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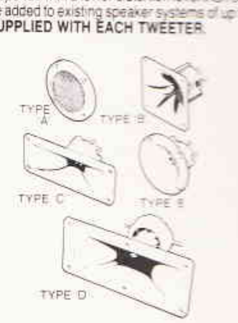

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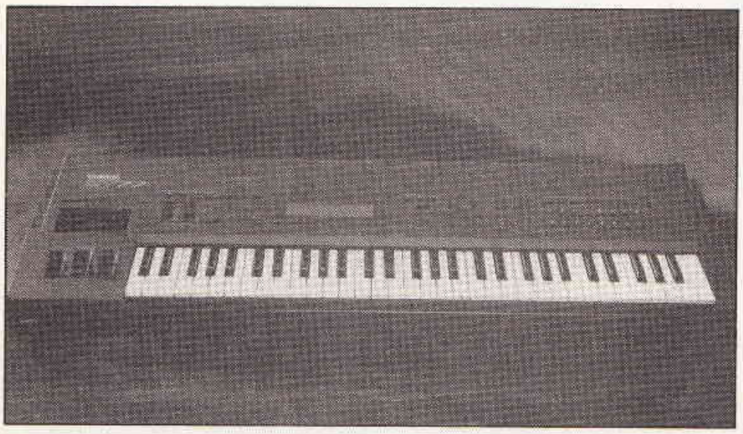

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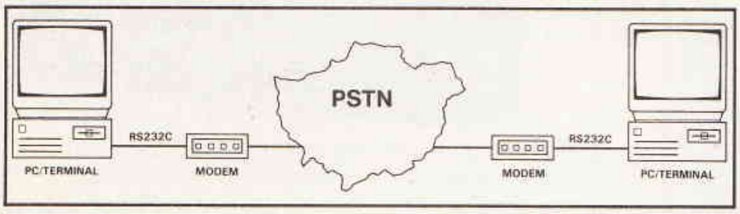

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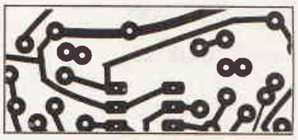

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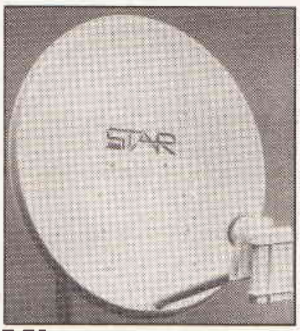

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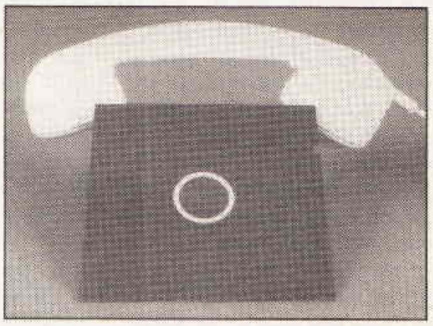

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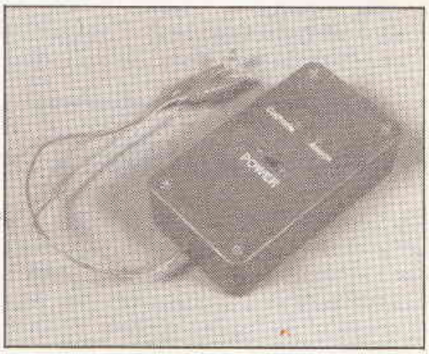

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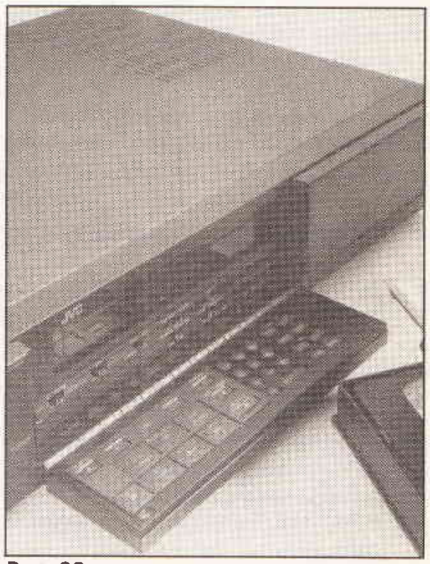

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READ\WRITE

ETI LETTERS

Milling The Earth's Elecric Field

The letter from Steve Thackery in the May issue reminded me that I have had for a long time an interest in and a fascination with the Earth's static electric field. I have looked at various ways of measuring the strength of the electric field and have come to the conclusion that the main problem is keeping the measuring equipment weather-proof. The electric field on a fine day is about 100 volts per metre but when thunder clouds appear this figure can change to several thousand volts per metre and reverse its polarity. Clouds however often bring rain and this is where the weather-proofing becomes important.

The Earth's field can be sampled by using an electrometer or a field mill. Of the two the field mill is probably the best instrument to use as it is sensitive enough to permit the use of low gain low frequency op-amps. A field mill consists of an earthed rotating vane, often with four blades like a cross and an electrode which is alternately exposed to the electric field and then shielded from it by the earthed rotor. The rotating vane chops (or mills) the electric field, producing an AC signal which is easily processed to drive a meter or a chart recorder. As the Earth's field may reverse its polarity near thunder clouds, some means of indicating the the polarity of the electric field is desirable. The electrode is connected to the electronics which may consist of a voltage follower input stage and a synchronous rectifier giving an output proportional in amplitude and polarity to the electric field.

The field mill I made used a cassette recorder motor to drive a 75mm diameter vane at about 5000 rpm. The electronics consisted of two op-amps of the TL081 type and an opto interruptor driven by a second smaller vane on the same shaft which produced the switching signal for the synchronous rectifier.

I have been unable to continue the project and so it has been put to one side for the time being.

Here are some references which I found useful in my research into this project:

1. Physics Of Lighting. D. J. Malan, E.U.P.
2. The Design of Simple Instruments for Measurement of Charge on Insulating Surfaces. Dr P. E. Secker, Journal of Electrostatics, 1 (1975) pp 27-36.
3. Apparatus for the Accurate and Continuous Measurement of the Earth's Electric Field. W. W. Mapleson and W. S. Whitlock, Journal of Atmospheric and Terrestrial Physics, Volume 7, 1955 pp 61-72.

John Noakes
Camberly, Surrey.

Power Amplifier Parts

D Lucas of Glasgow writes in your July issue about his efforts in improving the sound quality of his Audio Design power amplifier by John Linsley Hood.

Audiokits Precision Components have been supplying high performance parts to constructors of the original 1984 design as well as the more recently published version.

For 470nF capacitors, Audiokits offers a choice of parts including the fabulous Wonder Caps from America for those who can make the space. Or a Bourns conductive plastic volume control which sounds even better than the ALPS.

On the subject of connecting wires, I strongly recommend the use of PTFE insulated cables and have recently introduced a 1 × 0.9mm diameter silver plated copper wire specially for constructors who prefer to use solid cores to stranded cables. In technical terms, PTFE has much lower dielectric loss and dielectric absorption than any other cable insulator and this factor directly affects sound quality. The disastrous sonic effect of using PVC insulation on wiring in audio circuits can be easily observed simply by removing the insulation from a length of solid core cable and directly comparing it in the circuit with a similar insulated length. Providing that the solid cores are rigid enough not to touch when the insulation is removed, this test can quite easily be carried out.

For the benefit of readers who are building the latest version of John Linsley Hood's 80W power amplifier, Audiokits has produced a component note ACN22 which describes many more ways in which this amplifier can be further improved in sound quality simply through the use of better quality parts and cables. This is available from Audiokits for £2 post free.

Graham Nalty,
Audiokits Precision
Components, Derby.

Labcenter PRO-test

I feel I must point out the following errors and omissions in the write up of our PC-B PRO package in the July issue of ETI.

a) The package allows 20 sizes of circular pads, square pads and track widths (not 6) and the user can configure what these sizes are.

b) Connectivity highlight has always been a feature of PC-B PRO, as has the ability to generate a netlist from the layout for checking purposes.

c) Your reviewer fails to mention that ours is currently the only package with an auto-routing option.

d) Since October 89, PC-B PRO has been capable of netlist import i.e. the major difference between Boardmaker 1 and 2, so to say it is overpriced against the £295 Boardmaker 2 is debatable.

John Jameson
Managing Director
Labcenter Electronics

David Silvester replies:
I must initially apologize for the error that has crept into the review concerning Labcenter's PC-B PRO. The statement about 6 tracks relates to the low cost PC-B Package only; not to the PRO package which has advanced facilities.

I must however disagree that PC-B PRO AR is the only autorouting package that is available in this price range; there are also Ranger by Seetrax and EZ-Route by Brigden that are within the price range for autorouters. However it was specifically decided not to include autorouting as it would be impossible to do justice to the autoroute packages in such a short review. I had however tried out the PC-B PRO AR package and it had failed the test that I had set it. The simplest test that I already knew the answer to was to get the package to draw from a ratsnest a simple bus structure with three 14 pin chips. PC-B PRO AR did not give the output expected with tracks passing between pins but sent tracks all over the board. Ranger incidentally has a special bus algorithm to cope with this problem.

Whilst on the subject of autorouting, the professional will almost certainly be using a double sided board if he uses normal *components. For the amateur and the professional working with surface mount components a special autoroute algorithm that works on the minimum through board connections is needed. The amateur needs this to allow him to make his own boards which are vastly simpler if single sided with a few wires completing the circuit on the other surface. For the professional, hole drilling costs money.*

The test was kept secret to find out how good the company presentation of their product was. In fact they fall into two camps. Easy-PC, Boardmaker and EZ-Route come with large instructional manuals that after working through leave the user in no doubt as to the facilities. PC-B in all its versions and Ranger come only with a few sheets of A4 paper which cannot hope to cover the ground that a booklet can cover.

Readers of the electronics magazines will be in no doubt that Easy-PC and Boardmaker have undergone substantial price or facility revisions as they both take full and half page adverts in most of the magazines. PC-B is only advertised in small adverts at the back of the magazines that are easy to overlook unless specifically hunting for such adverts with a view to purchase such a package and as such it is easy to miss revisions. The other packages appear to be rarely advertised in the magazines that I read, Ranger was found by chance whilst attending the British Electronics Week in London earlier this year.

After the review I did in fact purchase one of the packages for personal use based on my experience which formed the basis of the review article.

Feedback On Feed

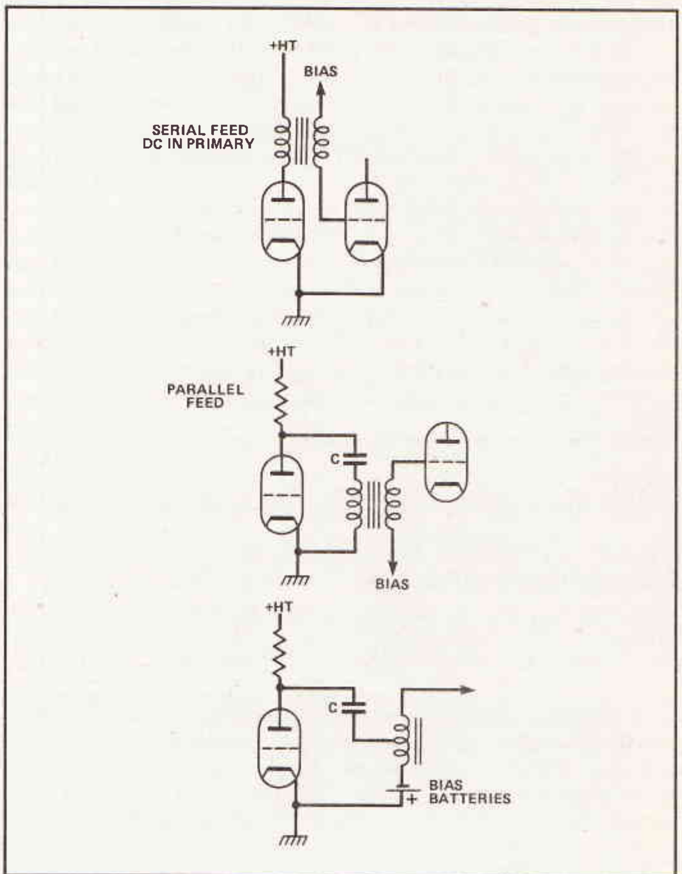
I was interested in John Linsley Hood's comments regarding Mr Christian's letter (ETI June 1990) and on series and parallel feed. Mr Christian's letter makes it clear that he is referring to the DC feed arrangements. In the Hartley oscillator, this can be via the coil — series feed (ETI April 90, Fig 7 on page 34) — in which case there is a DC component in the coil — or via a choke or resistance (ETI April 90, Fig 8 on page 35) — in which case the choke or resistance is at signal frequency, shunted across (in parallel with) part of the coil.

Each method had its pros and cons. In the early days, when fairly high powered valve oscillators were common, the presence of a high voltage supply in a sizeable coil wound with heavy gauge bare wire — or even thin copper tube — posed a few problems. Even as late as T1154 days, the danger still existed — 1250 volts fed via a 50k resistor and a bare tinned copper wire coil to the master oscillator. The parallel feed system avoids this, but loses out because of the shunting effect of the choke or resistance across part of the oscillator coil. In particular, efficient RF chokes are not easy to design, especially if a sizeable bandwidth is involved.

In the early days of radio, when battery powered receivers were still common, parallel feed was often used at SF to overcome deficiencies in the intervalve transformers generally used to give some inter-stage voltage step-up. Many of these transformers were very poor performers with DC flowing in the primary windings; parallel feeding was a way round this. "Roll-off" or resonance problems resulting from the value of C and the primary inductance were a small price to pay for the overall improvement.

The obvious next step was to increase the effective transformer ratio by an auto-transformer configuration, using the primary and secondary in series. During the early/middle thirties this circuit used specially designed small transformers with high inductance windings on mu-metal cores.

G W Ashford
Warrington, Cheshire.



Supplying The Answers

The following is in response to points raised in connection with my article Designing Power Supplies (ETI April 1990). Fortunately none of the mistakes are catastrophic. As you will see, the error on the heatsink calculation serves to make a couple of extra points.

On page 28, the full-wave rectified cycle duration for 60Hz is 0.00833 seconds, not 0.0833 seconds.

On page 30, the expression for calculation of I_{ripple} should be: 1.8 × 2π × 2 × 50 × 0.022. This does not change the answer which is correctly given as 14.36A.

The expression for V_{peak} (on-load) should be (1.414 × 9.71) − (2 × 0.7). This does not change the answer which is correctly given as 12.33V.

The expression for P_D should be 4 × (12.33 − (1.8/2) − 5). This changes the value of P_D to 25.72W. This value is used in the Equation for $\theta_{H\text{-}A}$. Putting in the new value of P_D gives a negative value which is clearly an impossibility. This negative value serves to illustrate a situation not covered in the article. If a negative value is obtained, this means that even an infinitely large heatsink would not suffice. There are two ways to overcome this problem, and in this example both measures would be required.

Firstly, reduce $\theta_{J\text{-}C}$. The 338K, for example, has much better thermal properties than the 78H05, having a $\theta_{J\text{-}C}$ of 1° C/W.

Secondly, reduce the ambient temperature below 50°C. 50°C is quite high, and the temperature would probably be lower in many enclosures, and could easily be reduced to 20° C by use of a fan. Alternatively, mounting the heatsink on the rear of the cabinet on the outside (like power transistors on many amplifiers) would reduce T_A to room temperature.

V_{AC} in equation 3 is used to represent a general AC voltage. V_{TX} MAX, on the other hand, is a particular AC voltage, namely the maximum transformer output, either off-load or on-load.

Mike Bedford
Keighley, West Yorks.

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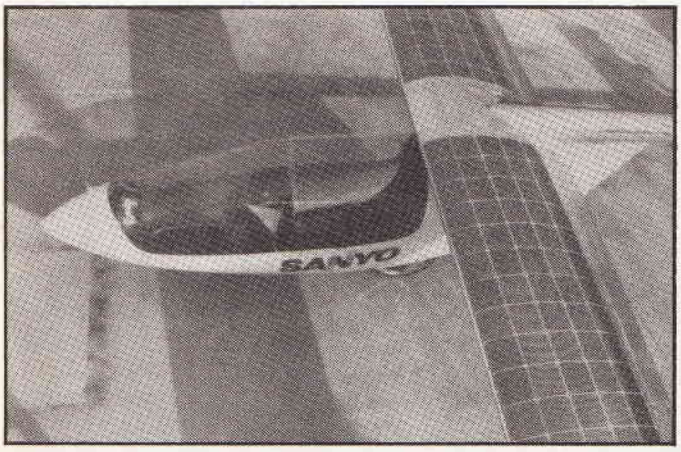
ETI NEWS

Sanyo Electric has announced a significant advance in its amorphous solar cell technology with the introduction of a new flexible light-weight, solar cell film material.

The new Amorton film, which is 0.12mm thick and is flexible enough to be bent into a tube 10mm in diameter, can be shaped to conform to three-dimensional surfaces that would not normally accommodate conventional cells which are fragile or rigid. Because the film is light, it yields a power-to-weight ration of 200 milliwatts per gram, 10 times that of conventional glass-type cells. The film can be used to apply solar cell technology to a new range of solar-powered products.

To demonstrate the potential for this new technology, the solar film has been used to power the "Sun Seeker" areoplane, the first solar aircraft to attempt a trans-continental flight across the United States.



UPS AND DOWNS

The principle aim of most Uninterruptable Power Supplies (UPS) is to keep a computer system running while the operator completes an orderly shutdown after a power cut. The power needed to do this for a PC is between 90 and 150 watts, and so UPS systems are typically stand-alone boxes with big batteries and big prices.

Emerson Electric have now launched a UPS within the budgets of most PC XT or AT users. Instead of trying to keep the whole system up and running, the ACCUCARD UPS provides just enough power to ensure that every bit of data is saved, and the computer is safely shut down whether the human operator is at the computer or not.

This requires only a small battery, and so may be slotted into the PC. The ACCUCARD hardware is fitted into an expansion slot on the DC side of the PC's internal power supply, and the Terminate and Stay Resident software is loaded onto the hard disk. Once installed, the system monitors the power being supplied to the PC.

In the event a power loss ACCUCARD is automatically activated. The memory resident program freezes the operating system and then saves to hard disk all data in the RAM as well as the video memory and all mode and status registers. Finally, it parks the disk heads and powers down the mother board.

When power is restored, ACCUCARD commences the restoration of the system software and user files, reloading every bit of data necessary to put the operator back on screen at the exact point reached prior to the power failure, irrespective of the program being used.

The ACCUCARD costs £199. Emerson Electric can be contracted on 0793 512669.

A DOG'S LIFE NO MORE

Betting on the dogs is not always easy. Punters who want to place bets face long queues at the tote — several times per race if they want to place win, forecast and other combination bets. There are long queues again to collect winnings.

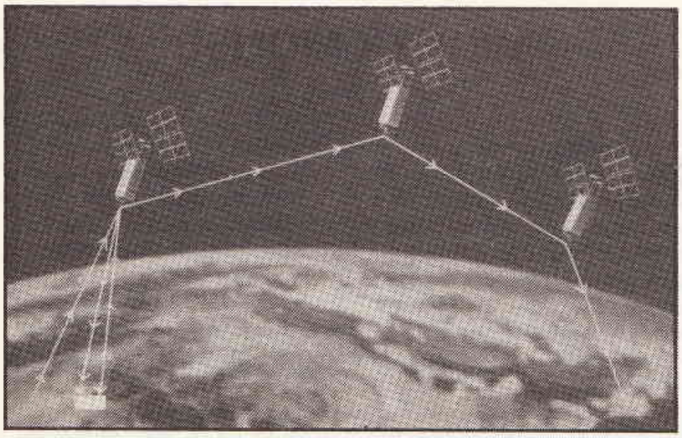
However, a Bristol-based company called Data Tote Limited is using computer systems from Control Universal to enable greyhound tracks to economically update their tote facilities. Data Tote systems are installed in many of the countries major tracks, including Wimbledon, Wembley, Bellevue and Bristol.

The systems comprise a central computer linked to a number of ticket issuing machines (TIMs) and video display units. Critical components are duplicated since a system shutdown during a meeting could lose the bigger venues £20,000, as well as the goodwill of racegoers. Systems vary in size from track to track — Bristol has 21 machines, while Wimbledon has 105 and even then has to borrow some for big events like the Greyhound Derby.

Successive developments have been aimed at making the TIMs more portable and easier to operate. The unit houses a customised keyboard, thermal printer and a large, clear, liquid crystal display. Unlike older manual methods, each operator takes bets in all pools, whether win, place, each way, forecast, trios, jackpots or other novelty combinations. The operator is prompted by the machine to enter pool, dog number and bet, then to press a button to issue the thermal ticket. Each station also has a barcode reader which enables operators to void bets and re-issue tickets if a mistake is discovered. So customers have to queue only once for each race, the queues move much more rapidly, and bets can be changed right up to the off.

During betting, the computer continually reads data from the TIMs, updating the pool and working out the odds for display on the video screens. The off is the signal for automatic shutdown of the TIMs. After the race, results are entered via a keyboard, and the computer calculates returns. Winning tickets are identified by the barcode reader, and the TIM automatically tells the operator the amount of money to be paid out. The payout is virtually immediate, contrasting with manual methods in which, even with high manning levels, customers sometimes had a long wait for their money.

For further information contact Edward Keating at Control Universal Limited. Telephone 0223 244447.



SATELLITE CONSTELLATION

Motorola has announced a new global communications system that will allow people to communicate by telephone anywhere on earth, on land, at sea or in the air — via portable cellular radio telephones operating as part of a satellite-based system. Callers using the new system will not need to known the location of the person being called, and can just dial that person's number. The system will be able to handle both voice and data.

The new system is called Iridium. Its core is a constellation of 77 satelllites in low-earth orbit, working as a digital switched communications network in space. The Iridium system differs from the geosynchronous satellite systems currently used from international communications. The low altitude of the Iridium satellites allows radio links with portable cellular radio telephones on earth, using small antennae rather than satellite dishes. It also supports re-use of radio frequencies, in a similar way to land-based cellular systems.

The system solves the problem of low-orbit satellites disappearing over the horizon by combining a large number of satellites in a space-based, inter-satellite switching system. The network of satellites will orbit the earth at a height of 413 nautical miles, ensuring that every point on the earth's surface is in continuous line of sight with one of the satellites. The satellites will be deployed in seven circular polar orbits, with 11 satellites per plane.

The satellites are approximately one metre in diameter and two metres tall, and weigh about 315 kilograms. Each satellite antenna pattern will project 37 cells onto the earth's surface. Each cell will provide communications coverage for an area of the earth's surface roughly 350 nautical miles in diameter. People will communicate with the satellites using equipment operating at frequencies of 1.5-1.6 GHz, just above land-based cellular telephones. In addition to voice, the digital system will be able to transmit data at a rate of 2400 baud.

The Iridium satellite can be placed in orbit by a variety of launch vehicles, including the U.S. Delta and Atlas rockets, the European Ariane and the Pegasus air-launched vehicle. Each satellite should have a life span of about five or six years.

A network of gateway surface systems will be able to link Iridium with the public switched telephone network. The gateways will store details of each user's location and bills.

Although Iridium uses cellular communications principles, it is designed to complement, not compete with, land-based cellular systems. Land-based cellular will remain the most effective way to serve high-density areas, whereas Iridium will bring communications to remote or sparsely populated areas that lack communications.

The Iridium system will be capable of supporting millions of users worldwide. Motorola hope it will be particularly suitable for low population density areas which currently lack cellular communications, and for undeveloped regions, which have no basic telephone service.

Motorola also anticipate that Iridium will be able to provide voice or data links and positioning information for ship and aircraft. It may also be able to play a valuable role in disaster recovery efforts following natural disasters such as earthquakes or hurricanes.

Motorola plan to place two demonstration satellites in orbit in 1992. Implementation of the entire system is planned to begin in 1994, and Motorola hope that the full service will begin in 1996.

DATA DISCMAN

Sanyo Corporation in Japan have introduced a new portable data retrieval system, the Data Discman, DD-1. This model accesses information from sources such as catalogues or dictionaries on an 8cm CD-ROM disc, and shows it on a liquid crystal display screen. The Data Discman is aimed at computer users who have previously been confined to a desk or laptop computer in order to retrieve information.

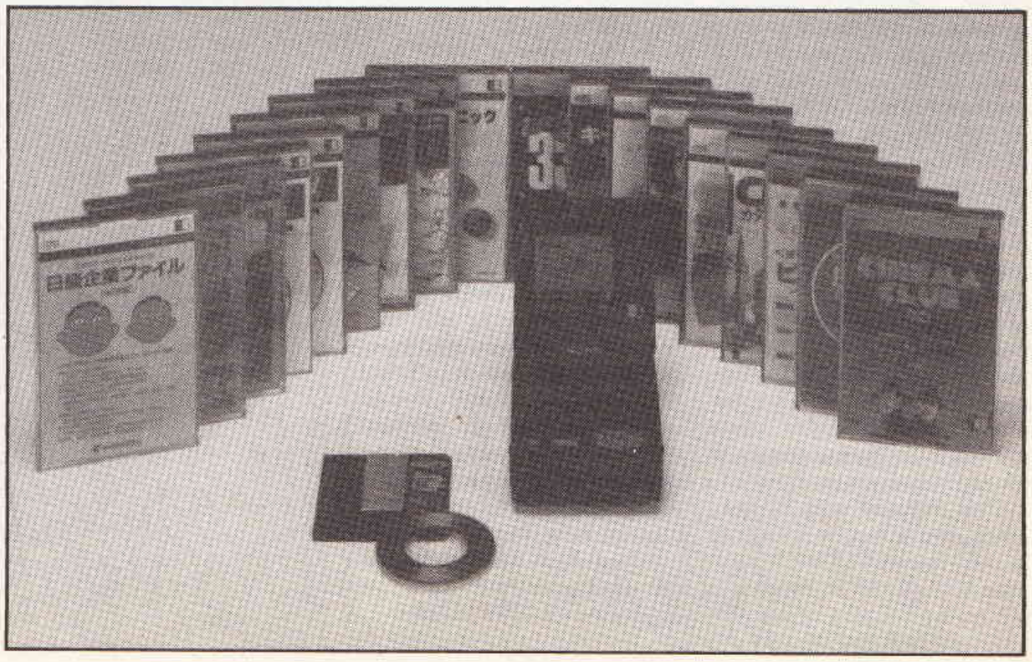
Sony Corporation began the portable audio revolution with the Walkman in 1979 and in 1984 introduced the audio Discman, the first portable compact disk player. These machines made music and sound available anywhere, in or out of doors. The Data Discman follows this pattern and allows for data availability anywhere.

The 8cm CD-ROM disc drive and the liquid crystal display allow the unit to be very small, with retrieval software included in the integrated circuits of the machine. Information access should be as easy as playing a CD.

The screen is able to display text 15 characters horizontally and 10 lines vertically. If additional text is available it will read out in a scroll fashion. As well as displaying data, conventional 8cm audio CDs may be played on the machines.

Software publishers will market information discs of many kinds: travel guides, textbooks, dictionaries, instruction manuals and so on.

For further information, contact Paul Cambell. Telephone 0784 467455.



ELECTROSTRICTIVE MOVEMENT

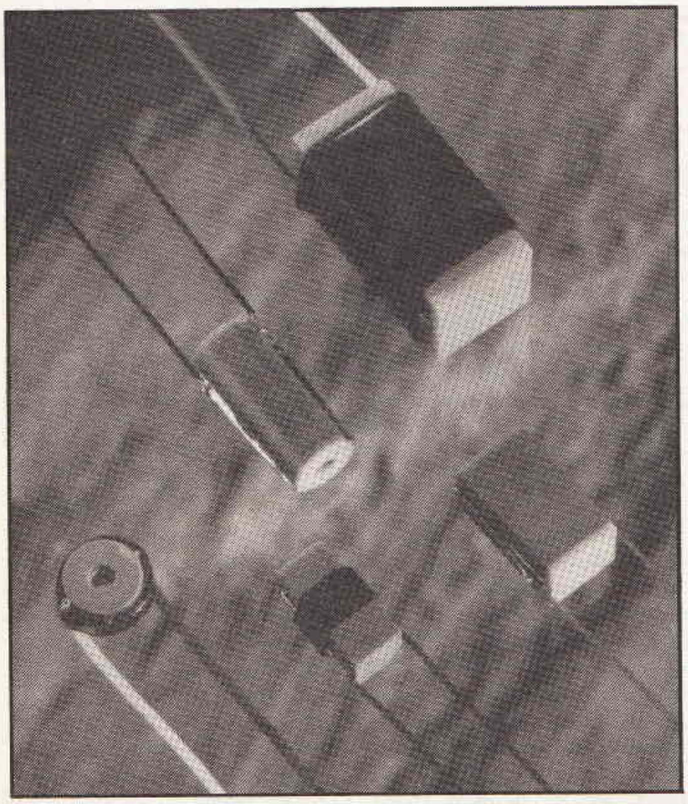
AVX Limited, who design, develop and manufacture multilayer ceramic capacitors, have used the same technology to produce an electrostrictive actuator for precision displacement monitoring.

Typical applications envisaged for the actuators include mirror angle and focus adjustment in optical and laser systems, micro-movement for tool wear compensation in machine-tools, usage of valves in automotive applications and video tape head adjustment systems.

According to AVX, the advantages of the multilayer ceramic device over its piezo-electric and magnetostrictive counterparts are repeatability of movement and cost. The multi-layer devices suffer very little hysteresis loss, and the absence of rare earth metals makes them cheaper than magnetostrictives.

The mechanical force of 7.5kg per square mm is higher than the peizoelectric product and AVX's devices produce a 90% deflection at 100Hz and 100-150V. In common with piezo electric devices, AVX's electrostrictive parts can be used in reverse to measure loads and forces.

For more information, contact Shirley Smart at AVX Ltd., Telephone: 0252 336868.



NEW UK PCB DIRECTORY

A new UK PCB Directory is now available from Technical Reference Publications, which sets out to improve on previous publications by incorporating more detail about the PCB manufacturer's capabilities, by supplying an index of those capabilities for purposes of cross-reference, and by giving manufacturers an opportunity to outline their capabilities and services in their own words.

The desire to present an overview of the PCB industry as a whole led to the addition of two further sections, the first listing suppliers of material, equipment, products and processes, and the second sub-contract services.

Priced at £55 plus £2.50 postage and packaging, this publication is available from Technical Reference Publications Limited, Asahi House, 10 Church Road, Port Erin, Isle of Man. Telephone 0624 834888.

MIGHTY MOUSE

Selectech Ltd have announced an easy-to-use remote controller for interactive video systems such as Compact Disk-Interactive, High-Definition Television, Cable TV and video games. The device, called the AirMouse, functions in a similar manner to a conventional computer-type mouse. However, the AirMouse is a hand-held remote, with no connection to the set. It uses patented sensor technology combined with digital infrared signalling to locate and select on-screen menu functions.

The AirMouse replaces other remote control technologies that either required numerous button functions or use joysticks, track balls and thumb pads. Those controllers are either cumbersome, require considerable hand-eye co-ordination or need two hands to operate.

Selectech are based in Vemont, USA. Telephone: (0101) 802 860 7600.

NEW DMM RANGE FROM QUILLER

Six new multimeters have been introduced by Quiller of Bournemouth. The QI Range comprises "low cost instruments with realistic specifications". From a modest 10A DMM at around £15, the range progresses through analogue units to two high specification DMMs.

The first of three analogue meters is a 500V insulation tester, also offering a 300VAC measurement scale. The remaining two offer large displays, dB ranges, semiconductor test and are suitable for general purpose and desk instrument work.

The range's penultimate DMM is compact, autoranging and features a bargraph display. Top of the range is a powerful and rugged DMM with a comprehensive selection of facilities including temperature, capacitance, frequency ranges and semiconductor test.

All the units are fuse protected except in 10/20A ranges, and are supplied with lead sets, full specifications and operating manuals.

For further information contact Quiller Limited. Telephone: 0202 417744.

COMPUTER NOTEPAD

GRiD Computer Systems has launched a graphics-based computer tablet capable of recognising handwriting.

The computer is called the GRiDPad. All information is entered via a stylus writing on the computer's glass screen. It can be operated while the user is standing up or walking, and is suitable for applications where desktop or laptop computers impose two many restraints. Development of the GRiDPad began three years ago. The algorithm it uses for user-independent handwriting recognition was developed by Jeff Hawkins.

GRiDPad is aimed at the market where the most common medium for data collection, retrieval and storage is the paper form, mounted on a pad or clipboard. GRiDPad replaces these forms and allows organisation to run a virtually real-time data collection system, bypassing the usual time and effort of having to transfer the data held on the paper forms to its computer.

The GRiDPad runs under the MS-DOS operating system. It weighs 2kg, and has 1Mbyte of random access memory (RAM). A 20Mbyte hard disk unit (of similar size to the main computer) can be clipped onto the back. The unit has built in modem facilities, which allow portable use.

The GRiDPad is already being used in the US. In some states, if someone uses a GRiDPad stylus to sign for a shipment or order, this can be stored and used as a legally binding acceptance.

For more information, contact Mike Daly at GRiD Computer Systems Ltd. Telephone 0372 60266.

MOTORWAY NETWORK

STC, the communications and information systems group, is to supply the first Digital Networked Managed Transmission system to the Traffic Control and Communications Division of the Department of Transport. This is for the National Motorway Communication System which the Department uses to provide an emergency telephone service and signal system for motorway users every mile along the motorway.

