THE ELECTRONICS, SCIENCE & TECHNOLOGY MONTHLY

ETI

ELECTRONICS TODAY INTERNATIONAL

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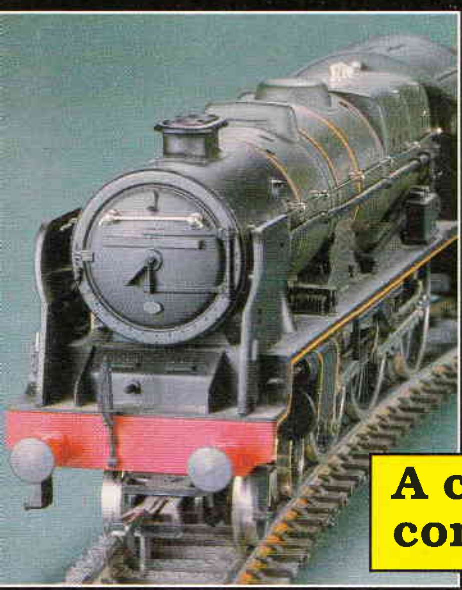
THE HEMISYNC
Using audio to create brain-wave effects

MODEL RAILWAY CONTROL



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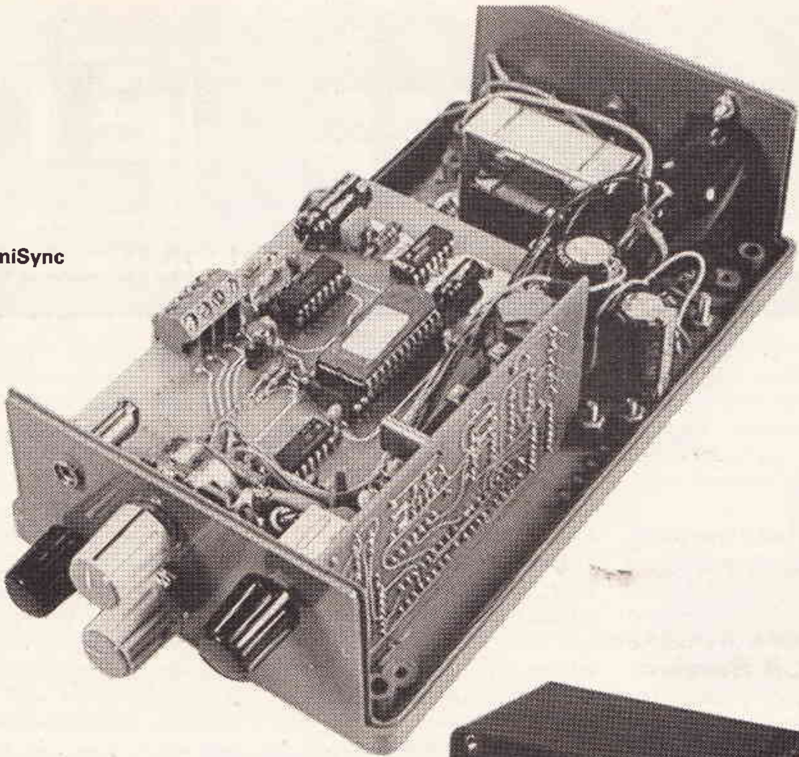

