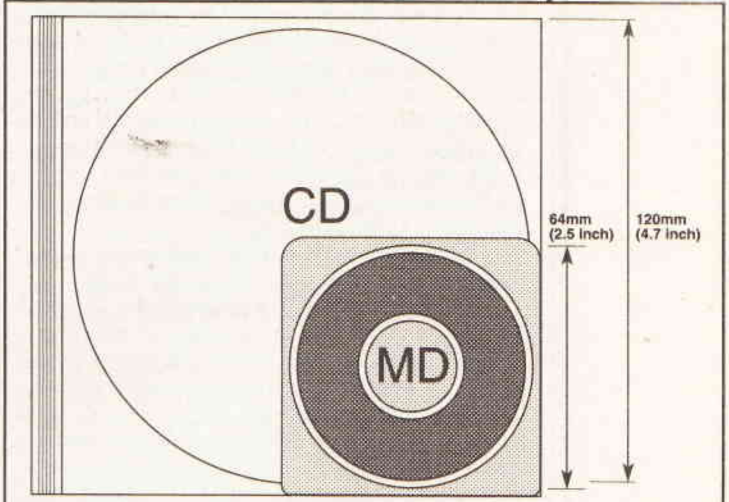


Fig.8 Sony mini disc (MD) relative to compact disc (CD)

2

Fault Finding

ndrew Chadwick
ontinues to solve the
any faults that occur in
ectronic equipment.

Blown Fuses

In the case of faults where a fuse has blown neither signal tracing not voltage measurement is applicable as the fuse has probably removed power from the part of the circuit in question.

It is always tempting to replace the fuse and try the equipment again. Don't. All you usually achieve is the death of another fuse. In 90% of cases the fuse has blown because of a fault which will still be present. The only exception to this is where the fuse protects an output, such as a loudspeaker, and the remainder of the circuit seems to be working correctly. In this case the blown fuse could have been due to a short in the wiring to the speaker or overloading of the amplifier in some other way.

What is needed is a method of locating the fault that does not involve powering up the circuit.

The first possibility is to measure the DC resistance of the circuit after the fuse with a multimeter. If the resistance is less than the normal voltage divided by the fuse rating then you can assume that there is a fault. Note that this applies to DC circuits only. If the fuse is in an AC circuit feeding an inductive load you need to consider the AC impedance not the DC resistance which you are measuring. The usual area where this is of concern is with a mains transformer. More details are given in the section on component testing.

If you obtain a low resistance reading examine the circuit diagram. If the fuse supplies more than one area of the circuit try disconnecting each one in turn by removing connectors or unsoldering links until the resistance increases. Once the area of the fault is known look for components that could be causing the problem and check them individually with the multimeter. Don't assume that there is only one faulty component as failure of one component can often cause the failure of another. A prime example is the usual class B discrete power amplifier where two or three transistors often fail together.Unfortunately a high resistance reading in the initial test does not necessarily mean that the circuit is fault free. The voltage from a multimeter is often not sufficient to 'activate' the fault. However faulty components will still show up if tested individually. If the fuse feeds a number of areas of the circuit then locate the faulty area first. This can be done rather crudely by disconnecting all areas of the circuit, powering up the equipment with a new fuse and then reconnecting each area in turn until the fuse blows.

If a variable current limiting power supply is available more sophisticated testing can be undertaken.

Firstly the circuit may be powered up at a suitable current lower than the fuse rating. This will determine the components that heat up. The nose is a very sensitive heat detector but beware of high voltages!

Alternatively the path of the fault current can be traced by measuring the voltage drop along the circuit board tracks by means of a DVM set to the millivolt range. The idea is illustrated in Example 3.

It may be possible to measure voltages within the circuit with the equipment powered from the current limited supply. However more often than not the current rises unacceptably before sufficient voltage can be applied to give sensible readings.

Intermittent Faults

In the case of an intermittent fault all the procedures described for partially functioning equipment can be used. The first problem is to make the fault appear.

From the description of the fault, symptoms you should know if it takes time to appear are, if it affects only one channel or one function or if it disappears when the equipment is turned off and on again. This will help you decide how to tackle the problem.

Many intermittent faults are caused by poor electrical contact due to oxidisation of contacts. Therefore its worth wiggling switches and connectors to try and make the fault appear.

Another cause of intermittent faults are dry solder joints. Flexing the circuit board can sometimes help to locate them. Carefully examine the solder joints in the suspect area. A 'dry' solder joint will have a very narrow darker ring either close to the component load or in the solder blob where the solder has not run together. Try measuring the voltage on the track leading to the pad and on the protruding end of the lead. If these differ, particularly when the component is moved,then there is a bad joint. The cure is simply to melt the joint with soldering iron and add a touch of new solder to provide some flux.

Breaks in the circuit board tracks can also be a problem. These often occur near the terminals of components soldered directly to the board that are subject to movement such as potentiometers and switches.If you suspect that heat causes the fault try warming the equipment with a hair drier. Remember to return the hair drier after use or you'll be in trouble!

For really elusive faults its worth ringing the manufacturers service department to see if they have come across anything similar. They have far more experience of their equipment and can often recognise the fault from a description of the symptoms.

I would advise very strongly against guesswork. It is easy to think of a plausible cause of the fault but remember there are probably dozens of other possibilities. If the fault won't appear and hence you can't disprove your theory it becomes very tempting to take this as proof in favour of your explanation. Resist the temptation as it only leads to disappointment!

Home Construction

There are two additonal considerations when dealing with home-built circuits.

Firstly if the circuit has just been constructed it is quite possible that there may be one or more wiring errors. It is wise to try and locate these before the equipment is powered up otherwise the first indication of a problem could be a burning smell and a wisp of smoke. This is an expensive way of fault-finding. When checking PCB and Veroboard layouts that you have designed use a photocopy of the circuit diagram and a highlighting pen. Follow the path of each track on the layout and compare it with the circuit diagram. If it is correct, highlight the corresponding part of the circuit. Work through the circuit in a logical fashion for example by starting with connections to pin 1 of the first integrated circuit, then pin 2 and so on. Eventually you should end up with a circuit diagram with all components and wires highlighted and you can be fairly confident that the layout is accurate.Assuming you have followed the above procedure but still end up with a faulty circuit don't despair. Split the circuit into blocks and test each one in turn. When you find the area of the fault simply remember to consider a wrong connection as well as the usual component failures amongst the possible causes. The type of things to look out for are solder bridges or splashes across tracks and, on Veroboard, track breaks where a tiny portion of copper remains still connecting the tracks.

The second consideration in home-built circuitry is that there may be more than one unrelated fault. The only advice I can offer is to cure each one and then pass on to the next. I was once asked to sort out a faulty synthesiser that someone had built from a kit. The final tally was about 25 different faults!

Component Testing

The methods described so far should enable you to quickly isolate the fault to a small area of the circuit. It is then necessary to locate one or two faulty components out of say ten or twenty. At this point it is feasible though rather tedious to test each of the components in that area individually. However with a little thought and a few simple calculations it is often easy to narrow the search down even further to one or two components. This idea is illustrated in Example 4.

Whichever fault-finding procedures you use you will eventually need to test individual components. The following is a summary of the normal failure modes and test methods for each type of component.

Resistors

Resistors usually fail by significantly increasing in resistance or by becoming totally open circuit. Modern equipment often contains fusible resistors which look like ordinary resistors but are designed to go open-circuit when overloaded. Unfortunately there is no indication that this has happened. A normal resistor overload tends to turn brown or discolour.

Measurement of resistors in circuit is not usually conclusive due to the parallel effect of other components. However if the value of resistance measured across the resistor in circuit is more than its nominal value then there's definitely something wrong. If it's less then there may be a problem. Confirm this is by unsoldering one end and measure the resistance again.

Fuses

The type of fuse normally found in domestic equipment is the glass cartridge fuse in which the element is visible. The ceramic cartridge fuse is filled with a white arc quenching powder and is designed to interrupt higher fault currents. As well as the glass and ceramic cartridge fuses you may come across sub-miniature fuses that lurk in packages similar to resistors, capacitors or even T092 transistors.

There are two basic types of fuse blowing characteristics, the quick blow, abbreviated F (fast), and the anti-surge type, abbreviated T (time delay). The characteristics of each type are shown in Figure 7 (see last month). It can be seen that for a given overload current the anti-surge fuse takes far longer to blow. Anti-surge fuses are used in circuits where brief periods of high current occur in normal operation. A typical example is in the primary circuit of a mains transformer when there is an inrush of current every time the power is turned on.It can be safely said that fuses fail open-circuit. In the case of a glass fuse the manner in which they fail can give a clue to the fault. A severely overloaded fuse will blow with a bright flash and a large section of the element will be vapourised and deposited on the inside of the glass. A slightly overloaded fuse fails more gently and there is normally only a small break in the element.

Even if the element is visibly intact lift one end of the fuse and check with a meter. I have been misled once or twice by fuses that break at a point inside the metal cap out of sight. In the case of ceramic fuses the fuse will have to be tested with a meter. Note that fuses of low rating have a significant resistance which can be surprisingly high. For example a T100mA fuse has a resistance of about 2R.

Switches

Switches fail either open circuit or high resistance.

They can be tested by measuring the resistance across the suspect switch contacts with the power off. Gradually move the switch so that the contacts close. The reading should go from some high value, depending on the circuitry attached, to zero. There should be no hesitation or variation when the switch is wiggled in the closed position.

Capacitors

Capacitors have no characteristic failure mode. They can develop low resistance or low capacitance or no capacitance.

Electrolytic capacitors are the most unreliable. All electrolytic capacitors have a certain amount of leakage current but this can increase up to a virtual short circuit. Unfortunately faulty electrolytics can also act as Zener diodes so that the fault will not show up with a normal multimeter. The only conclusive test is to apply a current limited voltage to the capacitor after removing it from circuit. Electrolytics may also lose some or all of their capacitance. Try bridging the suspect capacitor with a known good component if you suspect this is the problem. Non electrolytic capacitors tend to fail to a short circuit caused by breakdown of the insulation between the foils. However ceramic decoupling capacitors can also develop high leakage currents. This can cause intermittent crackling noises.

Power Transformers

The common faults on mains transformers are an open-circuit or shorted turns in one winding.

Open-circuits are fairly easy to test for with a multimeter. The DC resistance of the windings on a typical centre tapped mains transformer in an amplifier are 15R for the primary and 0.5R for each half of the secondary. It may not be the winding itself that has gone open circuit. Sometimes a thermal fuse is wired in series with the primary winding and buried in the windings. A fault such as shorted turns causing the transformer to heat up will blow the thermal fuse. However whether it's the fuse that is open circuit or the transformer winding you still need to replace the transformer.

Shorted turns are more difficult to test for. Shorted turns in any winding on a transformer have a similar effect to shorting the secondary terminals. Large currents flow with a corresponding rise in mains current. This results in the mains fuse blowing, often violently, or if the fuse is over-rated, a smoking transformer which hopefully has a thermal fuse that will blow. Measuring the DC resistance of the windings is no help. Even if you know what the resistance should be, the effect of one or two shorted turns will not be significant. Don't be tempted to divide the mains voltage by the DC resistance and compare the current with the fuse rating! On this basis a healthy transformer with a primary winding resistance of 15R should have a primary current of 16A compared to a fuse rated at 1A. The current is nothing like this as the transformer has mainly inductive not resistive impedance.

The best method of confirming shorted turns on a transformer is to disconnect all secondary circuits and connect the mains. If the mains fuse blows the transformer is faulty. Beware of condemning a transformer when it is a fault in the secondary circuit that is causing a high primary current.

Tape Heads/Cartridges

Tape heads and magnetic cartridges are both basically coils of wire. Although they don't often go open circuit themselves, the connecting wiring and contacts do. A typical tape record/playback head has a DC resistance of 220R and a cartridge 600R. The resistance of the left and right-hand channels should match to within about 5R. Knowing these figures a check can be made from the circuit board end through any interconnecting wiring which will show up open circuits and possible high resistance contacts.

Diodes

Diodes and rectifiers can fail open or short-circuit. They can be tested by measuring their resistance on a multimeter. Use the diode measuring range which gives sufficient voltage to bias the diode into conduction. With the diode forward biased you should obtain a low reading and reverse biased an infinite reading. Testing with the diode in circuit can be misleading due to paralled components. However, this is not as much of a problem with diodes due to their lower resistance compared to the parallel resistance.

The exception to the above is high voltage rectifiers as used in microwave oven power supplies and televisions. These require a higher voltage to forward bias them which may not be available from a multimeter.

Transistors

Transistors fail in a variety of open circuit and short circuit modes so it is essential to test in all four of the ways described below. These tests can be done with the device in circuit but there may be misleading results if there are parallel components. The best method is to firstly check with the transistor in circuit. If the results are not satisfactory there may be a fault or it could be just other components in parallel. To confirm this remove the transistor from circuit and repeat the tests. The tests apply to NPN and PNP transistors. Remember that NPN refers to collector, base, emitter and so to forward bias the base-emitter junction in an NPN transistor, you must connect the positive meter lead to the base and the negative to the emitter. The four tests are:

1. Forward biasing the b-e junction should give a low reading.
2. Forward biasing the c-b junction should give a low reading similar to the above. On a digital meter this reading can be seen to be slightly lower than the above. Note that the warmth of a hand can increase the readings while you are changing the test leads.
3. Measuring between the collector and emitter in one direction should give an open circuit reading if the transistor is out of circuit or a high resistance if in circuit.
4. Testing between collector and emitter in the opposite direction should give the same result.

Power transistors in general give lower values whilst PNP transistors give higher values than the corresponding NPN transistor. Table 1 shows some typical figures.

Signal	NPN Power	NPN Small Signal	PNP Small Signal
b-c	0.527	0.619	0.654
c-b	0.524	0.614	0.652

TABLE I: Typical readings for forward biased transistor junctions obtained using the diode measuring range of a digital multimeter

Integrated circuits

No real testing can be performed on IC's when unpowered. When powered up check voltages against those on the circuit diagram. As with any voltage comparisons allow for errors of ±10%.

Replacement Components

In the case of simple components such as fuses resistors and capacitors it is usually cheaper and more convenient to obtain replacements from a reputable components supplier. Mains transformers, parts designated as safety parts (shown by an exclamation mark in a triangle) and mechanical parts usually need to be obtained directly from the manufacturers or their appointed spares agents. I have found most spares departments very helpful. It's usually best to ring up first and obtain the exact manufacturers part numbers and prices. The goods can then be ordered on proforma invoice or by cash with order. Check whether VAT and postage and packing needs to be added to any prices quoted.

Replacement transistors fall into a grey area. Where an exact replacement is available from component suppliers then there's usually no problem. If not I would advise obtaining replacements from manufacturers. Although transistor data books and lists of substitutes are available its surprisingly time consuming to find a suitable alternative transistor. Often you discover a replacement with acceptable characteristics but find it has a different package or lead arrangement. More time is wasted trying to fit it to a heatsink or bend the leads to suit the board holes.