STC's order, worth £1.5 million, is for the supply and installation of improved communication networks for motorways in Manchester, the West Midlands and on the M25. STC will commence installations of the first network in October 1990 and should complete the contract by the end of 1991.

The Department's network, designed for maximum communication integrity and reliability, will be equipped with STC's Network 300 intelligent multiplexers. The intelligent multiplexers incorporate a special management facility enabling the systems manager to automatically reconfigure the network immediately if a rerouting is required.

These multiplexers are designed to be flexible. As the motorways spread during the next decade, the multiplexers should be able to handle the increased volume of telephone and data traffic without impairing the quality and resilience of the network.

During the past two years, there has been continual technical liaison between STC and the Department of Transport; a trial system is already operating successfully between Dartford and Swanley in the M25 area.

About 35% of the cost of a new office building development goes into the infrastructure necessary for efficient use of IT. And of the cost of refurbishing an existing building, 45% goes on IT. It is cheaper to demolish and rebuild a 1960s speculative office than to refurbish.

These are the findings revealed at Infrastructure 90, a conference organised by Applied Network Research and Commed.

Office buildings of the 1990s will have to accommodate ever increasing layers of communications channels, for voice, data and images, with cabling taking up a correspondingly greater proportion of available space. Communication network cabling is a long term investment, fixed in the building's fabric and expected to last as long as the building itself. A successful "intelligent building" requires co-operation between architects, contractors, design teams and IT specialists. Poor planning, installation and decisions can lock an occupant into a system which damages business performance.

The conference also discussed the transmission media used in intelligent buildings. Copper cable, particularly in the form of twisted pair cabling (the system used in telephone cables), is expected to have at least five years life left. However, fibre cabling is becoming increasingly popular. While the cost of fibre cabling is likely to fall, the cost of connection is likely to remain high. The blown fibre structured cabling system allows an empty plastic tubing to be inserted at strategic points during construction of the building. These tubes can later be used to blow fibre optic cable into the required operation environment.

In 1985, worldwide sales of personal computer local area network (PC LAN) systems and associated hardware and software products totalled nearly $600 million. By 1988, sales had reached $1.8 billion and by 1995 they are expected to exceed $9.1 billion. These findings are revealed in a report "World PC LAN Markets" published by Market Intelligence Research Corporation.

Several trends have emerged. These include the replacement of multi-user systems based on minicomputers by PC LANs, and the issue of standard, achieving a common or compatible set of standards, allowing PC LANs to intercommunicate. LANs will be based on network controllers increasingly using 80386 microcomputers.

Manufacturers are likely to try to tap the market potential of PC LANs for customers with specialised needs for communication or file sharing. The efficiency of software must be optimised for use in a LAN environment.

Competition is very strong in the PC LAN market. Manufacturers will be looking to provide the most differentiated systems features combined with optimised systems performance overall, including hardware and software.

OPEN CHANNEL

Since the second world war, worldwide electronics has been largely defence — more precisely, militarily — led. Apart from a monumental glitch when American president John Kennedy committed the USA to a course of manning the moon, first western electronic industries have catered primarily for military purposes. Missiles, rockets, telecommunications, computers, networks and so on are mainly results of this defence-orientated marketplace. A familiar term, the cold war, was coined to represent this electronic race to produce superior weaponry and systems.

Naturally, as a consequence, we consumers see a benefit (if benefit is the right word) in the off-casts of this race. Off-casts take the form of integrated circuits, without which a spacecraft could never have found its way off the launch pad into orbit, let alone to the moon and back. ICs in adapted forms have since changed most household contents, and continue to do so.

Now Mr Gorbachev comes in from the cold and the race slows to a friendly jog before breakfast. Defence budgets are cut and slashed with considerable ease, even by governments passionately committed to military priority. Many jobs, previously assumed safe, are lost. Worldwide electronic industries are now under considerable pressure to perform and pay their ways.

At home in the UK, we must take note of cold war thaw. It is not too late to make a shift in priorities, and shift we must. There is but one direction to shift, too. Consider Japan, which has not since the second world war had a military presence or requirement. It maintains a strong electronic presence worldwide instead, developed following a consumer-orientated course which has set it at the forefront of a new international electronics race. If our industry (or any country's national electronics base, for that matter) is to be maintained, that is the race now to be run! It would be ironic if we were to find ourselves out in the consumer cold, after being for so many years hot-stuff in defence.

Worldwide, several industries are taking initiatives. Philips, for example, appears to be selecting consumer markets which look as though they will be money spinners. Already, Netherlands-based Philips is forcefully trying to define worldwide opinions in matters like high definition television (HDTV) systems. It has teamed up with fellow European competitor Thomson of France to develop, make and sell HDTV products by 1995. Indeed, wide-screen receivers are expected before the end of next year.

What Philips and Thomson are hoping to achieve is not just first place in the HDTV race, but to completely define HDTV worldwide on a European basis. Previously, it looked like the Japanese HDTV system would be steamrollered through to being the worldwide standard. However Philips and others hit the Japanese steamroller head on and stopped it.

At a recent plenary meeting of the International Radio Consultative Committee (CCIR), Philips and Thomson presented sufficient evidence to prevent decisions being taken by the committee on number of lines and scanning rate. Thus a worldwide HDTV standard could not be defined. This was despite the fact the Japanese HDTV system is already in use in Japan, while a European system is only in early development. As you might expect, prior to this the Japanese system was expected to be accepted by the committee.

This is an interesting situation. CCIR plenary meetings are held only every four years. Philips and Thomson (and any other companies wishing to ally themselves) therefore have four years to prove their system. And if they can do so before the next plenary, a European HDTV system could just be accepted publicly on a de facto basis.

This, then, is an example of the new electronics race. Not now a cold war, more a hot one, trying to slow down the rising sun — or at least put on a sunhat and sunglasses before high noon.

There are many other areas where British and European manufacturers can team up. Telecommunications is probably the most important now, hence my high definition television example, although computing, networks and software are areas which we must maintain to the best of our ability also. Without excellence in these we will become little more than an offshore European cheap manufacturing base for Japanese companies. I'm not decrying this — after all, such industries employ British people, pay British taxes, and provided good quality products at economic prices — I just prefer to think we are capable of more. Without wishing to sound a zealous patriot, I believe Britain is a nation or innovators. Let us now innovate. We managed to maintain a high priority in the military-orientated market place. We can surely do it in the consumer-orientated complement.

Keith Brindley

BLUEPRINT

Blueprint is a column intended to provide suggested answers to readers' electronics design problems. Designs are only carried out for items to be published, and will not be prototyped by the columnist. Circuits published in Blueprint are believed to work, but may need minor alteration by the reader after prototyping. Individual correspondence will not be entered into, save as necessary to prepare items for publication.

Here is a somewhat topical enquiry:

> Dear Blueprint
>
> As you may be aware, the safety of clothes driers has been questioned as a result of the death of a toddler, who climbed into the machine while it was operating, and pulled the door closed.
>
> I have seen my toddler open the door while my drier was on, which prompted me to write to you.
>
> Ideally, I would like a circuit which will inhibit my drier from starting unless an external push to make switch is pressed. My drier is specified as 2400W max. It has a 0-120 minute timer, which also acts as the on/off switch, a 0-8 hour delay, and a door switch. Can it be done, and can I have a circuit please?
>
> Yours sincerely,
> Costas Kardasopoulos

Yes, it can be done. It would be easier to incorporate the required function into a machine from scratch than to add it on later, because it needs to interface with the timers and door switch to work efficiently.

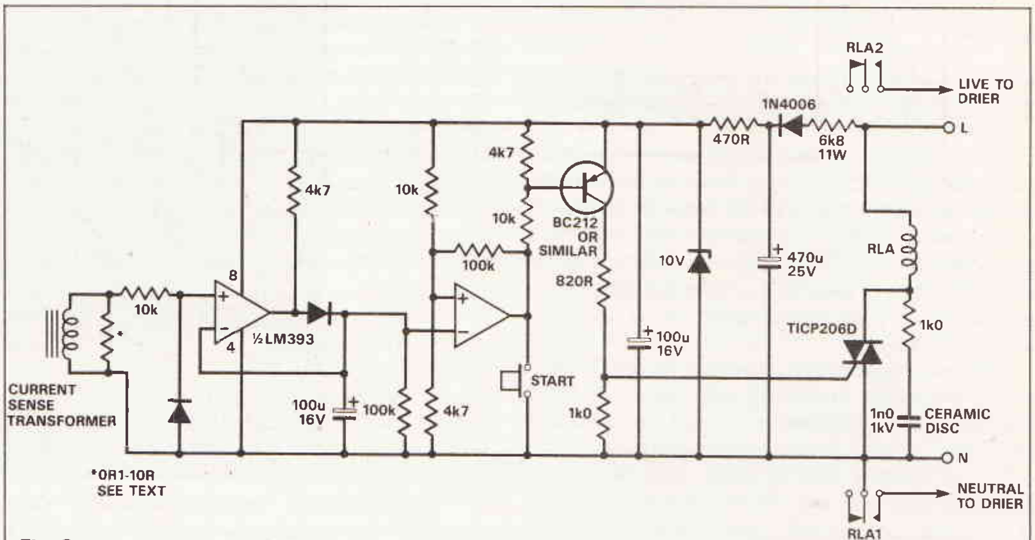


Fig. 2

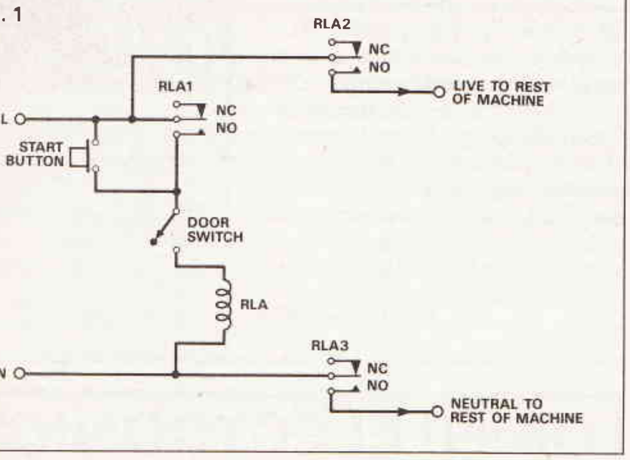


Fig. 1

I shall outline three approaches. The simplest, and the one I would do if I faced this problem, is shown in Fig. 1. The only disadvantage of this approach is that it involves altering wiring inside the tumble drier. Such wiring is sometimes almost inaccessible.

The circuit shown in Fig. 1 shows a relay supplying power to the whole drier, energised through its own contacts. To avoid the need for the entire running current of the drier to pass through the start buttom briefly at switch on, an extra relay contact is used. A suitable relay is Maplin type JG64U. This is a 10A triple change-over mains relay with a mains coil. It is a plug in relay requiring an 11 pin base, part no. JG53H. The choice of mains rated push button I leave to you, but it is probably best to use a recessed type.

The relay should be mounted as far as possible from heat sources and where the drum of the machine cannot contact it. All wiring should be secured away from moving parts, and connections should bear as little strain as possible and should be sleeved where appropriate. Failure to take account of these points could remove one danger and substitute another.

Current Measurement

The second approach is to measure the current drawn by the machine, and keep a relay energised only while the current continues to flow. The simple implementation of this precludes the use of the 8 hour delay timer, because current must be flowing in order to apply power to the machine. The drier must therefore draw current as soon as the start switch is presssed, or else the relay will switch off as soon as the switch is released.

There are many ways of designing such a circuit, using a mains transformer or a resistor to power it, and using a relay or triac to switch the load. In order to minimise the cost, a resistor power suppy is used, and to avoid the high dissipation of a triac with 10A flowing through it a relay is used. The circuit of this is shown in Fig. 2.

The triac chosen for this design is guaranteed to trigger with a gate current of 5mA except in quadrant 4 where it requires 10mA. Since this circuit uses quadrant 4, 10mA must be provided.

The power supply must supply the triggering current for the triac plus enough to run the rest of the circuitry, and it must do this without getting too hot. It is therefore important to calculate the current available from the resistive power supply. The current is not, as one might expect, simply half the AC which would flow in the resistor if the diode were not present. To calculate the current it is necessary to integrate the current (a half cycle of sinewave) and divide by the repetition period (2π). This gives $V_{pk}/(R \times \pi)$, where V_{pk} is the peak voltage (340 for 240V AC). From this formula the resistor value chosen will provide approximately 16mA DC. The dissipation will be approximately 8.5W, which is acceptable for an 11W resistor. This level of dissipation might justify the drilling of small ventilation holes in the case.

The current sense transformer is not required to provide accurate measurements, so a stack of steel washers drilled to accept a mains wire with extra insulation (to counter long term abrasion) will be suitable. The stack of washers should be wound with about 50 turns of enamelled copper wire. Some experiment with the value of the loading resistor may be necessary to achieve the correct sensitivity. Note that the sense transformer will almost certainly saturate at full load current, but this will not prevent it from detecting the presence or absence of current.

Component Choice

Note the use of comparators rather than op-amps in this circuit. The comparator chosen does not suffer from phase inversion on small negative voltage inputs, where if an LM358 op-amp were used, phase inversion could occur, depending on the characteristics of the particular op-amp and the protection diode in use. The phase inversion would give a very large positive output for a small negative input, and might trigger the circuit on the current drawn by the clock motor.

The time constant on the current sense circuit (approximately 5 seconds) should prevent brief current fluctuations from shutting off power, while not allowing time for a child to climb inside and shut the door.

For safety, the circuit should be built in a metal case, which must be earthed. Make sure that the cables entering the box are secured, and that the earth wires are the longest ones so that if the cables are pulled the earth is the last connection to break. As a point of general design philosophy, it is important to make sure that protection devices added to a system are not themselves so unreliable as to defeat their purpose.

A suitable relay would be the double pole version of the one specified earlier. The Maplin part number is

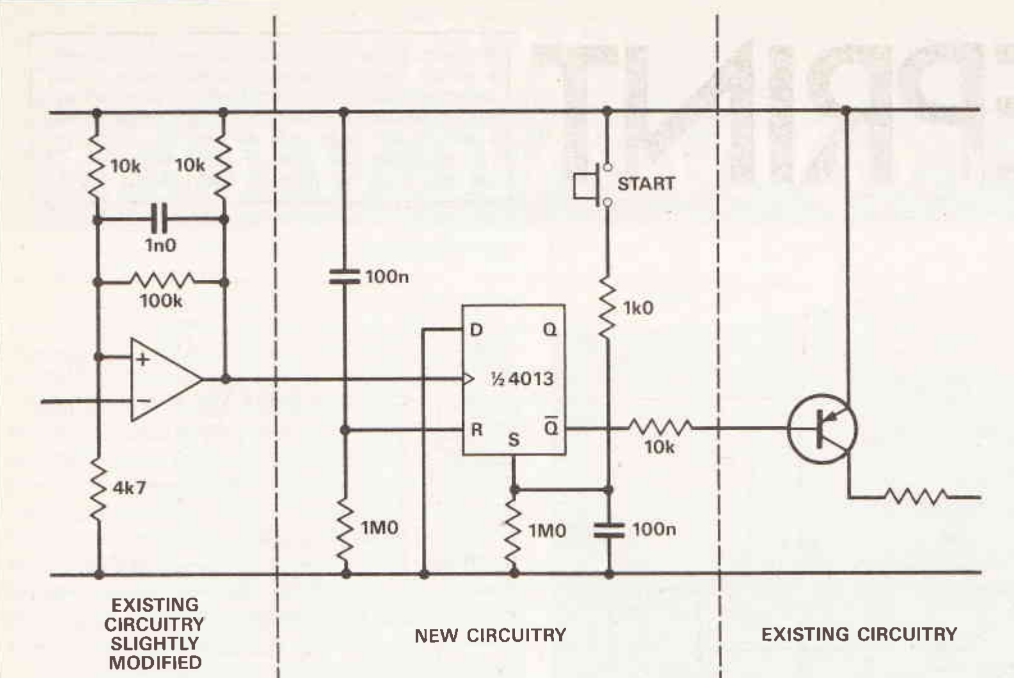


Fig. 3

JG60Q and it needs base part number JG54J. The switch, though it only switches low voltage, is connected to the mains neutral, so it should be a mains insulated type even if the contacts are only rated for less than 240V.

Set/Reset

The final possible elaboration is to add a flip-flop to the circuit of Fig. 2 to permit the use of the delay timer in the drier. The additional circuitry is shown in Fig 3.

The D-type flip-flop is positive edge triggered, so that when the load current starts to flow nothing will happen. If the current ceases at any stage, the flip-flop will switch over, which will de-energise the relay. Further clock pulses caused by noise will not switch the relay on again, because the output will simply follow the D input, which is permanently at logic 0.

Capacitors on the set and reset inputs make sure that, if the mains supply is interrupted and then switched back on, the circuit will not power up the drier. Do not forget to ground unused inputs (on the other flip-flop).

Afterthought

It might be worthwhile incorporating an alarm in the system, because a small child in unlikely to fare well in a hot clothes drier even if the heating is off. A means of doing this is shown in Fig. 4. A FET is used to switch the alarm to avoid excessive load on the comparator output.

Andrew Armstrong

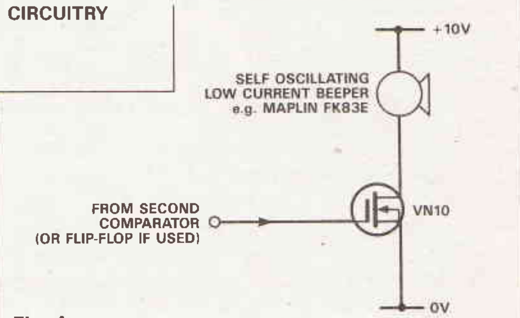
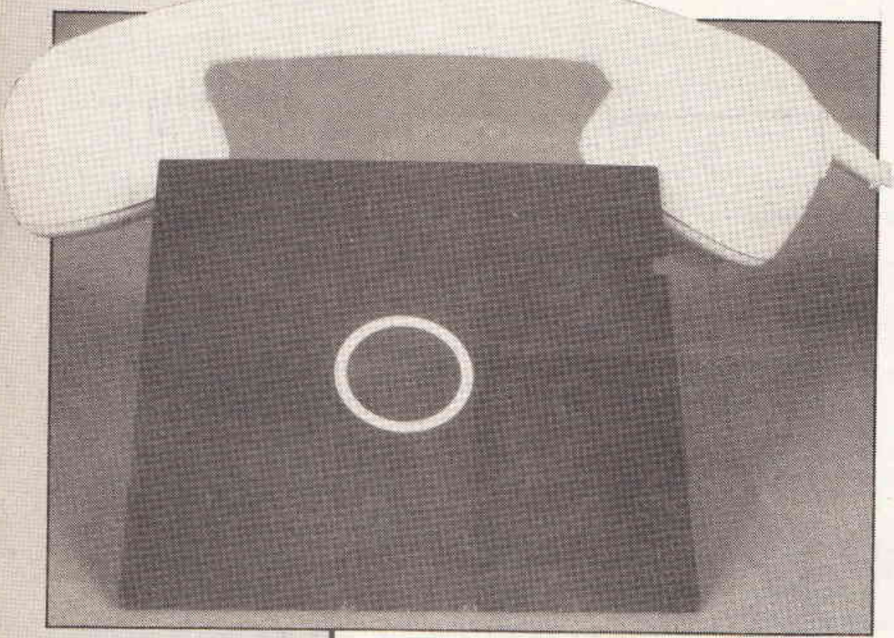


Fig. 4

DATA COMMUNICATIONS



In the first of two articles about how computers communicate with each other, Mike Bedford looks at modems.

In recent years, the use of computers has continued to grow rapidly. One aspect of computing which has grown particularly fast is data communications, the exchange of information between computers. Here we look at the methods and theory of data communications, both wide area and local.

Modems

Most of our experience of interfacing various peripherals to computers is carried out locally. The printer is probably sitting on the desk right next to the PC or is at most only a few metres away. In this situation the constituent parts of the computer system are interconnected using cables with either a couple of conductors in the case of serial communications or perhaps ten for a parallel interface. As most readers will be aware the binary data which passes along these cables is represented by discrete voltage levels. So, for example, in RS232C, +12V and − 12V are used.

Now, what happens if we wish to interface our computer to another which is on the other side of town, or even on the other side of the world? Clearly running a dedicated cable is out of the question, even if RS232C or even RS422 would operate over that distance (which they don't). The obvious solution is to make use of standard telephone lines but here we run into a problem. Since telephone equipment was intended to transmit and receive speech, all the circuitry is designed to operate with a bandwidth of 3kHz. Any signals with a frequency of less than 300Hz or greater than 3300Hz will not pass through the system. This means that if RS232C was pumped into the public telephone exchange a steady +12V level and a steady -12V level would both appear the same at the other end — neither would get through and our data stream would be lost. The answer is to convert the binary data into a form which is compatible with the telephone system or in other words to use the data to *modulate* an audio carrier signal.

A piece of equipment to generate a modulated audio signal from a binary signal is called a modulator. The piece of equipment at the other end of the telephone circuit which converts it back to a binary signal is called a demodulator. Normally we require a two way link and as such need to carry out both these functions. The piece of equipment which combines these functions in a single box is our old friend the modem, the name being derived from *modulator — demodulator*. The way in which two computers are connected via a telephone system and a pair of modems is shown in Figure 1. The amorphous shaped lump in the centre of this diagram, labelled PSTN (for Public Switched Telephone Network) consists of some combination of telephone lines, repeaters, exchanges and even satellite links. Although we have concentrated on telephone circuits, these techniques apply to any medium designed for speech transmissions. Modems are also used to effect data links via radio communications and, of course, this is exactly the way data was stored on audio cassette recorders in the early days of home computers.

Fig. 1 Typical Modem Application

Those who have dabbled in radio communications will be aware of the modulation methods available and in the most basic terms the options come down to amplitude modulation, frequency modulation and phase modulation. With AM, a frequency in the centre of the passband (say 1500Hz) would be picked and this would be transmitted at different amplitudes for a binary 0 and for a binary 1. The most obvious such solution would be to have zero amplitude for 0 and maximum amplitude for 1, the resultant signal being somewhat akin to morse code. This is referred to as on/off keying. However the signal-to-noise ratio of this modulation method turns out to be unattractive and this is aggravated by the fact that a constant amplitude signal may vary in amplitude at the other end due to varying conditions of the line or exchange. For these reasons, AM is rarely used, except when it is used in conjunction with phase modulation (as we shall see later).

Neither frequency nor phase modulation suffer from the drawbacks mentioned for amplitude and as such both are used extensively. Most of us will be concerned with general purpose communications, in which frequency modulation (otherwise known as Frequency Shift Keying or FSK) is used, this being relatively simple to demodulate. In phase modulation (Phase Shift Keying or PSK), two phases, 0° and 180° can be used for the two states. However, since detection of absolute phases is quite tricky, the alternative Differential Phase Shift Keying (or DPSK) is more commonly used. In this scheme there is a phase shift at the start of every time interval, +90° for a 0 and +270° for a 1.

Figure 2 shows a binary signal modulated by AM, on/off keying, FSK, PSK and DPSK.

An FSK signal can be considered as two on/off keyed signals of different frequencies, each on/off keyed. As each such signal is keyed, sidebands of a width proportional to the data rate are produced at either side of the mark and space frequencies. The maximum fundamental frequency produced is half the data rate, so the maximum bit rate which can be accommodated within the 3kHz bandwidth of a PSTN is 1200. This is shown diagramatically in Figure 4(c) which we will cover in further detail later.

PSK is more difficult to understand but in essence very similar constraints apply. In order to provide higher data rates, more advanced modems take data bits in groups of more than 1 at a time in order to reduce the number of transitions and hence the maximum modulation frequency. So, for example, taking bits two at a time (dibits), the possible combinations are 00, 01, 10 and 11, so 4 phase shifts are required and these are typically 0°, 90°, 270° and 180° respectively. This modulation method is often referred to as 4DPSK. Figure 3 shows some phase modulation techniques, and illustrates 4DPSK. We must now ue the term bits per second rather than band rate, since the two are no longer interchangeable. The reason for this is explained next month.

For higher speeds still, the next logical step after use of dibits is use of tribits. Now we have to go to 8DPSK, as shown in the phase diagram in Figure 3(d). As a quick explanation of phase diagrams, if a line is drawn from the centre to any point, its angle represents the phase and its length the amplitude.

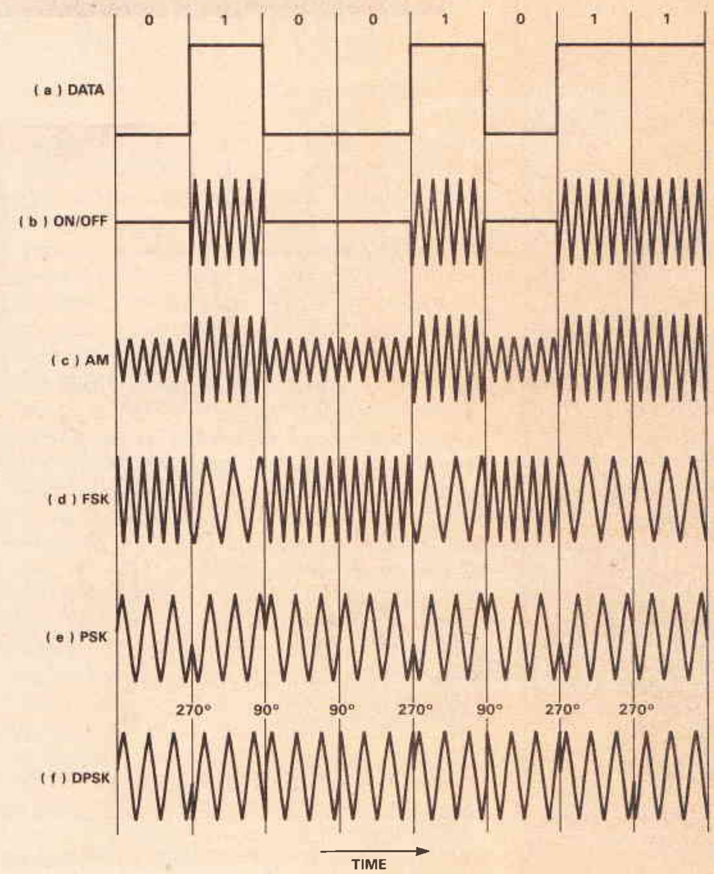
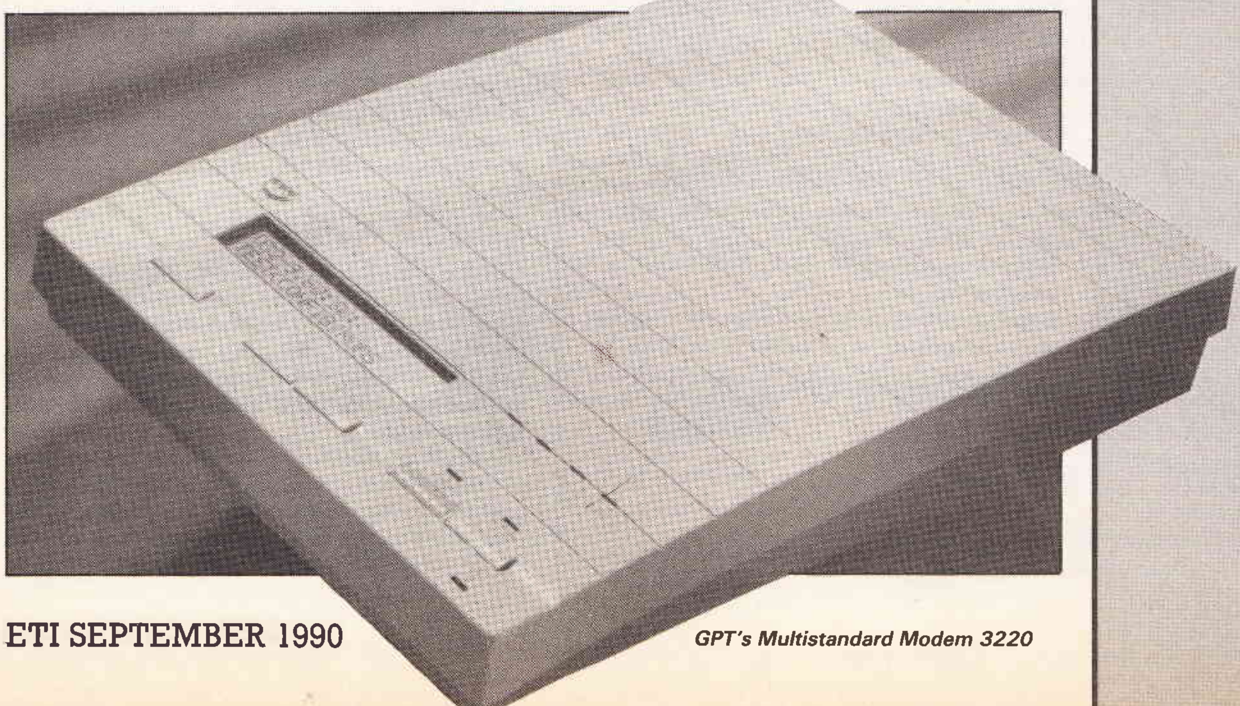


Fig. 2 Simple Data Modulation Techniques

The next logical step for achieving even higher speeds would be to go for 16DPSK but since we are the talking about detecting phase differences of only 22.5° this approach is not usually taken. Instead a modulation method called Quadrature Amplitude Modulation (QAM) is used for the highest specification



GPT's Multistandard Modem 3220

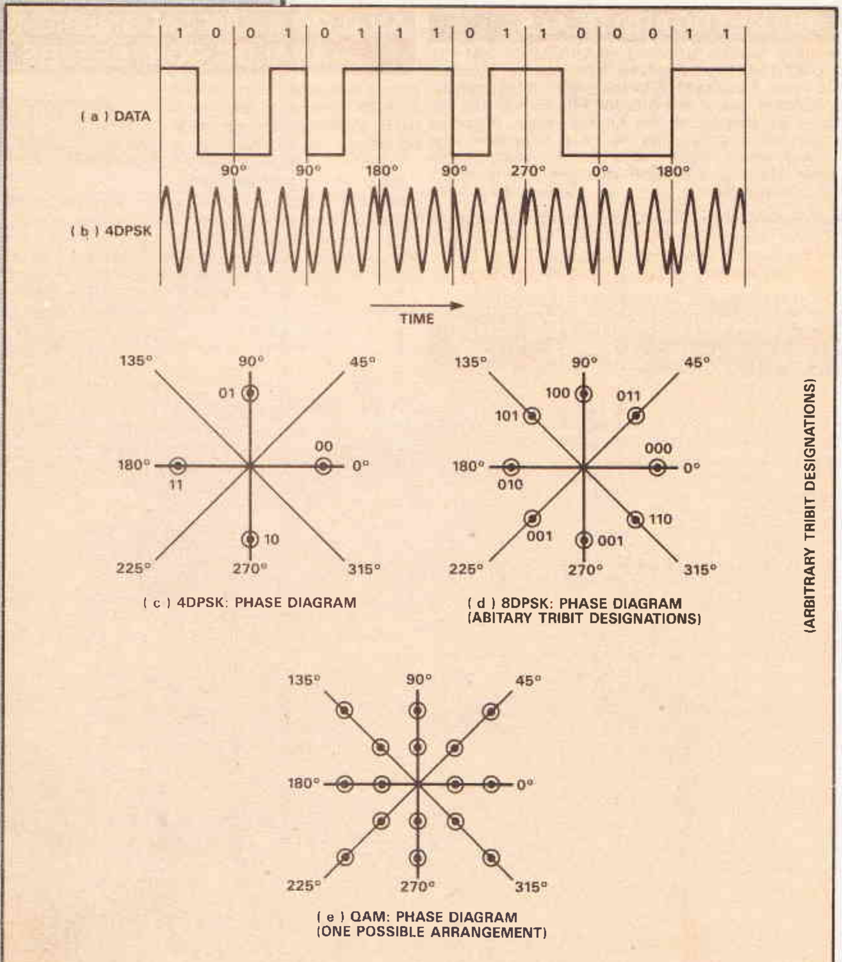


Fig. 3 Advanced Data Modulation Techniques

possible on switched telephone lines. QAM is a hybrid modulation technique in which various combinations of phase and amplitude represent quadbits. Of course, the amplitude modulation must be other than on/off keying, even though we get a poor signal-to-noise ratio, as it is not possible to detect the phase of a signal with zero amplitude! So, for example, four phases each with four amplitudes, or eight phases each with two amplitudes, both give the 16 combinations required for quadbits. The latter alternative is illustrated in Figures 3(e). In fact, there are numerous QAM systems possible.

I ought to point out that this technique of cramming more bits into each time interval cannot go on forever. There is a theoretical limit to the amount of information which can be transmitted on a particular channel, and this depends on the bandwidth and the signal to noise ratio. For those with a mathematical leaning, the formula is as follows:

$$\text{Information rate} = \text{Bandwidth} \times \log_2 \left(1 + \frac{S}{N}\right)$$

This suggests that the absolute maximum for a switched telephone circuit is about 20,000 bits per second (bps). In fact other factors tend to limit this and for all practical purposes, 9600 bps may be considered the limit.