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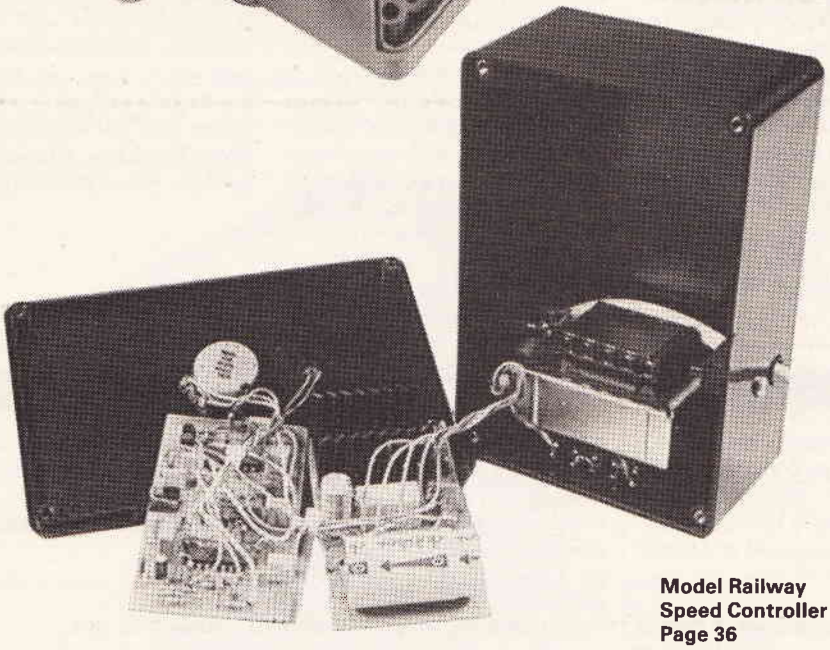

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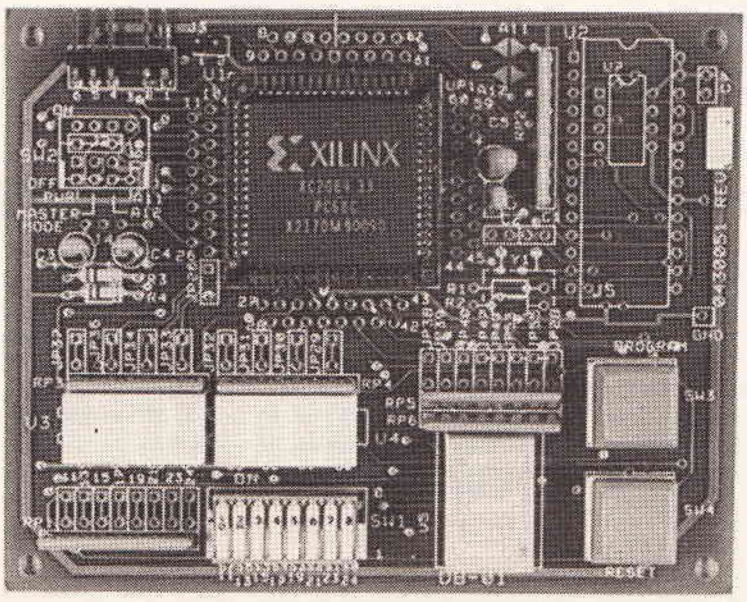

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Editorial

It is gratifying to hear and read your comments regarding ETI. Despite the downward trend in magazine sales in general throughout this recessionary period, ETI is increasing its established position as a leading journal in the technological world as judged by increased sales and circulation. This trend-bucking is indeed very encouraging considering the squeeze that everybody seems to be facing. Subject quality and diversity will remain our priority to cater for our huge range of discerning readers.

High Resolution

Keeping ahead with the latest technology like HDTV has proved an invaluable guideline for those 'in the business' or those intending to adopt the next generation of video communicating equipment.

Using audio, video and computing power at the highest quality and speed will serve as a very important tool in the future, not only through the realms of virtual reality and all that entails (see within these pages) but through high quality graphical detail of the microscopic and indeed the macroscopic. To be able to record time-lapsed events in space or high speed reaction kinetics on the ground with high resolution cameras and monitors with fast comparative replay with minute on-screen colour coded changes could enhance our understanding of mechanisms considerably.

High resolution 'audio' will give us access to smaller more definable nuances for the discriminating ear (A subject of hot debate as ETI readers will know) and could lead to important research into brain-interpreted audio and how it affects our subsequent actions. It might also provide a helping hand in understanding any mechanisms resulting from psychological influence in perceiving sub and supersonic frequencies.