Tips On Fitting Components

When replacing transistors or integrated circuits bolted to a heatsink don't forget to use heatsink grease and replace any insulating washers. Bolt the component to the heatsink before soldering the leads to the board. This avoids setting up any stresses in the leads which can cause dry joints.

When removing integrated circuits I would recommend the following procedure. With a pair of small wire cutters cut through the IC pins one at a time at the point where they bend at rightangles. I have a pair of cutters which I have ground down to fit between IC pins. With long- nosed pliers grip the remains of a pin. Heat the soldered side with a soldering iron and pull out the pin. If this is done slowly whilst keeping the solder molten with the iron you should be left with a clear hole. Remove all pins in this way. Clear any holes that are still blocked with a soldering iron and solder sucker. Insert and solder the new IC and scrape away most of the flux from round the pins. Remove the rest with circuit board cleaner. Make sure there are no solder bridges between pins.

Always observe static handling precautions when dealing with sensitive components.

Final Function Test

Having located and replaced the faulty components all that remains is to reassemble the equipment and check that it is now working. Try all functions not just those that were originally faulty. If you lack confidence in your fault-finding abilities then make an additional function check before you reassemble the equipment!

In the final section I have described six real-life faults to illustrate how the various fault-finding procedures are applied.

Example 1

The fault was on a popular microcomputer which would not operate a modern plugged into the extension bus socket. The relevant part of the circuit diagram is shown in Figure 8. The extension bus address and data lines are driven from the system busses via buffers IC1 and IC2. IC1 is a standard buffer which is permanently enabled via pins 1 and 19. IC2 is a bidirectional buffer or transceiver. The direction of data flow is determined by the logic level at pin 1. A low level on pin 19 enables the transceiver.

As IC1 is permanently enabled the input and output lines should be identical. I checked this by observing each input and output pair in turn on a dual beam oscilloscope. Simply turning on the microcomputer and leaving it idling provided sufficient activity on the bus for this test. The results showed that some of the outputs were not following the corresponding inputs and so IC1 was obviously faulty.

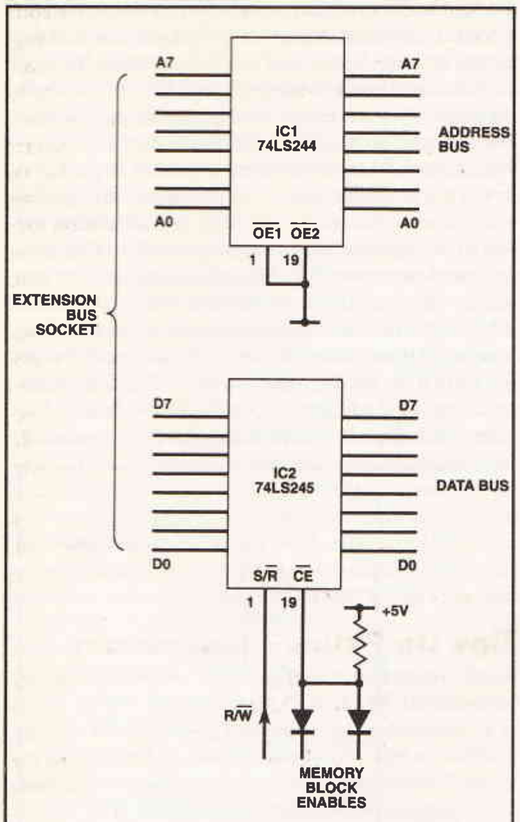


Fig.8 Part of the circuit diagram of microcomputer (Example 1)

IC2 could not be tested in a similar way as it is only enabled when specifically addressed. One possibility would have been to execute a Basic Statement sending data to the transciever. One execution of the statement would have given only a single brief output from the buffer which would not have been visible on an oscilloscope. Instead a repetive signal was produced by executing the following program.

```
10   ?&addr = &FF
20   ?&addr = &00
30   GOTO 10
```

addr is the hexadecimal address of the transceiver.

If IC2 was working this program should have produced alternate high and low levels on the outputs. I checked this on an oscilloscope, triggered externally from the CE pulse on pin 19. Again some of the outputs were not responding and so IC2 was also faulty.

Example 2

This fault cropped up in a video cassette recorder and illustrates the advantage of using a 'scope to measure voltages rather than a digital voltmeter. On playback the picture was very noisy and kept breaking up whilst the sound was varying in pitch. The sound symptoms suggested a problem in the capstan motor drive as this determines the speed of the tape through the machine and hence the pitch of the sound. Checking this area of the circuit revealed that the 18V power supply measured only about 16V on a digital multimeter. The 18V supply is produced in the power supply section part of which is shown in Figure 9. The voltages shown are the normal working values. Measuring again at the emitter of Q1007 confirmed that the 18V supply measured 16V. Was Q1007 faulty? The base was low at 16.7V but the collector was not far from normal at 21V. A possible explanation was that too much current was being taken from 18V supply thus starving D1014 and lowering the voltage at the base and therefore the emitter. A nice theory but unfortunately the voltage across C1009 was virtually the same as at Q1007 collector and so there couldn't be much current flowing through R1024.

Luckily before I became more confused I looked at the voltages on an oscilloscope and all became clear. The voltages across C1009 and at Q1007 emitter are shown in Figure 10. It can be seen that although the average value of the voltage across C1009 is 21V as indicated on the multimeter there are regular dips which are too severe for Q1007 to cope with. However there is still sufficient voltage to allow regulator Q1006 to operate as it is only producing a 12V supply. The cause was reservoir capacitor C1009 which had lost most of its capacity!

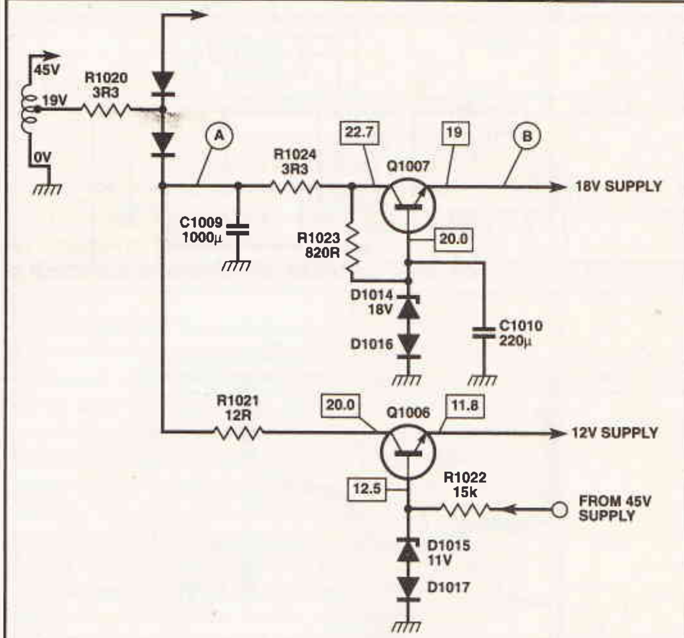


Fig.9 Part of the circuit diagram of a video cassette recorder power supply (Example 2)

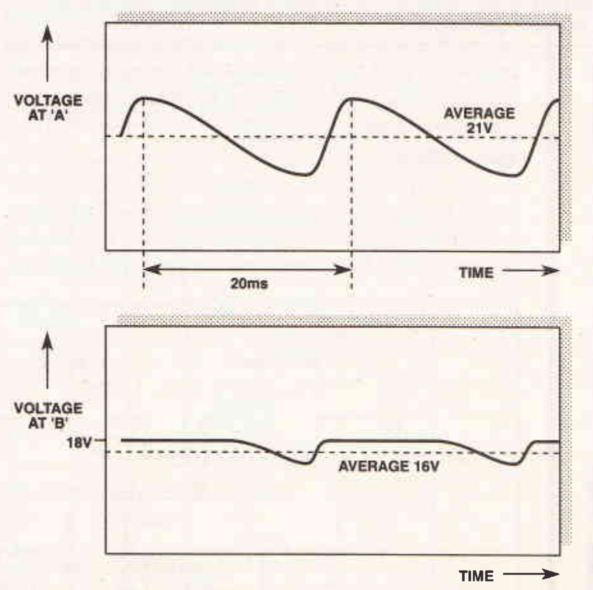


Fig.10 Waveforms in video cassette recorder power supply (Example 2)

Example 3

This fault occurred in an audio amplifier in which the mains fuse had blown with some violence. A simplified circuit diagram of the power supply is shown in Figure 11(a). The two possibilities that spring to mind are a faulty mains transformer or a fault on the secondary circuit causing a high mains current. I measured the resistances between the positive, negative and common rails and found a virtual short circuit between positive and negative rails. The obvious components to suspect were the power amplifier integrated circuits IC1 and IC2. Rather than try and disconnect the IC's to determine whether they were faulty I connected a variable current supply across the positive and negative rails set to give a current of 0.5A. I then measured the voltage drop along the printed circuit board track feeding each IC in turn as shown in Figure 11(b). One track gave zero reading the other about 5mV thus quickly identifying the faulty IC. If it hadn't been one of the IC's that was faulty I could have tested other possible components in a similar manner.

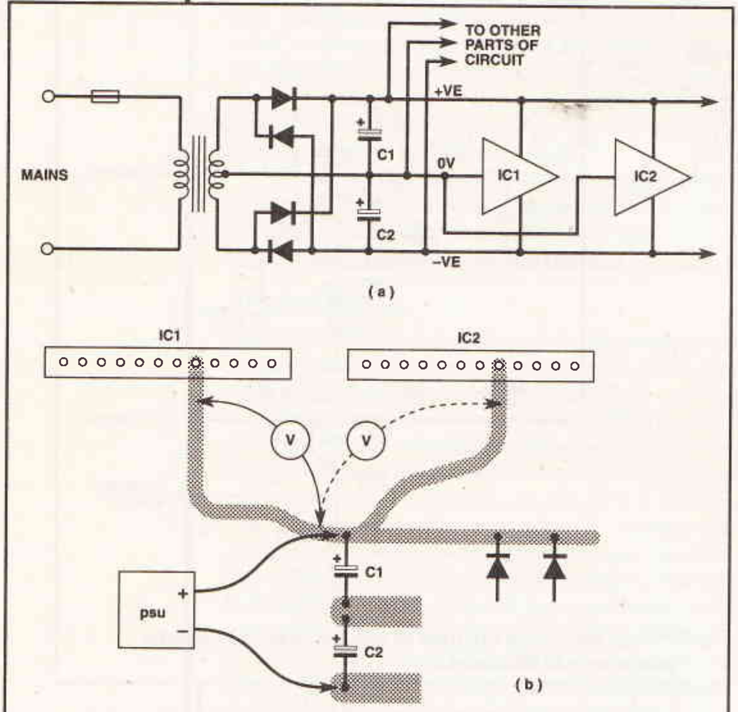


Fig.11 a) Simplified circuit diagram of an audio amplifier (Example 3)
b) Part of the track layout

Example 4

The fault was on an amplifier which was very distorted on one channel. Looking at the output on an oscilloscope it was obvious that there was virtually no negative drive from the output stage. The fault was quickly isolated to the small part of the output stage shown in Figure 12. Comparison with the good channel showed that the voltage at the junction between R1 and R2 should have been more like —45V not 1.48V so there was a problem. My first thought was that the voltage was low because of excessive current through R2. Was the current passing through R1 or R3? There was certainly not enough voltage across R3. Almost 50V dropped across R2 would imply 50 x 220/68 = 160V across R3 whereas there was only about 0.7V. Similarly the voltage across R1 would be 120/68 x 50 = 90V. Even if the upper end of R1 was shorted to the +48V rail there wouldn't be enough voltage. The obvious candidate was C1. Electrolytic capacitors frequently fail short circuit or partially short circuit. As I was about to reach for the soldering iron I had another thought. If there was almost 50V across R2 then shouldn't it be getting rather warm? The dissipation would be approximately 50 x 50/68 = 36W! The other possibility was that R2 had gone high resistance.

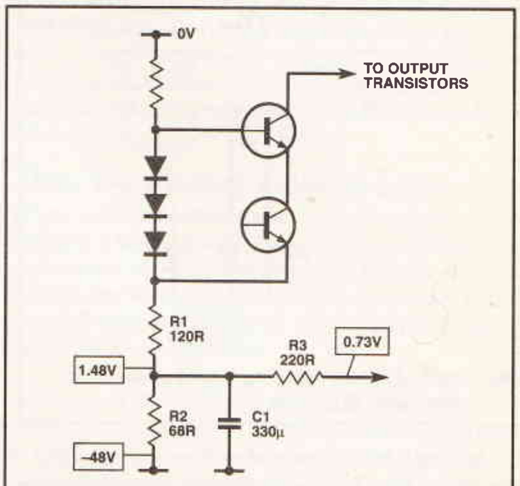


Fig.12 Part of audio amplifier circuit diagram (Example 4)

A check of the resistance across R2 gave a value far higher than the expected 68R. When removed from circuit R2 was found to be open circuit.

Example 5

This example is typical of the kind of fault that can quickly be found by signal tracing. The symptoms were straight forward — no playback on either channel of a cassette recorder/amplifier. Figure 13 is a very simplified schematic for part of one channel. With a constant tone tape playing I first looked for a signal at the input of the Dolby noise reduction integrated circuit IC401 using an oscilloscope. As a signal was present I could assume that the circuit up to that point was working.

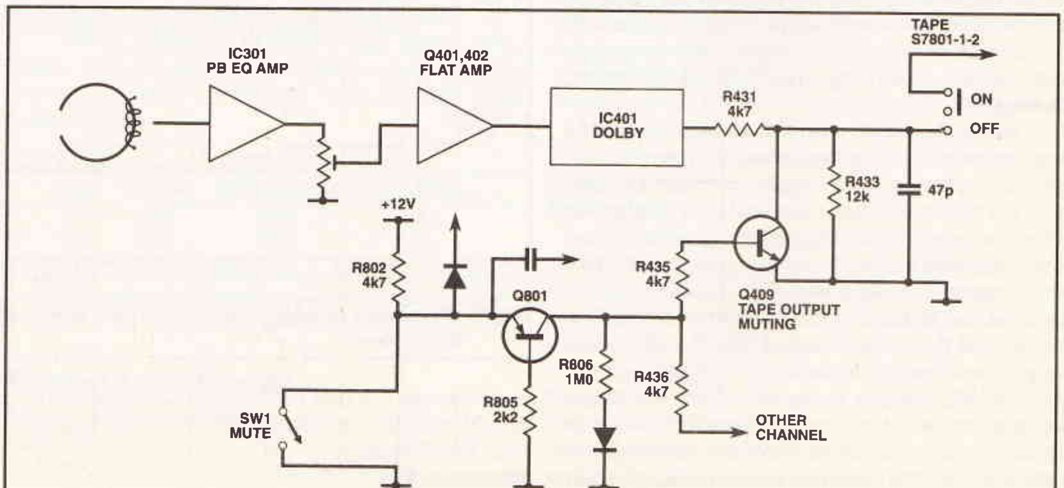


Fig.13 Simplified circuit diagram for part of one channel of a cassette recorder (Example 5)

There was a signal at the output of IC401 but not at the tape input selector switch. The first component to suspect was Q409. Was it shorted collector to emitter or was it turned on? The base-emitter voltage was 0.7V suggesting it was turned on. Q801 emitter was also high although it should have been low to turn off Q409. I suspected S11 a leaf switch on the cassette mechanism. On examining it closely I found it was damaged and was not closing when the mechanism was in the play mode. As is often the case it was a mechanical rather than an electronic component that had proved unreliable.