Duplex Communication

Figure 4(c) shows a 1200 bps signal, the highest of the normally encountered transmission rates possible on a PSTN (using FSK). As already mentioned, the mark and space frequencies need a separation of 1200Hz at this data rate and the half-way position between these frequencies if referred to as f_c, the centre frequency of the channel. If the data rate were halved, the mark - space frequency separation also halves to 600kHz and so two such channels could be accommodated. In this case one channel could be used for flow of data in one direction and the other for data in the opposite direction. A communications system in which data can travel in both directions at the same time is called full duplex — FDX, V21 is such a case and is illustrated as Figure 4(a).

To achieve 1200 bps in both directions the channel would have to be half duplex, used alternately for communications in each direction. Actually, a 1200 baud channel does not entirely fill 3kHz and V23 allows a so-called back channel at the reduced speed of 75 baud as shown be seen in Figure 4(c). This is the specification used for the Prestel system. The 1200 baud channel is used for the data passing from Prestel to the terminal whereas the 75 baud channel is used for the limited amount of data passing from the terminal.

The example shown in Figure 4(b) is V22, 1200 bps FDX. It should be noted that since 4DPSK is used here, the baud rate is only 600 and hence FDX becomes possible. This also differs from the other diagrams in not showing mark and space frequencies since we are now dealing with phase rather than frequency shift keying.

Having set the scene, the remainder of this discussion of modems will attempt to guide you through the modem jungle and assist you in selecting one which is suitable for your needs.

Acoustic Modems

It is quite possible to build a modem. Most of the basic functionality can be found in a single chip. These vary from the basic types to sophisticated VLSI designs offering multiple modes which cost in the region of £18.00. The bad news is that having built such a modem it would be illegal to connect it to the British Telecom system.

For this reason most home constructed units are of the acoustic modem variety. Here, instead of plugging directly into a telephone socket, the modem interfaces acoustically to the telephone handset via rubber cups. There is no direct connection to the

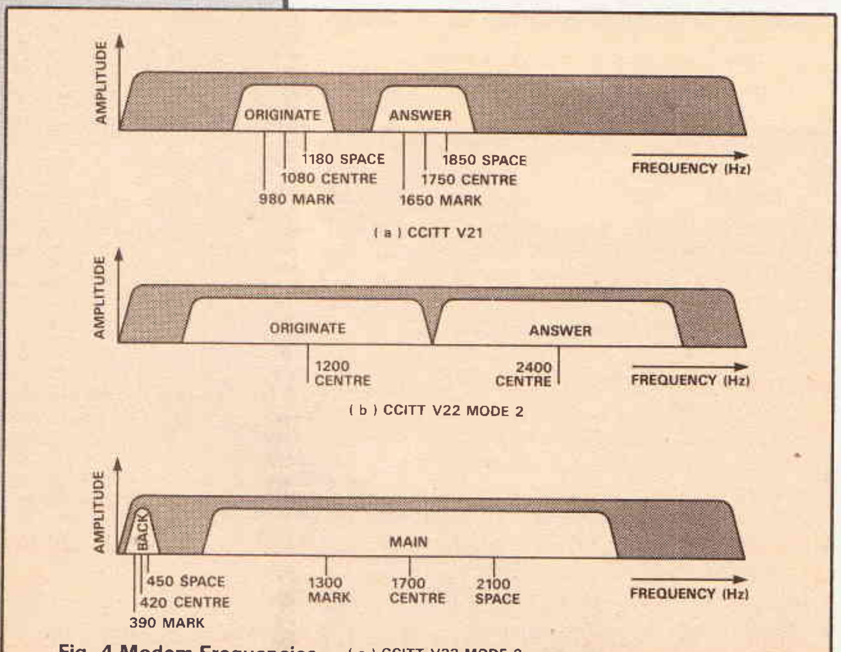


Fig. 4 Modem Frequencies (c) CCITT V23 MODE 3

telephone system. The modulated signal coming from the modem goes into the mouthpiece of the handset and the return signal to the modem comes from the earpiece. In the days before telephone sockets were as abundant as they are today, acoustic modems were quite popular as they obviated the need to have a modem socket installed at great expense.

Except for the fact that you can build such a modem yourself, the only advantage now is that they can be used in conjunction with a portable computer in hotel rooms, telephone boxes or wherever. The disadvantages, of course, is that acoustic modems can be prone to audible noise pickup.

Integral Modems

The integral modem is another deviation from the conventional modem. It is currently becoming popular, especially in the PC arena. Here, instead of connecting to the computer via an RS232C link, the modem plugs directly into one of the computer's expansion slots. The advantages are that it tends to be a less expensive alternative, it doesn't take up extra desk space and it doesn't tie up one of those valuable RS232C ports.

The disadvantage is that on changing computers, the modem becomes obsolete as it won't migrate to the new machine. This is much less of a problem with PC compatibles, which are stable long-term products with a downward-compatible upgrade oath (PC add-ons will plug into an AT 80286 or 80386 based machine).

Standards

So, now to the V numbers, which refer to any of the categories of modem which we have discussed.

V numbers are CCITT (Comité Consultatif Internationale de Telegraphie et Telephonie) recommendations in connection with data transmission over telephone circuits. Where as these recommendations refer to all sorts of aspects including character encoding, circuit definitions and error control, the ones which are of interest in selecting a modem are those which specify the baud rate and modulation methods which it uses.

Of these, some are only intended for leased lines and even of those intended for ordinary switched telephone lines some are quite obscure. Table 1 shows the more common numbers which define modem operating characteristics for use on general telephone circuits.

Now, if the modem is needed to communicate with one or more bulletin boards then it's simply a matter of ensuring that the modem obtained matches that specified for the services required. For example if you intend to use Prestel (the BT viewdata system) you need a V23 modem.

If, on the other hand, a pair of modems are being obtained to implement a specific link then it makes sense to get a pair which operate at the highest possible baud rate. Remember though, that the higher the speed, the more you can expect to pay. Also, it is possible to get modems which operate on a number of these standards but again these are more expensive.

Sometimes you may encounter modems specified as, say, Bel-103/113 or Bell-202 rather than by a V numbers. The CCITT standards are European, whereas the Bell standards are North American. Some Bell standards are CCITT compatible, others are not. However it is unlikely that many readers in the UK will specifically want Bell compatible modems unless they intend to access American bulletin boards and this practice tends to be prohibitive in terms of telephone call charges. If the modem is being used for say amateur radio data communications, on the other hand, it could be that there is more of a requirement for this compatibility. Modems from North America are unlikely to have the requisite BT certification. It is possible to get multiple standard (CCITT/Bell) modems which are BT certified, but if they are switched to a Bell standard, the certification may no longer apply and the user may be liable to prosecution — you have been warned.

Table 2 shows common Bell standard modems with notes on CCITT compatibility.

A quick word about Hayes compatibility. Simple modems require the telephone number to be dialled on a telephone before connecting the modem. More advanced models have an auto-dialling facility which, when driven by the computer, allows the user to select the name of the required service from a menu after which the computer will look up the number and dial it.

On an integral modem, the auto dialling is carried out by the dedicated software which comes as part of the package. With a conventional modem, auto dialling (and various other functions) are initiated by ASCII commands sent via its RS232C interface. The Hayes protocol is simply an industry standard syntax for these commands, use of which means that the modem will be compatible with most applications software.

Modems are available with either tone dialling or pulse dialling or can be switched between the two. In pulse dialling each digit is represented by a string of pulses varying from 1 to 10 (which represents 0). With

Table 1

Bell Standard	Speed (bits/s)	CCITT compatibility
103/113	300	Uses different mark and space frequencies from V21 hence not compatible.
212A	1200	Compatible with V22.
	300	This Bell 103 compatible mode is not compatible with any CCITT recommendation.
202	1200 (600)	Mark and space frequencies are different to V23 but only by 100Hz. They are interoperable under good conditions.
	1200/75	Some new Bell 202 modems have a 75 baud back channel for viewdata use. This is V23 compatible.

tone dialling, each digit is represented by a different frequency of audio tone.

Obviously it is necessary to ensure compatibility with the local telephone exchange. In the UK, pulse dialling is the most universally accepted and until System X came into existence was the only method used. The newer System X exchanges will accept both pulse and tone dialling. In other countries it would be necessary to check out the requirements of the local system.

Table 2

Standard	/Mode	FDX /HDX	Speed Bits/s	Modulation	Synch/ Asynch	Comments
V21		FDX	0-300	FSK	Asynch	
V22	1	FDX	1200	4DPSK	Synch	
	2	FDX	1200	4DPSK	Asynch	
	3	FDX	600	2DPSK	Synch	
	4	FDX	600	2DPSK	Asynch	
	5	FDX	1200/300	2DPSK	Asynch	300 is FSK
V22 bis	1	FDX	2400	QAM	Synch	
	2	FDX	2400	QAM	Asynch	
	3	FDX	1200	4DPSK	Synch	V22 compatible
	4	FDX	1200	4DPSK	Asynch	V22 compatible
V23	1	HDX	600	FSK	Asynch	
	2	HDX	1200	FSK	Asynch	
	3	FDX	1200/75	FSK	Asynch	Prestel
	4	FDX	75/1200	FSK	Asynch	
V32	1	FDX	9600	QAM	Synch	High price, normally only used for professional applications.
	2	FDX	9600	QAM	Asynch	
	3	FDX	4800	QAM	Synch	
	4	FDX	4800	QAM	Asynch	
	5	FDX	2400	QAM	Synch	
	6	FDX	2400	QAM	Asynch	

TAME THAT TIMER!

James Archer describes how PDC — the Programme Delivery Control System — will take the headache out of setting VCR timers

One of the major successes of the television industry over the past few years, and one that was never predicted by the crystal balls of the 'new technology' pundits, has been the pre-recorded videotape rental market. Who would have foreseen that within a period of about five years the demand for prerecorded tapes would have grown from virtually nothing, until it is now possible to find a video rental shop in some of the country's smallest and most isolated hamlets, and that it would be worthwhile for shops to stay open late into the night to satisfy the demands of viewers wanting to hire the latest 'movie' to watch whilst eating their takeaway suppers?

Pushing a prerecorded videocassette into the slot and pressing the 'play' button is so simple that anyone can do it, and some video machines are used solely for the playback of these tapes.

The vast majority of video recorders, however, are also widely used to 'time-shift' programmes that are recorded off-air, for playback at a more convenient time. Unfortunately, though, many people find it difficult or even impossible to understand the complex instruction books that come with their recorders, and so are unable to make the best use of their equipment.

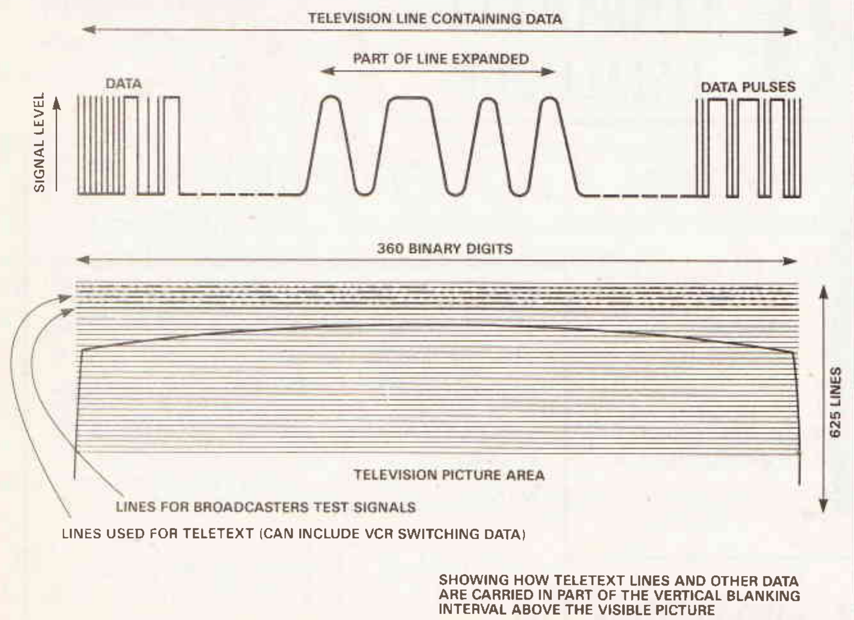


Fig. 1 Teletext lines and other data are carried in part of the vertical blanking interval above the picture

Timing Troubles

Modern video recorders offer very sophisticated timed-recording facilities, often allowing the viewer to record many different programmes at different times over a period of up to a fortnight, or to have individual episodes of a favourite soap opera recorded every night for a week.

Since the setting of the recorder timer often appears difficult, most viewers never take the trouble to learn how to make full use of the timer facilities and restrict themselves to being able to record just one programme, finding this sufficient for their everyday purposes. Installation engineers say that the only people who make use of the full range of the timer facilities are teenage children, and they well know that a return call to a customer with a new video recorder can often be avoided if the installer makes sure that the children of the family understand how it all works!

Another problem with recordings being pre-set for some time in the future, is that the broadcasters do not always keep to their published schedules, which can lead to great disappointment when the film doesn't start until later than the published time, and you find that you have recorded all but the last ten minutes of it and that you will never know who the villain was in the murder mystery!

VPS — The German Solution

These problems are not restricted to our own shores, and to help overcome them, the Germans designed a system of controlling timed recording sessions which is much simpler for the viewer to understand and operate. The VPS (Video Programme System) switching system was developed by the West German broadcasting organisations, in conjunction with their equivalent of BREMA, the ZVEI, and has been operational since the autumn of 1985.

Since the early 1970s some of the lines of the vertical blanking interval, the period at the end of a picture during which the scanning spot returns from the bottom right-hand side of the television screen to the top left in order to begin scanning the next picture,

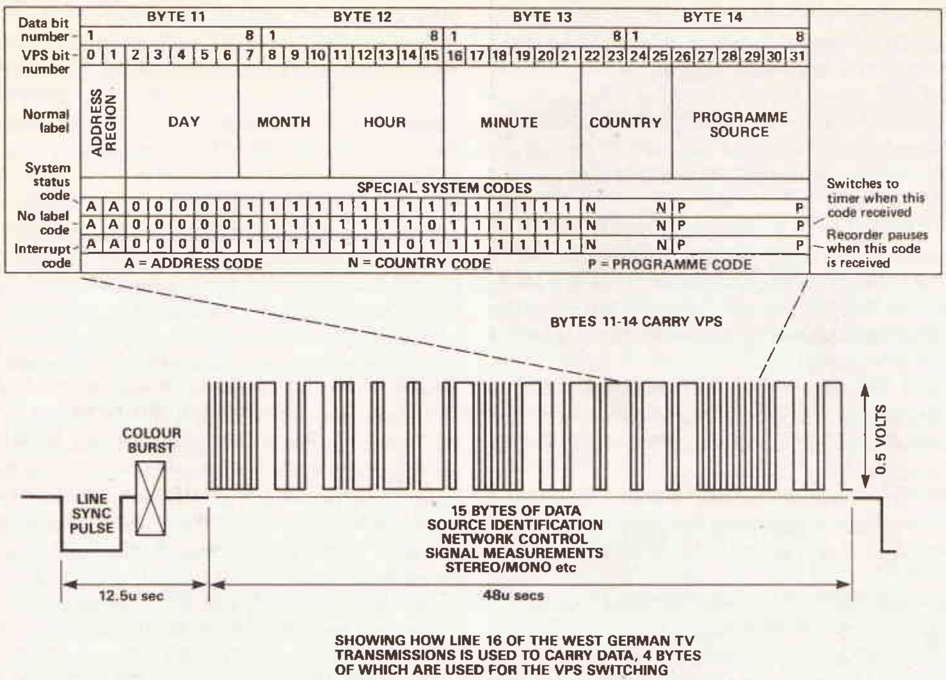


Fig. 2 Line 16 of the West German TV transmissions is used to carry data, 4 bytes of which are used for the VPS switching

have been used to carry Teletext, an information broadcasting system in which pages of text and graphics are transmitted in digitally coded form. This information is effectively carried on otherwise unused television lines situated above the visible picture.

With the VPS video recorder switching system, each programme is made to carry a teletext-like coded label with each picture, and when the information on the transmitted label matches the information that has been previously been put into the recorder, and not before, the programme will be recorded. At the end of the programme the recorder will switch off until it recognises another label for a programme which it has been asked to record. Therefore, the actual time at which the programme is transmitted is unimportant, since the video recorder will not start until it recognises the label at the beginning of the required transmission.

For some years now the West German broadcasters have been carrying coded data on line 16 of each TV picture, one of the data lines in the vertical interval between picture frames. This data is used to provide source identification, remote control of the network, indentification of stereophonic sound channels, and for the transmission of test measurement results. The VPS labels for each programme item are carried in four bytes of the data transmitted on line 16. The comparator in the home video recorder continuously checks to see if the label information decoded from bytes 11-14 of line 16 matches the information that has previously been programmed into it by the viewer.

Grundig have actually been making video recorders with VPS for some years now, several German networks are transmitting the labels, and Austria and Switzerland originally announced that they too intended to introduce VPS. Since this system is not in use in the UK, and our line 16 is used to carry ORACLE teletext information, Grundig (UK) have to remove a small VPS circuit board from their video recorders which are sold in the UK. For a long time UK engineers wondered why the Germans did not make use of the standard teletext transmissions for tape recorder switching purposes, since the IBA demonstrated that such a scheme was practicable back in the late 1970s. At that time the IBA's intention was to use automatic teletext-controlled switching to allow UK schools' broadcasts to be transmitted during the night. The UK teletext standard, on which the German teletext system is based, actually allocates a location in magazine 8, a so-called 'pseudo row address', specifically for this purpose, but the IBA idea was not taken up.

The search for a European standard

The German VPS system showed that it was technically possible to provide a more 'user-friendly' system of programming video recorders, but broadcasting engineers in other European countries were not convinced that this was the best system that could be achieved. It would obviously make sense to have a common system for Europe, in the interests of both manufacturers and viewers, and so for about the last five years members of the EBU have been involved in discussions amongst themselves and with European industry to try to agree on a system which would have all the features of the German VPS system, but with considerable enhancements, and which could encompass all likely future requirements. The Programme Delivery Control System (PDC) is the result of this work.

PDC in practice

The PDC system provides a service, designed for domestic use, which allows suitably equipped video recorders to record automatically programmes which the viewer has previously selected. PDC can essentially be divided into three parts: the labelling of the programmes prior to transmission by the broadcaster, the preselection of the programmes by the viewer, and the automatic control of the video recorder by the label data which is sent as part of the television broadcast signal.

Programme Labelling

Each programme can carry, as an integral part of its accompanying teletext service, various items of information which exclusively label the programme. Some of the components of the label are essential to the operation of the PDC system, others are optional, to provide extra information, such as the Programme-Type (PTY) byte which identifies the type of programme or the series to which it belongs, and the Conditional Access Flag (CAF flag), a bit of data which indicates whether or not a programme is in scrambled form.

The essential parts of the programme label consist of;

CNI — The Country and Network Identification.

AD — The Announced Date, which gives the scheduled date of start of transmission in terms of years, months, and days.

AT — The originally announced time. This is in two groups, the announced starting time, and the announced finishing time, both being expressed in hours and minutes.

MCP — The Menu Cursor Position. This is used to link the text information on the teletext 'TV-guide' page with the actual programme label information.

It is also desirable, but not essential to the working of the system, for the label to carry;

PTL — The programme title in clear text form.

LTO — The local time offset. All times used in the system are carried as Universal Time, UTC, with an adjustment being made for local time differences, so that the viewer need only ever be concerned with local time.

PD — The expected Programme Duration, in hours, minutes seconds.

A typical programme label therefore consists of a variable number of bits of information, which allow any programme to be uniquely identified, as well as giving further useful information about the programme.

newspapers, or from the appropriate pages on teletext.

Once the viewer has made these decisions, the relevant information must somehow be put into the memory circuitry of the PDC-equipped video recorder. The actual input of instructions, telling the recorder which programmes to record and when, can be achieved in several ways.

We have seen that the digital labels which accompany each programme contain, amongst other things, the month, date, hour and minute of the programme's starting time, plus the code for the programme source, so it is easy to use the remote control handset to insert the required information when prompted by a message on the television screen.

Even easier is to wipe a simple 'light-pen' over the bar-codes that will be printed in the programme journals such as Radio Times and TV Times. Merely passing this pen over the codes printed beside all the programmes you would like to record, sets up the required labels without any further action on the viewer's part, and this is bound to make life much easier for the non-technical. It is interesting to note that Panasonic have recently entered into an agreement with the BBC to carry a list of each weeks films accompanied by bar codes in the Radio Times which can be read only by viewers who have bought a particular type of Panasonic recorder, equipped with a light-pen code reader. This must not be confused with PDC, but is an indication that such methods of programming video recorders may well appeal to the public.

A third, and probably the best method of pre-programming the video recorder is to make automatic use of the teletext pages which contain the details of television programmes to be transmitted. There are two recognised methods of utilising teletext for this purpose.

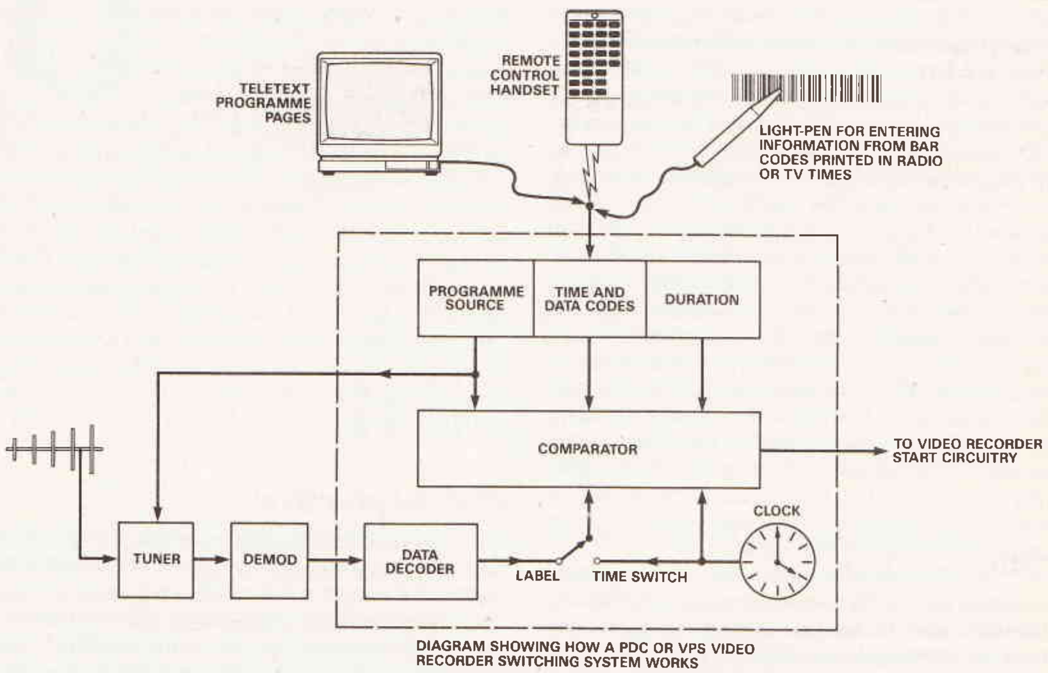


Fig. 3 Diagram showing how a PDC or VPS Video recorder switching system works

Preselecting The Programmes You Wish To Record

The viewer must first of all choose which programmes are to be recorded, and the basic information about which programmes will be transmitted and when, can be obtained from the Radio or TV Times, from the

The first, and simplest, is for the broadcaster to add data to teletext 'TV-guide' pages, which incorporates all the information needed for recording. Some of this information could be visible, such as instructions as to how to proceed, but some of the actual labelling information could be concealed. To preselect a programme to be recorded, the viewer merely moves a cursor up and down the screen until

VCR

it is in line with the desired programme, and then presses a button on the teletext handset. The process is repeated for all the other programmes that are to be recorded, and the PDC equipment will then automatically take control.

A further development of the use of teletext programme pages is for the broadcaster to send information which is additional to the normal teletext TV-guide pages, using the so-called 'ghost rows', rows

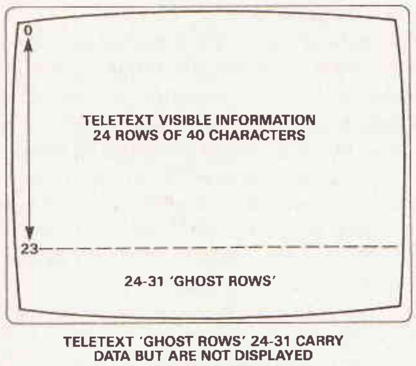


Fig. 4 Teletext 'ghost rows' 24-31 carry data but are not displayed

of teletext which can carry data, but which are not displayed on an ordinary teletext screen. (A normal teletext page displays only 24 rows of information, but has the technical capability to carry 32 rows.) This additional information can be in the form of a computer programme which can be used to provide a more extensive menu than the normal TV-guide, which can carry more details about the programmes and which can incorporate error-checking to alert the viewer if incorrect entries are made.

Automatic Control Of The Video Recorder

The menu selection process described above first of all causes the labels appropriate to each of the programmes to be inserted into the memory of the PDC-equipped recorder. The recorder then goes into 'stand-by' mode, silently monitoring each of the transmitted programmes until one comes along which is accompanied by a programme label which matches one in the recorder's memory. Once an incoming transmitted label is found to match a label stored in the PDC memory, the recorder switches itself on and records the programme, switching itself off again when it receives a label indicating that the programme has ended. The recorder then continues to look out for a programme containing the next label which has been pre-programmed.

Other Options

Since it is unlikely that all programmes will be labelled with PDC information, especially in the first few years after its introduction, the system allows for the automatic selection of label-controlled or timer-controlled operation of the video recorder, so as to cope with programmes that haven't been labelled. It is possible to envisage that the use of the timer could be arranged to allow the recorder to wait for a label only during a particular time slot, perhaps half an hour before and an hour after the expected transmission time, thus minimising power consumption.

Provision have also been made to allow for the recording of programmes which are unscheduled, and for programmes which are transmitted at different times from the scheduled time of transmission to be recorded properly.

Interruptions to programmes

If a broadcaster has to interrupt a scheduled programme part way through for any reason, the PDC system allows the broadcaster to send signals to interrupt the recording, and to start it again when the scheduled programme resumes.

Whilst it is true that if the broadcasters would co-operate by putting 'off' and 'on' labels at the start and finish of advertisements, the PDC system could even allow films to be recorded without recording the advertising breaks, it is even more true that in any system supported by advertising there must be sound commercial reasons for preventing this from happening!

Future Applications

PDC has been designed to be compatible with the future MAC satellite transmissions, so that a PDC-equipped recorder will be able to automatically record PDC coded transmissions from satellite as well as from terrestrial sources.

PDC might well turn out to be a good method of enabling teachers to automatically 'download' the schools programmes of their choice. If schools programmes were transferred to night hours, this might free the daytime schedules for more profitable programmes. To do this at present, would require the teacher to learn the intimate workings of the video recorder timer, in order to record some schools broadcasts but ignore others. PDC would make the whole task simple.

Starting Soon — Perhaps!

The PDC system, as defined so far, is a technical transmission specification, which does not yet include any rules for day to day operation of the service. EBU members are to continue their collaboration with industry to ensure the orderly implementation of the service, and the controlled introduction of any new features.

In the UK, Channel Four are likely to take the lead in introducing this exciting new facility, as early as next year, and although this should encourage the video recorder manufacturers to begin to build-in PDC circuitry, there could still be potential problems on the horizon.

Earlier this year the BBC let it be known that it was considering introducing a somewhat different system in which each programme would have its own discrete label, but that these labels would not be in the standard PDC format, and might be exclusive to the BBC and its programme journal Radio Times. The idea was that the BBC's special teletext decoder, which could plug into the back of existing video recorders, would decode the transmitted label, and that the adaptor unit would then emulate the standard infra-red transmission from a remote control unit in order to switch the recorder on and off at the beginning and end of the chosen programme. Novel though the use of this technique would have been, and with the advantage that existing recorders could easily be converted to the new service, the introduction of such a different system could only serve to delay the universal use of the PDC system, and so it was with some relief that manufacturers learned that this idea has now been dropped. Let us hope that all the broadcasters, both satellite and terrestrial, will adopt the PDC system before too long.

TESTING, TESTING

Mike Barwise explains how to test the frequency response of a megaphone amplifier

The final test of our megaphone amplifier which is of interest, is a quick look at its *bandwidth* or frequency response. The basic method of testing is obvious; apply constant amplitude input signals over a wide range of frequencies, and record the output amplitude obtained. There are, however, several different practical approaches to this test, and the chosen approach will depend on how much money and/or time you have.

If you are rich and in a hurry, the tool you will use is the *network analyser*. This consists of a spectrum analyser combined with a very accurate and stable oscillator. The oscillator supplies the input signal to your circuit under test (CUT), and the output from the CUT is fed to the spectrum analyser. The oscillator sweeps through a user-determined range of frequencies in an extremely linear manner, and the oscillator signal and output signal from your CUT are compared to provide a display image which is a direct graph of gain against frequency. The network analyser is extremely quick, reliable and accurate, but expect to pay about £3000 for a very basic one.

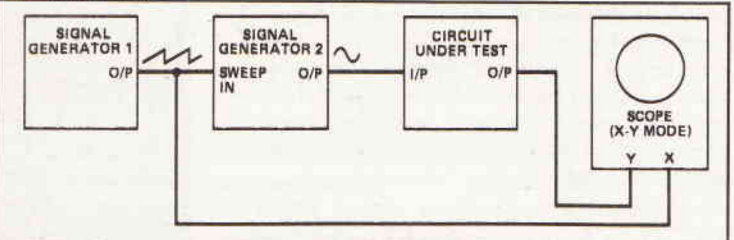


Fig. 1 General layout for test

At the other end of the scale, if you are poor but have lots of time (the position of most amateurs) you can manually switch your signal generator through its frequency range, and, using your 'scope in dual trace mode, take readings of the input and output amplitudes at your CUT by hand and eye. The results from this will be in terms of peak to peak values, whereas the network analyser RMS power values, but for sinusoids the two are directly proportional anyway, so this does not really matter. Just divide your peak to peak values by $2\sqrt{2}$ or about 2.8, and you get the RMS.

There is, however, a very neat third alternative, which is possible if you have a signal generator and 'scope which are a little more than basic instruments. It is effectively to automate the manual method just described. For this, you will need two signal generators; one capable of outputting a reasonably linear sawtooth ramp at low speed, and the other equipped with a sweep input; a voltage control of frequency. You will also need a 'scope either capable of X-Y operation, or equipped with an external trigger socket. The X-Y mode is distinctly preferable.

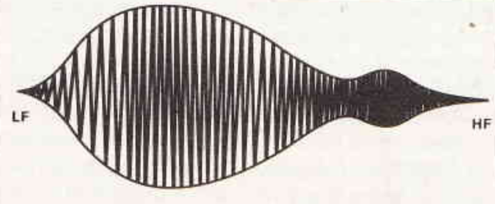


Fig. 2 Amplitude envelope

What we are going to do is drive the CUT with a swept frequency sinusoidal signal from the lowest to the highest frequency of interest and synchronise the 'scope image so that it shows the peak to peak value of the CUT output across the whole frequency range, in a single screen.

The general layout of the test setup is shown in Figure 1. The Y (vertical) axis of the 'scope displays the voltage swing of the waveform as normal. The X (horizontal) axis is driven by the sawtooth ramp which also causes the main signal generator to perform its sweep. The sweep time must be very long compared with the cycle time of the lowest frequency of interest, so that several cycles of each frequency band, from the bottom up, are present on the display. For example, if you are interested in frequencies from 100Hz to 1kHz, there should be about ten cycles at least of even the 100Hz range covering the first division (cm) or so of the display, so the sweep rate should work out to be around 1cm for every 10x1/100 = in other words, 1/10 seconds, 10cm/sec. Thus the whole frequency sweep (ten horizontal divisions) will take 1 second. The minimum cycle count per frequency band is the important factor, we are not trying to resolve individual cycles in the display. What we want is the *amplitude envelope shape* across all frequencies (Figure 2). For wider frequency ranges, the sweep time is correspondingly longer, so either a long persistance phosphor (which glows for about twice as long after the electron beam has passed) or an X-Y pen plotter could come in useful, although the latter might fail to resolve the upper frequencies of the sweep adequately. Probably the best all-round alternative is an instant picture camera with the shutter kept open for the whole duration of the sweep. This is a standard technique.

The alternative setup using an external trigger to the 'scope, is shown in Figure 3. In this case, the 'scope timebase must be set so that it takes slightly longer to sweep the whole screen than the ramp time of the controlling sawtooth, and the fast falling edge of the sawtooth is used to trigger the sweep via a high-pass filter, which is often built into the 'scope trigger as an option (HF TRIGGER).

The advantage of the X-Y mode approach is twofold: firstly, the sweep control ramp duration does not have to match a preset sweep time available from the 'scope, and, secondly, any non-linearity in the ramp will not matter. What is essential, however, is a near perfect linearity in the V/F conversion of your signal generator, as any errors here will make interpretation of the display very difficult. There is also another general drawback of both these approaches. The display on the 'scope screen is a broad trace of varying amplitude, and is quite difficult to interpret; not least because the horizontal axis is linear, and we normally want a logarithmic horizontal axis. We normally express rolloff and cutoff in dB per octave.