Paul Freeman

READ\WRITE

ETI LETTERS

Hear-Here

How refreshing it is to have a contribution from Mr Linsley-Hood in the June issue, to bring a whiff of JLH sanity into audio chaos. Loudspeaker leads are a good example; if some gullible innocent has just spent several pounds on single-crystal copper cable with some exotic insulation the system will seem better — although it may only be due to the connections having been renewed! I drew attention to the dodginess of connections in a letter to HiFi News in May 1988 - there was not a single comment.

Another thing about loudspeaker leads, with moving coil units, is that they are in series with a voice coil of, usually, a few ohms resistance. So much for amplifier output impedances of tenths of ohms and extraodinary damping factors.

A non-electrical aspect, rarely mentioned, is that loudspeakers in a room add to the room's acoustics to those of the original source. Headphone listening seems the only way to avoid this and accounts for (some of) its relative superiority.

Observations on the complexities of electrolytic capacitors in the audio chain should be taken seriously and one wonders if Jung and company really have had the last word; meanwhile, 'electrolytics' should surely be restricted to smoothing circuits. Capacitor coupling to loudspeakers seem particularly suspect and perhaps responsible for more ills than a well-designed transformer would contribute as a means of keeping power supplies from loudspeakers. Direct coupling with some quick-acting safety system is needed — suggestions would be welcome.

The human ear being so tolerant is useful for purveyors of so-called 'Hi-Fi' but, as you suggest, ears (golden or cloth) often fail to agree with instrument readings. Instruments and sophisticated analysis convince us of extremely low distortion levels — but we then listen to the sound it reproduces from microrhones and pick-ups adding perhaps 1% of distortion and listen to it via loudspeakers adding even more! But the instruments assure us that it is near-perfect.

A puzzling feature to me is what happens to the DC? Sounds are essentially 'puffs' and 'sucks'; speech, vocal and wood-wind music at its source is more 'puff' than 'suck' and we conveniently ignore this, for we lose the DC in the amplifier's fast AC coupling — letter to H.F.N, Nov. 1988 — one comment, re organs, Jan.1988.

Another factor, not mentioned as far as I am aware, is that the puffs and sucks become 'AC' soon after leaving the source — or if we had real 'Hi-Fi' of a near-by trumpet, the loudspeaker diaphragm would move across the room!

Yes, there still are too many unanswered questions, and John Linsley-Hood does a good service in pointing them out so well. It is time for some feet-on-the-ground researcher to get back to basics like candle-flames and rotating mirrors as used by the early physicists and leave sophisticated instrumentation alone until it is known what the readings mean.

Alan Tomkins, Stourbridge, West Midlands.

TV Detector

Despite being out of the electronics trade for some considerable time I still receive the latest edition of ETI.

However, with itchy feet and the desire to use my old Verotool and soldering iron I feel its about time I built another project. Therefore, I set the brain into gear to think of something useful to build

After looking for ideas by browsing through past editions of the great magazine (and the endless test equipment projects), I could never recall a project for a level meter that could be used to measure and set up television aerial systems. If I am correct in my assumption, could you please place this idea on your future projects file.

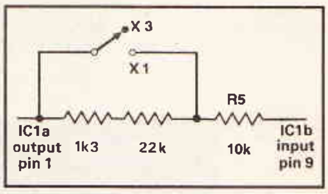
Perhaps such a project could be designed to include the setting up of a satellite systems as well.

P Parsons, Cowley, Oxford.

We will see what can be done for you Mr Parsons

Millivoltmeter Tech Tip

Thank you for publishing my 'Tech Tip' regarding the AC millivoltmeter attenuator. Unfortunately there is one error and one omission (both mine). Firstly, the x1/x3 attenuator should be implemented as shown:



Secondly (obviously) R1 should be omitted since its function of providing a DC bias path for IC1a is now performed by the attenuator chain.

Incidently, John Linsley-Hood's article on audio components was very fair, quite comprehensive and, I believe, entirely correct. I'm sure it won't be the end of the audio debate though.