Example 6

Fault-finding without a circuit diagram is a lot more difficult and it also shows how even simple equipment can produce challenging faults.

The equipment was an audio amplifier which was off on one channel. Not having the circuit diagram, I traced out part of the circuit as shown in Figure 14.

Visual examination showed the 2A supply fuse had blown on the faulty channel. I also noticed resistor R1 in the Zobel network showed signs of overheating.

Taking the blown fuse first the only components connected directly across the supply (other than high value resistors) were Q4 and Q5. A quick check showed that they were both short circuit. This is very common in audio power amplifiers of this type. After removing Q4 and Q5 from the board to avoid spurious readings, I also checked the other transistors in circuit using a multimeter. This is a wise precaution as failure of the output transistors can damage other transistors in the output stage. However there seemed to be no further casualties. Overheating of R1 was something I should have taken more notice of but didn't. Instead I simply replaced R1 and checked that C1 wasn't short-circuit. As R1 is in series with a capacitor C1 then the overheating must have been caused by AC current (assuming C1 is not short-circuit). More significantly a rough calculation shows that it would need about 15V at 80kHz to cause enough current to produce the overheating! The explanation was obvious as soon as I turned on the power having replaced Q4 and Q5. The amplifier had become unstable and I had a tidy RF signal generator instead! The amplifier showed signs of distress had to be turned off. Another fault had made the amplifier unstable and caused the original failure of Q4 and Q5.

To allow me to fault-find without further damage I disconnected the good channel and connected the faulty channel to a variable power supply increasing the voltage until the amplifier just started to oscillate. Common causes of instability are the failure of roll-off capacitors such as C2,C3 and C4 or decoupling capacitors such as C5 and C6. Bridging each of these in turn with a capacitor of the same value made no significant difference. Things didn't seem to be making any sense and so I had another look at the board and discovered the second feedback path via the tone controls and C7. I had assumed the tone controls were before the power amplifier as is usually the case. A proper circuit diagram would have told me immediately.

There was now another possibility that the fault lay in the feedback path through the tone controls. I realised that feedback through R2, R3 and R4 should be sufficient to give stability without the additional feedback through the tone controls. Therefore I could check whether the fault lay in the tone controls by disconnecting the feedback path at point A. This I did and found that the amplifier immediately stabilised. All I had to do was find the fault in the tone control circuitry.

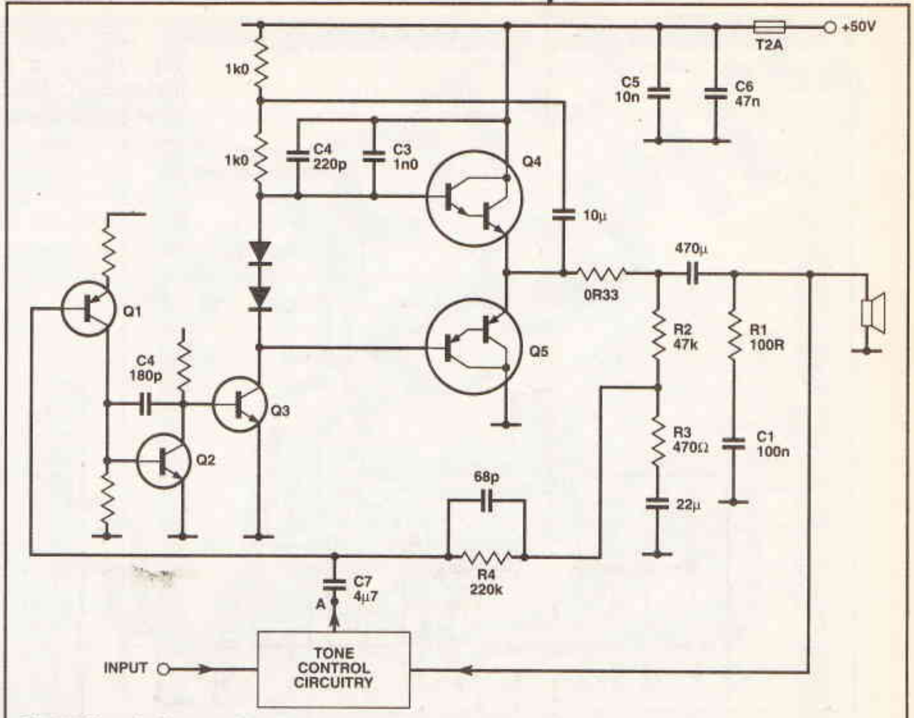


Fig.14 Circuit diagram for the power section of an audio amplifier (Example 6)

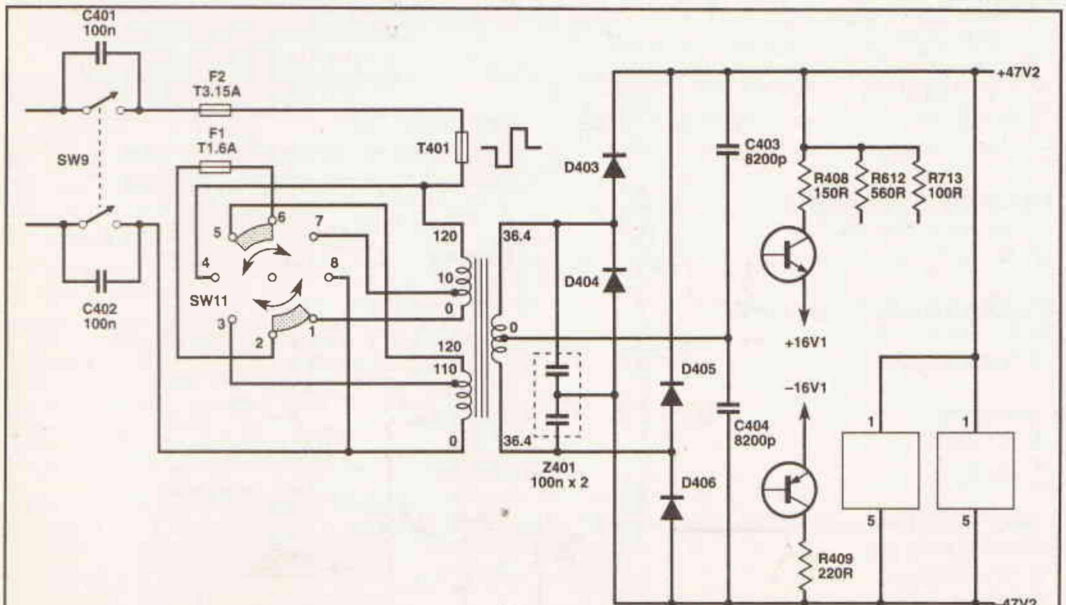
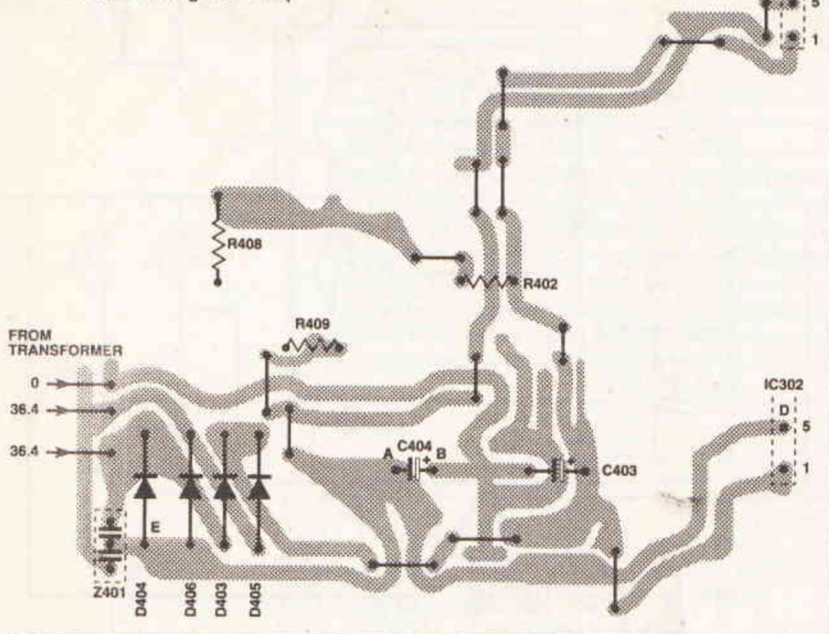


Fig.15 Part of the circuit diagram of an audio amplifier (Fault-finding exercise)

Fig.16 Part of the board layout for amplifier shown in Figure 17 (Fault-finding exercise)



I left C7 disconnected and used it to inject a signal into the main amplifier. This produced a signal at the output of the amplifier and hence also at the input of the tone control circuit. I disconnected the corresponding capacitor on the other channel and did the same there. Comparing the outputs of the tone control circuits in the faulty and working channels I found the faulty signal level was far higher. Starting back at the input I quickly found that the signal seemed to disappear somewhere along a track connecting one end of a resistor to the track of a potentiometer. Looking closely I thought I could see a hairline break in the track just before the solder pad of the potentiometer. With power off I measured the resistance between one end of the track and the other and found it was definitely high particularly if the potentiometer was rocked slightly. Resoldering the connection to cover the crack cured the fault.

Fault-Finding Exercise

The following exercise is designed to test your skills at fault-finding. It is based on a real fault that occurred on an audio amplifier. Part of the circuit diagram is shown in Figure 15 and the board layout in Figure 16.

Start at the symptoms of the fault described in paragraph 1 and decide which of the courses of action A to E you would take. Move on to the paragraph whose number is shown at the right-hand side of your choice. This will describe the results of your action and present another list of possible actions. Have fun!

Last month

A couple of errors crept in. Figure 1 bottom corner block should read 'overload and mute circuit' Figure 5. In (a) Actual voltage across 47k in 3.2V and in (b), the meter reading is 2.8V. The last paragraph in the Section on 'Types of Fault' should refer to Figure 6.

1 Fuse FI blows
- A Fit new fuse and try again — 10
- B Measure resistance of primary of transformer — 5
- C Measure resistance of diodes in situ — 2
- D Measure resistance between positive and common, negative and common and positve and negative rails — 3
- E Measure resistance of secondary of transformer — 18

2 D404, D406 give very low resistance both ways. D403, D405 give normal readings
- A Fit new diodes D404, D406 — 15
- B Disconnect mains transformer and test diodes again — 4
- C Remove D404 and D406 and test again — 8

3 Positive to negative and positive to common reasonable. Negative to common very low
- A Fit new power amp IC's — 6
- B Measure resistance of diodes in situ — 2
- C Connect current limited power supply set at 1A across C404 positive to point B, negative to point A. Measure voltage drop A to C and A to D — 7
- D Connect current limited supply across B and E. Measure voltage drop E to C and E to D — 12

4 All diodes give normal readings
- A Fit new mains transformer — 6
- B Start again — 1

5 Resistance is 20 ohms. 240V/20 ohms = 12 A
- A Fit new mains transformer — 15
- B Uprate fuse to 3.15 A — 10

6 Fuse blows again
- A Start again — 1
- B Give up — 20

7 Voltage A to C and A to D both virtually zero
- A Fit new power amp ICs — 15
- B Measure voltage A to E — 11
- C Reverse connections to power supply. Measure voltages A to C and A to D — 17

8 D404, D406 give normal readings
- A Solder diodes back in place and think again — 1
- B Return equipment to owner saying it's not worth repairing. — 20

9 Resistance is very low
- A Fit new capacitor — 19
- B Solder capacitor back and think again — 1

10 Fuse blows — 1

11 Voltage is virtually zero
- A Connect power supply to points E and B. Measure voltage E to A — 14
- B Increase current to 2A. Measure voltage A to C and A to 0 — 7

12 Voltages very similar at about 4mV
- A Fit new power amp ICs — 6
- B Measure voltage E to A — 14
- C Measure voltage E to B — 16

13 If you've arrived here you must have misread something

14 Voltage is 4mV
- A Remove D404 and D406 and check resistance — 8
- B Remove C404 and check resistance — 9
- C Fit new Z401 — 6

15 Fuse blows — 1

16 Voltage is 0.4V
- A Reassemble the amplifier and take it to a shop for repair — 20
- B Think again — 12

17 No difference — 7

18 Each 0.3 ohms, total 0.6 ohms
- A Fit new mains transformer — 10
- B Think again

19 Success

20 Failure

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Portable Geiger Counter

A handy radiation detector by Malcolm Plant.

It may be an obvious fact of biology, but one fascinating aspect of seeing, hearing, touching and smelling is that the sensing process is unique to the individual. For example, when you look at starlight your eyes absorb photons that were the result of atomic reactions which released the photons millions of light years ago — those photons end up in your eyes alone and no one else's. In the same way, your view of a rainbow is unique to you.

I'm similarly intrigued by the fact that when you design an instrument like a Geiger Counter, the 'click' you hear in the headphones might be produced by a rapidly moving cosmic ray particle originating from some distant point in the Milky Way galaxy before life on Earth began. That particle or photon loses its energy in the instrument you may have designed and you alone may have experienced its passing. Of course, you might say there are countless millions of photons and atomic particles, so who cares?