There is a quite simple gadget you can construct to solve both these problems in one go. A block diagram is given in Figure 4. This gadget replaces the first signal generator (the sweep ramp generator) in the X-Y mode alternative (fig. 1). What it does is to generate a staircase ramp with logarithmic steps instead of a continuous ramp. With steady voltage on the X input to the 'scope, the spot will stop at some point along the horizontal axis, and the Y signal will cause the spot to draw a fine vertical line. The spot only moves horizontally at the transition between steps, so the resulting trace on the 'scope screen looks like Figure 5a; a bar graph or histogram. The half wave rectifier removes the negative-going half of the signal, producing a horizontal baseline to the graph and simplifying analysis of the data. The EPROM between the counter and the DAC provides the linear to logarithmic conversion, and the excess resolution of the DAC additionally allows compensation of any non-linearity in the sweep function of your signal generator.

In its most basic form, this setup has fixed overall span, resolution and set points, but this should not pose a problem for audio work, where you want nominal half octave points in the range 20Hz to 20kHz. You can, of course, pick any frequencies you choose by putting the right codes in the EPROM. The method of setting up is to monitor the sweep voltage from a stable source using a DVM, measure the associated frequency using your ETI frequency meter, and, when the frequency you want is generated, calculate the DAC input code for programming into the EPROM. The one limitation of this system is that the HF end of the display is crowded together, as the 'scope has a linear sweep. A small refinement is an additional DAC driven direct off the counter outputs. The voltage out of this second DAC feeds the 'scope X axis, and the ramp DAC feeds the signal generator alone. The display then looks like Figure 5b. The diagram of Figure 4 assumes a maximum of 32 lines on the 'scope screen, which is about as many as can be easily read individually. The 8 bit DAC uses five bit input, allowing a user defined 'gap' between the lines.

The beauty of the solution of Figure 4 is that there is no longer any uncertainty in the display. Each line corresponds to a specific spot frequency. Using the methods of Figures 1 and 3, it is much more difficult to determine the response at a particular frequency, as there are no on-screen markers.

This type of add-on is a very common requirement in more advanced testing. The ability to come up with such tricks comes with experience, but the need is the most important thing: however much you spend on a given piece of test gear, there will always be a job it cannot do. We will look at a selection of test rig tricks for analogue in the next part of this series, before going on to digital techniques.

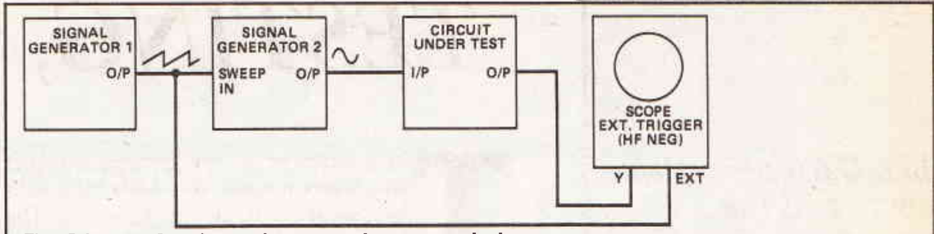


Fig. 3 Layout for alternative test using external trigger

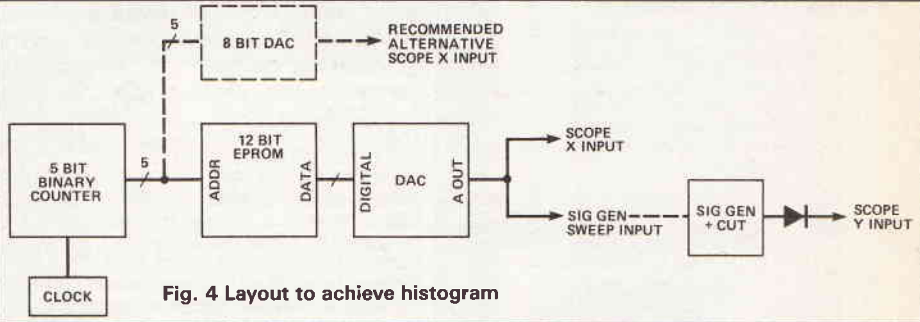


Fig. 4 Layout to achieve histogram

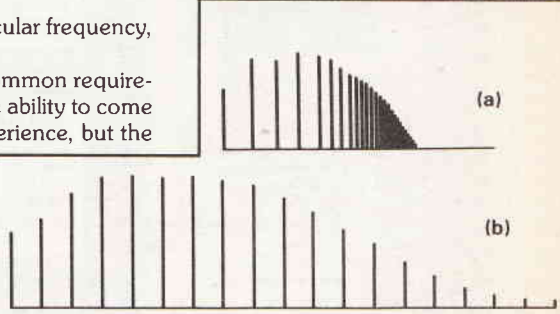
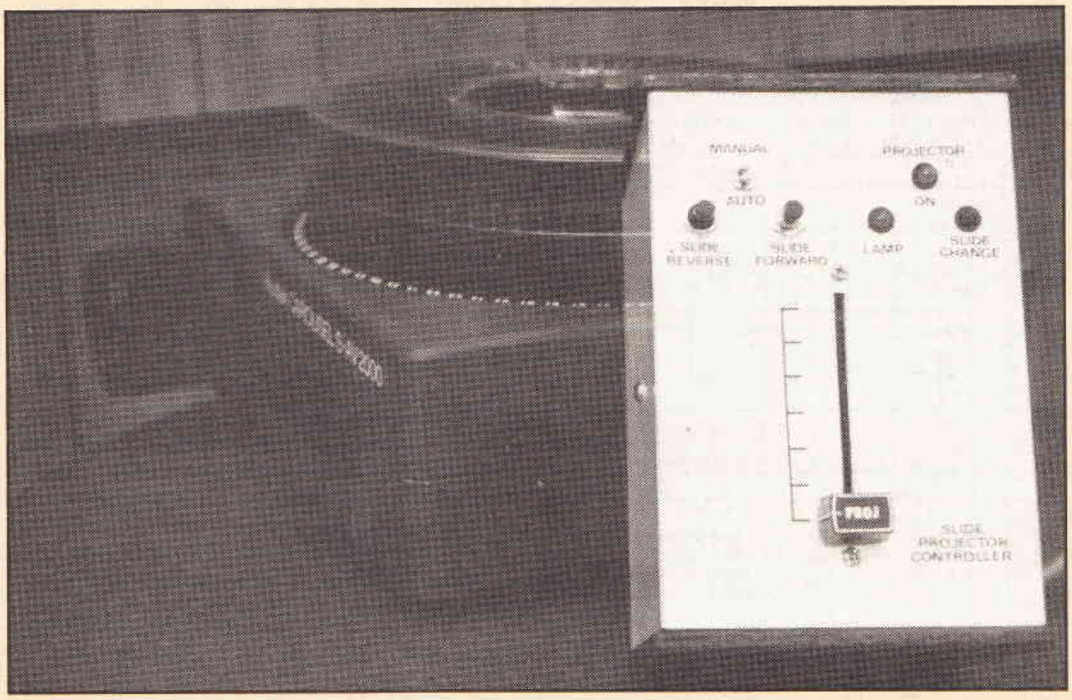


Fig. 5 Histogram 'scope traces

PROJECT

SLIDE PROJECTOR CONTROLLER



Give that slide show a more professional finish. From the States, David Ponting tells of how its done.

I am just tired of hearing a projector fan whining away whenever I give a talk which needs slides! And I am sure the audience is too. The solution? . . . . a small control unit that turns the projector on only when a slide is needed, and changes to the next slide before it switches itself off. As a bonus, it allows each slide to be faded in and faded out for a far smoother presentation. And all this, as they say, with as little inconvenience to the lecturer as possible.

First then, a relatively simple but different phase control circuit which will allow the projector's lamp to be faded in and faded out.

The Dimmer Circuit

Safety has to be a primary feature of this circuit and, as it is controlling mains voltages, it has to be well isolated from them. Secondly, there is a need to control the light output linearly which usually means a highly complex circuit as the light output of a lamp is very far from linear. Another requirement is that it should operate from a single voltage rail and make it simple enough to be built inexpensively from readily available components.

In order to meet some of the above requirements, the circuit was develop around the LM393 dual voltage comparitor integrated circuit which is designed to operate from a single voltage rail. Ultimately I came up with the circuit for the dimmer section shown in Figure 1.

Switching The Projector On

It would easily be possible for the lecturer to turn the projector on and then fade the lamp in; but it would be more convenient if starting to move the fader up was, in itself, the way the projector is switched on. This is accomplished by the projector switching circuit shown in Figure 1.

Changing The Slide

Conveniently, the 4538B contains a second and totally independent monostable which can be employed to change the slide before the projector finally switches off. The slide changing circuit can be seen in Figure 1.

The Control Cable: Connecting the projector

Two control cables from the project box to the slide projector are required: One supplies switched mains to the projector and the other, a lightweight 6-core cable (which can be of any reasonable length; 100 yards or more is possible) will control the brightness of the projector's lamp and slide change mechanism. This second cable can terminate at the projector end in a small diecast box which will also accommodate special Kodak twelve-pin plug which fits into the side socket on the Carousel Series projectors. The triac Q5 which controls the lamp's brightness, should, if possible, be mounted inside the projector and bolted to the projector's metal case. This component will get hot when the projector is on and it needs the metal body of the projector as a heat sink. The connections to the Kodak twelve pin plug and socket are shown in figures 4a and 4b. The 12 pin plug (Kodak Part No. 2 605 4850)

comes as a 'lamp-saver' unit. For use in this project, remove the plastic cover and unsolder and discard the shorting connection which joins pins a2 and a3. Cut a 41 by 11mm hole in the lid of the diecast box and mount the 12 pin plug in this hole.

Let me at this point say something about the external triacs. They both carry considerable current. Always use a triac with specifications well beyond the apparent requirements of the circuit. Also bear in mind that the triacs will get hot when the projector is on and their metal tabs must be bolted to heat-sinks. For these reasons I recommend BTA 16 600B triacs, which are 600 volt, 15 amp devices and which have isolated metal tabs making heat-sinking a lot simpler.

In the complete circuit, the timing sequence is shown in Figures 5a and 5b.

Setting Up

I repeat: be careful! The PCB carries mains voltages so extreme care should be exercised when the board is being tested; it must be properly insulated from the box in which it is fitted.

There will be no problem in setting up if you have an oscilloscope and can check the waveforms at the various points; but there will be no major problems if you have not.

Before inserting IC2 and IC3 each into its socket, check that there is a 5 volt supply at pin 3 of IC1, and that there is about 6 volts of (pulsating) DC at the junction of R2 and ZD1. If all is well, set RV3 and RV4 to about halfway, fit IC2 and IC3 into their sockets, plug the projector into its mains socket, join the control

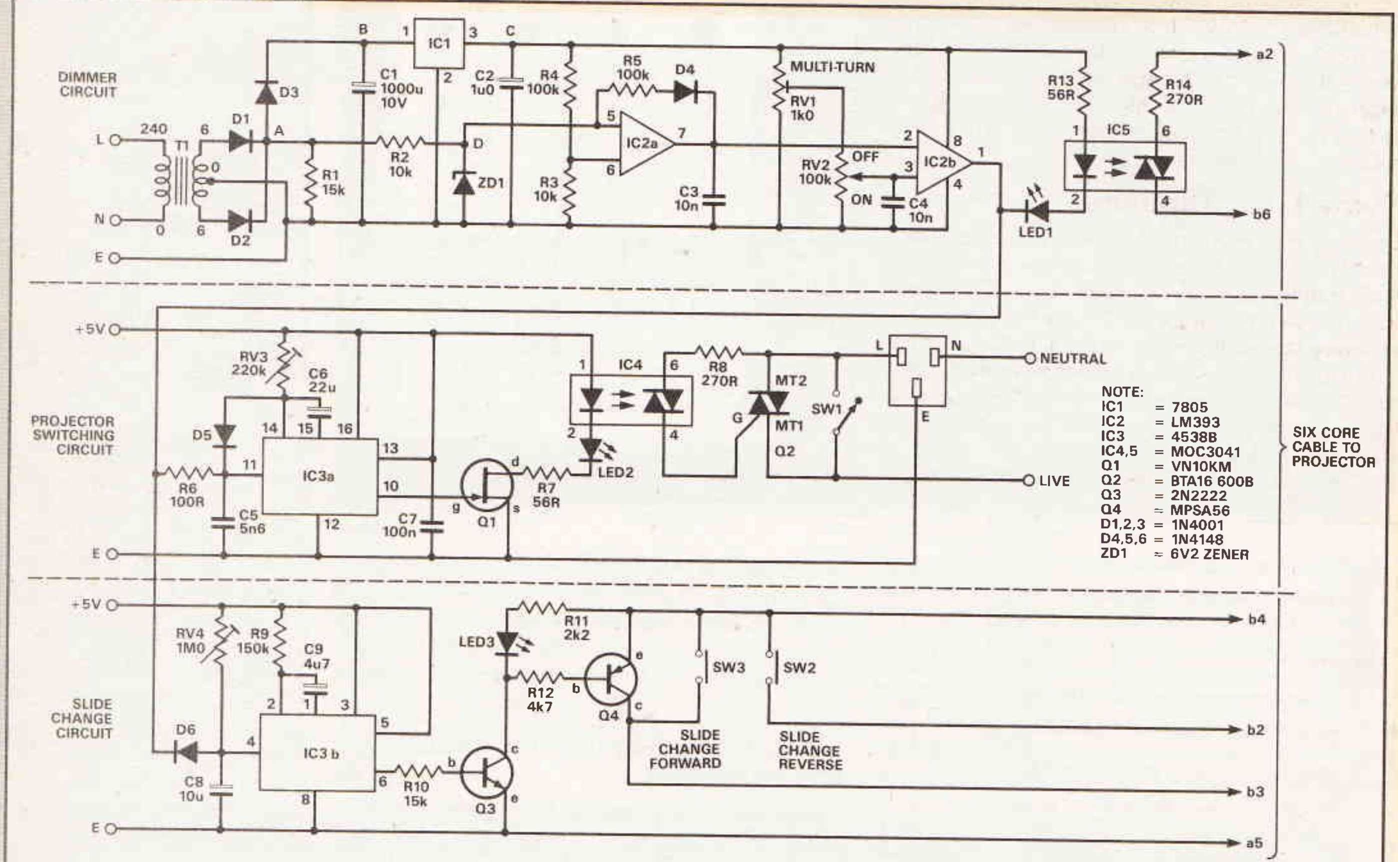


Fig. 1 Complete circuit of the control box

Making The Unit

The whole of this circuit can be built using the printed circuit board outline shown in Figure 6.

Great care should be taken to see that all the polarised components, electrolytic and/or tantalum capacitors, and the diodes are connected the correct way round. The metal tab of the voltage regulator and the triac are shown and these devices should be inserted into the PCB in the way indicated. Make sure that the ICs and the opto-isolators are inserted correctly with pin 1 of each (usually indicated by a dot on the top of the IC) mating with socket pin 1 on the PCB. Incidentally, you probably will not be able to find 6 pin, dual-in-line sockets for the opto-isolators and so carefully cut off two pins at one end of two 8 pin, dual-in-sockets, or, if you prefer, the opto-isolators can be soldered directly into the boards without sockets.

There is not a great deal of space to fit all the components, and most of the resistors and diodes will need to be bent into a U shape, inverted and inserted into the board with the component standing vertically.

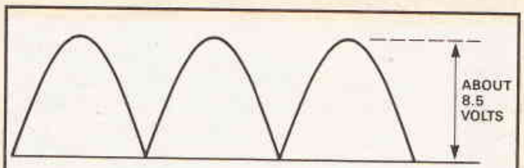
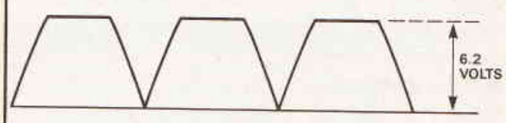
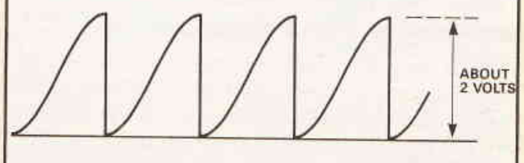


Fig. 2 a) Waveform at A. Amplitude is about 8.5V



b) Waveform at D. Amplitude is about 6.2V



c) Waveform at Pin 7 (IC2)

box to be projector by the 6 core cable, and . . . . switch on!

The projector fan may very well start and the lamp be lit, perhaps not fully. Operate RV2 and see if this dims and brightens the lamp. If it allows the lamp to go out completely, the projector should then advance one slide and switch off. Adjust RV3 until the whole slide advancing process is over before the projector switches off. Now leave RV2 in a position so that the lamp is just glowing. Adjust RV1 to brighten the lamp and move P2 until the lamp just glows again. Repeat the process until RV2 is at the 'out' end of its travel, with the lamp just glowing. Now adjust RV1 to fade the lamp out completely, at which time the slide should change and then the projector switch off. This is quite a critical adjustment and so RV1 is a multi-turn potentiometer allowing very fine control. If this potentiometer is set too critically, switching on electrical appliances close to the control unit might trigger the projector on and change a slide. If this happens, back RV1 off a little when the only loss will be that the projector will not switch on at the very bottom of RV2's travel.

Some Final Thoughts

Concern was expressed to me that the projector would not have a chance to cool down if switched on and off in the manner described above. This is not true. In tests on a number of different projectors, no excessive temperature was reached. If the projector is on for a long period, the temperature stabilises after about 4 minutes. If the projector is used intermittently for short periods, it never gets hot enough to reach even this stabilised temperature.

Provided the time period is adequate between the end of time period T2 and the end of time period T1 in the timing sequence (this can be adjusted by RV3), consecutive slides can be shown without the projector turning off after each. If the projector is still running when fader RV2 is opened again, it will continue running without a break and maintain the correct sequence of events.

Although this circuit has been designed with the Kodak Carousel slide projectors in mind, almost any projector can be controlled with this unit. Even a projector using a mains voltage lamp can be dimmed in and out with no change in the component values of the circuit shown above.

Some slide projectors use different ways of changing slides from the Carousels' and another way to forward-change the slide would be to drive a relay directly from the 5 volt supply and the collector of Q3. If you use this method, immediately parallel with the relay's coil, a 1N4002 diode should be connected with its positive end to the 5 volt rail. This will damp potentially harmfull transients each time the relay is switched off.

Good viewing!

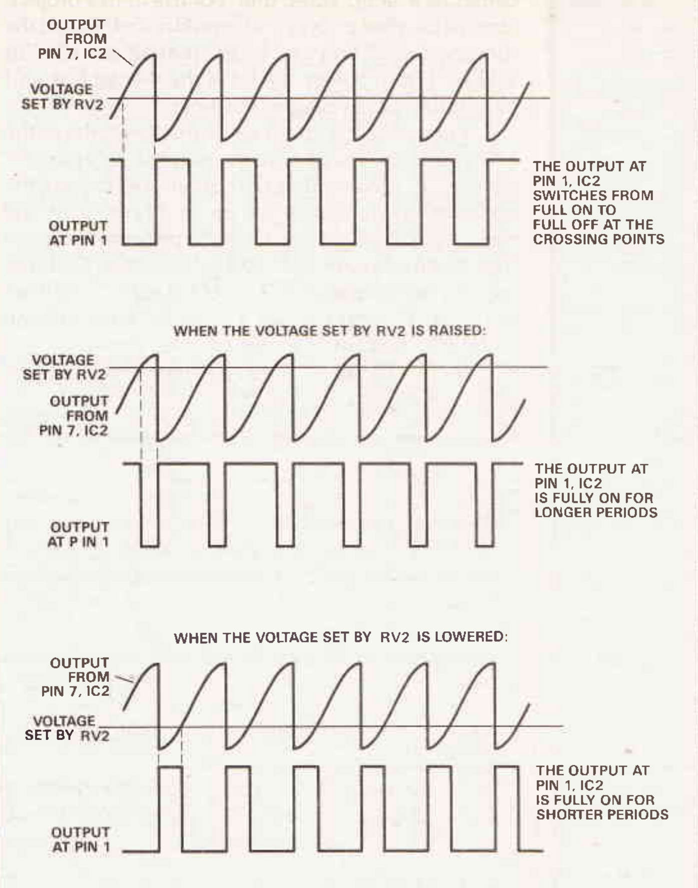


Fig. 3 Various control waveforms

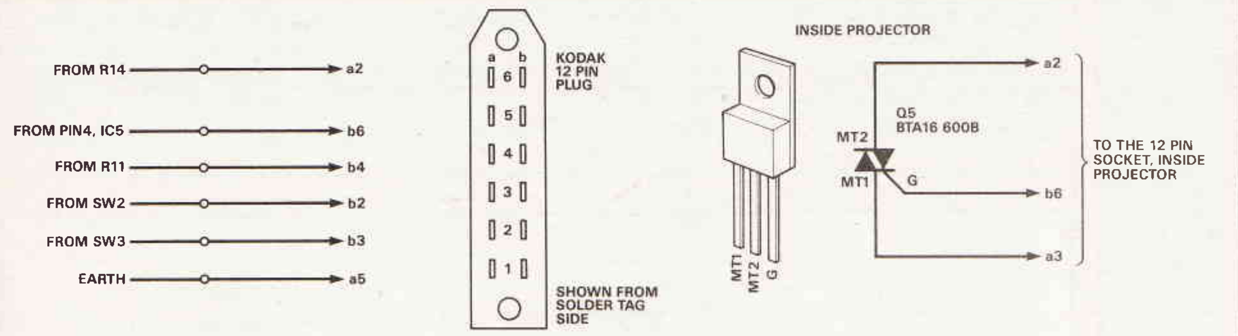


Fig. 4 a) Connections to 12 pin plug

b) External triac connections

HOW IT WORKS

DIMMER CIRCUIT

The output from the transformer is half-wave rectified by diodes, D1 and D2; R1 is there just to make certain that enough current flows to switch the diodes fully on (Figure 2a).

D3 isolates point A from the smoothed DC so that the voltage at B should be about 8 volts of pure DC. The IC 7805 ensures that the output at C is a well regulated 5 volts with C2 smoothing out any feedback noise.

R2 and ZD1 regulate the pulsating DC supply and, as far as possible, make this independent of varying mains voltages (Figure 2b).

This waveform appears at pin 5 of the IC LM393, which has an 'open collector' output. This means that until the moment when the inputs at pins 5 and 6 are the same, the output of the IC is effectively an open switch. So, initially, the capacitor C3 is charged by the waveform from point D, via R5 and D4. Clearly this is a very non-linear charging current but it does produce an almost ideal output waveform at pin 7 of IC2. The voltage divider R4/R3 ensures that the input at pin 6 is held just above zero volts. When the pulsating DC at pin 5 returns almost to zero at the end of each half cycle, the inputs to IC2a become equal and the internal transistor at the output of the IC switches on, discharging C3 each time (Figure 2c).

The vertical sections of this waveform are caused by the output transistor switching on and discharging capacitor C3. The curved sections have this almost ideal shape, which allows the lamp to hurry to start lighting without wasting the low end of the main fader RV2, and to hurry towards full brightness at the high end, while being acceptably linear in the middle. RV1 and RV2 form two other voltage dividers: adjusting RV1 ensures that the lamp is fully off at one end of the main fader RV2. So the two inputs (pins 3 and 2) of the second section of IC LM393 are, respectively, a set voltage which can be varied from about 2 volts to 0 volts by RV2, and a 'sawtooth' voltage of the same amplitude. With RV2 set at halfway, the superimposed inputs are shown in Figure 5.

When the voltage set by RV2 rises just above the sawtooth, the pulses disappear and the output at pin 1 is always high. conversely, when the voltage set by RV2 is below the sawtooth, the pulses again disappear, but this time leave the output continuously low.

So when the output of IC2 at pin 1 is zero, both LED1 (which is there to give an indication of how bright the lamp is) and the LED inside IC6, the opto-coupler MOC3041, will always be lit. The triac inside the opto-coupler will be fully on, turning the external triac fully on. As RV2 is moved along its travel, pulses synchronised with the 50Hz mains start, and so both LEDs will briefly be switched off each cycle, as will the triacs. The lamp will not now be supplied with the full voltage all the time: it will be dimmed progressively as RV2 is moved towards its other end. (C4 is a bypass capacitor which prevents any noise that might be picked up on the leads from the main fader, RV2, from entering pin 3 of IC2. It should be placed as close as possible to pin 3).

All the above assumes that the mains supply to the projector is on but, at the beginning of the process, the projector is off, waiting for the time when the first slide is needed.

PROJECTOR SWITCHING

The 4538B is a CMOS dual monostable. This IC contains two independent timers each of which, when triggered by an incoming pulse, outputs a pulse timed by the charging of a capacitor through a resistor.

If we now assume that our projector is off, and that the lamp fader RV2 is in the off position, the output from pin 1 of IC2 is high. However, as soon as the fader is moved up, a series of initially thin pulses will start, the first of which is used to trigger the monostable IC2A. When triggered, the output at pin 10 of IC3a will go high, switching on the VMOSFET VN10KM, and hence the LED in the opto-coupler, IC4. That will turn on both the internal and external triacs as before and power will be supplied to the projector.

At this stage we do not want the timer to time out and switch the projector off until the projection lamp has been faded right up, watched the first slide, the lamp has been faded out, and the slide-change mechanism has advanced to the next slide. So early timing out is prevented in the above circuit simply by adding the diode D5. The first pulse comes in, triggers the start of the output pulse, and capacitor C6 starts to charge through trimpot RV3. But each succeeding incoming pulse short circuits C6 via D5 and so discharges it.

Further, when the lamp is fully on, pin 11 of IC2 is low and so the capacitor will not charge at all. C6 will only be allowed to charge fully when RV2 has returned to its fully faded out position and all the incoming pulses have ceased. Only now can the timed output pulse really begin. Provided this pulse length is long enough to allow a third part of the circuit to change the slide (and this time interval can be adjusted by varying RV3), our purpose is achieved.

SLIDE CHANGE CIRCUIT

Initially with the projector off, the output of the 4538B at pin 6 is low, while the input at diode D6 is high. C8 is fully charged via RV4. When the first negative going pulse from pin 1 of IC2 arrives via D6 at pin 4 of the 4538B, C8 immediately discharges through D6. Further pulses keep C8 discharged. As monostable IC3B is configured so that it will only trigger on a rising input, the output at pin 6 remains low and will not be triggered to a high state until C8 is again allowed to recharge fully. This will not occur until the projector lamp fader has been brought back to its fully faded out position. Only now will C8 recharge via RV4 and, as its potential rises through the input threshold of the 4538B, the output pulse start. The slight delay before the output goes high allows the projector lamp to be completely out so that the slide change will not be seen. By using a transistor Q3 to further switch Q4, the "slide forward" connections in the projector can be made without using a relay, and the slide-change mechanism will advance the slide tray by one. LED3 will light briefly to indicate the slide changing.

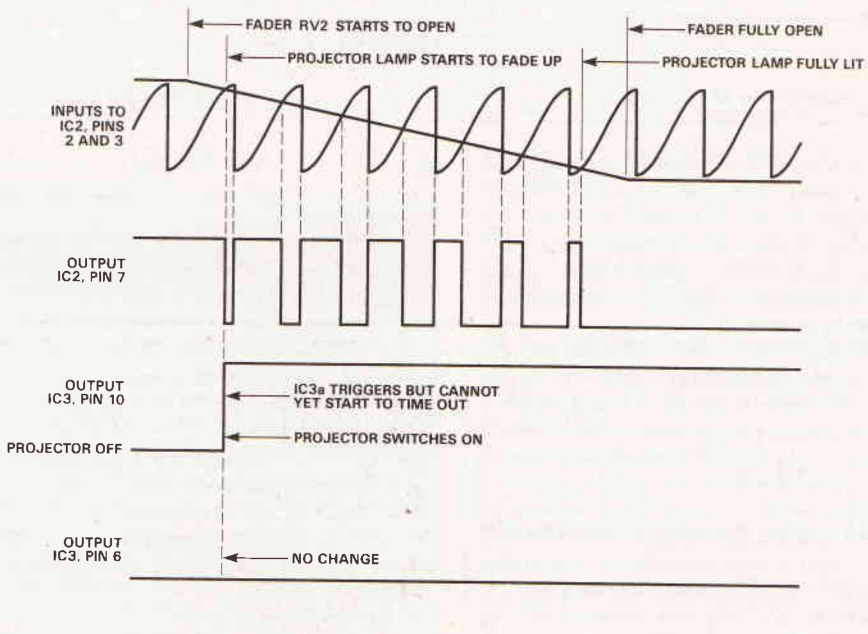
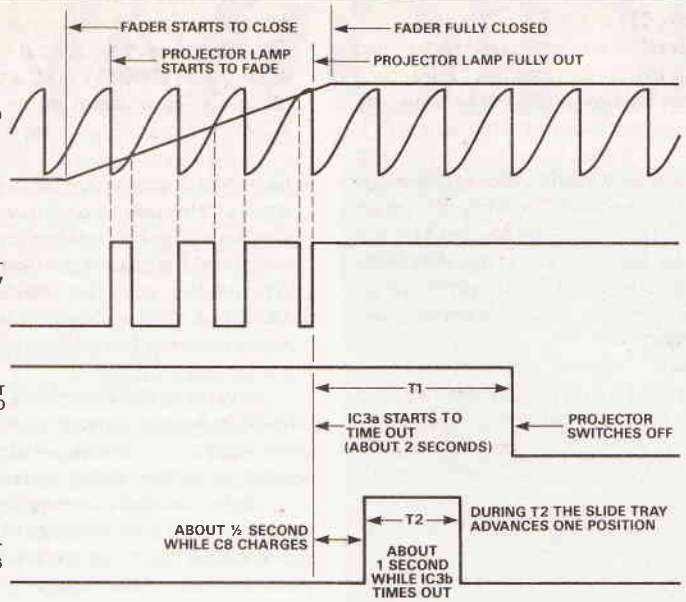


Fig. 5 a) Timing for switching the projector on and fading the lamp up



b) Timing for fading the lamp out, changing the slide and switching the projector off

PARTS LIST

RESISTORS (all ⅛ watt or larger)	
R1	15k
R2,3	10k
R4,5	100k
R6	100
R7,13	56
R8,14	270
R9	150k
R10	15k
R11	2k2
R12	4k7
RV1	1k multi-turn trim
RV2	100k linear slide pot
RV3	220k trimpot
RV4	1M trimpot
CAPACITORS	
C1	1000µ 10v electrolytic
C2	1µ 50v elect/tant
C3,7	100n min polyester
C4	10n min polyester
C5	5n6 min polyester
C6	22µ 10v elect/tant
C8	10µ 16v elect/tant
C9	4µ7 16v elect/tant
SEMICONDUCTORS	
D1,2,3	1N4001 (50 piv, 1A7)
D4,5,6	1N4148 (any silicon)

LED1,LED2,LED3	T1 ¾, yellow, green, red
ZD1	6.2v, 0.4watt zener
IC1	7805 volt reg
IC2	LM393 comparitor
IC3	4538B (MC14538B) CMOS
IC4,IC5	MOC3041 opto-isolators
Q1	VN10KM (any N power-MOSFET)
Q2,Q5	BTA 16 600B triacs
MISCELLANEOUS	
TR1	6-0-6v transformer 0.1A min
SW1	240v, 3A lever switch
SW2,SW3	push-to-make momentary
IC sockets	one, 16 pin DIL two, 8 pin DIL (see text)
6 pin plug	
6 pin socket	
12 pin plug, A12 DIN 41822, Kodak Part No. 2 605 4850.	
LED chassis holders	
3 mains plug and lead	
6 core cable (length as required)	
Knob for slide potentiometer	
Suitable box for control unit	
Suitable box to accommodate the 12 pin plug.	

BUYLINES

There should be no difficulty over the supply of any of the above components. Maplin can supply the BTA 16-600B triacs (Order No. UK55K) and many of the other components.

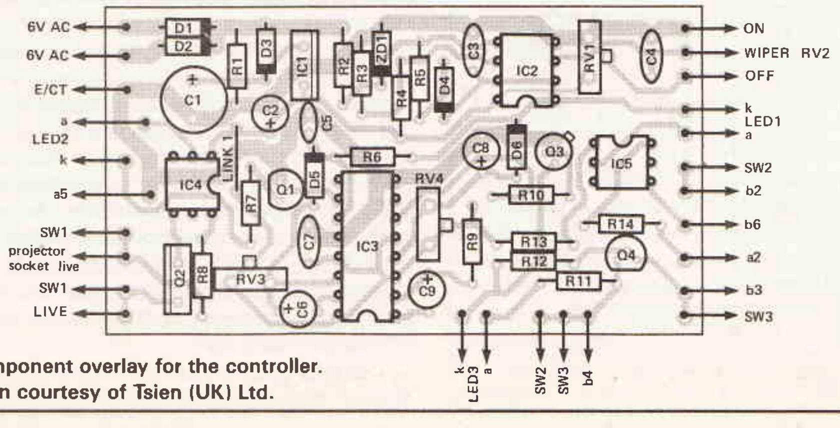


Fig. 6 Component overlay for the controller.
PCB design courtesy of Tsien (UK) Ltd.

1 MICROWAVES

From cooking to television, microwaves are fast becoming an important part of our lives. Colin White looks at the past, the present and the future of the technology.