Simon Bateson, Middlesbrough

Accuracy That Counts

Arising out of the letters from Mr Harms and Mr Silvester in the May ETI, may I be permitted to offer some views.

Considering the latter's ultimate comment, some tone controls and graphic equalisers' (abhorred by numerous listeners) can produce a near-RIAA response, so why trouble about an RIAA equaliser at all?

But being serious, one should not despise Mathematics — after all, is that not what Mr Silvester used to determine the values in his February article? Unfortunately, he used the wrong formulae. A prudent engineer designs accurately and ultimately compromises when he knows what tolerances are involved. In the present case, because Mr Silvester's 1kHz gain of 20 is relatively low, the usual ratios associated with his network can be slightly modified with advantage, and I have taken R2/R1=7.07, R1 C1 =307µs, and C1/C2=2.8. Keeping R2=200k, we get C1=10n87, C2=3880p, and R1=28k3.

When practical values are selected, I concentrate on the larger capacitor C1, and C1=10n looks attractive. By adjusting the other items proportionally, we have C2=3570p, R1=30k8, and R2=217k. I think we can settle for C2=3600p, and R1=30k; and for R2, by paralleling 390k and 407k (=213k), we finish very close to the ideal (1kHz gain = 21.4).

Maybe capacitor tolerances are not as close as those for resistors, but many suppliers offer them with 2 or 2½% tolerance, so that an accurate equalisation can be achieved at no great expense.

Finally, I have a maxim; believe only half of what you see, and only a quarter of what you hear.

S E M Vening, Batley, W Yorks

Mr Harms has pointed out to us the time constants in his article should be t_2=318 · 3µs and t_3=3183µs.

OPEN CHANNEL

One of the more interesting aspects of observing telecommunications as an evolving science is when you see the birth of a new type of technology. Often it's not so much the technology is brand new, more a new way of using an existing technology. Occasionally too, it's pertectiy obvious to the observer what is going to happen next, it's just a question of time before the various agents in the evolutionary step get their act together to allow it to happen.

So it is with inter-office computer communications. In most computer systems, peripherals and computers communicate digitally over wires. In many setups this involves no more than just a handful of leads between the various devices. But in larger systems, particularly those networked between isolated system parts, wired communication becomes a bit of a headache. Usually the solution is either a bird's nest of cables dangling behind everyone's desk or, if carefully planned and funded, a ducted cable network (typically in the form of a local area network — a LAN).

Although such LANs can be effective in simplifying connections between isolated parts, however, they are still quite complex to install in the first place. Newly built premises can be fairly easily ducted and cabled but older premises require an extensive refit to install cabled LANs. Each office move-round may require repositioning of LAN terminals, too. Whatever cabled option is chosen, LAN solutions are generally costly in terms of installation.

Recently, North American LAN providers have been turning their attentions to LANs which use radio communications to replace standard cabled techniques. It's a pretty obvious solution which has rapidly caught on over the big pond, but not yet here in Europe. The US government was quick to allocate radio frequency for the wireless LAN services so manufacturers were able to get systems off the ground quickly and easily, knowing that a market would exist as soon as the product rolled off the line. Allocated frequencies for systems are around 900MHz, and 2.4GHz to 6GHz. Available wireless LANs operating at these frequencies offer ranges of upto about 400 metres at data rates around 200Kbits s^{-1} or more (depending on frequency range adopted). The whole thing comes together in a small box which connects to the back of a device, and each box incorporates a tiny aerial (around 75mm). The concept is neat and clean and leaves you wondering why it wasn't thought of before.

As you might expect, on the other hand, European airspace has not been so easily granted, although the Department of Trade and Industry in the UK Government is at least considering the idea. It looks as if a range around 2GHz is to be allocated to wireless LANs here, although there is no conclusive news at the time of writing.