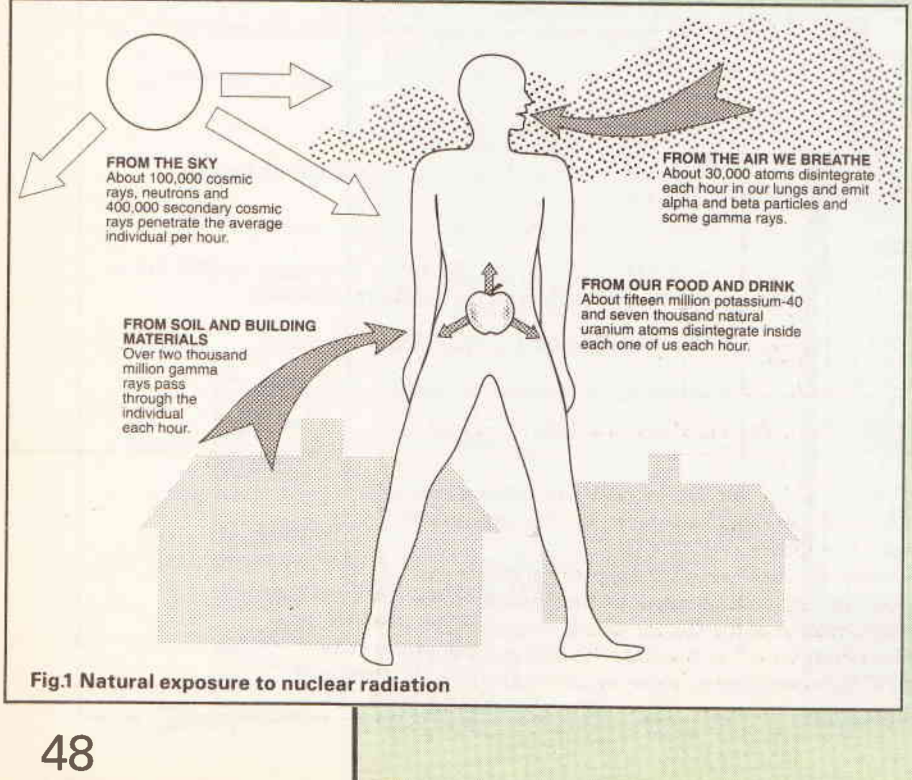


Fig.1 Natural exposure to nuclear radiation

Nuclear radiation is a fact of life. It's one of many forms of radiation which have to be handled with caution. For example, too much sunlight can cause skin cancer; over-exposure to X-rays used in dentistry and medicine, and to microwaves used in communications and for cooking, can be harmful. It seems that the benefits of technology cannot be had unless we accept some danger in the use of the technology, so a careful balance needs to be made between the risks and the benefits of the practice that causes the exposure. The subject of radiation safety has a high profile in the public's mind, partly because most harmful radiation is invisible and it is one cause, among others, of illnesses that people particularly dread. Aware of this public concern, the nuclear industry has responded with a great deal of positive information about nuclear energy and the uses to which it is put. For example, the National Radiological Protection Board (NRPB), which is an independent statutory body provides advice on radiation standards, and carries out research to improve protection.

It is useful to consider two classes of radiation, non-ionising and ionising, when assessing the useful and harmful effects of radiation. Non-ionising radiations are the electromagnetic waves of ultraviolet light, visible, infrared, microwave, and radio waves. Ionising radiation includes gamma rays, X-rays and cosmic rays. Cosmic rays reach us from space and include gamma rays, X-rays, and high-speed atomic particles. The public seems to be less anxious about non-ionising radiations than ionising radiations, though evidence is accumulating of the medical effects of the former. These include damage to the skin and eye and, for those radiations that enter the body tissues, damage to internal organs due to excessive heating. Undoubtedly it's the association of ionising radiations with atomic weapons and the accumulation in ecological systems of the long-lived waste products from nuclear power stations that makes ionising radiations such a sensitive public issue. And this concern is not eased when we read that one method under discussion for 'de-commissioning' a nuclear power station is to entomb it in earth arid concrete to make it safe from future human (and animal?) interference!

However, it's as well to get ionising radiations from man-made and natural sources into perspective. Figure 1 shows the contribution of this radiation from our surroundings. There is a significant amount of radiation from the natural environment and we can do very little about it.

Detection of ionising radiations

There are several methods of detecting ionising radiations including the photographic plate, thermoluminescent materials, Geiger tubes, solid-state pn junctions, and scintillation counters. Of these the Geiger

PROJECT

tube, is an efficient detector of the backgound nuclear radiation, especially of secondary cosmic ray emissions and gamma rays from surrounding materials. The design of present-day Geiger tubes is still much the same as the original Geiger-Muller tube, but nowadays it is available in miniaturised form for use in portable instruments. Different types of tube are available depending on which atomic radiation, alpha or beta particles, or gamma rays, you want to detect.

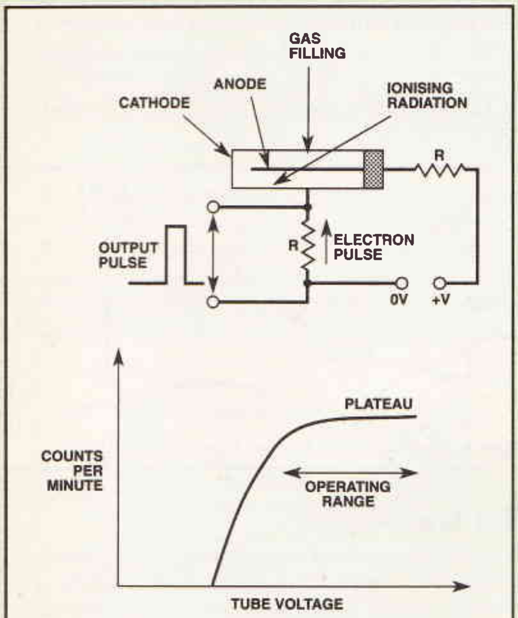


Fig.2 The connections to the Geiger counter tube and its characteristic

The Geiger Tube

Figure 2 shows the basic principle of the Geiger, or Geiger-Muller, tube. Detection of an atomic particle relies on the particle releasing energy by collision with a gas filling in an almost completely evacuated tube. The energy is released in the form of electrons and positively charged ions which move rapidly towards two electrodes, an anode and cathode. The further collision of these ions with the gas releases more energy through an avalanche effect. The sudden surge of electric charge constitutes a small electric current which flows in the external circuit connected to the electrodes. The processing of this current pulse produces a 'count', eg a click in an earpiece or an increment on a digital display.

A drawback of the Geiger tube is that a voltage in excess of 300V is usually needed to operate the tube and produce the avalanche effect required for particle and photon detection. Though semiconductor pn junction detectors are available which operate from a few volts, they are not very efficient for detecting gamma rays which might be of interest to the amateur scientist simply looking at changes in background radiation in the environment.

The number of counts per minute the tube is able to respond to rises with the voltage across the tube and begins to saturate at the threshold of the plateau along which the count rate is approximately constant. In the design of a circuit for operating the Geiger tube, it is essential that the tube is applied with a DC voltage which is approximately constant and somewhere in the middle of the plateau. The requirement for a stabilised operating voltage is not particularly critical in the Pocket Geiger Counter which is being used only for monitoring not for accurate measurement or comparison of counts. However the circuit to be described does provide reasonable stabilisation of operating voltage. It should be noted that while the operating voltage should place the tube on the plateau, it is important not to operate the tube in excess of a voltage that puts it into continuous discharge without initiation by a particle, for this will rapidly damage the tube. The choice of gas in the tube is critical and includes a quenching agent to ensure that the tube quickly reverts to a neutral state after a discharge event. This precaution ensures that the tube quickly recovers ready for the next detection of an ionising particle.

The Circuit

The circuit shown in Figure 3 provides all the component drive, detection and signal conditioning required to operate two output devices; an LED and headphones. For each gamma ray or beta particle entering the tube and causing ionisation, there is a sharp click in the headphones and the LED flashes briefly. The circuit is best described via the block diagram shown in Figure 4 which highlights the principal functions of the circuit.

The 'engine' of the circuit is the astable based on one of the gates, IC1a, of the quad 2-input Schmitt Trigger, IC1. The frequency of this oscillator is set at about 500Hz by means of components C2 and R1. This provides rectangular pulses which, via the current amplifier, Q1, drives the step- up transformer, T1. The output from this transformer is an AC voltage which is processed by the rectifier and voltage-doubler section based on the high voltage capacitors and diodes, C4

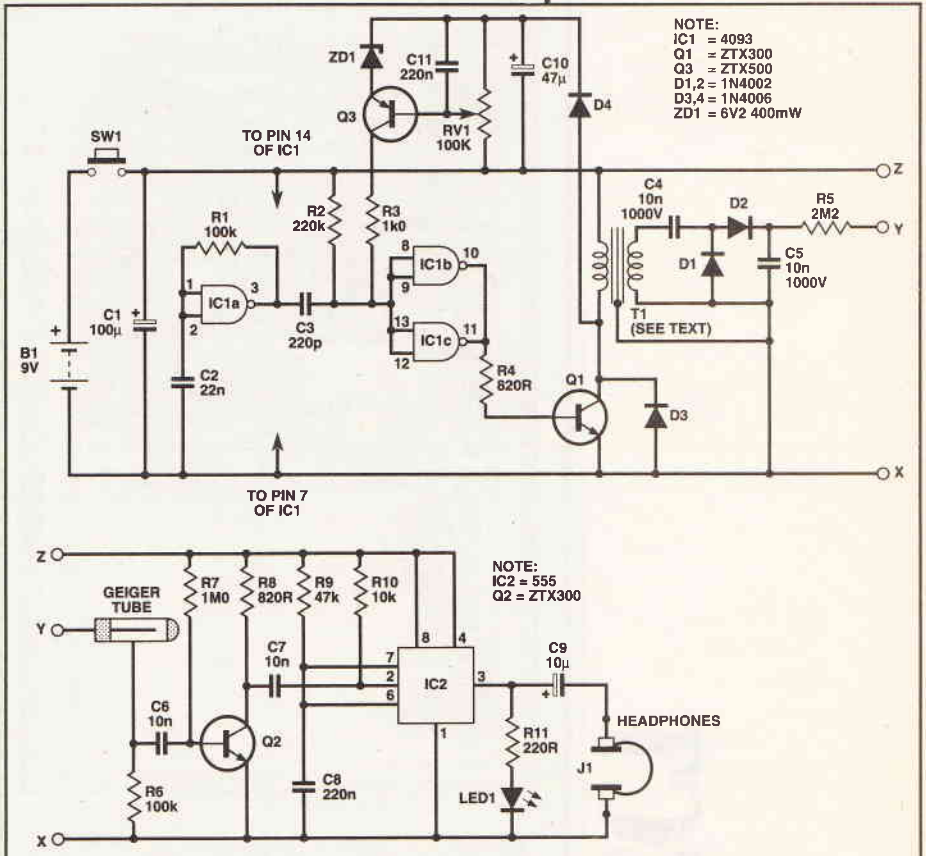


Fig.3 Circuit diagram of portable Geiger counter

and C5, and D1 and D2, respectively. T1 is a prewound pot core available from the suppliers listed under 'Components'

In order to conserve battery power and maintain a constant high voltage output within the limits of the plateau voltage of the Geiger tube, a variable pulsewidth circuit based on transistor Q3 and gates IC1b and IC1c is used. Since T1 is a ringing-choke inverter, energy stored in T1 when Q1 is switched on is released when Q1 is turned off. Most of this energy is passed into capacitors C4 and C5 via the secondary winding of T1, but a small remainder is used to charge capacitor C10 via diode D4. When the voltage across C10 rises to a value which switches on Q3, the voltage on the gates IC1b and IC1c rises and reduces the pulse width of the signal delivered to the transformer. This reduces the supply current and stabilises the peak primary voltage and hence the peak secondary voltage. The voltage selected for the Geiger tube is set by RV1 which determines the switch-on voltage for Q3.

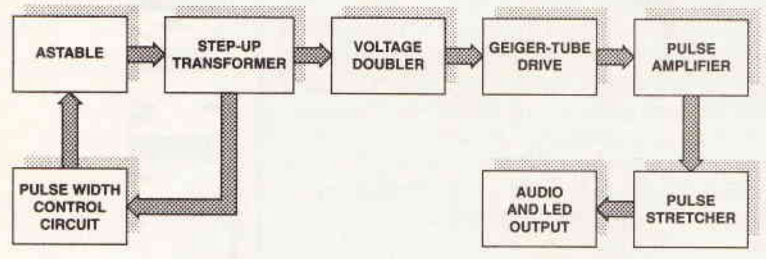
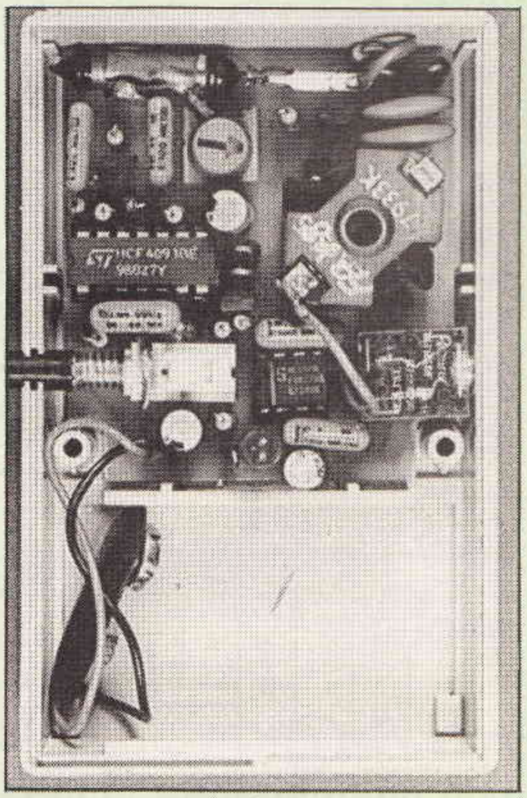


Fig.4 Block diagram of portable Geiger counter

The DC voltage from the voltage doubler is applied to the Geiger tube via resistor R5 which limits the peak Geiger current to a safe value. In order to detect the passage of particle through the tube, resistor R6 is connected in series with the cathode of the tube. A current increase in R6 raises the voltage across it and switches on transistor Q2. This sharply pulls down the



voltage on the trigger pin of IC2 which is wired as a monostable to produce a stretched pulse for operating the light emitting diode, LED1, and the headphones. The length of this pulse is determined by R9 and C8 and is set at about 0.01s. This is rather a long pulse and would need to be shortened if pulse rates of more than 100 per second need to be detected. The reasons for stretching the pulse is to ensure that LED1 registers the entry of a particle in the tube and to provide a recognisable 'click' in the headphones.

The Geiger tube

The Geiger tube selected for this portable Geiger Counter was type ZP1310 available from Alrad Instruments. This tube is beta particle and gamma ray sensitive and is small enough to fit into the box selected for the project. Its sensitive length is 16mm, its plateau threshold voltage is 500V and it has a plateau length of 150V. It has a recommended working voltage of 550V and this is provided by the circuit described above. The maximum background count rate with this tube is only about 2 per minute (but obviously is higher depending on environment and locality) and is due to its small active volume. The tube has a metal cathode envelope and is supplied with a flexible metal band for connecting the cathode to the circuit. The anode pin is supplied with a sleeve connector for soldering to the circuit. Figure 5 shows the basic shape and connections to this Geiger tube.

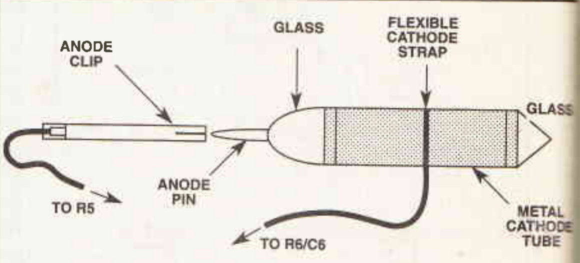


Fig.5 Structure of the Geiger tube type ZP1310

The transformer

This is a pre-wound pot core supplied by Maplin order code FP78K. The pin connections to this pot core are shown in Figure 6. Note the soldered wire link from the metal clip round the transformer to a 0V connection on the PCB. The transformer has two primary windings but only one is used in the design. Note this transformer is fragile and the pins may easily become detached so take care to keep it in its wrapping until you are ready for soldering it into the circuit.