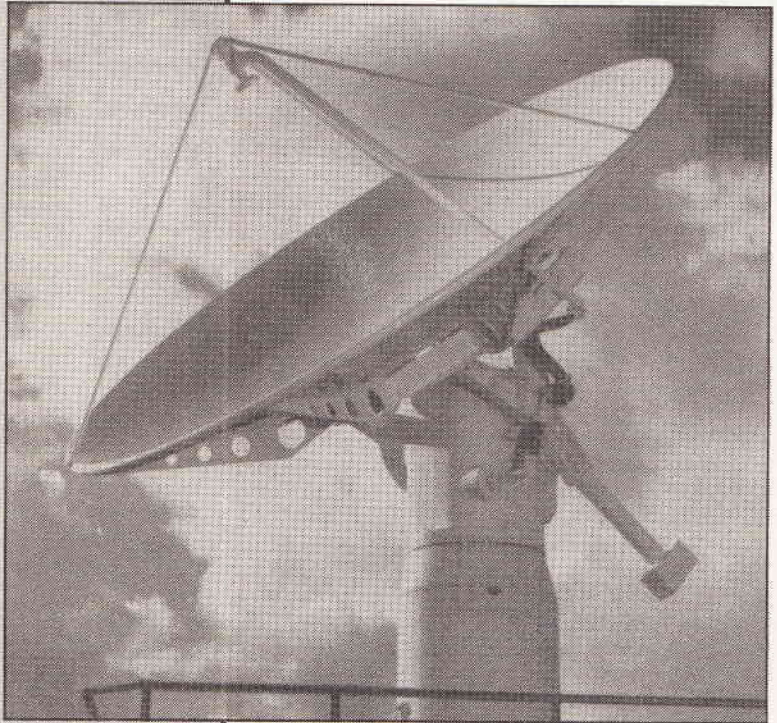


Fig. 2 Satellite Newtonian reflector antenna

"Thank you Rupert Murdoch!" Why? . . . Because whilst he is losing £200,000 a day on his satellite TV concept, the layperson is not under the misapprehension that microwaves are only useful for cooking the veg! So how *can* something which casseroles the greens in a tenth of the time of a conventional cooker, be used to beam entertainment from 23,000 miles out in space down to your own haunted fish-tank called a TV.

This article, together with next month's, endeavours to answer this question, as well as to describe the many other applications of microwave technology in use today. It concludes with a prediction of where the microwave industry is heading as we go forward into the 1990s.

So What Are Microwaves, And Why Are They So Useful?

Microwaves lie in the region of the electromagnetic spectrum from 1GHz (10^9Hz) to 300GHz (3×10^{11}Hz). As such, they possess all the properties one expects from electromagnetic waves. They are reflected and refracted at boundaries. They can also propagate through a vacuum, and they also travel at the speed of light (3×10^8m/s).

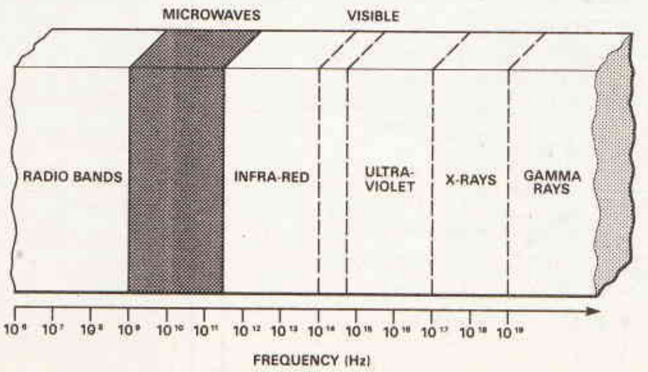


Fig. 1 The electromagnetic spectrum

Figure 1 shows the complete EM spectrum. (Well, nearly! . . . Not much propagates below 100kHz and although some cosmic rays exist beyond gamma-rays, we have yet to succeed in harnessing them for applications).

Note how the microwave band is sandwiched conveniently between two exceedingly useful parts of the spectrum — radio waves and light waves. Therein lies the importance of this region. Microwaves behave as a hybrid of light and radio waves, possessing attributes from both regions. Microwave circuits can for instance, be constructed in a broadly similar manner to radio frequency circuits, although more care must be taken in the design and construction at these higher frequencies. A microwave oscillator may produce a signal which can be modulated with information using AM or FM techniques in the usual manner. However, it can then be transmitted from an antenna which bears a remarkable resemblance to an optical telescope (See Figure 2). Such an antenna can produce a very narrow concentrated beam of energy — an attribute normally associated with light rays by the use of lenses and/or mirrors.

If one considers the radio region of the spectrum in terms of information content, an important trend becomes apparent as the frequency increases. At the low end of the region lie the long wave and medium wave stations — poor quality, hissy, narrow audio bandwidth, monaural reception. Moving up into the VHF region, we then have the capability of low noise, Hi-Fi, stereo reception. At the top of the VHF band black and white TV used to be transmitted on 405 line resolution. To obtain good quality colour TV on 625 line (and by quality here, I refer to quality of the received signal, not program content!) a further increase in frequency is required, taking us now into the UHF region.

Beyond UHF lies the microwave region. We tend not to stop thinking in terms of information quality, but consider quantity of information. We talk in terms of the capability of so many thousand simultaneous telephone conversations on the microwave link, or so many TV channels. Our hero, Rupert, for instance, has the theoretical capability of approximately 150 simultaneous broadcast channels (perish the thought!) He has, in fact, opted for 16 channels using a slightly different frequency for each. This is a reflection of the limitation of the cheap mass-produced receiving equipment, rather than the maximum theoretical channel capacity available.

Let us now consider the effects of diffraction as the frequency is increased. At low frequencies there is no problem picking up radio signals under the shadow of hills and buildings. As the frequency is increased, however, the signal follows a more direct route, skimming over hills with little diffraction. Ultimately, light rays follow a near perfect straight line with diffraction effects only detectable under very special circumstances. Microwaves also follow straight lines with negligible diffraction over hills, buildings, or even the earth's horizon. Microwave communication through free space must, therefore, follow what is known as 'line-of-sight'.

A final property of microwave which may be gleaned from the spectrum of Figure 1 is that of absorption by, and consequential heating of non-metallic substances by EM radiation (broiling the chicken!) Efficiency of absorption improves as the frequency reduces. Unfortunately RF ovens at frequencies below the microwave region would be too large to be accommodated in the average kitchen.

Having dealt with the properties and attributes of microwave radiation, we are now in a position to consider actual microwave applications. By way of an introduction, and to put things in perspective, I will commence with a short history of microwave technology.

Historical Landmarks In Microwave Technology

The story begins just over a century ago when Hertz proposed the concept of radio propagation and Maxwell first succeeded in generating radio transmissions using spark generators. These produced RF power over a very broad spectrum, including the microwave region. They were of course, unaware of their emission frequencies. They contributed enormously to the theory of RF propagation around this era.

In 1894 Sir Oliver Lodge surrounded a spark generator with a metal tube and noted that this succeeded in guiding the signal into a specific direction. This was in fact, the first waveguide, a component much used to this day.

The 1920s saw much theoretical analysis of the concept of microwave propagation and the advantages of this part of the spectrum were beginning to be appreciated. In particular, George Southworth (of Bell Telephone Laboratories) and Sir Robert Wattson-Watt considered applications in communications and Radar, respectively. The first purpose built microwave oscillators were developed during the 30s and more especially, the early 40s. These were obviously thermionic devices although their operation principle was totally different from low frequency valves.

A device known as a magnetron has had a particularly interesting history. It was the first microwave oscillating valve to be developed. It was the most widely used device during the war years, generating high power microwave pulses for radar applications but became obsolete during the early to mid-50s, only to be reborn during the mid-60s for the sole purpose of powering microwave ovens. As such, more magnetrons are presently manufactured than all other microwave oscillators put together.

The war years produced perhaps the greatest number of technological advances in the microwave region, including wide band high power amplifiers (travelling wave tubes) and a variety of new oscillators such as backward-wave oscillators. the klystron, invented by the Varian brothers in 1935 was perfected and became popular during this period. Radar and microwave communication systems were designed, manufactured and successfully implemented supporting the war effort. On the other hand much research went into developing a microwave 'death-ray' at this time. The necessary technology eludes us to this day, much to Mr Reagan's and Mr Bush's dismay.

In 1956 the first non-reciprocal device, the gyrator, was invented by C. Lester Hogan. The gyrator is a two-port device which allows a signal to pass through in one direction with some phase shift θ, but when the signal is sent through the device in the other direction, there is a phase shift of $\theta + 180°$. Although now obsolete, it marked the beginning of a family of non-reciprocal devices which have many applications in switching, protecting, modulating and controlling microwave signals.

Satellite communications were 'launched' in 1962 when Telstar was placed in low earth orbit. The first geostationary satellite Early Bird was launched some three years later. However, the theory of geostationary satellite communication was conceived in 1945 when Arthur C. Clarke (2001 fame) wrote a most prophetic article on the subject, in the journal Wireless World, of that year.

Another major advance of the 60s was the development of microwave semiconductor devices, used to replace thermionic valves in some applications. The first such device was the Gunn diode discovered, so it is said, by accident, by J. B. Gunn. This was followed by junction diodes and transit time diodes, which today can produce oscillations beyond 200GHz.

The 70s brought the first microwave transistors, initially bipolar, then MESFET (Metal Epitaxial Semiconductor Field Effect Transistor types. Current MESFETS can produce appreciable powers, even at 20GHz. Finally, bringing us up to date, the 80s have seen the development of Microwave Monolithic Integrated Circuits (MMICs); several MESFETS, together with their supporting passive components on a substrate 0.5mm square producing a complete system on a chip.

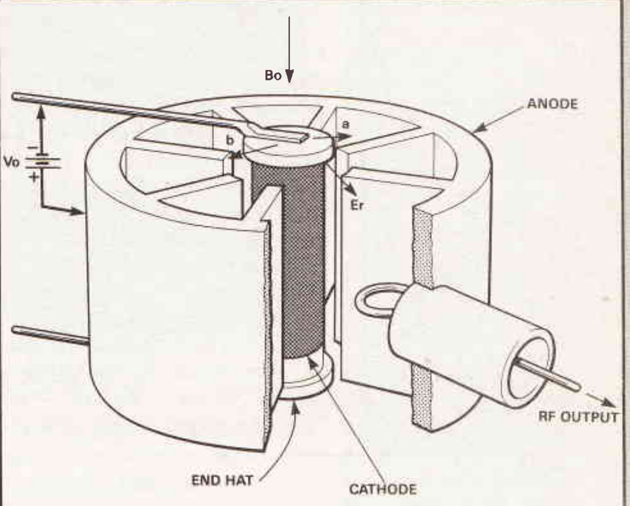
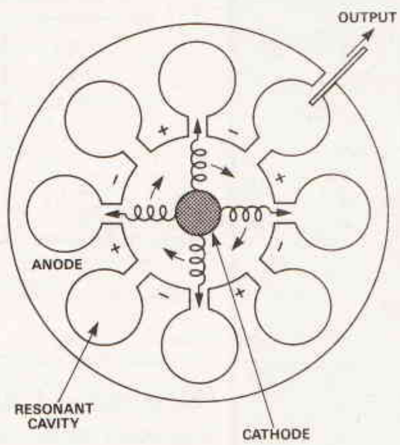


Fig. 3 a) Schematic diagram of a cylindical magnetron



b) Electron path within the magnetron

Microwave Ovens

This is the most popular application of the science by far, with over 15 million ovens installed in the United States to date. The history of these appliances began in 1945, when a manufacturer of magnetrons discovered, supposedly by chance, that microwaves are capable of producing heating effects.

The phenomenon occurs as a consequence of the vibration of atoms within the water molecules of the food, causing frictional warming of the produce. The key to the importance of microwave heating is the fact that the radiation penetrates more deeply than other forms of cooking. When using hot-air, for instance (ie a conventional domestic oven), the heat is generated outside the object and conveyed to the food by conduction and convection. The surface of the object is therefore heated indirectly, and heat then flows towards the inside by conduction only. Infra-red heaters, very popular among the fast-food emporiums, produce heat directly on the surface of the food. The surrounding air is then warmed by convection while the food is heated by conduction from the surface. Microwave heating, however, occurs within the food, and is therefore more energy efficient than the other methods.

Referring to Figure 3, the method of operation of a microwave oven is as follows. A magnetron operating at 2.45GHz generates microwave power at a few kilowatts. A length of waveguide connects the output the magnetron to the main chamber of the oven which acts as a resonant cavity. This means its size is such that it exactly supports the electric and magnetic wavelength inside the cooking volume. This ensures efficient radiation of the food rather than the energy attempting to creep out of the door seals, or back up the magnetron's own output. The mode stirrer, a sort of microwave fan, distributes the energy within the cavity and ensures homogeneous heating.

So what is so special about the choice of 2.45GHz? Not much! Heating efficiency is dependent on radiation at the various resonant frequencies of the molecules, atoms, neutrons, electrons etc, which make up the food substance. In practice it is the resonances within the water molecules which are paramount. These are many and various, particularly within the 1.5GHz to 3.5GHz band.

The choice of 2.45GHz reflects an agreement between the communication channel users, principally military, to minimise communication interference. The implications are that, if your domestic microwave oven radiates into the atmosphere, and if this frequency is detected by the local army base, they will say "Ah-ha, 2.45GHz! — That's no enemy . . . That's the sprouts being cooked."

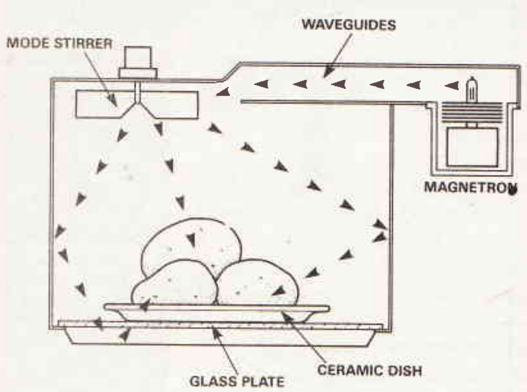


Fig. 4 Microwave Oven

The subject of microwave oven safety is a complex one, and although statistically the chances of permanent health risk from these appliances are minimal, work is still being carried out in an attempt to quantify the dangers.

Microwave Communications

Microwaves are also used extensively in communications either between two ground stations or between satellite and ground station. The advantages of communication at these frequencies are two-fold. Firstly, because antennae at these frequencies are so directional (they send out a narrow pin-point of radiation), a more efficient link can be set up, since much of the energy leaving the transmitting antenna actually arrives at the receiving antenna with minimal spillover. Little diffraction occurs at these frequencies so line-of-sight communication is essential. For military secure communications this is an advantage, since if an enemy attempted to intercept the information, not only would a drop in power be detected at the receiver, but the foe would find it quite difficult to eavesdrop without being seen. Of course, cover of darkness affords little protection, as the modern day soldier is equipped with infra-red night-sight.

The second advantage of using microwave frequencies lies in the broad-bandwidth capabilities. Most microwave links are digitally modulated on either AM or FM (or both) using some form of multiplexing techniques. A typical link would have the capacity of 300 telephone channels, 10 colour TV channels, a few high quality audio channels, facsimile channels and several computer data links; all these transmitted at one carrier frequency.

Microwave propagation over the horizon is not feasible due to negligible diffraction effects, so long distance communications are only possible using cable, repeaters or more importantly, geostationary satellites as a mirror for the communication channel around the earth. A geostationary satellite is one which rotates around the earth above the equator, once every 24 hours, therefore appearing stationary above a fixed point on the equator. The geostationary orbit is 35,800 kilometers above the surface of the earth. At this distance, the gravitational force pulling the satellite towards the centre of the earth is exactly matched by the centripetal force due to the rotation of the satellite attempting to pull it away and out into space. What is more, the velocity of rotation of the satellite exactly matches the velocity of rotation of the earth. The satellite therefore remains in that orbit and above a fixed point on the equatorial line.

The use of a stationary orbit presents very significant advantages for communications:

a) The antenna of the ground station points towards a fixed location in the sky, only small corrections being required to compensate for varying atmospheric diffraction.

b) Since there is no relative movement between transmitter and receiver, Doppler shift of the frequency is non-existent. This can cause major problems with motional satellites.

c) Since the satellite lies well beyond the earth's atmosphere, it is not slowed down by friction due to air molecules. The satellite could remain in orbit for more than a million years theoretically. Its operation is however, limited in time by the fuel required for stabilisation.

On the other hand, the stationary orbit also presents some drawbacks:

a) The time taken for a signal to travel from ground station to ground station, via a geostationary satellite, is twice the geostationary orbit height divided by the velocity of light. This amounts to approximately half a second delay and may be potentially inconvenient.

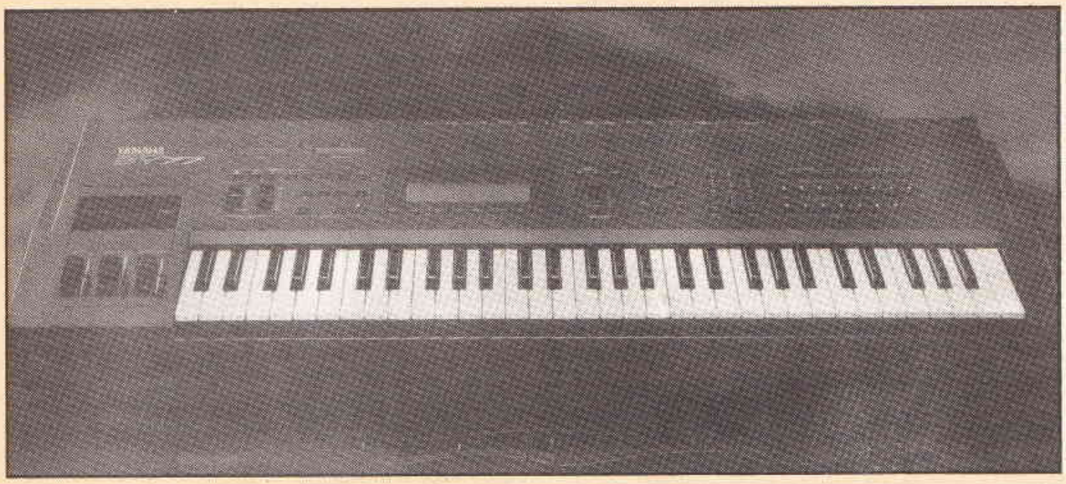
b) The large distances involved attenuate the signal levels considerably. The signal received from our Rupert's Astra at the first amplifier mounted on the Sky dish is about 1×10^{-13} watt. Only a few years ago it would have been a major research activity to amplify such low levels; today the equipment can be found in the high street stores at 'knock-down' prices — such is progress.

The geostationary orbit is now so densely populated with satellites carrying military, domestic, business, and educational information that the current satellite density of one satellite every 3° of arc is being increased to one satellite every 2° of arc.

A technology closely related to satellite communications is that of space communications to and from deep space probes. Communication is obviously over much larger distances so time delays are longer; 1.28 seconds for a message to the moon, 43 minutes for a message to the Voyager 1 and 2 spacecraft as they orbit Jupiter — still beats first class mail though! The received signal levels are minute, consequently extremely specialised receiving equipment is required.

Next month, we'll see how microwave technology is applied to the fields of medicine, navigation, target detection and space photography.

SY77 MUSIC SYNTHESIS



Mike Barnes continues his look at the workings of the latest Yamaha synthesizer.

2

The LSI Architecture of SY77

Having looked at the development of RCM and what it actually means, the next step is to dig deeper to the hardware level, before discussing the different operating system modes used by the musician as the final part of this article. The block diagram shown in Figure 7, illustrates the connection of the SY77 system components. The custom Yamaha LSIs shown in the diagram and their function is discussed as follows.

The M3 chip (YM7119)

The M3 is synonymous with the AWMii portion of the tone generator. It is a 16 channel waveform-processing LSI developed in 1988-89. It features a fixed sampling rate using 6th Lagrange Interpolation and time varying Low Pass and High Pass Filters. (LPF/HPF). The LSI reads wave data sampled at 32 or 48kHz in 16 bit format and includes the following key features:

(1) A 5-segment Amplitude Envelope Generator (AEG).
(2) Pan Control.
(3) A Resonant Filter which can be configured as 24, 18, 12, 6 dB/Oct in Low-Pass/High-Pass/Band-Pass modes.
(4) Wide Cutoff Frequency (10Hz-24kHz for LPF and 10Hz-12kHz for HPF at 48kHz sampling frequency.
(5) No Microprocessor wait-time allowing continuous data writing and thus user realtime control.
(6) D/A Convertors are Yamaha AFDO and Burr/Brown PCM56 for Individual Outputs.

The OPS3 chip (YM7107)

OPS3 is the heart of the AFM sound generation system. It takes voice data from the CPU into its internal register and receives additional pitch and envelope information from the EGM2 chip. Pitch data from EGM2 and Pitch Bend wheel are converted into Hertz and then into phase data in the phase accumulator and output to the oscillator. OPS3 and EGM2 work together since OPS3 does not implement its own envelope generator as in M3. OPS3 has the following key features:

[1] Ability to read a sample as a Carrier/Modulator
[2] 16 Sine Wave variations available as waveforms for conventional FM
[3] Operator Fixed Frequency to 0.00Hz
[4] Operator Phase Control
[5] 45 Preset Algorithms (and Open Algorithm via MIDI)
[6] 3 User-definable Feedback Loops per Operator
[7] 2 LFOs (a main and sub LFO for each FM voice)
[8] Individual Operator sensitivity to Pitch Envelope Generation

The EGM2 chip (YM7103)

Developed in 1988, this LSI creates envelope and pitch information (eg. pitch envelope and portamento) which is sent to the AFM sound generation chip OPS3 (YM7107). EGM2 permits envelope looping around any one of 4 envelope segments for each operator.

The PAN LSI (YM7102)

The Yamaha PAN chip is designed to integrate with the OPS3 signal channels individually, allowing 16 PAN registers. The PAN chip contains a 6-segment fully user programmable internal Envelope Generator with repeat and delay capabilities which can be controlled for each channel individually. This enables all 16 Voices in a Multi setup to have a completely unique stereo trajectory if required allowing complex spatial movement during the evolution of sounds. SY77 contains 64 Preset panning movements which can easily be applied to any sound that is created. Since an SY77 sound (called a 'Voice') can consist of a number of sound elements, each element can have an independent pan movement.

The LDSP chip (YM3413)

LDSP is responsible for the reverb, delay tone and distortion type of effects in SY77. SY77 implements two LDSPs, one for each stereo output.

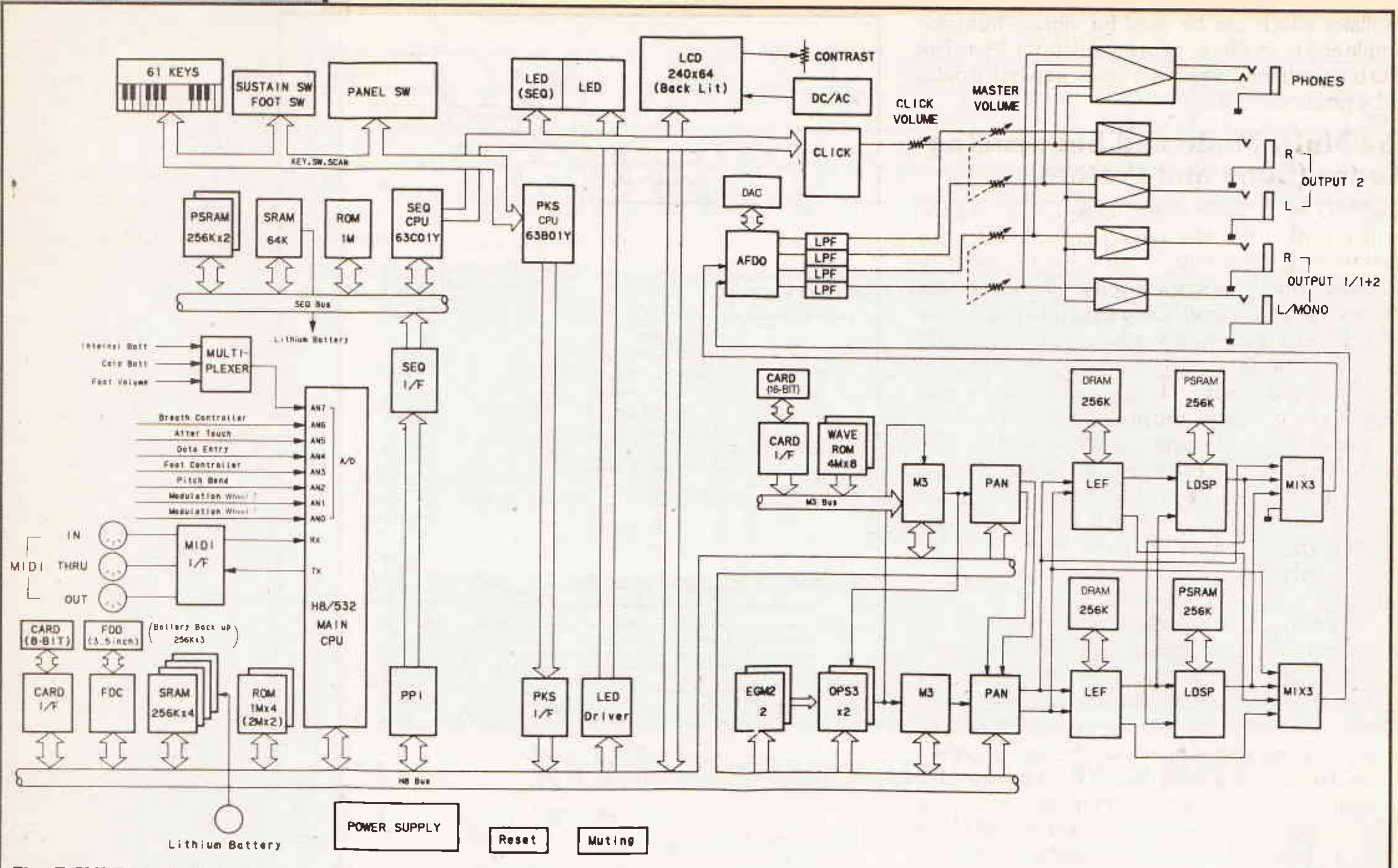


Fig. 7 SY77 block diagram

The LEF chip (YM3415)

LEF is responsible for the modulation effects of SY77 including flange, stereo chorus and symphonic. Again there are two units, one for each stereo output.

The Functional Architecture Of SY77

On top of all the hardware discussed earlier sits the operating system which divides SY77 into five fundamental modes of operation. These are represented to the user as 5 switches on the top-left of the instrument front panel. Each mode is for a specific musical activity. Voice Mode is the most common mode used for simply playing or editing sounds. Multi mode is used to arrange and mix a group of up to 16 sounds/instruments to be played by the sequencer. Song Mode gives access to all the recording and editing functions of the sequencer which is analogous to a 16-track tape machine, and is where all the musical parts are arranged. Pattern mode is really a specialised part of Song Mode where a repeating pattern of music can be made (for example, an 8-bar chorus) and then inserted at all the Chorus points during the song. Utility mode contains all the specialised functions for setting up SY77 to communicate via MIDI and store its internal data to external media.

The Voice Mode Of SY77

On SY77, a Voice is the label used to define all types of sound groupings including single sounds (eg. a solo piano), layered sounds and keyboard split sounds (eg. where a number of sounds occupy predetermined positions on the same keyboard). The Voice is the highest level of sound organisation in the instrument. A Voice consists of parameter settings for one, two or four AFM or AWM 'Elements' (Element Data). These elements are themselves sub-sounds which can be combined in 11 master configurations:

The AWM Element block structure is shown below:

The waveform block defines which of the 112 preset sampled waveforms to playback, and sets its pitch and fine tuning. The output is fed to the filter block which modifies the tone using a pair of digital

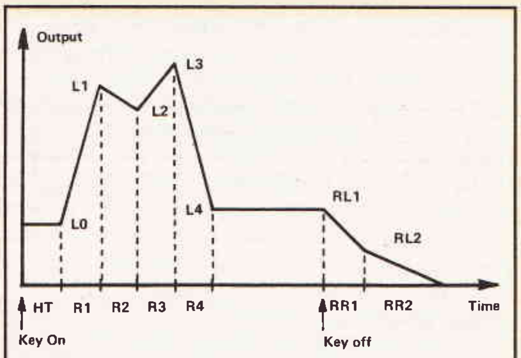


Fig. 8 Typical envelope showing different adjustable rates and levels

filters. These filters can each be configured to both be LPF in which case acting as one 24dB/octave filter or one LPF and one HPF acting as 12dB/octave filters. If the filters are not required, they can be set to THRU position where they have no effect. There is also a resonance control for the filter pair which is the first digital resonance that actually works! (Since each element can use two filters, a 4-element voice can use 8 digital filters simultaneously!) From the filter block, the signal is passed to the Amplifier block and then to the Pan block where the element can be given its own pan table and/or be routed into an AFM element to be used for further sound generation.

The AWM section has one Low Frequency

Oscillator which can be used for vibrato/tremolo/ sample and hold effects, or to modulate the filter. This LFO has 6 different waveform types, a speed, a delay and a phase control.

The Multi Mode and Sequencing Modes (Song and Pattern)

The SY77 Multi mode allows up to 16 Voices to be set up and played by the sequencer (ie. it is 16 voice Multi-timbral). Each voice is allocated to one of 16 tracks (like a multi-track tape recorder), and each track is given a MIDI channel. Only data referring to one MIDI channel is allowed to play a voice. The MIDI channel allocation in multi-mode has been fixed to simplify the process of making music so that the user simply chooses a voices and places it on a track (1-16). The track number also represents the MIDI channel number so there is no need to assign a MIDI channel to a particular track. Each Voice in Multi Mode has its own Volume, Tuning, note Shift, PAN, and Output Select Functions. There is also an effects section which is connected to the stereo outputs allowing a degree of mixing.

The Sequencer is really a completely independent part of SY77 and has its own set of control buttons located left of the LCD. This allows the sequencer to be stopped and started even whilst editing a voice enabling changes in sound whilst the sequencer is running. Additionally, the sequencer will not only record data from the SY77's keyboard but also from the MIDI In port, and it can playback on the internal tone generation system or via the MIDI Out port. The tone generator can respond to the internal sequencer or via the MIDI In port. The Sequencer is loosely based around the Yamaha QX3 hardware sequencer, and in fact it will read QX3 sequencer files directly from the SY77 disk drive. It features 16 tracks (15 assignable and 1 drum track), approximately 16000 note recording capability, and a recording resolution of 1/96 of a quarter note. The sequencer has its own dedicated CPU (63CO1Y). The Sequencer can record in real-time (by playing the keyboard), or step-time (by programming individual notes) and also has the ability to Punch-in and out. It also implements a series of automatic functions which can

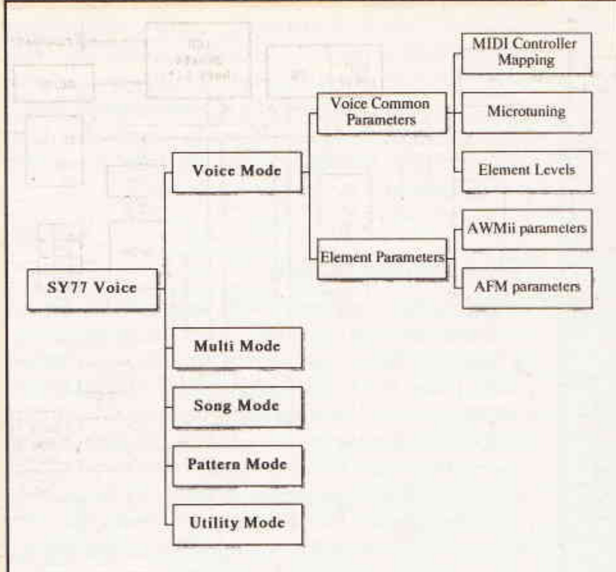


Fig. 9 SY77 modes of operation

Mode	Element	E1	E2	E3	E4
01	1AFM mono	AFM	–	–	–
02	2AFM mono	AFM	AFM	–	–
03	4AFM mono	AFM	AFM	AFM	AFM
04	1 AFM poly	AFM	–	–	–
05	2AFM poly	AFM	AFM	–	–
06	1AWM poly	AWM	–	–	–
07	2AWM poly	AWM	AWM	–	–
08	4AWM poly	AWM	AWM	AWM	AWM
09	1AFM & 1AWM poly	AFM	AWM	–	–
10	2AFM & 2AWM poly	AFM	AFM	AWM	AWM
11	Drum Set	61 AWM waves			

Fig. 10 SY77 element configurations

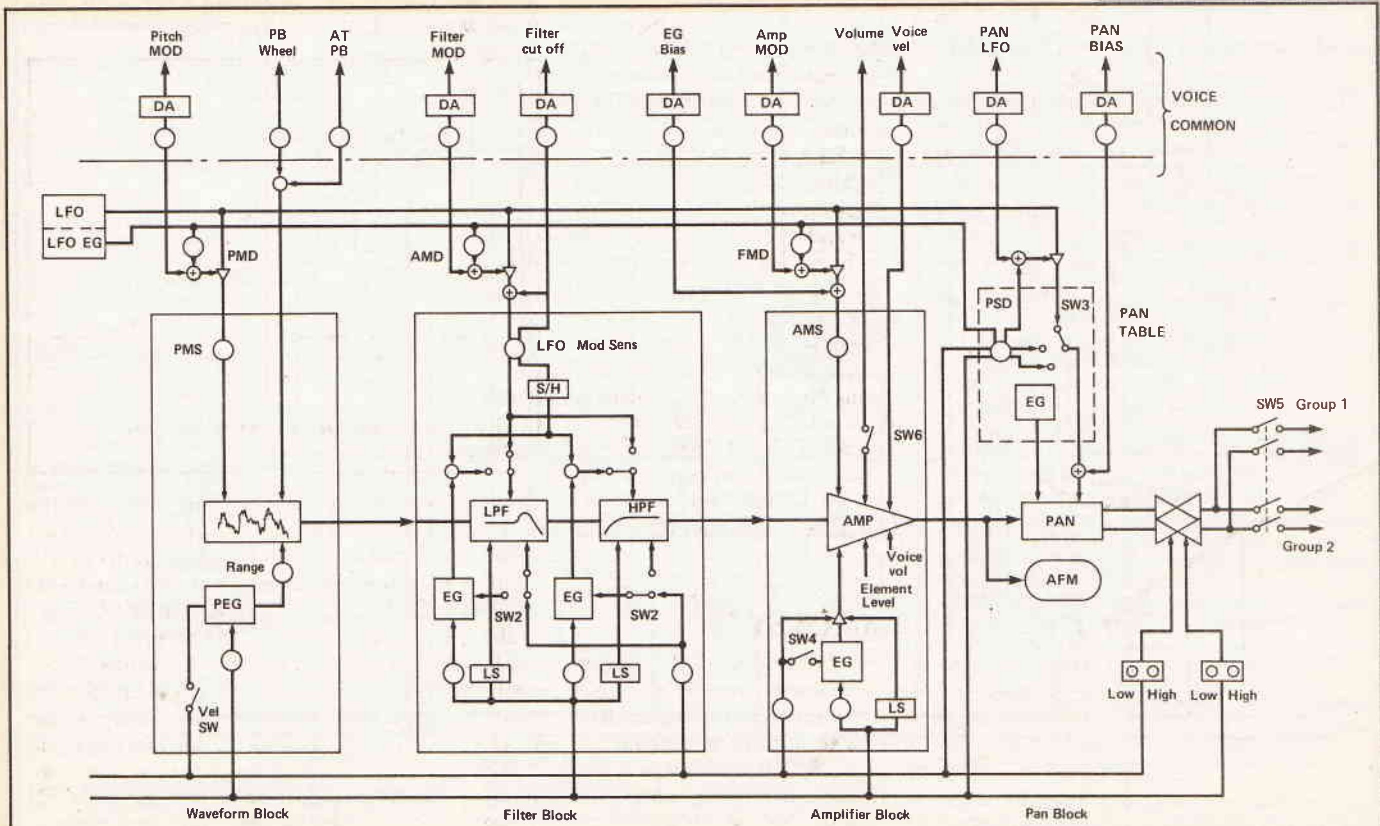


Fig. 11 The structure of an AWM element

quantize (modify the timing) or transpose a specified track or section of the song, make a crescendo, remove bars of music, insert bars of music, etc., etc.