Speaking as someone currently using networked computers almost daily, and frequently coming across limits imposed by hard-wired cabling solutions (who's pinched my cable,) it just seems pitiful that a solution as elegant as wireless LAN should be held up by legislation.

Sharp Image

Japanese electronics manufacturer Sharp expects to have available a 21cm about 8.6in) flat panel LCD display colour television shortly. The 21cm screen is some 7.5cm bigger than anything available before, which represents an approximate doubling in surface area. The idea is to produce the television in a flat form, allowing it to be hung on a wall if required.

Based around a thin-film transistor (TFT) LCD panel, the display has 456 rows and 960 columns of pixels — some 437,760 pixels in the total matrix. TFT colour LCD technology is not new, but producing so many in such a large display is no mean feat. Colour LCD displays suffer from vast wastage rates, with estimates of some 90% of all product having to be scrapped. Initial production rates of working products are calculated at 1000 per month. These two factors probably account for estimated initial retail costs of around £2500 for the television.

Large monochromatic LCD displays, on the other hand, don't seem to be affected by such high wastage rates or low volume production runs. Some £700 million is being invested in production of displays upto around 35cm (about 14in) this year, by Japanese companies alone, This investment is, merely prudent planning for the expected boom in lap-top notebook computers. These are expected to access a potential market of millions of users, and rely on large-screen LCD displays (initially monochromatic but eventually colour, too).

Our cousins in the US are already getting anxious about Japanese investment in the displays, and anti-dumping legislation is being called for to prevent the American market being flooded by Japanese displays. However, with such high investment, Japanese companies may be the only ones capable of supplying displays to worldwide computer manufacturers at the volumes expected to be needed for the computers. It may simply be a case of supply and demand — with demand not being met unless world-wide computer manufacturers use Japanese-supplied displays.

Up For Grabs

The old British Satellite Broadcasting satellites (they've only been up there a few months, but I still feel justified in calling them old) look as though they may have a new use, offering business communications services in sound and vision (videoconferencing and so on) and data forms. Current operators, National Transcommunications Limited (NTL — the pheonix risen from the ashes of the engineering section of the recently defunct independent Broadcasting Authority), has applied for a license to distribute such services via the Marcopolo satellites. Ah well, at least it's not all pie in the sky!

NTL incidentally is in the process of privatisation, and it should be announced anytime now who the new owner is. Anyone with around £200 million of spare pocket money should apply to . . .

Keith Brindley

ETI NEWS

RECORD/PLAY MINI DISC SYSTEM

Sony announced the development of the Mini Disc (MD) system in Tokyo last month. The ultra-compact optical disc player/recorder can be manufactured using existing CD production facilities. It also records and plays back 74 minutes of digital audio sound on an ultra-compact magneto-optical disc. Sony is working to gain the support of domestic and overseas hardware and software companies for the new format while preparing for its own product introduction targeted for late 1992.

The Mini Disc system has been designed to combine the portability and shock-resistance of analogue compact cassettes with the sound quality and quick random access of optical discs.

The new system uses a 64mm (2.5 inch) diameter, record/playback magneto-optical disc which comes in its own cartridge protecting it from physical damage, similar to a computer diskette.

The Mini Disc will offer vibration proof music from a newly developed 'shock-proof memory'. Sony has also developed a special pickup for the Mini Disc system which can read both magento-optical discs and CD-type discs. This will help bring about a smooth transition to the prerecorded software of the future.

Why the Mini Disc?

The analogue compact cassette tape, launched in 1963, gave consumers a portable, shock-resistant machine with recording facility. Sony then produced the 'Walkman' headphone stereo and sales of analogue compact cassette related products has produced a present level of about 150 million units sold per year worldwide.

The compact disc introduced in 1982 has established a strong market because of its digital sound quality, quick random access and ease of operation.

Sony's research indicates that consumers now want a system which combines the two systems. The company believes that the Mini Disc will meet this demand, creating a new portable, personal stereo market for both hardware and software industries.