Circuit Assembly

The box chosen for this project can be obtained from Farnell Components Ltd and is a sub-miniature case with an integral PP3 battery compartment. The circuit was designed to fit into this case and a push-to-make

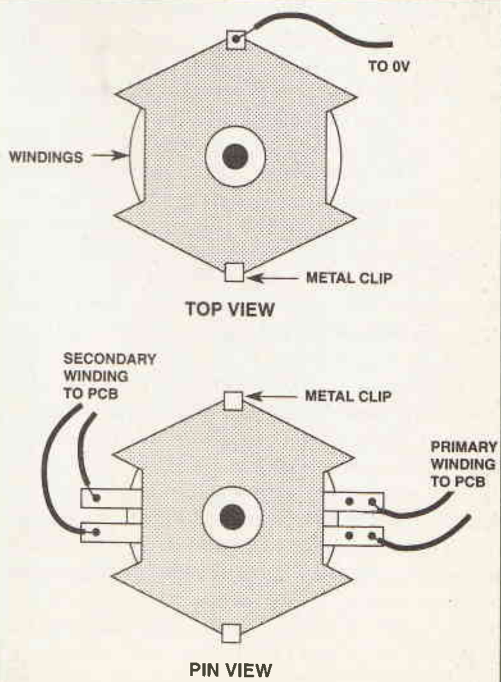


Fig.6 Connections to transformer

release-to-break switch was used to avoid the unit being left on inadvertantly. Figure 7 shows the finished unit complete with a screen printed label to give it a professional appearance. Ordinary headphones of the type used for a personal cassette players are ideal for use with the Portable Geiger Counter.

The printed circuit board layout is shown in Figure 8. The dense packing of the components and fine tracking requires the use of a soldering iron with a small tip.

Notes On Assembly

1 Solder a short wire from the metal strap round T1 to the 0V connection on PCB; this prevents the audio buzz from the astable from breaking through to the headphones.

2 The push switch, SW1, has a clip holding the two parts together —remember to order this as well.

3 The battery clip should be threaded through a hole in the upright panel that separates the battery compartment from the PCB. Tie a knot in the battery leads to ensure that they do not tug on the connections to the PCB.

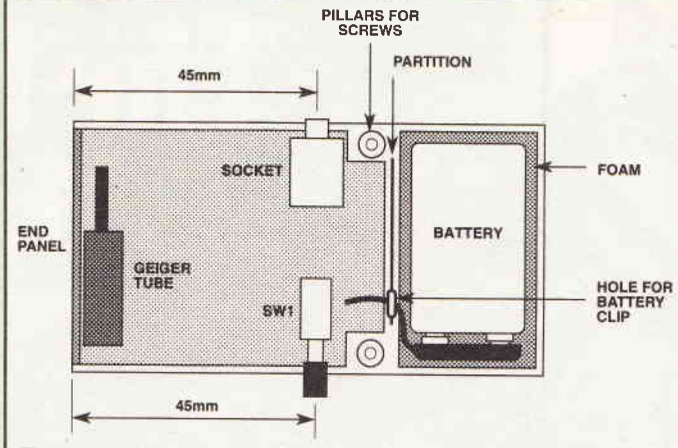


Fig.7 Positioning of components in box

4 The PCB is held in place by means of the PCB socket and push switch. Therefore the holes for these two components need to be drilled with some care and positioned as shown in Figure 7.

5 Cut a small piece of polystyrene foam to fit inside the battery compartment to cushion the movement of the battery.

6 The fling nut for the jack socket is not required. Three holes need to be drilled in the box after the PCB has been carefully fixed in position, one for the jack socket, one for the push switch and one for the LED.

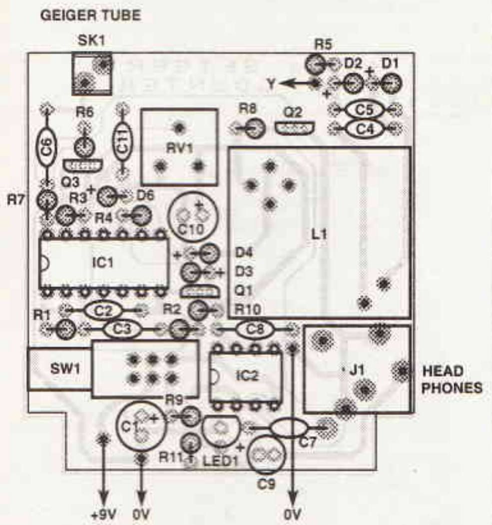


Fig.8 Component overlay

Testing

Ideally a high resistance voltmeter needs to be used to set the DC voltage for the tube to between 500V and 550V by adjusting RV1 - it will not be possible to initiate continuous discharge in the tube. Alternatively, set RV1 to its mid position and wait for the random clicks and the flash of the LED — about 2 to 6 clicks per minute depending on geographical location. Try finding sources of radiation, eg some smoke alarms, old luminous watch and clock faces, rocks and soil and along parts of the coastline.

PARTS LIST

RESISTORS (all 0.25w metal film)

R1,6	100k
R2	220k
R3	1k
R4,8	820R
R5	2M2
R7	1M
R9	47k
R10	10k
R11	220R
RV1	100k preset

CAPACITORS

C1	100µ/15V
C2	22n ceramic
C3	220p polystyrene
C4,5	10n/1000V disc ceramic
C6,7	10n ceramic
C8,11	220n ceramic
C9	10µ/15V
C10	47µ/15V

SEMICONDUCTORS

IC1	4093, quad 2-input NAND
IC2	555 timer
Q1,2	ZTX300 NPN
Q3	ZTX500 PNP
D1,2	1N4002
D3,4	1N4006
ZD1	6V2 400mW
LED1	Red LED

MISCELLANEOUS

T1	Transformer pot core from Maplin, order code FP78K (see Fig.6)
SW1	Push-to-make
J1	Jack socket 3.5mm pcb type from Maplin order code FK20W
BAT1	9V PP3

Geiger tube: Type ZP1310, from Alrad Instruments Ltd, Turnpike Road Industrial Estate, Newbury, Berks, RG13 2NS

Single fuseholder as clip for tube or glue tube to surface of PCB

Headphones: Personal radio or cassette type with 3.5mm plug

IC sockets: 14-pin for IC1; 8-pin for IC2

PCB: size 51mm x 56mm; use glass fibre type and cut corner notches as shown in Figure 9

Case: Sub-miniature with PP3 battery compartment; Farnell Order Code 148-580

Solder, insulated connecting wire

The Hemisync Machine

Final Assembly

2

PROJECT

Aubrey Scoon continues his project to encourage brainwave patterns.

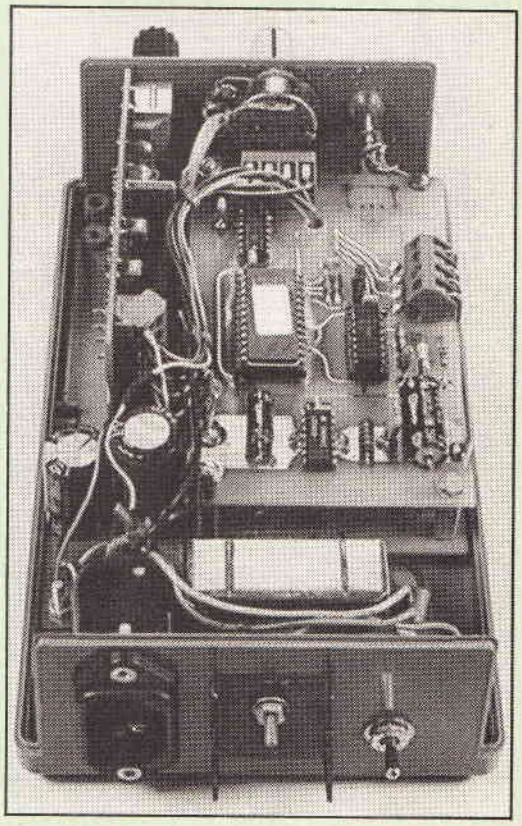
We are now ready to start the final assembly into the case. Figure 5 last month highlighted the final positions of the component boards. Firstly, mount the IEC socket or cable gland as appropriate into the rear panel, and then mount the mains switch. Before wiring the mains connections it will be necessary to mount IC12, the voltage regulator. This is simply bolted against the rear panel from the inside. The securing bolt (a brass bolt is recommended) runs through the rear panel to a heat sink which is mounted on the outside of the case. The securing bolt will be sufficient to conduct heat from the regulator to the heat sink. The heat sink is probably overkill since the regulator gets only slightly warm in normal use, however, I prefer to play safe and use one! Don't use a nylon bolt to mount the regulator as this will defeat the object of the heatsink.

Flying leads should now be soldered to the pins of the regulator IC from where they will run to the power supply PCB. I recommend routing these along the rear and side of the case. It is a good idea to place small rubber sleeves over the regulator pins to prevent them touching and shorting.

The next thing to do is to wire the mains leads to the IEC socket if used. Solder on the connections and run the live and neutral wires to the upper poles of the DPST mains switch. I recommend using short lengths of rubber or preferably heat shrink sleeving to cover the solder connections at both ends once they are made. Additionally I strongly recommend using a proper rubber boot to sleeve the whole IEC socket. Remember to thread the sleeves and the boot on to the wires before soldering both ends. Once the sleeving and boot is in place on the IEC socket it is a good idea to tie the cables to the boot at the neck using a cable tie. This serves the dual purpose of securing the cables and the boot itself in place.

Solder two short lengths of appropriate mains lead (sleeve the connections as before) to the middle contacts of the switch. These will run to the transformer when mounted.

It is now time to mount the transformer. The transformer is positioned as far back as it will possibly go in the case, up against the switch and the regulator. Make sure that no exposed connections from the switch terminals (especially any unused poles) come into contact with the transformer case. Also make sure that none of the exposed transformer poles touch any part of the regulator or vice versa. When the transformer is in a suitable position, mark out the mounting holes for it on the base of the box. Remove the transformer and drill the mounting holes.



Solder the leads from the switch to the transformer primary terminals and flying leads to the secondary terminals. The transformer is a 6VA 12V type with either two separate 6V windings or a single 12V centre tapped winding. If it has two separate secondaries these should be wired together in the middle to simulate a single centre tapped winding. When this has been done there should be three output wires: two connections to either end of the secondary and one centre tap. Again it is best to sleeve all the transformer connections. The transformer may now be bolted to the base of the case. Two eyelet connections are attached to the transformer case by one of the mounting bolts. One should be soldered to the Earth lead from the IEC socket and the other should have a flying lead attached which will eventually run to the ground power connection on the pulse board connector CB1.

Temporarily fix or hold the power supply PCB in place where it will be mounted and measure out the flying leads that come from the secondary of the transformer and the leads for the regulator. Trim all the wires to the appropriate lengths and then solder them into their respective positions on the power supply PCB. Tie off the wires with cable ties so they will run neatly round to the rear of the case. Attach two flying leads to the power supply PCB for the output connections, for the 5V and ground lines. These two wires will only need to run to connector CB1 on the pulse board which is adjacent to the power board. Do not attach a wire for the 17V output as this will be directly connected to the waveform boards. Do not secure the power supply PCB in place at this time.

The next step is to mount the waveform boards. Before doing so it is a good idea to secure the lower 5mm spacers under the bottom board into position as they will be impossible to reach when the board is in place. A small blob of hot melt glue is perfect for this, if not available try a little polystyrene cement.

Firstly mount the two pots for the waveform boards on the front panel in the two central holes, one above the other. If you have decided to use both optional switches for the waveform control you will need to drill another hole in the front panel for the shaft of the upper switch. I have not given dimensions for this hole as its exact position will depend on the length of the board mounting spacers you have used. When the pots are in place slide the two waveform boards into position behind the pots. The boards should just fit in, with their front edges against the base of the pots. The pots should be oriented so their terminals are facing to one side where they will not short against anything on the waveform board.

The boards may now be secured in position. Take a long bolt and run it up though the base of the case, through the 5mm spacers underneath, and through the 16mm spacers separating the two waveform PCB's. Secure the boards and spacers in place with a nut on the top board. The PCB's should now be securely mounted. The lower hex switch (and the upper if installed) on the waveform boards will be standing back from the front panel by about ½" but the shaft should protrude through the panel. You may at this stage if you wish attach the collet knob, pointer and cap to the waveform switch and trim the pot shafts and secure the knobs. If you have only installed one waveform switch you can now mount the output jack socket in the upper left hand optional position marked on the template. If you have the second switch installed there will not be room in the upper left position, in which case you should have drilled the second optional hole at the lower right hand side of the front panel and should mount the jack socket there. Attach the flying leads from the output terminals to the jack socket as described earlier, routing and shortening the wires as appropriate.

Now you can mount the pulse generator board. Slide it into position and secure the hex switch mounting collar to the front panel. Run the two lateral securing bolts through the base of the case on either side of the pulse PCB and tighten them into position. The pulse PCB should now be held firmly in place.

Trim the shaft of the hex switch on the pulse board as appropriate and attach the collet knob and accessories.

All that remains is to complete the interboard wiring, see Figure 6 for a schematic. Run the flying leads for the 5V and ground power connections and the inputs from the waveform boards to the connector CB1 on the pulse board. Connect the two waveform input leads to the two output poles on CB1. Either way round will do, the orientation isn't critical. Now make parallel connections at CB1 between the power leads from the waveform boards and the two input power leads from the power supply PCB. Additionally, connect the extra earth connection from the transformer case eyelet to the main ground connections on CB1 pin 3.

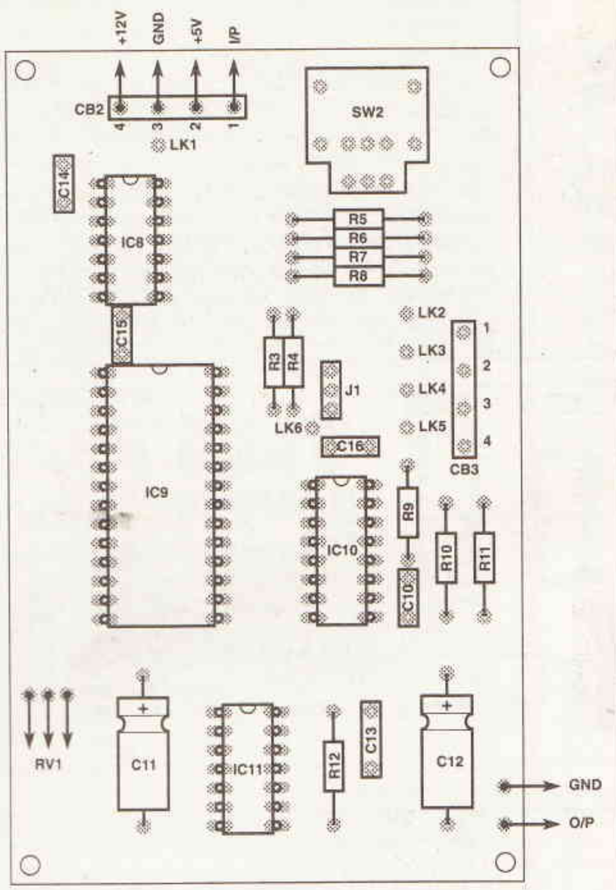


Fig.9 Hemisync waveform generator overlay (2 boards required)

The 17 volt line from the waveform board connector CB2 should be soldered directly to the appropriate connection on the power supply PCB. Once this is done you can mount the power supply PCB on four 5mm spacers and secure it in position.