The Sequencer can run in Song or pattern Mode, and the tone generator operates in either Voice (one channel) or Multi Mode (16 Channels). This enables four possible sequencer/tone generator configurations.

The Utility Mode

Utility Mode is concerned with setting up the SY77 to fit a studio with other MIDI products so that it has a unique identity channel for receiving and transmitting data. Master instrument tuning, and keyboard velocity curves (eight different types to weight the keyboard response to your playing style) are under the System menu of Utility mode. It is also the mode used for data storage and retrieval to 3.5" floppy disk (DOS format) and Yamaha data card. To simplify data storage there is an option to store all data types (Multi, Voice, Sequencer, etc.) as one file.

Conclusions

All the technical details focused on here should not overshadow the fact that SY77 is after all a musical instrument. It is well crafted, attractively designed and capable of fantastic expression in the hands of a professional keyboard player. It is always hard to examine something like an instrument from a cold technological standpoint. The experience is in playing and listening to it which is when the impressive technical specifications actually begin to say something relevant. Like a well-designed car, it has to be driven to appreciate it. So giving it a listen at a music shop will put all the details into perspective.

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NB. The views expressed here are those of the author and are not necessarily the views of Yamaha Corporation.

Mike Barnes is a postgraduate in Music Information Technology, works for the Yamaha Research & Development Centre, London as MIDI Product Specialist and is currently involved in voicing, sampling and demonstration work for the new SY/TG series.

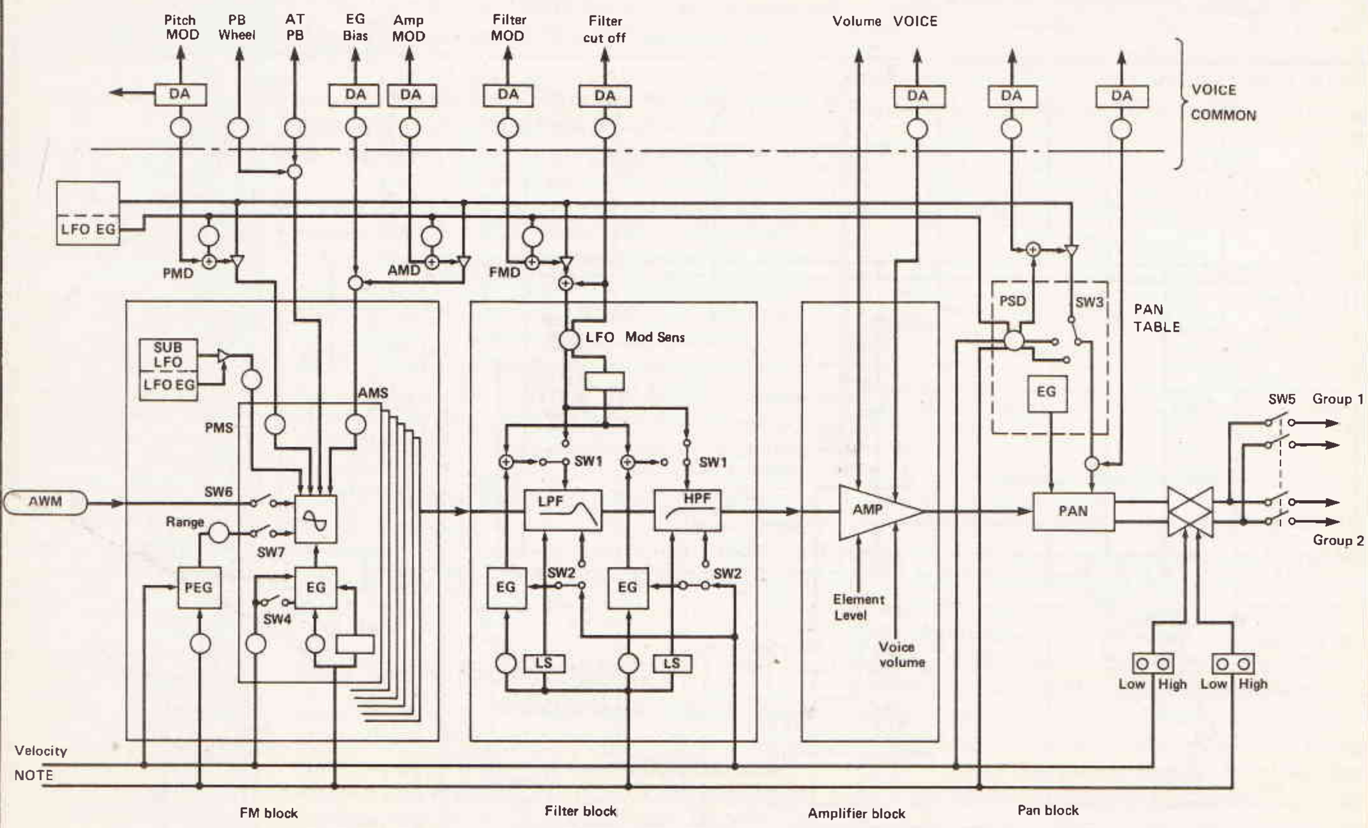


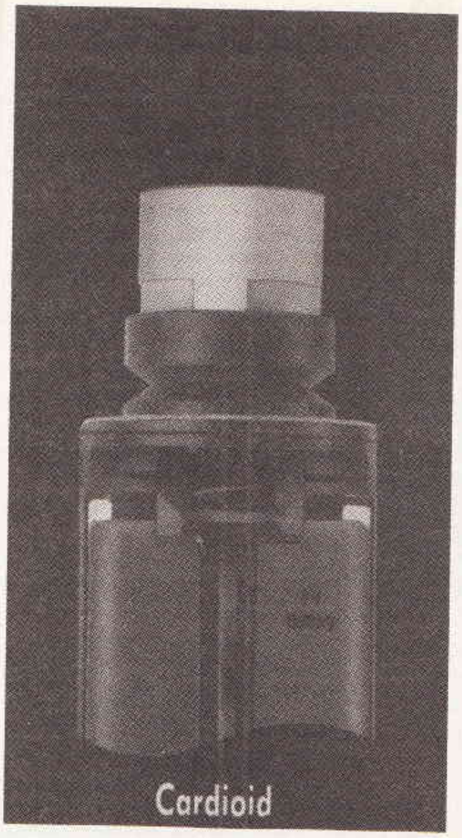
Fig. 12 The structure of an AFM element

NEWS

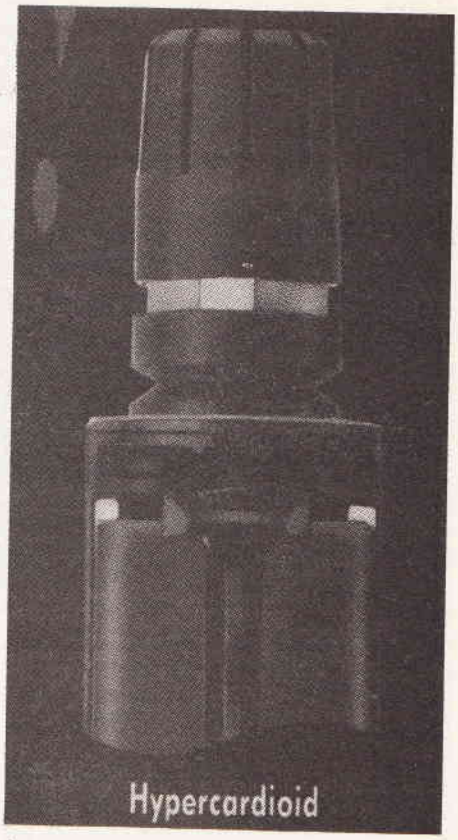
Anyone who is worried about acoustic feedback when performing on stage could try this latest adaption to the C1000S microphone from AKG.

This studio quality microphone is frequently used on stage and if amplifier levels are too high, howlround can result.

The new Polar pattern converter (PPC1000) is a small capsule that fits over the mic insert and will change the familiar heart-shaped response pattern to one of Hypercardioid shape, making it more sensitive and less vulnerable to feedback from the monitors and giving the vocalist a greater presence on stage.



Cardioid



Hypercardioid

The pattern converter will not affect the frequency response and is available separately if an existing C1000S is already to hand. The microphone capsule is a backplate transducer which reduces handling noise to a minimum and is either battery or phantom powered.

The AKG C1000S retails at £149+VAT.

Wilmslow Audio have now settled in their new premises in Knutsford. They now have 4 single speaker Dem rooms and a large selection of Hifi equipment is now available as well as an extensive range of drive units and kits.

The new catalogue has just been released and contains new kits from KEF, AUDAX, SEAS, PEERLESS and VOLT and is available from Wilmslow Audio at a cost of 1.50.

Wilmslow Audio's new address is Wellington Close, Parkgate Trading Estate, Knutsford, Cheshire, WA16 8DX. Tel No. 0565 50605.

A Hifi journal aimed specifically at the DIY constructor is changing format. The magazine Audio Conversions has only been available to people attending Hifi shows, and to associates of the contributors. Up until now, the magazine has been published in black and white and in A5 size.

The magazine now has over a thousand subscribers and from the next issue will be published in colour and in A4 size. Audio Conversions provides information and advice ranging from simple modifications through to kits and full projects and is published quarterly at an annual rate of £8 or £10 for overseas readers and 8 back issues are available at a cost of £1.50 each.

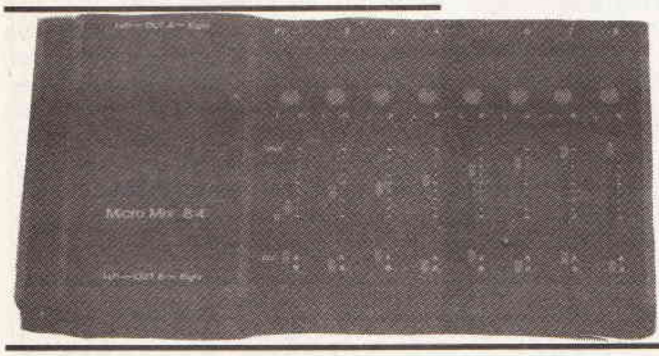
Audio Conversions is available from: Audio Conversions, Coley Lane Farm, Wentworth, Rotherham, S62 7SQ.

Digital audio multi-track recording is fast becoming the normal method of recording and as prices start to tumble with increasing competition, the hardware will eventually find a niche in the home recording market.

Akai has released ADAM, the Akai Digital Multi-track system, which consists of a multi-track recorder, a programmable auto-locator and a meter unit. It gives studios and individuals access to 12 track digital recording using 8mm compact video tapes. The 16 bit linear quantisation recording system uses 48/41.1kHz sampling rates in PCM format via the now familiar rotating helical-scan head. Three record and three playback heads are mounted in the rotating drum with stationary heads for erase and control. Digital inputs and outputs enable direct transfer of signals from one recorder to another and synchronised control allows up to three 12 channel recorders to be linked.

The retail price of the multi-track recorder (DR1200) is £13950+VAT, the programmable auto-locator (DL1200) £1050+VAT and the Meter Unit (DM1200) £695+VAT.

NEWS CONTINUED



Music mixers are getting smaller and smaller. The AKG Micro-Mix can even be clamped to a drum stand and gives the drummer control over mic mixing of any of his percussion instruments.

The Micro-mix 8 into 4 and 8 into 2 will allow the input of 8 condenser microphones or line inputs. Apart from the normal slide faders, each channel has a switchable output and pan control. Phantom power controlled, the mixer can boast of a 96dB signal-to-noise ratio, a crosstalk figure of 53dB and a frequency response of 20-20kHz.

The 8 into 4 retails at £189+VAT and the 8 into 2, £175.50+VAT.

HHB Communications has landed the contract for the design and installation of audio and video facilities at ITN's impending headquarters in Grays Inn Road.

The main deal is worth more than half a million pounds to the West London-based company. They will install and commission complete audio systems within two separate studios and a sound dubbing suite. The company is also re-locating a further dubbing suite and designing outside broadcast interface facilities for a third studio. HHB has also been contracted to re-locate and part equip the video presentation suite. This requires meticulous planning, since the suite itself cannot be out of service for more than 72 hours.

The project will include several extensive custom designs and complex hardware configurations and will include the integration and installation of two Solid State Logic 5000 Series consoles. HHB is reporting directly to ITN and most of the work is to be completed by the end of 1990.

Ten years ago the world had its first taste of personal music on the move from Sony. The now legendary Walkman has given pleasure to over 55 million people and earned its place in the Oxford dictionary. Often imitated, the Sony Walkman celebrated its 10th birthday with a dedicated programme of the Design Classics Series on BBC Television, June 19th, 1990.

Now the choice is wider than ever with 25 models to choose from.

The WM2011 is finished in black with new styling and complete with lightweight headphones. Auto shut-off in the play mode and normal/metal tape selector plus belt clip are provided at a price of £19.99. The slim WM2051 fills a new slot in the range with auto reverse tape playback. Battery power can be saved by the use of an optional AC adaptor and this Walkman will sell at around £27.99.

With stereo FM and AM radio the WMF2015 follows the new angled styling of the 2011 model. DC in socket, headphones and belt clip are all supplied for only £29.99.

Finally, for the active user is a new sports model the WMF2078 with water resistant casing and showerproof following headphones. This Walkman is complete with digital FM/AM tuner, 14 presets, clock timer, auto reverse and Dolby B. Finished in bright sports yellow this model completes the line-up at £119.99.

MORE NEXT MONTH

AUDIO TIPS

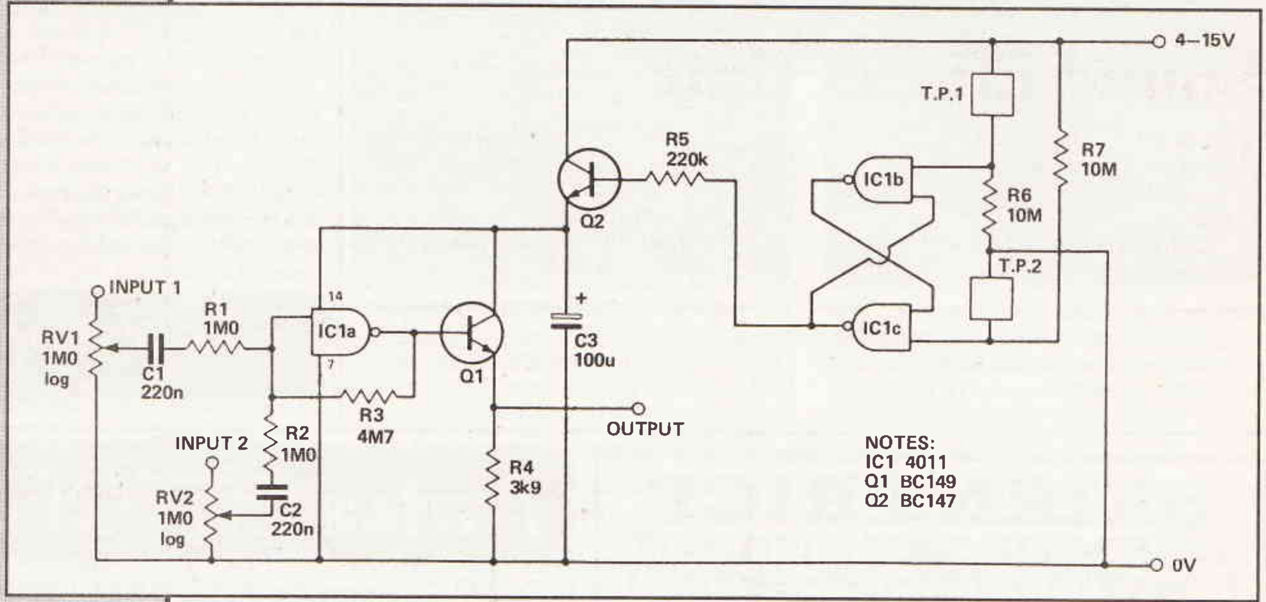
CMOS Mixer

Although this circuit employs only one cheap CMOS IC and two transistors it is capable of high quality results. The IC, a 4011, contains four dual input NAND gates. Two of these are used with their inputs connected together to form inverters and biased into the linear mode by means of the feedback resistors, R2. Inputs are applied through the pots RV1/2 and are mixed by the gate to which they are coupled by C1, R1, R3 and C2. Although only two inputs are shown here, the circuit will mix up to four inputs by duplicating the input circuitry.

For clarity only one mixer gate is shown in the schematic. The other gate, along with all the components to the left of C3 are duplicated on the other channel. The other two gates are used in a touch operated on-off switch.

The plates, which may consist of a small piece of Veroboard with alternate strips linked together and connected to the input of the gate and line respectively, control the output polarity of the gates.

When the circuit is turned on, by placing a finger on the touch plate, the output of this gate goes high switching Q2 hard on and supplying the circuit with current. To switch off the other touch plate is touched with the finger. The output then goes low removing the operating current from the circuit. The transistor Q2 gives the circuit a low output impedance and the gain with the input pot at maximum is four.



Soft Limiter

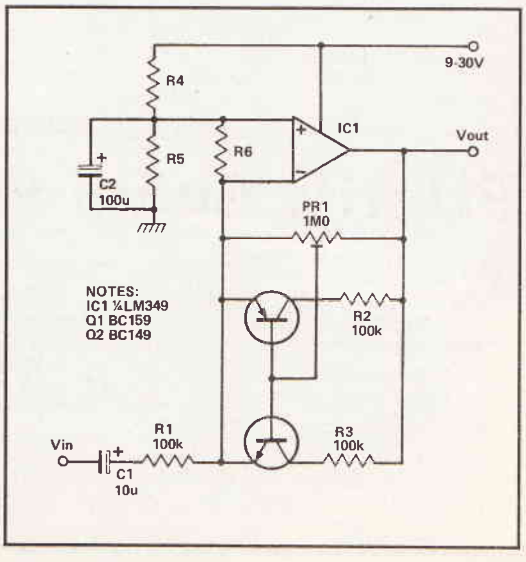
One of the fundamental differences between valve and transistor amplifiers is their behaviour when driven into clipping. The valve amps go into so-called soft clipping whilst their transistorised counterparts generate large quantities of harmonic distortion. The circuit shown simulates the soft clipping of valve amplifiers and is intended to be used between the power amplifier's input and the preamplifier's output.

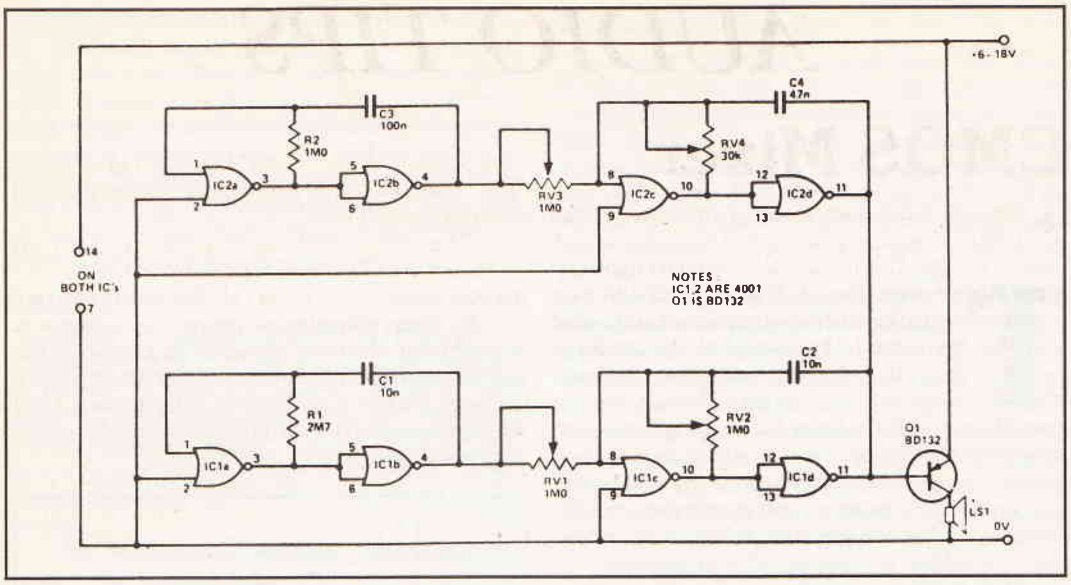
R4 and R5, decoupled by C2 set a half supply reference for the non-inverting input of the op amp. Input signals are fed into the inverting input via the DC blocking capacitor and R1, the latter defining small signal gain and input impedance.

For small signals the amplifier's output is an exact unit gain copy of the input. As the signal level increases, however, the time will come when the voltage across the output and slider of RV1 will be sufficient to bias Q1 or Q2 on. When this occurs the feedback increases due to the shunting effect of R2 and R3.

The net effect is that musical peaks above a certain threshold are reduced in amplitude to prevent the power amplifier going into hard clipping. As a result, distortion is noticably decreased whilst the subjective loudness appears unaffected.

The circuit is adjustable in operation between 130mV and 10V rms input sensitivity by means of RV1. To set the circuit up simply set the slider so that it is shorted to the output of the amp. Play some music at high volume through the system and adjust until the harshness just disappears. It's easier to do than describe.



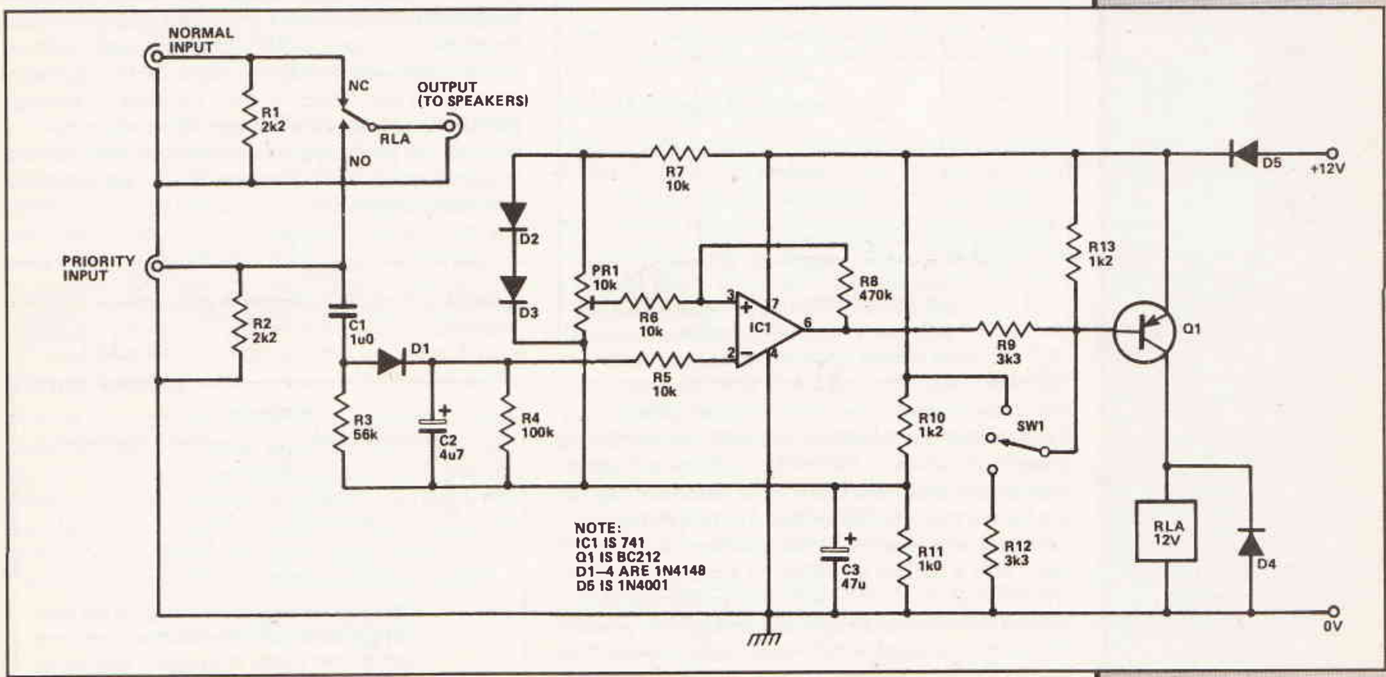


Sound Effects Unit

This circuit consists of four CMOS oscillators gated together in a configuration that will produce a multitude of effects from white noise to a multibanked Trimphone.

Each IC is connected as a warble tone generator and mixed together at the base of Q1. LS1 can be from 8 - 100R, but the transistor tends to get a bit hot below 30R, so a small heatsink may be needed.

None of the component values are critical and if desired, RV1,3 can be replaced by ordinary resistors without affecting the variety of sound effects too much.



Priority Audio Switch

This circuit switches a single loudspeaker from a 'normal' to a 'priority' circuit whenever a signal appears on the priority input. The prototype was used to switch between a cassette player and a two-way radio whenever a call was received. Other uses include priority calls in PA systems, monitoring several infrequently-used radio channels, etc.

Audio from the priority input is rectified and applied to the Schmitt trigger circuit, IC1. If the rectified voltage exceeds the voltage set by RV1, IC1 switches and the relay is operated by Q1. The switching level is set by RV1. The hysteresis is controlled by R8 and the delay before the relay switches back to the normal channel at the end of a priority call depends on C2 (approximately 2s with the value shown).

If stereo outputs from the cassette recorder are to be switched, RLA will require two changeover contacts. Several of these circuits may be cascaded to provide more than one level of priority.

CROSSOVER NETWORKS — A NECESSARY EVIL?

Vivian Capel discusses the effects that crossover units can have on loudspeaker sound.

DESIGN

The majority of hi-fi loudspeakers in use today use two separate drivers to handle the treble and bass frequencies. Often a third is used to reproduce the mid frequencies and occasionally a sub-woofer is used to extend the bass about an octave below that of the bass driver. Super tweeters are sometimes used to extend the response well beyond the content of most programme material and beyond the range of human audibility, though no doubt Nipper, the HMV dog, would have wagged his tail with approval!

Most tweeters would be wrecked if fed with a good bass signal so a crossover network is used to separate the frequency bands and ensure that only

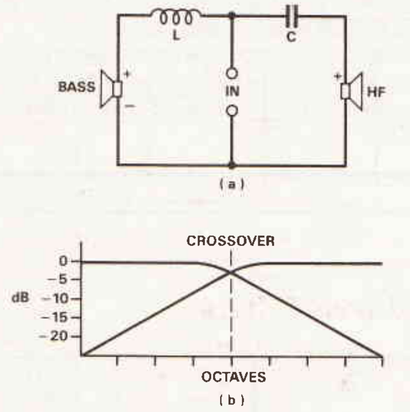


Fig. 1 (a) First-order crossover circuit
(b) Frequency response of each driver. Crossover point is at the −3dB level at which both drivers are giving equal output. The result is a smooth response but with too gentle a roll-off at 6dB per octave.

the correct ones are fed to the appropriate drivers. Such circuits are therefore regarded as a necessary part of a hi-fi speaker. But because of their side effects they are often described like some medical drugs, as a necessary evil. Is this epithet justified though?

To discover just what those effects are, we will firstly take a look at the different types of crossover and how they work. They are made up from combinations of inductors and capacitors arranged to provide *low-pass, high-pass,* or *band-pass* characteristics. The degree of attenuation outside of the pass band depends on the type of circuit which are classified according to order.

First-Order Network

The simplest circuit is of a single capacitor connected in series with the tweeter which prevents low frequencies reaching it. Both low and high frequencies are fed to the bass unit which will reproduce some of the highs due to cone flexure. Having two speakers reproducing high frequencies in close lateral proximity results in interference at certain angles, reinforcement taking place at some frequencies and cancellation at others. Because of this the circuit is used only in cheap radio units, but it can be and is used effectively with co-axial speakers where the tweeter is mounted within the bass cone.

To avoid interference effects, an inductor is connected in series with the bass unit to filter out the high frequencies. This single capacitor/inductor circuit is known as a *first-order* network, each leg attenuating the signal outside of its pass range at the rate of 6dB per octave (Figure 1).

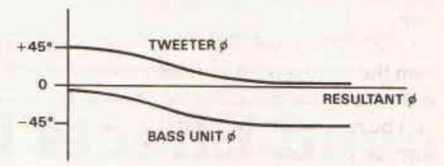


Fig. 2 Phase relationship of tweeter and bass unit. Resultant output is zero phase difference.

The point where they overlap is known as the *crossover frequency* and the values of the components are chosen so that at this point the response of each driver is −3dB or at half power. Now current through a capacitor leads the voltage, whereas it lags through an inductor. In the first-order network, the lead and lag is 45° in each case. These compensate acoustically to produce an in-phase signal from the drivers at the crossover frequency (Figure 2). The two half-power signals thus add to produce full power and so the response through the crossover region is flat. The formula for calculating the theoretical values are:

$$L = \frac{Z \times 10^3}{2\pi f_c} \qquad C = \frac{10^6}{2\pi f_c Z}$$

in which L in the inductance in millihenries; C is the capacitance in microfarads; Z is the speaker impedence; and f_c is the crossover frequency.

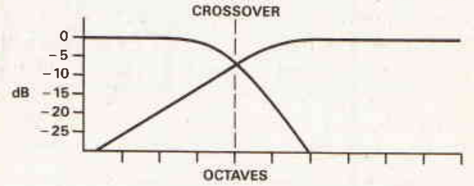


Fig. 3 If the natural frequency roll-off of the bass unit coincides with that of the crossover circuit, the result is steeper, and so an asymmetrical response is produced resulting in a dip below the crossover frequency.

There is a snag here though. The 6dB per octave roll off is too gentle. It means that at two octaves from the crossover point, both drivers are handling a −12dB signal that is outside of their respective bands, while at three octaves there is still a −18dB signal.

The problem arises when the natural frequency roll off of one of the drivers coincides with that of the filter. Then the total roll off for that drive is augmented and made steeper. So the two roll offs for the two drivers are non-symmetrical, one being steeper than the other. This produces a power level of less than −3dB for the affected driver at the crossover frequency resulting in a dip in the response (Figure 3).

A further snag lies in the fact that the tweeter will be fed with substantial proportions of the bass signal which would not only produce distortion due to overloading it, but could result in damage. Yet another undesirable factor is that the tweeter resonant frequency (which should be kept below the crossover point and so out of the range it is required to handle) can be excited. The result is a peak at that frequency which is general in the mid-frequency range.

Second Order

The solution to these problems is to use filters having a sharper roll off. A 12dB per octave characteristic can be obtained by adding a capacitor across the bass driver and an inductor across the tweeter. This circuit is a *second-order* network (Figure 4), and it is also known as an L-filter because the series and parallel components form an L when drawn in a circuit diagram.

The disadvantage is that the phase difference between the drivers is 180° which produces a dip in the response at the crossover frequency. This can be avoided by reverse connecting the tweeter, but then a hump is produced instead. Also, all the high frequencies are then in an opposite phase relationship to the low, compared to what they were in the original signal.