Trim all the leads to length as appropriate and tie the flying cables together with cable ties.

Your hemisync machine is now complete. And hopefully working!

Testing

The circuit is pretty straightforward to test although ideally an oscilloscope and frequency counter should be used. Before switching on double check all connections and junctions against the wiring schedule and check for short circuits or contacts between components. Take particular care to check the mains input wiring, especially in the area around the switch and transformer. When you are sure everything is OK switch on.

If there are no sparks and smoke its a good sign The first thing to check is the power supply voltages. You should see 5V on the 5V line, nothing on the ground and approximately 17V on the unregulated 17V line. The 17V line may vary by about 1.5V either way without indicating any problem.

If the voltages are not correct, switch off immediately as you may damage the IC's if you apply the wrong voltages for any length of time. If there is a problem triple check the interwiring. Make sure the diodes are the right way round on the power supply PCB (remember the stripe on the diodes is the negative end and check the electrolytic capacitors are also the right way round in polarity Also make sure that you have not swapped C17 and C18 inadvertently. The 17V line will damage C18 if you have them in the wrong places

Now check the output of the pulse generator. If you have a 'scope, check that there are pulses at the two output terminals on CB1. A logic probe may be used if you don't have a 'scope. The duty cycle of the variable channel is very low so it may be hard to see the pulse on a 'scope and some frequency counters may be unable to obtain an accurate reading. The fixed channel through CB1 pin 1 is a square wave and should be easy to detect. The frequency of the fixed channel should be exactly 52083.33kHz. If you are able to read the frequency of the variable channel it should be somewhere between 51546kHz and 47846kHz, depending on the position of the pulse board switch. Varying the position of the switch should vary the output frequency of the variable channel.

If you see the above pulses all is well with the pulse board. If you are getting no output then it is a good idea to check the clock signals further back in the circuitry and see if they are present.

The first thing to eliminate is the master clock generator. Check the output of the crystal oscillator on pin 8 of IC1. You should see a stable 10MHz square wave signal. If that is not present the crystal may be damaged internally, they are fragile and can easily shatter if dropped.

If the 10MHz signal is OK check the output of pin 9 of IC2. This should be a 3.333333MHz signal with 33% duty cycle. If this is not present try replacing IC2, after checking all the connections.

The rest of the pulse board is pretty straightforward so there is little that can go wrong if carefully constructed. If you do have problems I would suggest checking carefully for solder bridges between pins on the IC's and make sure that wire cuttings, loose solder and filings have not worked their way into the circuitry. Double check that all through hole connections have been soldered properly on both sides of the board.

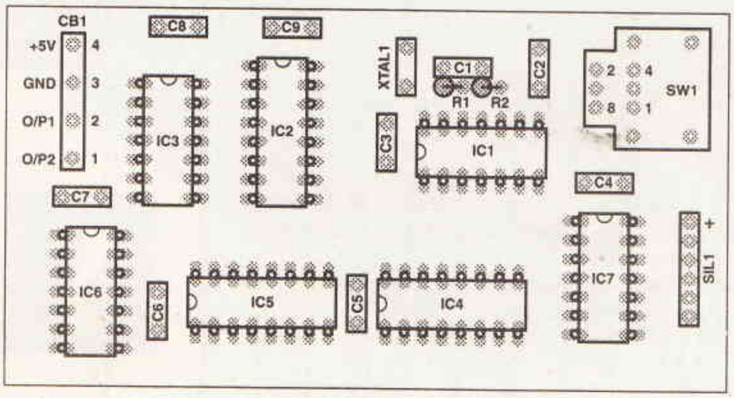


Fig.10 Pulse generator component overlay

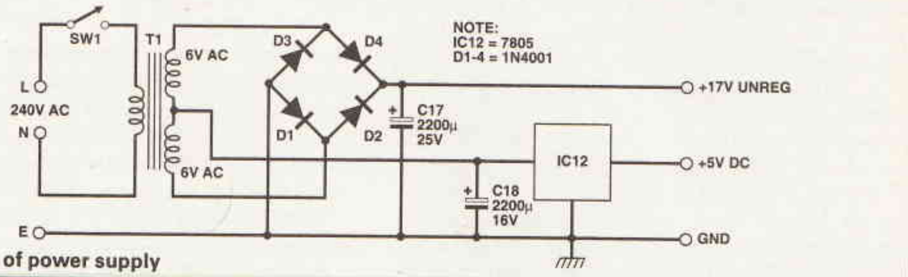


Fig.11 Circuit of power supply

Once the pulse board has been verified its time to check the waveform generators. Place a 'scope probe on pin 16 of the ZN559 of either wave board and you should see an analogue waveform with a peak to peak amplitude of about 5V and frequency around 200Hz. The shape will depend on the programming of the EPROM. If you have only programmed the default sine wave then only one of the 16 switch positions will be working unless you have filled the whole EPROM with the same pattern. So try turning the hex switch for the waveform until the trace appears. If you have multiple waveforms you should see the trace change shape as you turn the switch.

If the waveform isn't present, check the setting of jumper J1. If the EPROM you are using is a 2732 the jumper should be connecting the leftmost two terminals of the jumper block when pin 1 of the EPROM is on your left. If the EPROM is not a 2732 the jumper must be installed so that it connects the rightmost two terminals.

If the jumper is OK make sure that you have installed the through hole wire links, LK1 through LK6.

If the problem persists check that the wiring to the pulse generator is correct and that you have pulses and power coming in on the appropriate terminals of CB2. Also double check all soldering on the board and make sure all the chips are in the right way round, and soldered on both sides of the board where necessary.

When you manage to get a waveform from the D/A converter its time to test the output amplifiers. Connect a pair of stereo headphones to the output jack and listen for a 200Hz tone. This will sound like a low hum. You may hear beats between the channels. This indicates the hemisync machine is working properly, the beats do not in fact exist they are a kind of audio illusion that your brain creates when it integrates the signals.

If you don't hear anything immediately, try turning the pots, these are the volume controls and it may be you have the volume turned right down

Try varying the position of the hex switch on the pulse generator. You should hear the beats speed up or slow down as appropriate. If you have more than one waveform programmed in the EPROM, try changing the waveform by moving the switch(es) on the waveform boards. You should hear a change in the tone and quality of the sound if the wave is sufficiently different. You should also find that varying the pot positions will alter the volume of the output signal independently for each channel.

If you still get no output then check the wiring to the jack socket and test the 17v input line by measuring the voltage on pin 14 of the LM380. Also double check the wiring to the pots.

The circuit has been designed for use with miniature 8R stereo headphones. If you find the volume is very low then it may be because your headphones have a higher impedance. One possibility to increase the available volume is to replace the pots with larger ones. The volume pots may be replaced by any value up to 2M2 without adversely affecting the operation of the circuit. Larger values will increase the input signal and hence the output volume. If that fails, get yourself some new headphones

The waveforms of the hemisync machine are quite accurate but extreme hi-fi is not required. An ordinary set of miniature headphones as used on a personal stereo will suffice. They usually cost only a few pounds and are easily obtained in many high street stores.

Technical Specification and Programming

The two output signals are obtained by division of the master oscillator frequency. The fixed channel uses a constant division ratio of 49152 (192 on the pulse board and a further division by 256 on the waveform generator) which results in an output of 203.45Hz for a 10MHz input signal. The variable channel allows 16 different intermediate division ratios of 194 to 209, which are again divided by 256 on the waveform board. The resulting final frequencies and the differences relative to the fixed channel are shown below in Table 2.

Intermediate division Ratio	Final Ratio	Output Frequency	Difference from fixed Channel
194	49664	201.35	2.10
195	49920	200.32	3.13
196	50176	199.30	4.15
197	50432	198.29	5.16
198	50688	197.29	6.16
199	50944	196.29	7.16
200	51200	195.31	8.14
201	51456	194.34	9.11
202	51712	193.38	10.07
203	51968	192.43	11.02
204	52224	191.48	11.97
205	52480	190.55	12.90
206	52736	189.62	13.83
207	52992	188.71	14.74
208	53248	187.80	15.65
209	53504	186.90	16.55

Table 2: Output Frequencies for Hemisync Machine. All frequencies are in Hertz.

The resultant difference frequency is settable in approximate 1 Hz steps over most of the range.

The waveform envelope is determined by the programming of the EPROM on the waveform generator. This is fairly straightforward. The waveform generator cycles the EPROM address lines through 256 different addresses per cycle of the output wave. To construct a given wave envelope you must simply program in the values of 256 successive evenly spaced samples of the desired wave. The D/A converter used has 8 bit accuracy and so the amplitude of the samples must be expressed as a number in the range 0-255. A value of 0 corresponds to the negative peak of the output wave and a value of 255 to the positive peak. A value of 127 may be considered to be the arbitrary baseline for the envelope.

The values for the wave samples may be generated easily using a computer spreadsheet, if you know the mathematical formula of the desired wave. If not you will have to use a manual method. The way to do this is to draw a grid of 256 by 256 squares (a piece of graph paper is perfect) and sketch one cycle of the desired wave envelope on the grid, ensuring as far as possible that the peaks of the wave reach the top and bottom edges of the grid. The values for the 256 amplitude samples may now be read off from left to right from the graph paper and programmed directly into the EPROM, one value per byte in binary.

To get you started I have supplied a hex dump of the values for a basic sine wave pattern in Table 3 . A square wave is easy to do also, the first 128 values will all be 0 and the second 128 will all be 255 (or vice versa) For those of you who do not want to get involved in the details of custom waveform design, or do not have EPROM blowing facilities, I will be offering a pre-programmed set of EPROMs with 16 interesting and varied wave patterns. See Buylines for details.

You are now equipped to try all kinds of fascinating experiments with your Hemisync machine. If you do happen to discover a combination of frequencies and patterns which gives an unusual result then write in to ETI and share it with the rest of us. If anyone develops the paranormal powers claimed by some Hemisync fanatics and makes a fortune on the stock market as a result, I hope they'll remember who made it all possible.

HOW IT WORKS

Pulse Generator Circuit

Three gates of IC1 are used in conjunction with XTAL1, R1, R2, C1 and C2 to form a TTL oscillator at 10MHz. The output of the oscillator is fed to two independent sub circuits. The first comprises IC's 2 and 3. IC2 is a dual JK flip flop wired in a divide by 3 configuration. The output from this is fed to IC3, a dual 4-bit counter cascaded to form a single 8-bit counter. The signal is divided by a further 64 using 6 stages of this counter. The result is the 10MHz input signal divided by a total of 3×64=192. This corresponds to a fixed output frequency of 52083.33Hz.

The second sub circuit is the variable divider. IC's 4 and 5 are 74191 4-bit binary counters connected together in cascade to form a composite 8-bit counter. The basic idea is to pre-load the counters with a binary value applied externally to its load inputs and then to count down to zero from that value and reload. A single output pulse (the ripple carry output) is generated every time the counter hits zero. The applied binary value thus represents the number of input pulses required to generate one output pulse and so forms a divider. At first sight it would appear simple enough to connect the ripple carry output from the counter directly to its load trigger input. This would then cause an automatic reload. The problem with this method is that the 74LS191 requires the load signal to be held for a minimum of 25ns. If the ripple carry is connected directly to load, it will cause the ripple carry to change within only a few nanoseconds of applying the load value and so the hold time will not be met.

The solution to this problem is IC6. The ripple carry output from the counter is always generated on a falling edge of the main clock input. In this circuit, the ripple carry is fed to the asynchronous clear input of a 7474 D-type flip flop. This results in the a output of the flip flop being driven low which in turn drives the load trigger input of the counter. The flip flop will remain in the clear state even when the ripple carry changes. The clock input of the flip flop is connected to the main clock driving the counter, so on the next rising edge of the clock (one half cycle — 50ns later) a high value at the D input will be clocked through to the output thus removing the load trigger. In this way then the load trigger lasts precisely 50ns, long enough to meet the hold time constraint of the counters.

The value to count down from is set using a hexadecimal encoded (rotary) binary switch SW1 to vary the load inputs of IC4 between 0 and 15. The 4 most significant bits of the divide count, represented by the inputs of IC5 are hard wired in the pattern 1100. The output of the switch incidentally is inverted so IC7 corrects for true binary.

In this way the count loaded can vary from 11000000 binary to 11001111 which appears to represent a ratio from 192 to 207. In practise, the actual ripple carry pulse from the counters adds an extra 1 to the overall count in each counter and so the actual division ratio is always two more than the binary input value. So the division ratios in practise are 194 to 209.

This results in an output pulse at a frequency variable between 51546.39Hz (10MHz divided by 194) and 47846.89Hz (10MHz divided by 209). when divided by a further 256 in the waveform generator circuit this gives approximate 1Hz steps around 200Hz.

The actual output pulse is taken from the min/max output of the counter, this is simply a variant of the ripple carry.

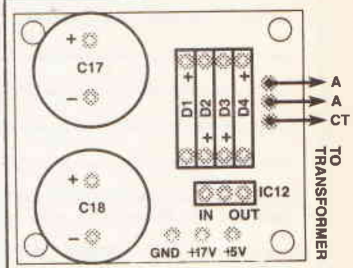


Fig.12 Component overlay of power supply

PROJECT

Waveform Generator Circuits

The outputs from the pulse generator circuit are fed independently to two identical waveform generators. On each waveform generator the input pulse is fed to the clock input of IC8, a 74393 connected as an 8bit counter. The outputs of IC8 drive the lower 8 address lines of the EPROM chip (IC9). This means that the EPROM constantly cycles through 256 consecutive addresses, one per input pulse. The data outputs of the EPROM go to the data inputs of a digital to analogue converter IC10. As the EPROM cycles through its addresses the corresponding data at those addresses causes the D/A converter to generate an appropriate analogue voltage. This means that the D/A actually generates 256 consecutive analogue voltage steps, one per input pulse. Taken in this way the output voltage steps appear to comprise a cyclical analogue waveform, one cycle per 256 input pulses, with a voltage amplitude resolution of 256 steps. In this way any desired cyclical wave envelope can be generated simply by loading an appropriate set of data values into the EPROM.

The four most significant address lines of the EPROM (the four that are actually used, depending on EPROM type) are connected to another hex switch. This allows the user to select one of 16 sets of different data values and therefore, one of 16 different corresponding waveforms.

The analogue output from the D/A converter is used to drive an audio amplifier IC (IC11) an LM380. This in turn drives one channel of a pair of headphones. The volume of the output signal can be varied using RV1.

Power Supply

The power supply is very straightforward. A transformer is used with a 12V AC centre tapped secondary. Alternatively, the secondaries of a dual secondary 6V transformer are wired in series to form a single 12V centre tapped winding. The secondary output runs to a full wave rectifier formed by four diodes. The rectified output is smoothed by C17 and forms an unregulated DC output at approximately 17V. The centre tap is used as an independent output and drives smoothing capacitor C18 and a 5V regulator IC12. In this way, two independent DC outputs are available using only a single rectifier bridge. The 5V output drives the logic circuitry and the 17 volt unregulated output drives the audio output IC.