A musical instrument rich in harmonics such as the cello, may have its fundamental and second harmonic reproduced by the bass driver and the higher harmonics by the tweeter. Having the tweeter reversed thus changes their relationship and so also the signal waveform. While this seems to have little effect on quality, the stereo images could be impaired and it is a departure from the ideal that the reproduced signal should correspond as closely as possible to the original.

Sometimes a resistor is included in series with the tweeter and its series capacitor. This is done to attenuate its output when the tweeter sensitivity is greater than that of the bass driver which is often the case. Sensitivities are thus matched to give a uniform response. A bonus effect of this is to reduce the degree of current lead through the tweeter due to the capacitor, and thus the phase difference between the two drivers.

Third Order

Further components can be added to form a *third-order* network. This has an extra inductor in series with the bass unit and an extra capacitor in series with the tweeter. The circuit for each section looks like a T so it is often called a T-filter (Figure 5). The roll off slope in this case is 18 dB per octave (Figure 6).

The formula for calculating theoretical values is:

$$L_1 = 3L_2 = 2L_3 = \frac{3Z \times 10^3}{4\pi f_c}$$

$$\text{and } C_1 = 2C_2 = \frac{2C_3}{3} = \frac{2 \times 10^6}{3\pi f_c Z}$$

Fourth Order

Adding another capacitor across the bass driver and a further inductor across the tweeter forms a fourth-order filter. This looks like the Greek letter π in circuit form, and so is called a π filter (Figure 7). It has a roll off of 24 dB per octave. As with the second-order filter there is a 180° phase reversal so the tweeter can be reverse connected unless other components are included which affect the phasing. Fourth-order filters are rarely used for crossover networks; second and third being the most common.

Optimised Design

The above formulae assume that the driver impedance is constant, which is not the case; it varies with frequency and resonances. They should therefore be considered as a starting point, and the values be modified according to the response of the driver. Sometimes irregularities in the response of one of the drivers can be partly compensated for by extra components, usually resistors across or in series with the main filter components, but additional inductors and capacitors are often used as well (Figure 8). It is thus possible to achieve a very flat response for a particular pair of drivers and enclosure. With so many variable factors the design frequently needs to be carried out by computer.

For any published design therefore, neither the type of drivers nor values of the network should be changed. They have, or should have been, carefully optimised. It follows that choosing a pair of drivers at random, then using an off-the-shelf crossover is very unlikely to give satisfactory results. However, some speaker manufacturers do little more than that, and certain ones have been known to substitute a quite different driver with no modification of the crossover filter at all, for the sole reason of lower cost.

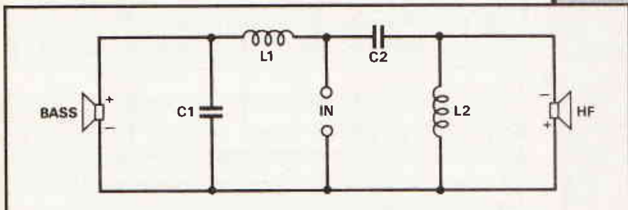


Fig. 4 Circuit of second-order or L network.

Band-pass Filters

When a mid-range driver is added it must be fed via a filter that supplies only the mid frequencies, so it must offer a rising impedance to both high and low frequencies. A first-order bandpass filter consists of a capacitor and inductor in series, while a second-order network has an extra capacitor and inductor, one in parallel across the driver and the other from the junction of the series components (Figure 9). Here too, additional components are often added to compensate for vagaries in the response of the driver.

Compensating components can be in nearly any part of the network circuit, but there are two general rules. No parallel component is ever connected directly across the input as this would be shunting the amplifier output. All attenuating resistors are on the amplifier side of the filter because the crossover

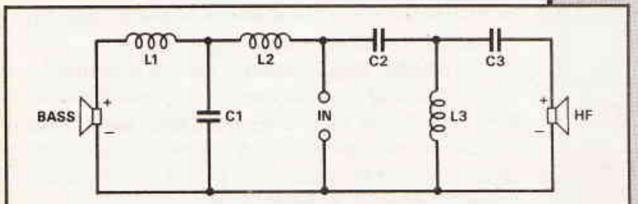


Fig. 5 Circuit of third-order or T network.

frequency would be affected if they were connected on the driver side.

A further convention is that all inputs are in parallel across the amplifier output so that each section may be considered a separate and independent filter circuit. This means that it is not necessary for both, or the three in a three-way system, to be of the same order. Thus a second-order filter may be used for the treble unit to limit the amount of bass it will be fed, while only a first-order circuit is used for the bass driver, as it may be considered less important to limit the high frequencies it handles. While this may result in some interference effects as we have seen, it reduces the phase difference and the effects of 'ringing'.

Components

The capacitors used are generally in the range of 1 — 10μF. Polarised electrolytics with a positive and negative connection are not used as the signal is pure AC. Furthermore, electrolytics have wide tolerances and so a precise value cannot be obtained. So while non-polarised electrolytics can be used, other types are preferable.

The inductors can be either air-cored or ferrite cored. The ferrite components are smaller because they are magnetically more efficient, most of the generated flux being concentrated in the windings by the core. The disadvantage is that it is possible for the core to saturate at high signal levels, thereby varying the inductance, hence also the impedance. The result is harmonic distortion and changing of the crossover characteristics.

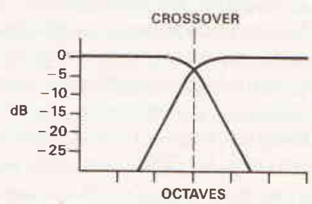


Fig. 6 **The response of each driver in a third-order network. Roll-off is at 18dB per ocatave.**

Air-cored inductors do not suffer from this possibility, but they are large and heavier. A problem can be the large leakage field which can interact with any other inductor within range and so introduce mutual coupling between them. The effects of this can be strange and unpredictable. All coils, but especially air-cored ones, should be mounted well apart, and if possible with their axes at right-angles.

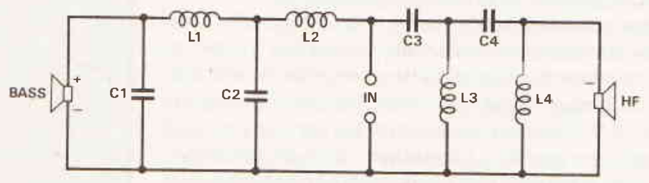


Fig. 7 **A fourth-order network giving a 24dB per octave roll-off. It is not often used because of phasing and ringing problems.**

A printed circuit board is the usual methods of interconnecting the components, but which ever way the components are connected, they should be fixed securely with no possibility of adjacent ones touching and thereby able to produce buzzes or rattles when subject to high level sound waves.

Ringing

But now the the undesirable side effects. If the signal applied across a capacitor ends abruptly, a charge is left which subsequently discharges through any parallel circuit. In the case of a crossover filter this will almost certainly include the associated driver. Thus terminating transients in the signal are blurred.

A similar effect occurs in the case of an inductor. An abrupt cessation of current flowing through it causes a rapidly collapsing magnetic field which cuts across it own windings. Th[illegible] generates a voltage that produces a current through any parallel circuit. In the case of a collapsing field, the current so produced is of the same polarity as the original. So the effect is to sustain the current after the signal has ceased. Again a blurring of terminating transients results.

By themselves these overhang effects may not be too bad, but there is worse to follow. The induced current in the inductor recharges the capacitor, which discharges back through the inductor when the current ceases. So another field builds up which produces further current to recharge the capacitor again and so on.

Thus current surges backwards and forwards in oscillatory cycles until the losses in the circuit reduce it to zero. The effect, which is known as *ringing*, is greatest at the crossover frequency and can be clearly seen on tone-burst oscilloscope traces. It is also greater with the higher order filters which have more reactive components. This is one reason why first-order filters are sometimes employed for bass drivers and fourth-order circuits are rarely used at all.

There is another possible effect. Negative feedback from the output of the amplifier is commonly applied to earlier amplifier stages to cancel spurious harmonic distortion. But it can only do this if the fed-back signal is truly out of phase at 180°. Any delay causes phase shift and could even turn into positive feedback thereby increasing distortion instead of reducing it.

Now, the oscillatory voltages generated by the crossover filter appear at the amplifier output terminals, and so are fed back to the earlier stage along the feedback path. They thus appear amplified in negative phase back at the output stage. However, the other reactive crossover components cause a phase shift so that they arrive back too late cancel the original oscillation. Instead, they tend to make matters worse by adding to it.

So some amplifiers that have a low distortion specification on paper achieved by heavy negative feedback, can sound worse than those having higher theoretical distortion due to a more modest feedback level. As the precise effect depends both on the amplifier feedback conditions and the nature of the speaker crossover network, this is one reason why some speakers sound better with certain amplifiers than others.

Cone Oscillation Damping

Another reason for many matching anomalies and a further undesirable side effect of the crossover circuit, is its effect on amplifier damping. When the signal ceases the cone tends to oscillate to and fro for several cycles before coming to rest due to the springiness of its suspension. Spurious sounds are thus generated.

These cone oscillations generate currents in the coil, which set up a magnetic field around it that opposes the cone motion. The oscillations are thus self-dampening. The same effect tends to reduce peaks in the speaker frequency response. If the cone motion at one frequency is greater than that of the others for the same input, the induced current is also larger. Thus the opposing force is greater and the excess cone motion is reduced.

Now the only path for the induced current is through the amplifier ouput stage. As the damping depends on this current, it also depends on the total resistance it has to encounter, the lower the resistance the greater the damping current.

A figure is often quoted in amplifier specfications for *damping factor*. This describes the ability of the amplifier to dampen spurious speaker cone motion

DESIGN

by providing a low resistance shunt path. Output stage internal resistance is much lower than the specified output impedance, and the damping factor is the ratio between the two. Factors of 20 are nowadays considered low, and some go as high as 1,000. Taking a typical damping factor of 100 and the usual 8R load, this gives an internal resistance of 8÷100=0.08R. Connected directly across a driver, such a low resistance permits a high damping current and very effective control of spurious cone motion.

However, when a crossover network is in circuit, each driver has at least one reactive component in series, possibly more, and often as we have seen, resistance as well. These may represent a series impedance of several ohms and make nonsense of those very low-resistance high damping factors. The result is that damping is severely impaired.

So, the crossover produces phase anomalies, spurious oscillation, and reduces the control over cone overshoot and minor resonances. To our question as to whether crossover networks are a necessary evil, the answer would thus appear to be positive. But is it? Undoubtedly it is an evil but is it really *necessary?*

Dispensing With The Crossover

Before considering this, we can first make the point that the fewer the drivers, the fewer the crossover components and the fewer the problems. One well known manufacturer gave demonstrations of a range of speakers a few years ago. They all sounded quite good except one which had a distinctly raw sound. This was their top of range model with three drivers; all the others had two.

At one time makers vied with each other as to the number of drivers they fitted. Front covers were made detachable, ostensibly to minimise HF loss, but in reality for the owner to show off to all and sundry, the drivers so exposed. A *'my-speakers-have-more-drivers-than-yours'* syndrome was the order of the day. This practice seems to be dying out, the two-driver systems are the most common at present.

Can the crossover be completely eliminated? There are three possibilities. The first is to divide the audio signal into two bands *before* the power amplifier. This can be easily done and it eliminates all the problems that arise from splitting it at the loudspeaker. The snag is that it requires two amplifiers per channel, and the loudspeaker must provide connections for both drivers separately. Not all speakers do. Different sensitivities for each driver can readily be compensated by adjusting the gain of each amplifier.

The second is to use a piezo tweeter, a range of which is made by Motorola. Being capacitive, they have the characteristic of having a rising impedance as the frequency falls. It is typically 1,000R at 1kHz, and increases exponentially below that. In one model the roll off is at 24dB per octave below 3kHz, which is equivalent to a fourth-order filter. At bass frequencies the impedance is so high that the unit can be connected directly across the amplifier and the bass driver without any crossover, and without damage to it.

Frequency response is up to 40kHz, higher than most super tweeters, and even higher than Nipper would appreciate. More importantly, the harmonic distortion is very low for a transducer, at a mere 0.75%.

If it was required to restrict the HF output of the bass unit to reduce mutual interference, a simple first order crossover, i.e. a series inductor could be included. This would impair its magnetic damping, but would avoid the other vices of the higher order circuits.

Single Driver

Both these solutions suffer from the same drawback, the phasing and interference effects of running two adjacent drivers in the same plane. As it is not possible to arrange a totally sharp cut-off, both reproduce the same frequencies around the crossover point. One answer is the co-axial speaker in which the treble unit is mounted in front of the bass one. The sound produced is coherent, and the phasing does not vary with the off axis angle.

As a result of this, a single capacitor in series with the treble unit is likely to be all that is required by way of a crossover circuit. There can be masking of mid frequencies by the tweeter unit, and sound reflection between the units. These effects can be minimised by careful physical design.

The alternative is to use a single full-range driver. There is an increasing range of these now available. Some have a frequency response from 40Hz-16kHz so there is little lost except at the extreme ends of the spectrum, but many two-unit loudspeakers do no better.

Full-range drivers make use of an effect that has for years been considered a drawback with the moving-coil speaker, that is cone flexure. Ideally, the cone should act like a rigid piston, all parts moving backwards and forwards in unison. Any stroboscopic examination of paper loudspeaker cone will reveal that this does not happen: ripples move out from the centre and back again, some parts flap backwards while others are going forward, in fact it is a wonder that the reproduced sound bears any resemblance to the original at all!

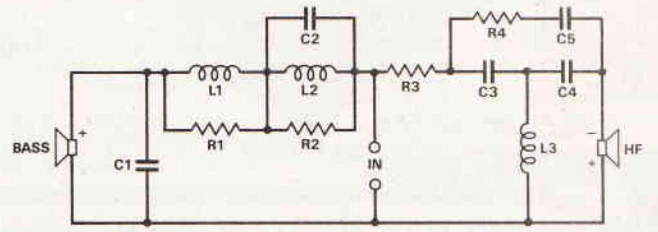


Fig. 8 **Extra components are often included in commercial designs to modify the response to compensate for irregularities in frequency response and sensitivity differences between the drivers. The circuit is thus designed for a specific pair of drivers.**

To avoid this, cone have been made from various rigid materials such as metal and polystyrene. These have tended either to be too heavy and so unresponsive to transients and high frequencies, or have added coloration. In spite of all the progress in materials over the years, paper pulp of various types continue to be used for the best subjective uncoloured results.

The full-range speaker has a cone with a curved contour which actually encourages flexure and also controls cone break-up. At high frequencies, the central area moves independently of the rest which has too great an inertia to respond. It thus behaves as a small tweeter. At mid frequencies, a larger area comes into play, while at the bass the whole cone responds. The effect is termed *controlled flexure* and is a prime example of turning a vice into a virtue! In effect there is a separately operating tweeter, mid-range unit and bass driver, without any crossover network, and with true cohernet radiation from a single source.

One objection to the full-range driver is that of doppler distortion. The 'tweeter' being the centre of the cone, is moving backwards and forwards at bass frequencies that are being reproduced at the same time, and so the HF is modulated by them. Critical listening tests suggest though that a bass cone excursion of 20mm is the lower limit below which doppler distortion cannot be detected. This is unlikely to be even approached in domestic hi-fi systems. Using the comparison of the doppler effect heard from a speeding ambulance siren as it passes, normal domestic cone excursions are equivalent to an ambulance siren at walking pace.

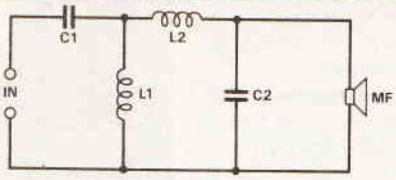


Fig. 9 **Circuit of second-order bandpass filter for feeding the mid-range unit.**

Doppler effect is thus no real obstacle to the use of single full-range drivers. The biggest obstacle is the public who, having been brought up with multi-driver speakers and conditioned into believing that the more the better, cannot accept that a single-unit speaker is anything but a maker's cut-price exercise. In turn manufacturers dare not risk producing speakers that would be so regarded and unlikely to sell.

Of course, single-driver speaker enclosures need to be properly designed and constructed to give first-class results, just as the multi-unit variety. The cheap lo-fi unit using an ordinary speaker in a box as supplied as extension speakers or with low cost players, is no criterion of the results that can be obtained with a good single unit design. For such a design readers are referred to ETI July 1987, which described the Kapellmeister transmission line speaker.

So in answer to our original question, are crossover networks a necessary evil? We can reply no, they are indeed an evil, but they are not necessary!

ETI

ETI Audio

Listen to your favourite music in FM stereo using a cordless headphone. Kenelm Rawlings shows us how it can be achieved.

THE ENTERTAINER

This project was designed to effectively relay music from your hi-fi system all round the house in stereo at low cost to the builder. It's a miniature FM stereo radio station, and you control the music content of the programmes!

Listening to the Music Relay on a Personal Stereo FM radio, such as a Walkman gives you a high quality cordless headphone system, which is more effective than infra red cordless headphones. So this means you no longer have to be in the same room as your hi-fi system, and can now listen to your favourite music in any room of the house, or even in the garden.

The design of the music relay is based on easy to obtain components. The design uses an ELC1042 TV tuner as an FM VHF low power transmitter. This simplifies the design and eliminates troublesome winding of coils etc. The unit can be hooked up to any audio equipment as long as the auxiliary line outputs are used as the signal source. These can be found on many amplifiers. Sockets marked 'tape output' will also work. The unit should not be connected to the speaker terminals of your amplifier, as this will produce very distorted sound.

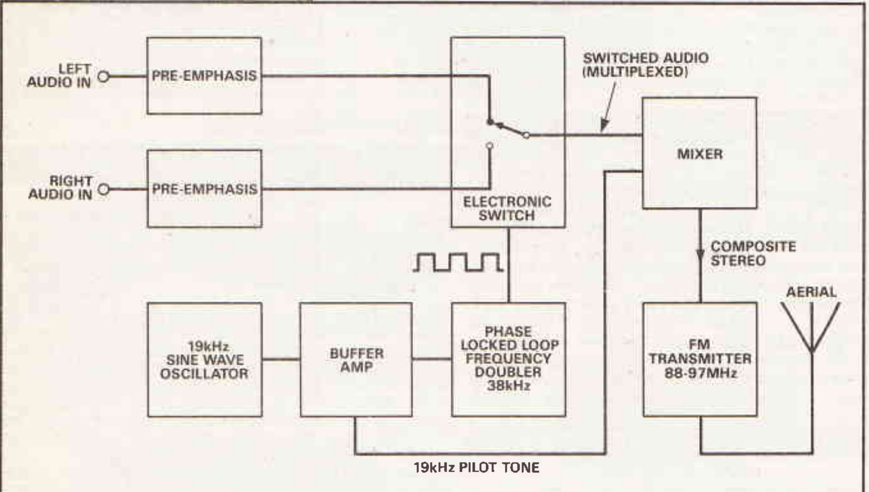


Fig. 1 Block diagram of Stereo Relay System

Testing And Trouble Shooting

When the printed circuit board is assembled and the TV tuner is wired up there are only a few simple adjustments to make. If you don't have a Digital Frequency Counter, don't panic! You can still get the project up and running.

Firstly power the project up with 12V either with batteries (8 'AA' cells) or a regulated 12V mains adaptor.

Then tune your FM stereo receiver (radio etc) anywhere between 88MHz and 97MHz. Choose a frequency that isn't being used by any local radio station. Slowly adjust R23. When a click is heard from the radio, the transmitter and receiver are at the same frequency. Now adjust R7 while having R10 set midway. At some point, the stereo pilot LED on the radio will light. If a Digital Frequency Counter is to hand, connect it to test point 1 and slowly adjust R7 until you get a reading of 19kHz. Then connect the DFM to test point 2, you should get a reading of about 38kHz. Don't worry if its not exactly 38kHz.

It is now time to connect the left and right audio inputs of the project to the auxiliary line outputs of your hi-fi equipment. You will need phono leads to do this. They can be made up or bought ready made. All that remains now is to adjust R10 for good stereo separation. The way to do this is to adjust R10 so that the pilot LED goes out, then slowly turn R10 until it just comes on. You should now have good channel separation and a good stereo image.

Finally, the aerial can be a piece of bell cable 15cm to 70cm long. You could also use a telescopic whip aerial. The range of the unit depends on the aerial. If it is a piece of bell cable which is 30cm long the range will be about 10m. In practice the unit can be received all over the average house and even in the garden.

PARTS LIST

RESISTORS (all ¼W 5%)	
R1	18k
R2	2k2
R3,4,11,17,19	10k
R5	5k6
R6	470R
R7,8,9	220k
R10,13	100k
R12	10M
R14,20	150k
R15,21	39k
R16,18	22k
RV1	1k Miniature preset
RV2	220k Miniature preset
RV3	4.7k Miniature preset
CAPACITORS	
C1,2,3,7,10	560p Ceramic, polyester
C5	150n Ceramic or polyester
C6,9	100n
C8	1n5
C11,15	5n Ceramic
C12,13,14,16	10µ 16V electrolytic
C17	100p Ceramic
C18	330p
C4,19,20	1n
SEMICONDUCTORS	
IC1	LF351 or 741
IC2	4046BE
IC3	4017
IC4	4011BE
IC5	4066BE
Q1,2,3	BC109

MISCELLANEOUS
1 ELC1042 TV tuner.
1 On/Off switch.
2 Phono sockets.
8 AA size batterys.
2 6V 'AA' battery holders.
1 Plastic project case to suit.

BUYLINES

All components should be readily available except perhaps the TV tuner. The tuner used in the project was obtained from SENDZ Components, 63 Bishopsteignton, Shoeburyness, Essex SS3 8AF for £6.

PROJECT

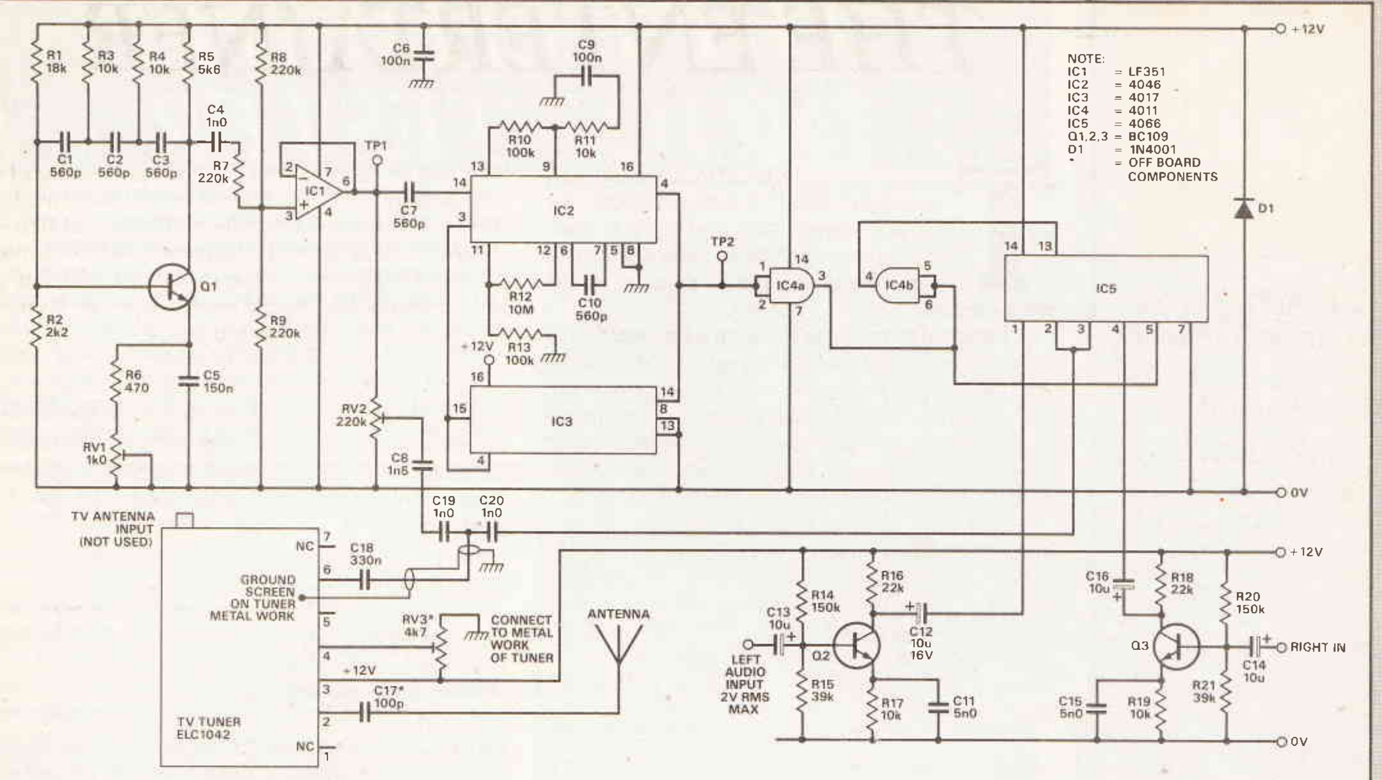


Fig. 2 Circuit diagram of Relay System

HOW IT WORKS

The circuit described is a Switching Encoder. It enables two signals, the left and right audio channels, to be transmitted by one radio carrier.

Q1 and its associated components form a phase shift oscillator, which produces a 19kHz sine wave. IC1 is used as a high impedence buffer. This prevents loading of the oscillator by other parts of the circuit. The next stage generates a 38kHz square wave carried out by IC2 and IC3. IC2 is a phase locked loop and its function is to double the 19kHz sine wave in frequency to 38kHz to provide a switching signal for IC5. IC5 is a 4066 which contains 4 electronic switches. Only two of these switches are used.

Before the audio is multiplexed by IC5, it is given pre-emphasis (high frequencies are boosted) by Q2, Q3 and associated components. This improves the signal to noise ratio and hence the sound quality. The electronic switches within IC5 (4066) alternate left and right audio channels at a frequency of 38kHz. This produces a multiplexed stereo signal at pins 2, 3 on IC5. The signal is then mixed with the 19kHz sine wave using C8, C19, C20. It FM modulates a VHF carrier generated by the TV tuners local oscillator.

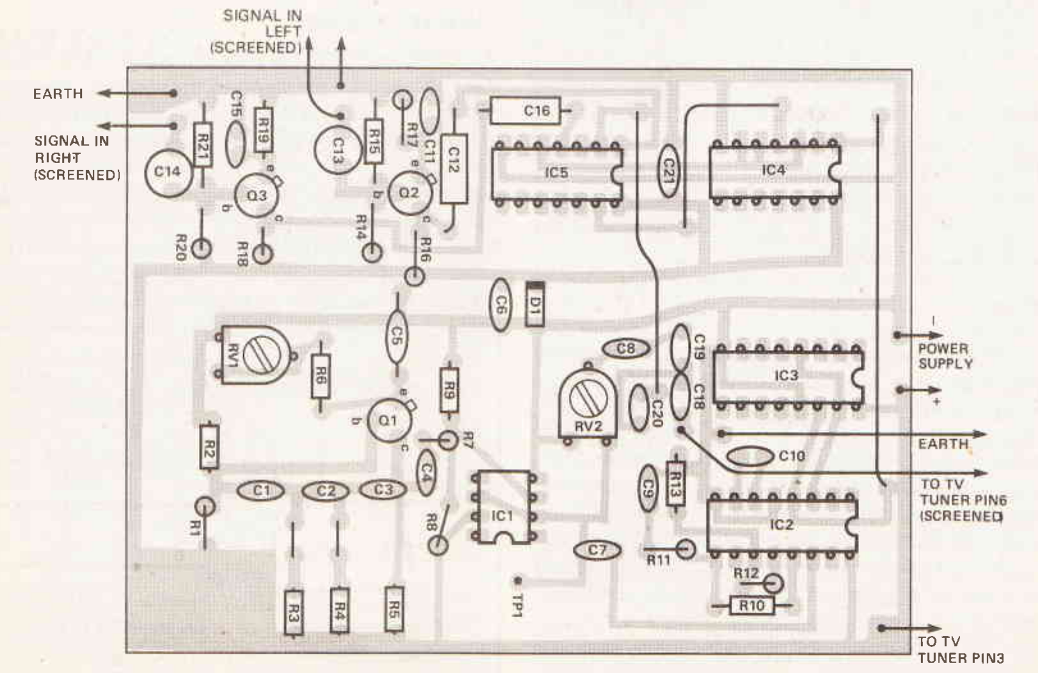
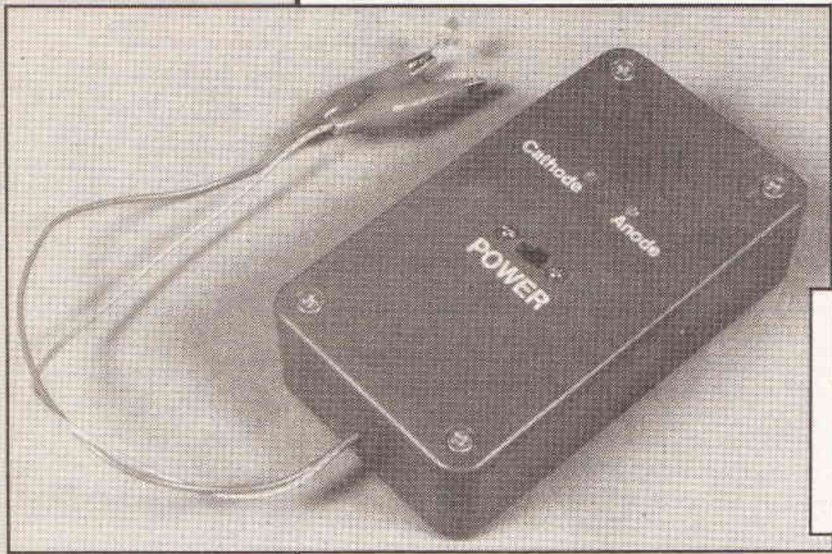


Fig. 3 Component overlay for System Relay

THE ULTIMATE DIODE TESTER



Test all your diodes with a simple and quick visual indication. Jeremy Siddons builds this simple piece of test gear.

Invariably, whilst working on various bits and pieces in the workshop, either a project or just experimenting, the need will arise for testing the odd component or two. Testing is not a means by which a good or bad component can be found, but also a means of finding out more about the component. For instance, one may use the trusty multimeter to test an old diode, by applying the test leads to the diode under test and checking the continuity on the resistance range. The diode is then turned round and the test repeated. This tells you whether the diode works or not, and of course you can then work out which leg is the cathode and which leg is the anode.

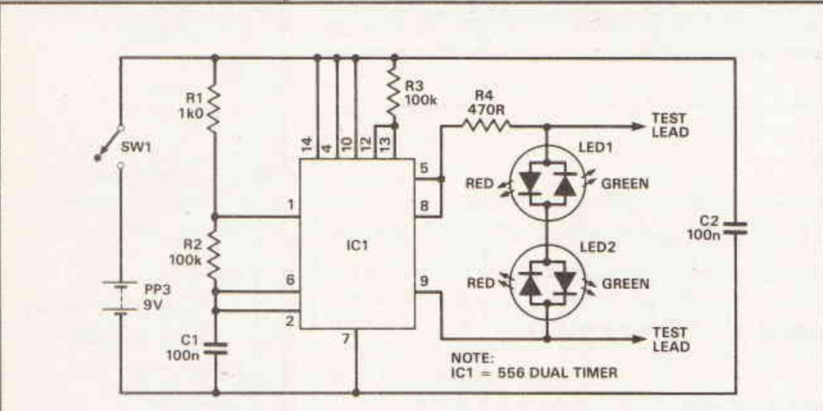


Fig. 1 Circuit diagram of diode tester.

When it comes to testing the contents of your 'bargain pack' of LEDs, the story is different. First of all, few multimeters are capable of testing LEDs. Secondly, testing an LED with a PP3 in one hand, 1k resistor in the other and LED in the other hand is a bit of hassle, especially for those of us with less than three hands. Also the LED has got to be the right way round. By this time, the thought of testing more than one is just a little bit daunting, you could be spending the time doing something much more interesting instead, like reading your favourite mag.

The device described here is simplicity itself and is capable of testing all types of diode, LED (including infra-red types) and even devices such as speakers, bulbs, fuses and wire. Testing is carried out in one simple operation and no lead swapping is necessary. The tester consists of two bi-colour LEDs and two test leads, one green and one red, labelled 'Anode' and 'Cathode'. When the unit is connected to a diode under test, one of the LEDs will illuminate red and the other green, thus displaying the colour of the lead which is connected to the anode of the diode and the colour of the lead connected to the cathode! If the diode under test is short circuit in both directions, both LEDs will be extinguished. If the diode is open circuit in both directions, both LEDs will light up yellow. Checking LEDs is just as simple, the unit will illuminate any working LED without the need to know the polarity of the LED beforehand. Indeed, in the same way as above, the tester will display which test lead is connected to the anode and which is connected to the cathode. Current through the device under test will not exceed 18mA peak, 9mA average and the peak voltage across the test leads is limited to about 4V. This ensures that there is no possibility of destroying any component by either too much current or excessive reverse voltages.

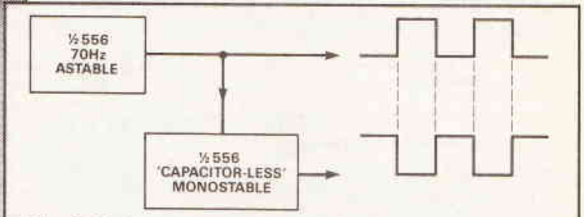


Fig. 2 Dual square wave generator.

The unit can also be used for simple continuity tests too: both LEDs light up yellow for an open circuit, or both LEDs off for short circuity. Furthermore speakers can be tested, a buzz will be heard from any working speaker under test.