PARTS LIST

POWER SUPPLY

CAPACITORS

C17 2200µ/ 25v Radial Electrolytic
C18 2200µ/ 16v Radial Electrolytic

SEMICONDUCTORS

D1,2,3,4 1N4001 or equivalent Rectifier Diodes
IC12 7805, +5 volt Voltage Regulator

MISCELLANEOUS

SW3 DPST Miniature Toggle Switch, 240v 3A
TR1 6-0-6v, 6VA Miniature Mains Transformer i.e. RS 207-194
Heatsink for IC12 (recommend RS 401-863), IEG Mains socket and LEG cable or glands and cable.

PULSE GENERATOR BOARD

RESISTORS (20% tolerance or better)

R1,2 33OR 1/4W
SILI SIL Resistor Network 4k7, 6 way, or 6 off 4k7 resistors 1/4W

CAPACITORS

C1,2 1n ceramic
C3-9 100n ceramic

SEMICONDUCTORS

IC1,7 74LS04
IC2 74LS112
IC3 74LS393
IC4,5 74LS191
IC6 74LS74

Note: 74 'HG' series CMOS devices may be substituted for the above IC's for lower power operation.

MISCELLANEOUS

XTAL1 1OMHz Crystal
SW1 Hexadecimal Coded Switch RT angle, RS 333-091
CB1 PCB mounting connector block, RS 424-305

WAVEFORM GENERATOR BOARD

Note that two identical waveform generator boards are needed for this project however some components are only required on ONE of the boards. These will be marked with an asterisk *.

RESISTORS (all 20% tolerance or better)

R3,4 4k7 1 /4W
R5-8 4k7 1/4W *
R9 330R 1/4W
R10 47k 1/4W
R11 1k0 1/4W
R12 3R3 1/2W
RV1 500k Linear Pot (see text)

CAPACITORS

C10 4µ7/16v Tantalum bead
C11 10µ/25v Electrolytic Axial
C12 470µ/25v Electolytic Axial
C13 100n Ceramic 100V
C14-16 100n Ceramic for decoupling

SEMICONDUCTORS

IC8 74LS393 (or 74HG393 if HG devices used on pulse board)
IC9 EPROM, any from 2732 thru 27512, 2732 recommended
IC10 ZN559 D/A Converter
IC11 LM380 Audio Amp

MISCELLANEOUS

CB2,3 PCB mounting connector blocks (as CB1)
SW2 Hex encoded switch (as SW1)
J1 PCB Jumper, 2 position
SK1 28 way turned pin IC socket for IC9 (see text)

OTHER MISCELLANEOUS PARTS

1 off Stereo 3.5mm panel mount jack socket for headphones
2 lengths (approx 150mm each) of twin core screened audio cable
4 off PCB spacers approx 16mm
4 off PCB spacers approx 5mm
2 off collet knobs for hex switches RS 498-772
2 off caps for collet knobs RS 499-517
2 off Pointers for collet knobs RS 499-545
2 off Knobs for volume pots
1 off plastic Verobox (188mm × 1 10mm × 60mm) i.e. RS 509-585
Nuts and bolts for mounting boards, wire for interconnections, rubber or heat shrink sleeving for mains connections on switch and transformer.

BUYLINES

All the components for this project are available from Electromail, PO Box 33, Corby, Northants, NN1 7 9EL. Tel (0536) 204555.

Additionally, a set of EPROMs for this project, pre-programmed with 16 different wave patterns is available from the author. Contact Scoon Consultancy Services, 49 Honeyhill Road, Bracknell, Berkshire, RG12 1YH or Tel: (0344) 868188 for details. The prices for the EPROMs are £8 each if bought singly or £14 per pair all inclusive. The author is also able to construct custom waveform programs to order at additional cost, depending on complexity.

Happy Hemisyncing!

Table 3:

Hex Dump for basic EPROM Sine Wave Pattern

00 –	80	83	86	89	8C	90	93	96	99	9C	9F	A2	A5	A8	AB	AE
10 –	B1	B3	B6	B9	BC	BF	C1	C4	C7	C9	CC	CE	D1	D3	D5	D8
20 –	DA	DC	DE	E0	E2	E4	E6	E8	EA	EB	ED	EF	F0	FI	F3	F4
30 –	F5	F6	F8	F9	FA	FA	FB	FC	FD	FD	FE	FE	FE	FF	FF	FF
40 –	FF	FF	FF	FF	FE	FE	FE	FD	FD	FC	FB	FA	FA	F9	F8	F6
50 –	F5	F4	F3	FI	F0	EF	ED	EB	EA	E8	E6	E4	E2	E0	DE	DC
60 –	DA	D8	D5	D3	DI	CE	CC	C9	C7	C4	C1	BF	BC	B9	B6	B3
70 –	B1	AE	AB	A8	A5	A2	9F	9C	99	96	93	90	8C	89	86	83
80 –	80	7D	7A	77	74	70	6D	6A	67	64	61	5E	5B	58	55	52
90 –	4F	4D	4A	47	44	41	3F	3C	39	37	34	32	2F	2D	2B	28
A0 –	26	24	22	20	1E	1C	1A	18	16	15	13	11	10	0F	0D	0C
B0 –	0B	0A	08	07	06	06	05	04	03	03	02	02	02	01	01	01
C0 –	01	01	01	01	02	02	02	03	03	04	05	06	06	07	08	0A
D0 –	0B	0C	0D	0F	10	11	13	15	16	18	1A	1C	1E	20	22	24
E0 –	26	28	2B	2D	2F	32	34	37	39	3C	3F	41	44	47	4A	4D
F0 –	4F	52	55	58	5B	5E	61	64	67	6A	6D	70	74	77	7A	7D

UNIDEN SATELLITE RECEIVER Brand new units (model 8008) £60.00 ref 60P4 also some 7007s also £60.00 ref 60P5
SPECTRUM +2 COMPUTER Built in data recorder, 128K, psu and manuals £59.00 ref 59P4
SPECTRUM +3 COMPUTER Built in disc drive, 128K, psu and manuals £79.00 ref 79P4
AMSTRAD CPC464 COMPUTER No manuals but only £79.00 ref 79P5
AMSTRAD CPC6128 COMPUTER Again no manuals but only £149.00 ref 149P4
AMSTRAD GT65 Green screen monitor £49.00 ref 49P4
AMSTRAD PORTABLE PC'S FROM £149 (PPC1512SD). £179 (PPC1512DD). £179 (PPC1640SD). £209 (PPC1640DD). MODEMS £30 EXTRA.NO MANUALS OR PSU.

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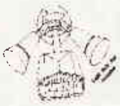
HIGH POWER CAR SPEAKERS. Stereo pair output 100w each, 4ohm impedance and consisting of 6 1/2" woofer 2" mid range and 1" tweeter. Ideal to work with the amplifier described above. Price per pair £30.00 Order ref 30P7
2KV 500 WATT TRANSFORMERS Suitable for high voltage experiments or as a spare for a microwave oven etc. 250v AC input. £10.00 ref 10P93
MICROWAVE CONTROL PANEL Mains operated, with touch switches. Complete with 4 digit display, digital clock, and 2 relay outputs one for power and one for pulsed power (programmable). Ideal for all sorts of precision timer applications etc. £6.00 ref 6P18
FIBRE OPTIC CABLE. Stranded optical fibres sheathed in black PVC. Five metre length £7.00 ref 7P29
12V SOLAR CELL. 200mA output ideal for trickle charging etc. 300 mm square. Our price £15.00 ref 15P42

PASSIVE INFRA-RED MOTION SENSOR. Complete with daylight sensor, adjustable lights on timer (8 secs -15 mins), 50' range with a 90 deg coverage. Manual override facility. Complete with wall brackets, bulb holders etc. Brand new and guaranteed. £25.00 ref 25P24.



Pack of two PAR38 bulbs for above unit £12.00 ref 12P43
VIDEO SENDER UNIT Transmit both audio and video signals from either a video camera, video recorder or computer to any standard TV set within a 100' range! (tune TV to a spare channel). 12v DC op. £15.00 ref 15P39 Suitable mains adaptor £5.00 ref 5P191
FM TRANSMITTER housed in a standard working 13A adapter (bug is mains driven). £26.00 ref 26P2
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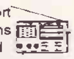
10 BAND COMMUNICATIONS RECEIVER. 7 short bands, FM, AM and LW DX/local switch, tuning 'eye' mains or battery. Complete with shoulder strap and mains lead **NOW ONLY £19.00!! REF 19P14.**



WHISPER 2000 LISTENING AID. Enables you to hear sounds that would otherwise be inaudible! Complete with headphones. Cased. £5.00 ref 5P179.
CAR STEREO AND FM RADIO Low cost stereo system giving 5 watts per channel. Signal to noise ratio better than 45db, wow and flutter less than .35%. Neg earth. £25.00 ref 25P21
LOW COST WALIKIE TALKIES. Pair of battery operated units with a range of about 150'. Our price £8.00 a pair ref 8P50

7 CHANNEL GRAPHIC EQUALIZER plus a 60 watt power amp! 20-21KHZ 4-8R 12-14v DC negative earth. Cased. £25 ref 25P14.
NICAD BATTERIES. Brand new top quality. 4 x AA's £4.00 ref 4P44. 2 x C's £4.00 ref 4P73, 4 x D's £9.00 ref 9P12, 1 x PP3 £6.00 ref 6P35
TOWERS INTERNATIONAL TRANSISTOR SELECTOR GUIDE. The ultimate equivalents book. Latest edition £20.00 ref 20P32.
CABLE TIES. 142mm x 3.2mm white nylon pack of 100 £3.00 ref 3P104. Bumper pack of 1,000 ties £14.00

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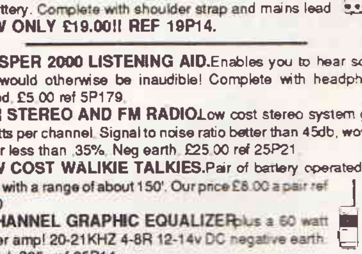

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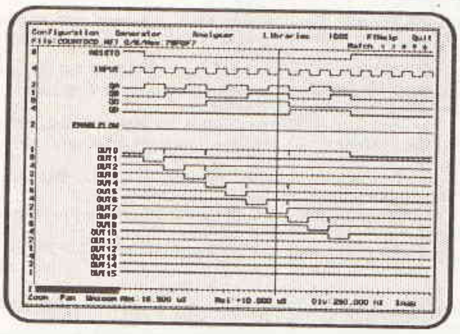

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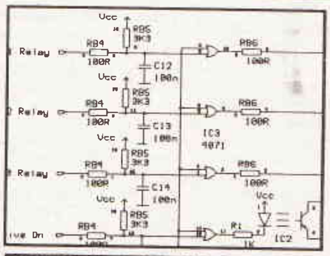

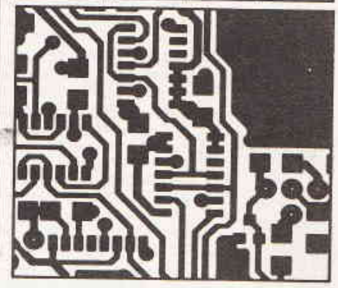

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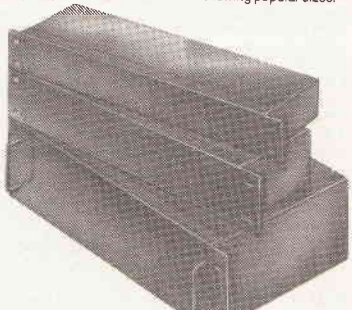

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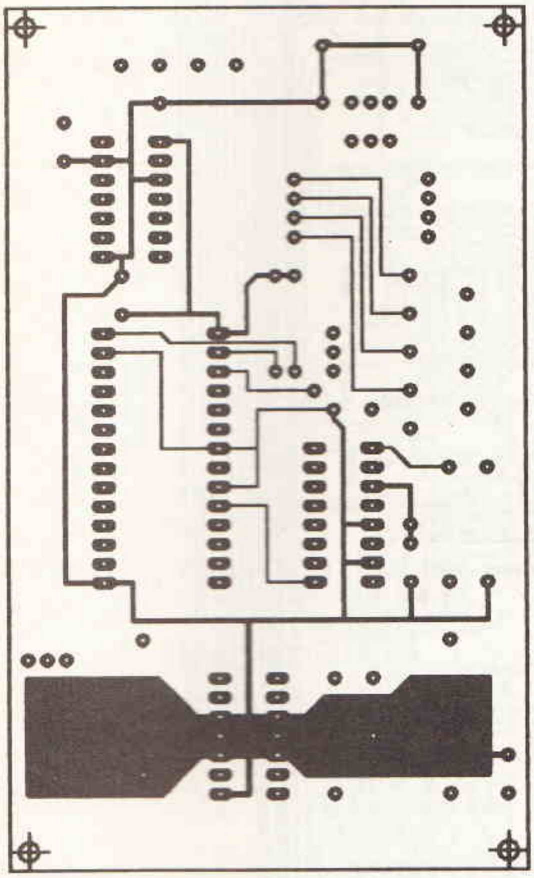
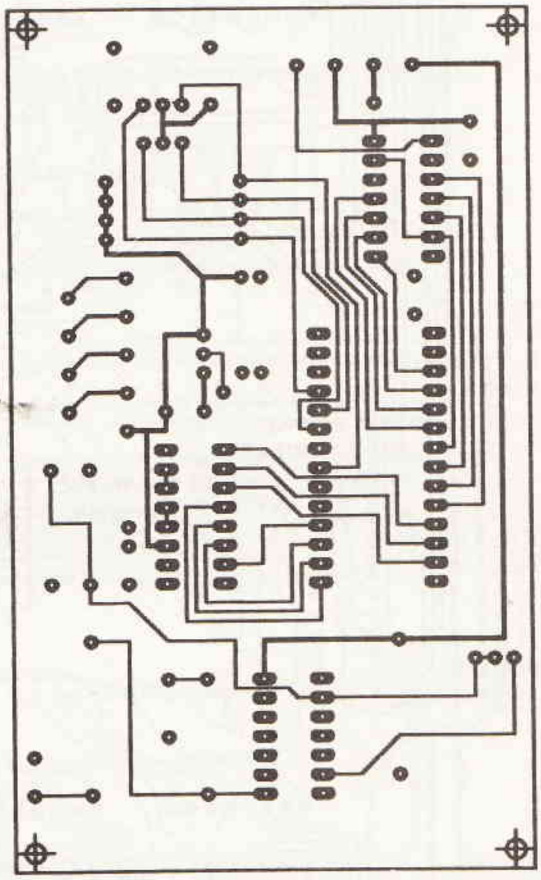
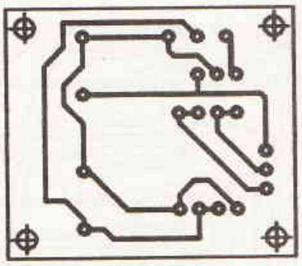