Construction

The component overlay is shown in Fig. 3 and is quite straightforward. First insert all the resistors, then the capacitors, ensuring that they are mounted as close to the board as possible. The IC should be inserted next, taking care over correct orientation. It is preferable to mount the IC without a socket to provide a very low profile of the whole circuit, allowing the board to be fixed to the unit's panel directly using the switch mountings. The LEDs can now be mounted, the base of each LED must be 6mm from the board

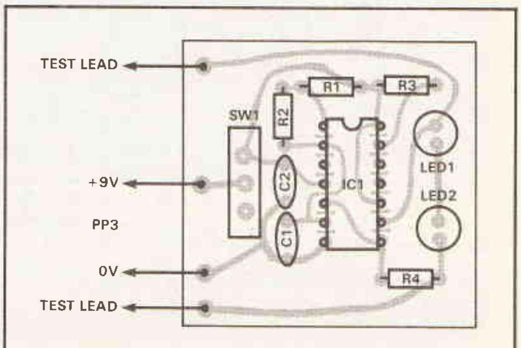


Fig. 3 Component overlay for the tester.

to allow panel mounting. The polarity of these bi-colour LEDs is very important, because their polarity directly affects their output colour under various test conditions, see Fig. 4 for details. Dual-colour LEDs do not have defined anode or cathode terminals and so connection polarity is determined from the lead length. The final component to be soldered onto the PCB is the miniature slide switch. The battery clip can then be connected and the board mounted in the box, fixed using two M2 screws through the front panel onto the switch fixing tags. Once the test leads are connected, the unit can be tested before the box is screwed together.

Testing

Ensure the test leads are not connected to anything, connect the battery and switch on. Both LEDs should light up yellow and you may notice the individual red and green segments in each LED. If the unit is not working at this stage, check the battery and connections. The LEDs will not light if the test leads are connected together and this shows correct operation so far.

Finally, connect a working diode or LED across the test leads and observe the result. One LED should revert to green and the other to red. If they are both the same colour, then reverse one of the bi-colour LEDs. If the test leads are connected to an LED, this should also illuminate regardless of its polarity. Note that the colours of the bi-colour LEDs reverse if the diode under test is reversed. The panel markings can then be applied to finish off your simple yet very useful piece of test equipment.

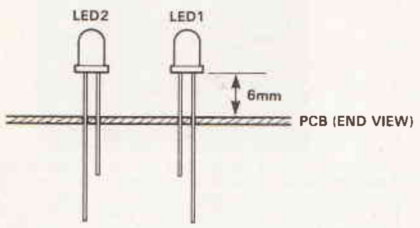


Fig. 4 LED mounting.

PARTS LIST

RESISTORS (all ¼W 5%)

R1	1k0
R2,3	100k
R4	470R

CAPACITORS

C1,2	100n epoxy case ceramic.

SEMICONDUCTORS

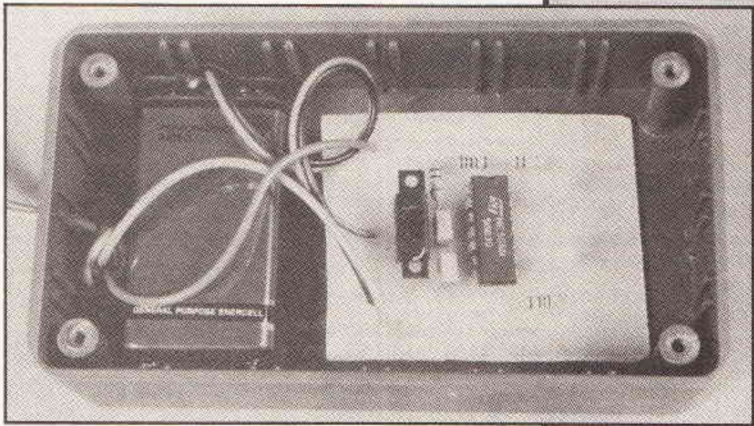
LED1,2	3mm bi-colour.
IC1	NE556

MISCELLANEOUS

SW1 Sub-miniature slide switch.
PP3 battery clip,
box to suit,
2×M2 screws,
2×croc-clips (one green, one red),
PCB.

BUYLINES

All parts should be easily obtainable from your local supplier. The bi-colour LEDs can be ordered from Maplin, part number UF96E. The slide switch must be the correct size to fit the PCB, Maplin supply a suitable switch, part number FF77J.



HOW IT WORKS

The circuit diagram for the Ultimate Diode Tester is shown in Figure 1. The circuit is based around the NE556 chip which is the dual version of the popular NE555 timer IC. One half of the 556 is configured as a standard astable multivibrator working at a fequency of about 70Hz. The output of this half, pin 5, is required to be a square wave and this is ensured by making R1 very much smaller than R2. The second half of this IC is wired as a monostable circuit but with no timing capacitor. This causes the monostable to act as a simple inverter. Thus, if the output of the astable is connected to the input of this capacitor-less monostable, the output of the monostable will be a square wave precisely 180° out of phase with the output of the astable. The arrangement is shown in Fig. 2 and illustrates the action of the capacitor-less monostable. This rather strange configuration is merely a simple way of providing two square wave outputs, one the inverse of the other. In essence, I have produced a pair of outputs that provide an alternating square wave voltage from a DC source, the PP3. Pin 5, the output from the astable is connected to one of the test leads via a current limiting resistor R4. The other output, pin 9, is connected directly to the other test lead. The two bi-colour LEDs are connected in series across the test lead outputs. Because of the alternating voltage set up across these LEDs, they both illuminate as on yellow. This results from each LED oscillating red and green giving the appearance of yellow at about 70Hz.

If a diode is placed across the test leads, then for one half cycle of the square wave, the diode will be forward biased and shunt LED1 and LED2 causing them to extinguish for that half cycle. For the other half cycle, the diode under test will be reverse biased and have no effect on the illumination of LED1 and LED2 during that half cycle. This results in only one segment of each LED being illuminated at some time over the full period of the alternating voltage. If the diode was reversed, the other segment of each LED will light for the same reasons.

The series combination of the two bi-colour LEDs require about 4V in order to conduct. By limiting the voltage across the test leads to less than 4V by the application of an external diode or LED, the bi-colour LEDs will not illuminate during the half cycle in which the external diode or LED is forward biased. A short circuit on the test leads will shut LED1 and LED2 for the entire period of the square wave, resulting in no illumination at all. LED1 and LED2 in this case perform two functions, firstly to display the polarity of any applied diode, and secondly to limit the peak reverse voltage across any device under test to 4V. This is very important in the context of testing LEDs which can be damaged by reverse voltages over about 5V. This is why an LED will illuminate safely regardless of the polarity.

C2 is a supply decoupling capacitor to make sure the 556 behaves itself.

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4

MODERN DIODE CIRCUITS

Ray Marston looks at LED, photodiode, and varicap diode applications in this final part of his mini-series.

The first three parts of this series looked at the basic characteristics of the junction diode and associated devices (zeners, varicaps, LEDs, etc), and then showed a whole range of practical applications of ordinary diodes, rectifiers, and zeners. This month's concluding episode rounds off the subject by looking at practical applications of LEDs, photodiodes, and varicap diodes, etc.

LED Basic Circuits

A LED (light emitting diode) is a special type of junction diode that emits a fairly narrow bandwidth of visible (usually red, orange, yellow or green) or invisible (infra-red) light, when stimulated by a forward electric current.

LEDs have typical power-to-light energy conversion efficiencies some ten to fifty times greater than a simple tungsten lamp and have very fast response times (about 0.1μS, compared with tens or hundreds of mS for a tungsten lamp), and are thus widely used as 'visual' indicators and as moving-light displays; a variety of basic LED circuits are shown in the present chapter.

COLOUR	RED	ORANGE	YELLOW	GREEN
Vf (TYPICAL)	1V8	2V0	2V1	2V2

Fig. 1 Typical forward voltages of standard LEDs at I_f = 20mA

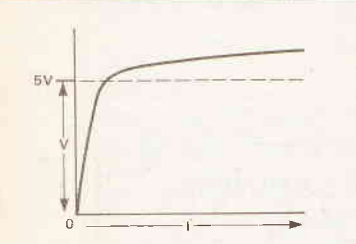


Fig. 2 A reverse biased LED acts like a zener diode

A significant voltage (about 2 volts) is developed across a LED when it is passing a forward current, and Figure 1 shows the typical forward voltages of different coloured standard LEDs at forward currents of 20mA. If a LED is reverse biased it avalanches or 'zeners' at a fairly low voltage value, as shown in Figure 2. Most practical LEDs have maximum reverse voltage ratings in the range 3 to 5 volts.

In use, a LED must be wired in series with a current-limiting device such as a resistor. Figure 3 shows how to work out the 'R' value needed to give a particular current from a particular supply voltage. In practice, R can be connected to either the anode or the cathode of the LED. The LED brightness is proportional to the LED current; most LEDs will operate safely up to absolute maximum currents of 30 to 40mA.

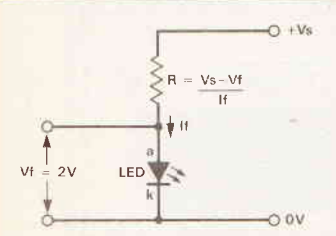


Fig. 3 Method of finding the 'R' value for a given V_S and I_f

A LED can be used as an indicator in an AC circuit by wiring it in inverse parallel with a normal diode, as shown in Figure 4, to prevent the LED being reverse biased; for a given brightness, the 'R' value should be halved relative to that of the DC circuit. Note that if this circuit is used with high-value AC supplies, 'R' may need a fairly high power rating; thus, if used with a 250 volt supply it will need a minimum rating of 2.5 watts at a mean LED current of 10mA. This snag can be overcome by replacing 'R' with a current-limiting series capacitor, as shown in Figure 5. Here, the C_S impedance limits the LED current to the desired value, but C_S dissipates near-zero power, since its current and voltage are ninety degrees out of phase. C_S values of 100nF and 220nF are usually adequate on 250 volt and 125 volt 50-60Hz AC lines respectively.

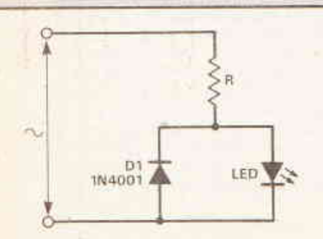


Fig. 4 Using a LED as an indicator in a low-voltage AC circuit

The basic Figure 5 circuit can be used as a 'blown fuse' indicator by wiring it as shown in Figure 6. Normally, the circuit is shorted out by the fuse, but becomes enabled when the fuse is 'blown'; under this condition the load current is limited by the C_S value.

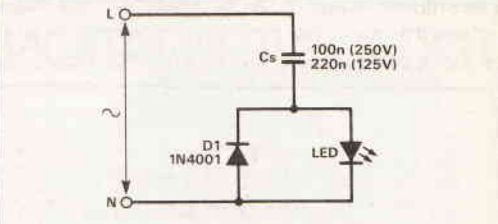


Fig. 5 Using a LED as an indicator in an AC power line circuit

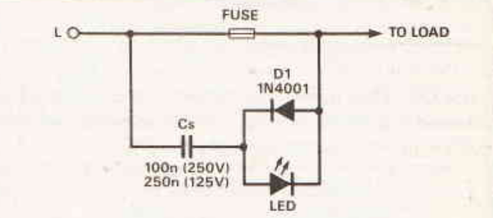


Fig. 6 AC power line 'fuse blown' indicator

Practical Usage Notes

The first practical problem that will be met when using a LED is that of identifying its polarity. Most LEDs have their cathodes identified by a notch or flat on the package, or by a short lead, as indicated in the 'outline' diagram of Figure 7. This practice is not universal, however, so the only sure way to identify a LED is to test it in the basic Figure 3 circuit. Try the LED both ways round, when it glows, the cathode is the most negative of the two terminals; always test a LED before soldering it into a circuit. (Alternatively, the Ultimate Diode Tester project, in this month's ETI!—Ed).

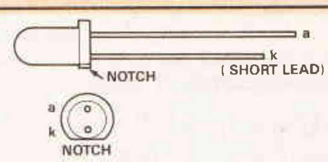


Fig. 7 Typical outline and method of recognising the polarity of a LED

Special mounting kits, comprising a plastic clip and ring, are available for fixing LEDs into PC boards and front panels, etc. Figure 8 illustrates the functioning of such a kit.

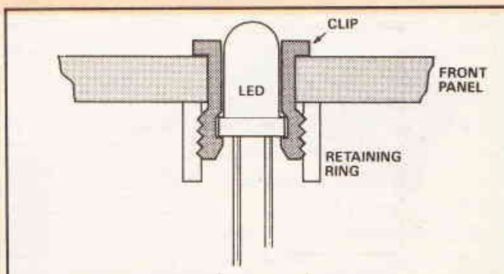


Fig. 8 CLIP and RING kit used to secure a LED to a front panel

Most LEDs come in the form of a 'single LED' package of the type shown in Figure 7. Multi-LED packages are also available, however. The best known of these are the 7-segment displays, comprising seven (or eight) LEDs packaged in a form suitable for displaying alpha-numeric characters. So-called 'bargraph' displays, comprising 10 to 30 linearly-mounted LEDs in a single package, are also available.

Most LEDs provide only a single output colour. A few specialist devices do, however, provide 'multi-colour' outputs. These are actually 2-LED devices, and Figure 9 shows one such device that comprises a pair of LEDs connected in inverse parallel, so that the colour green is emitted when the device is biased in one direction, and red (or yellow) is emitted when it is biased in the reverse direction. This device is useful for giving polarity indication or null detection.

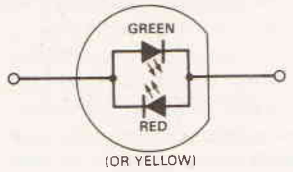
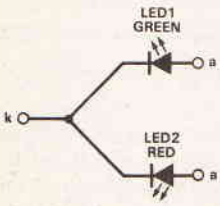


Fig. 9 'Bi-colour' LED actually houses two LEDs connected in inverse parallel

Another type of 'multicolour' LED is shown in Figure 10. This comprises a green and a red LED mounted in a 3-pin common-cathode package. This device can generate green or red colours by turning on only one LED at a time, or can generate orange and yellow ones by turning on the two LEDs in the ratios shown in the table.



OUTPUT COLOUR	RED	ORANGE	YELLOW	GREEN
LED1 CURRENT	0	5mA	10mA	15mA
LED2 CURRENT	5mA	3mA	2mA	0

Fig. 10 'Multicolour' LED, giving four colours from two junctions

A very important practical point concerns the use of 'second grade' or 'out-of-spec' devices advertised as 'Bargain Packs'. These devices often have forward volt drops in the range 3 to 10 volts, and may thus be quite useless in many practical applications. Always test these devices before use.

Multi-LED Circuits

Several LEDs can be driven from a single power source by wiring the LEDs in series as shown in Figure 11. Note that the supply voltage must be significantly greater than the sum of the individual LED forward voltages. This circuit thus draws minimal total current, but is limited in the number of LEDs that it can drive. A number of these circuits can, however, be wired in parallel, so that almost any number of LEDs can be driven from a single source.

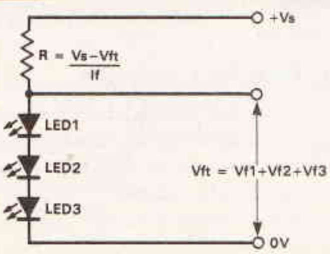


Fig. 11 LEDs wired in series and driven via a single current-limiting resistor

Another way of powering several LEDs is to simply wire a number of the Figure 3 circuits in parallel, as shown in Figure 12. Note, however, that this is very wasteful of current (which is equal to the sum of the individual LED currents).

Figure 13 shows a 'what NOT to do' circuit. This design will not work correctly because inevitable differences in the forward voltage characteristics of the LEDs will usually cause one LED to 'hog' most of the available current, leaving little or none for the remaining LEDs.

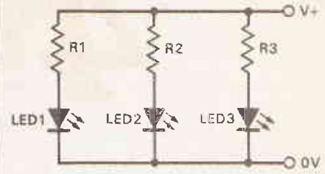


Fig. 12 This circuit can drive a large number of LEDs, but at the expense of high current

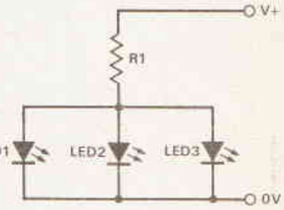


Fig. 13 This LED-driving circuit will NOT work. One LED will hog all the current

LED-Control Circuits

The three most widely used types of visible-output LED-control circuits are (ignoring the ones used for alpha-numeric LED control) those used for LED 'flashing', for LED 'sequencing', and for LED 'dot' or 'bar' analogue-value indication.

'Flasher' circuits turn a LED repeatedly on and off, to give an eye-catching display action. They may control a single LED or may control two LEDs in such a way that one turns on as the other turns off and vice versa.

'Sequencer' circuits drive a chain of LEDs in such a way that each LED in the chain is switched on and off in a time-controlled sequence, so that a ripple of light seems to run along the chain.

Finally, analogue-value indicator circuits drive a chain of linearly-spaced LEDs, in such a way that the length of chain that is illuminated is proportional to the analogue value of a voltage applied to the input of the driver circuit, eg, so that the circuit acts like an analogue voltmeter.

Simple LED-Flasher Circuits

One of the simplest types of LED display circuit is the LED flasher, in which a single LED repeatedly switches alternately on and off, usually at a rate of one or two flashes per second. A 2-LED flasher is a simple modification of this circuit, but is arranged so that one LED switches on when the other switches off, and vice versa. To complete this look at simple LED circuits, Figures 14 and 15 show practical examples of 2-LED flasher circuits (readers looking for more complex LED display circuits will find stacks of them in the author's 'Optoelectronics Circuits Manual', available from Heinemann Professional Publishing Ltd).

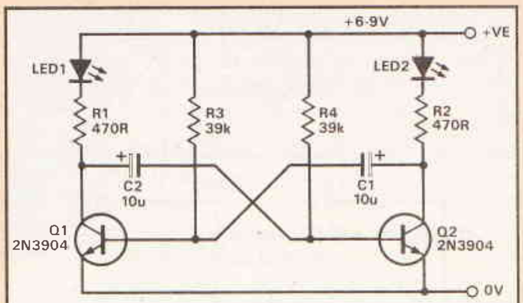


Fig. 14 Transistor 2-LED flasher circuit operates at 1 flash-per-second

Figure 14 shows the practical circuit of a 2-transistor 2-LED flasher, which can be converted to single-LED operation by simply replacing the unwanted LED with a short circuit. Here, Q1 and Q2 are wired as a 1 cycle-per-second astable multi-vibrator, with switching rates controlled via C1-R3 and

C2-R4.

Finally, Figure 15 shows an IC version of the 2-LED flasher. This design is based on the faithful old 555 timer chip or its more modern CMOS counterpart, the 7555. The IC is wired in the astable mode, with its time constant determined by C1 and R4. The action is such that output pin-3 of the IC alternately switches between the ground and the positive supply voltage levels, alternately shorting out or disabling one or other of the two LEDs. The circuit can be converted to single-LED operation by omitting the unwanted LED and its associated current-limiting resistor.

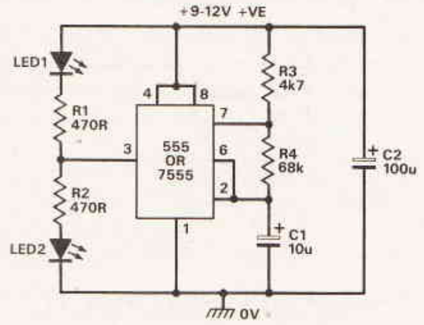


Fig. 15 IC 2-LED flasher circuit operates at about 1 flash-per-second

Photo-Diodes

When p-n silicon junctions are reverse biased their leakage currents and impedances are inherently photo-sensitive, they act as very high impedances under dark conditions and as low impedances under bright ones.

Normal diodes have their junctions shrouded in opaque material to stop this unwanted effect, but photo-diodes are specially manufactured to exploit it, and have their junctions encased in translucent material. Some photo-diodes are designed to respond to visible light, and some to infra-red (IR) light. In use, the photo-diode is simply reverse biased and the output voltage is taken from across a series-connected load resistor, which may be connected between the diode and ground, as in Figure 16a, or between the diode and the positive supply line, as in Figure 16b.

Photo-diodes have a far lower light-sensitivity than cadmium-sulphide LDRs, but give a far quicker response to changes in light level. Generally, LDRs are ideal for use in slow-acting direct-coupled 'light-level' sensing applications, while photo-diodes are ideal for use in fast-acting ac-coupled 'signalling' applications. Typical photo-diode applications include IR remote-control circuits, IR 'beam' switches and alarm circuits, and photographic 'flash' slave circuits, etc.

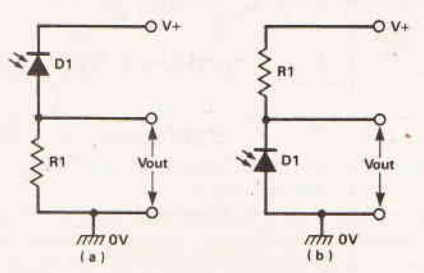


Fig. 16 Alternative ways of using a photo-diode

Photo-Transistors

Ordinary silicon transistors are made from an npn (or pnp) sandwich, and thus inherently contain a pair of photo-sensitive junctions. Not surprisingly, they are also available in photo-transistor form, and use the standard symbol of Figure 17.

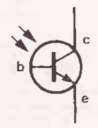


Fig. 17 Photo-transistor symbol

Figure 18 shows three different basic ways of using a photo-transistor. In each case the base-collector junction of the transistor is effectively reverse biased and thus acts as a photo-diode. In Figure 18a the transistor base is grounded, and the device acts as a simple photo-diode. In Figures 18b and 18c the base terminal is open-circuit and the photo-generated currents of the base-collector junction thus feed directly into the base and, by normal transistor action, generate a greatly amplified collector-to-emitter current that produces an output voltage across series resistor R1.

The sensitivity of a photo-transistor is typically one hundred times greater than that of a photo-diode, but its useful maximum operating frequency (a few hundred kHz) is proportionally lower than that of a photo-diode (tens of MHz). The sensitivity (and operating speed) of a photo-transistor can be made variable by wiring a variable resistor between the base and emitter, as shown in Figure 19; with RV1 open circuit, photo-transistor operation is obtained; with RV1 short circuit, photo-diode operation occurs.

Note in the Figures 16 to 19 'opto' circuits that, in practice, the R1 'load' value is usually chosen on a compromise basis, since the circuit voltage gain increases but the useful operating bandwidth decreases as the R1 value is increased. Also, the R1 value must, in many applications, be chosen to bring the photo-sensitive device into its linear operating region.

Opto-Couplers

An opto-coupler is a device housing a LED (usually an IR type) and a matching photo-transistor (or photo-diode); the two devices are closely optically coupled and mounted in a light-exclusing housing.

Figure 20 shows a basic opto-coupler 'usage' circuit. The LED is used as the input side of the circuit, and the photo-transistor as the output. Normally, SW1 is open, and the LED and Q1 are thus off. When SW1 is closed a current flows through the LED via R1, and Q1 is turned on optically and generates an output voltage across R2. Note that the output circuit is thus controlled by the input one, but that the two circuits are fully isolated electrically (this is the major benefit of the opto-coupler). In practice, this simple circuit can easily be modified to give coupling of either digital or analogue signals.

Varicap Diode Circuits

Finally, to complete this look at modern diode circuits, Figure 21 shows a basic varicap diode usage circuit. The diode is reverse biased via R1 and a stable external control voltage (usually variable from zero to about 10 volts), and the varicap is coupled to an external circuit via blocking capacitor C1. The varicap capacitance is maximum at zero bias, and decreases as bias is increased.

CIRCUITS

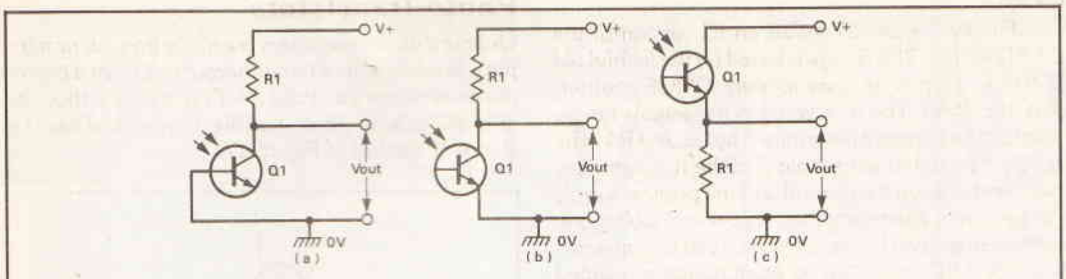


Fig. 18 Alternative ways of using a photo-transistor

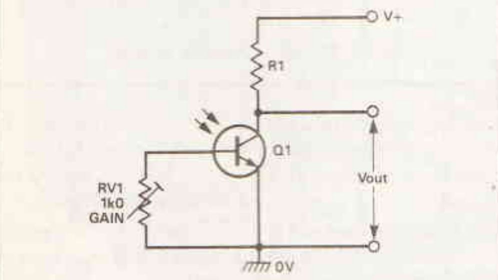


Fig. 19 Variable-sensitivity photo-transistor circuit

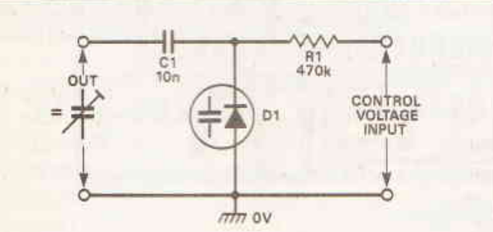


Fig. 20 Basic optocoupling circuit

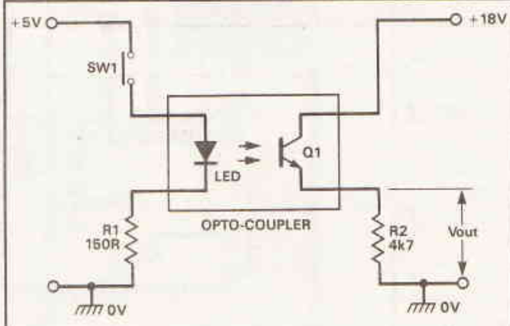


Fig. 21 Basic varicap diode usage circuit

Ordinary silicon diodes have maximum (zero bias) capacitances of a few pF and have typical maximum-to-minimum capacitance ratios (cap ratios) of about 2:1. Specially manufactured varicap diodes (which are often available as a matched pair) are available with maximum values of about 500pF and cap ratios of 20:1 (ie, the capacitance can be voltage-controlled from 25pF to 500pF). They are widely used in voltage-controlled tuning applications, etc.

OOPS!

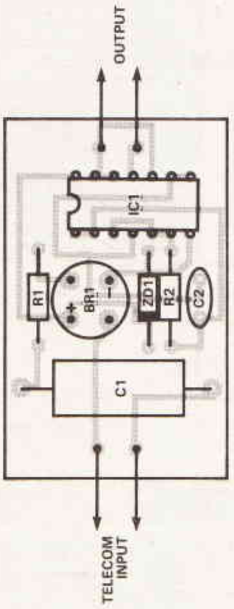
Some new corrections . . .

Digital Noise Generator (December 1989)
On Fig. 4, C4,5 should be 68n, not 68p. In the Parts List, C6,7 should be 560p, not 560n.

Power Supply Theory (April 1990)
See Read/Write for corrections to the maths.

Flatmate (May 1990)
IC5 and IC6 should be rotated by 180 degrees from the orientation shown in Fig. 4. "Mains In" should read "To Transformer". C12 is missing from the Parts List, and should be 1n0.

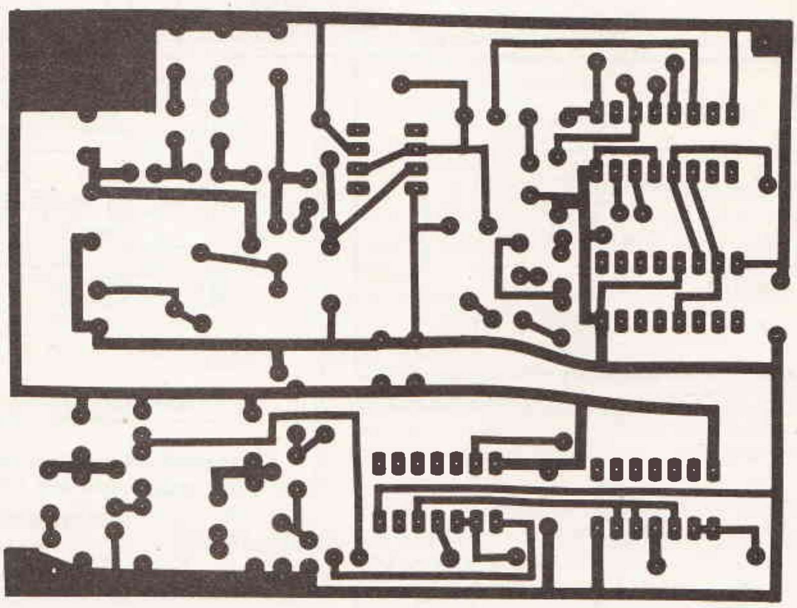
Telephone Extension Bell (June 1990)
The foil was incorrect. A correct foil is printed in this issue. Boards from our PCB service are correct. In Fig. 9, the component overlay was printed wrongly. It should be as shown below.



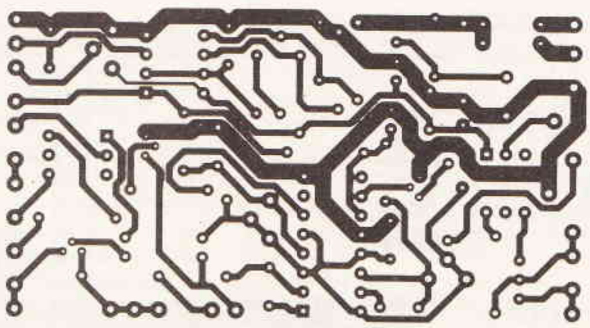
Testing, Testing (June 1990)
All references to ± voltages in the section on quiescent current should be + voltages.

Digital Frequency Meter (July 1990)
The resistor connecting IC4 and IC6 should be labelled R13, not R18. The circuit diagram is correct. On the Parts List, PB1 and PB2 should be SW3 and SW4. XTAL1 is not listed; HC-49U 10MHz would be suitable.

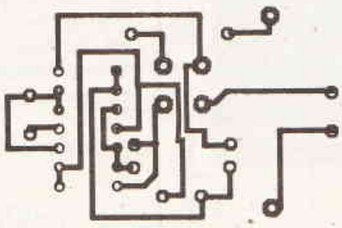
PCB FOIL PATTERNS



The Entertainer



Slide Projector Controller
Board designed by Tsien UK using Boardmaker 2



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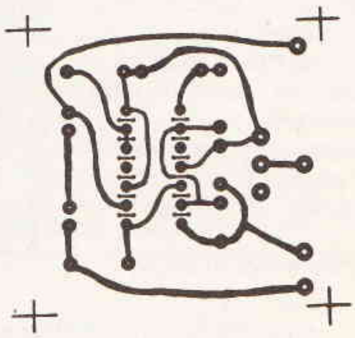

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All you do is fill in the coupon stating clearly the code number, your name and address and your remittance made payable to: A.S.P. Reader Services.

For the choice of colour you must add two letters to the end of the code. They are these: BW — Black panel, white lettering, RW — Red panel, white lettering, WB — White panel, black lettering, WR — White panel, red lettering.

The ultimate in personal service must be to offer a front panel made to your design requirements and this does not have to be limited to electronic projects. It could be a design for a clockface, a door-panel insignia, even your own logo. Now we can offer that facility too. Send us by letter or Fax, a neat dimensioned millimetre drawing of your panel design and we will be happy to give you a quote for a coloured front panel. On acceptance of the quote just send in the artwork and we'll do the rest. There's a minimum charge of £10.00 + VAT for this custom service but we reckon it's worth it.

Here are some recent popular projects to start this brand new service on its way, the prices are inclusive of VAT and postage and packing:

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NEXT MONTH

In our Audio supplement, we present the first in a series of loudspeaker designs. We start by taking a comprehensive look at electrostatic types with plenty of design considerations in order that you may build one yourself.

In the concluding part of Microwaves, Colin White discusses the uses within the fields of RADAR, astronomy and medicine. Still on the subject, we present a feature on Instrument Landing Systems at airports where microwaves are essential for the safe landing of aircraft.

Will solar power ever become cost effective and establish a place in the energy generating game? The renewable energy series tries to find the answers to this and the different methods of utilising the sun rays.

If you feel like plugging in the soldering iron, we can offer a component tester, a digital countdown timing facility to improve your powers of oratory, be it in lecturing or disco presentation and a guitar pick-up to convert your ageing acoustic music box to perform something rather louder.

Order your copy today and collect the October issue on September 7th.

The above articles are in preparation but circumstances may prevent publication

LAST MONTH

In August we featured the first part on the workings of a modern-day synthesiser. The second in our energy series featured an article on wave and water power and in Electric Eye, we reviewed the latest trials to give blind people easier access to written information.

Projects covered were a Temperature controller, an FM generator, an AC millivoltmeter and an Update on a stereo decoder featured in ETI in 1987. A limited number of back copies are still available from Select Subscriptions (address on contents page).

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