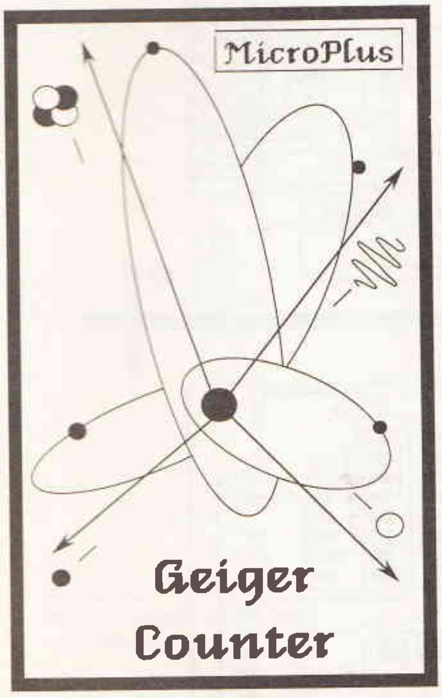
Heisync Waveform Gernator Foil
Component Side



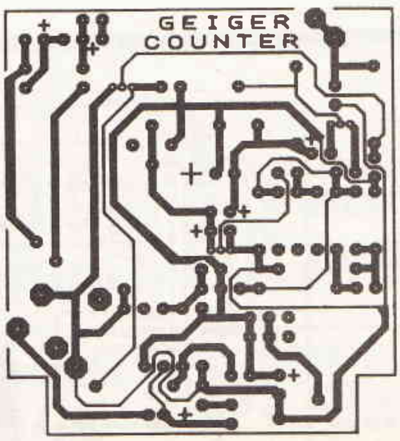
Hemisync Waveform Generator Copper
Side



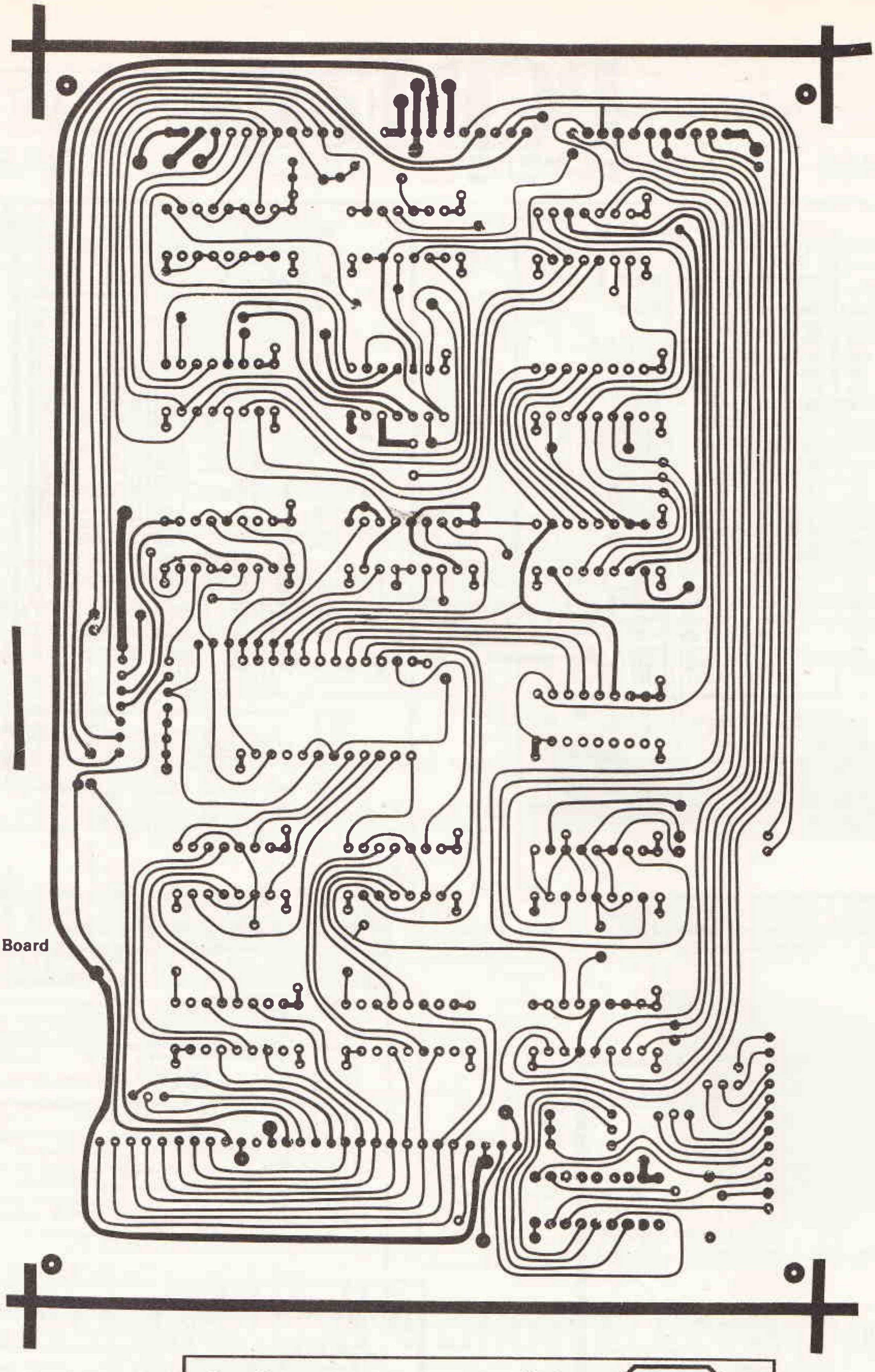
Hemisync Power Supply



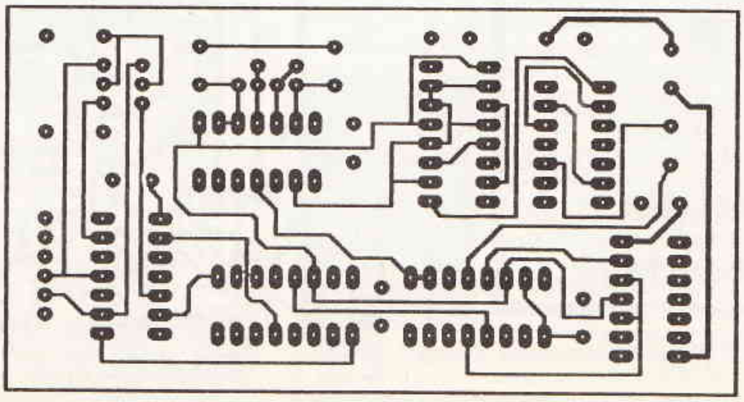
Counter Front Panel



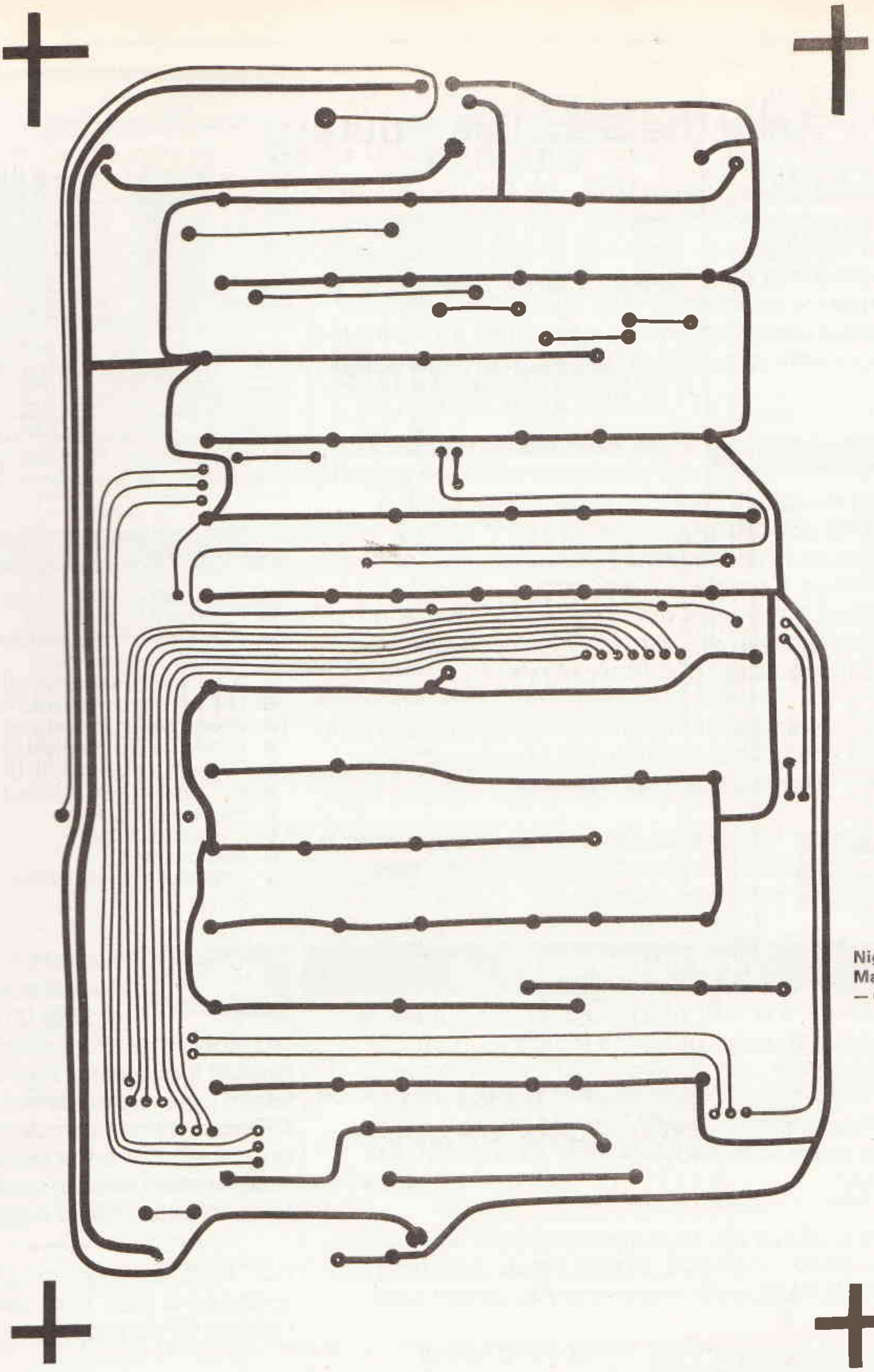
Geiger Counter Foil



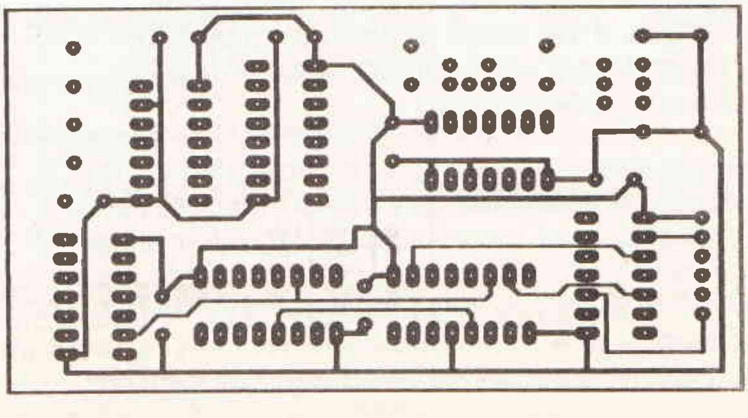
Nightfighter Main Processor Board — Copper Side



Hemisync Pulse Generator Foil — Copper Side



Nightfighter
Main Processor Board
— Component Side



Hemisync
Pulse Generator Foil
— Component Side

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E9109-2 Hemisync Waveform Generator Board .... G
E9109-3 Hemisync Pulse Generator Board .... F
E9109-4 Hemisync Power Supply Board C
E9109-5 Nighfighter Main Processor Board .... O

PCBs for the remaining projects are available from the companies listes in Buylines.

Use the form or a photocopy for your order. Please fill our all parts of the form. Make sure you use the board reference numbers. This not only identifies the board but also tells you when the project was published. The first two numbers are the year, the next two are the month.

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V	£35.80
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E9006-3 Telephone External Bell .... D
E9006-4 Fecko Box .... G
E9006-5 Bug Spotter .... E
E9007-1 Guitar Practice Amp .... G
E9007-2 Digital Frequency Meter .... M
E9007-3 Footstep Alarm .... E
E9007-4 Transistor Tester C
E9007-5 Decision Maker .... J
E9008-1 AC Millivoltmeter .... K
E9008-2 Temperature Controller .... N
E9008-3 FM Generator L
E9009-2 Slide Projector Controller .... E
E9009-2 Ultimate Diode Tester .... D
E9009-3 The Entertainer .... G
E9010-1 Component Tester .... F
E9010-2 Active Contact Pickup .... E
E9010-3 R4X Longwave Receiver C
E9011-1 The Autocue (2 boards, 1 double sided) .... N
E9011-2 Infra-lock transmitter (2 boards) .... K
E9011-3 Infra-lock receiver .... H
E9011-4 Four-track cassette recorder (record/playback one channel) .... F
E9011-5 Four-track cassette recorder (Bias/erase oscillator board .... K
E9012-1 Infra Switch .... F
E911-1 Remote Control — Main Board .... J
E9101-2 Remote Control — Display Board .... H
E9101-3 Remote Control Timeswitch — Transmit board. E
E9101-4 SBC Micro-Controller Board .... F
E9101-5 SBC Practice Interface Board .... F
E9101-6 5 in 1 Remote Sensing Switch .... E
E9102-1 Remote Control Timeswitch — receiver board.. F
E9102-2 Anti Theft Alarm (2 bds) .... H
E9103-1 Ariennes Lights L
E9103-2 64K EPROM Emulator .... N
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NEXT MONTH

The Nightfightrer, the rack-mount lighting control system is still very much in our thoughts next month. The second part introduces a Triac switching board. This additional high-power switching element will receive instructions from the master controller to blitz the disco floor or party with directional light and colour.

We also present an article on the history of the resonant cavity Magnetron, the device that has given us microwaves to help the war effort in the early days of aeroplane detection to its developmental modern-day use for cooking TV dinners.

Usual features include Back To Basics on simple resonant ciricuits, Circuit File looks at modern Unijunction transistor circuits and we present the last part of Fire Detection Systems.

Projects include, a test bed for proto-type circuits using a variable power supply with bread-board, a mains failure alarm, freeze alarm and a power on and overload indication circuit.

The October issue of ETI is available at your newsagent from Friday 6th September

The above articles are in preparation but circumstances may prevent publication

LAST MONTH

The August issue contained articles on:

Two projects for Model railway control
The Hemisync Machine — Encouraging brain-wave patterns Part 1
Field Programmable Gate Arrays
Loudspeaker damping problems
Medical Laser systems
Fault-finding in electronic equipment Part 1

Back issues are available from Select Subscriptions (address on page 3)

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