The technology of the Mini Disc system includes a Digital Audio Compression System where the digital signal is compressed five times more than in CD or DAT, allowing 74 minutes of high quality digital sound recording on a 64mm disc. It also has a Shock-proof memory to prevent skipping by storing data read from the disc in a memory chip, (e.g. a 1Mbit chip will store approximately 3 seconds of music). If the player is jolted and the optical pickup is shifted off the correct track, uninterrupted playback continues while the pick up returns to the correct position. Sony also developed a magnetic layer, the polarity of which can be reversed using a third of the magnetic power used in conventional magneto-optical discs. Also developed was a magnetic head which reverses polarity of magnetic signals with low power consumption. This combination does away with the necessity of consecutive erasure and rewriting and results in a smaller, less complex record/playback device.

Sony is planning to incorporate into the Mini Disc system the Serial Copy Management System (SCMS), a copy protection device that adheres to the Athens Agreement.

ENGINEERING MERGER

In a move which strengthens the vital UK engineering profession, members of both the Institution of Electrical Engineers and the Institution of Manufacturing Engineers, have voted to join forces and create a combined institution to meet the challenges presented by rapidly changing technologies.

Work will start immediately to implement the proposals which will come into effect on 1 October 1991. The IEE (110,000 members) and the IMfgE (20,000) will jointly form the largest of the 46 UK engineering institutions. A new Manufacturing Division will be created within the new Institution which, with some 40,000 members, will be one of the most powerful voices for the UK manufacturing industry.

SOLID STATE LASER

Designed as an inexpensive and convenient laser light source for electronics and telecomms work, the new solid state laser diode unit from Spindler & Hoyer provides an output of 1mW at 670nm (multi mode) with an amplitude stability of ±3%.

Beam divergence is typically 0.5mrad. The beam profile, at exit, has a diameter of 3mm (circular) while polarization is linear at 1:60. The self-contained package measures 45 x 25mm complete with collimator and all optics.

Input requirement is 5V DC which is applied via two 1m flying leads with tinned ends. The unit can be used in a wide variety of applications and also offers an inexpensive alternative to expensive He:Ne lasers.

A similar model offers a single mode output of 3mW at 790nm. Both models can be used as 'stand-alone' sources or can be directly accepted by optomechanical constructions such as Microbench.

Further information Tel: 0908 262525

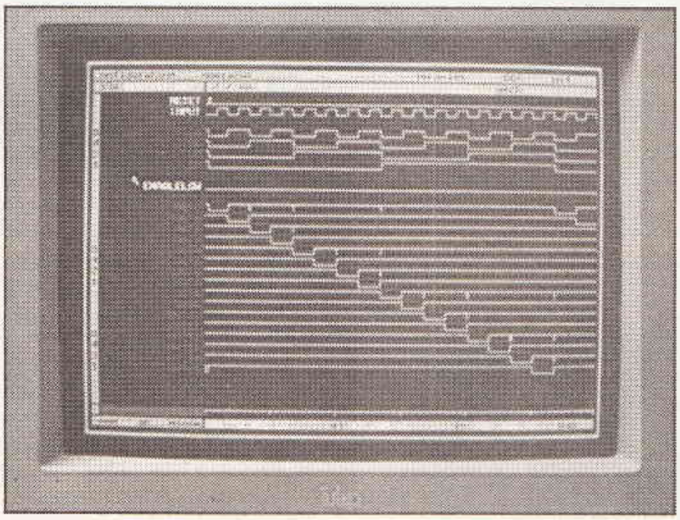
LOW-COST SIMULATOR

Number One Systems Limited, famous for its EASY-PC PCB CAD Program, has just announced a new Digital Logic Circuit Simulator Program, aimed at freeing engineers from the frustrations of designing with a 'scope and soldering iron.

Designs can now be tested and proved before a single component is soldered without the need for expensive test equipment. In many cases the breadboarding stage can be eliminated completely, allowing prototypes to be built directly on the PCB.

Pulsar is a digital logic circuit simulator with a logic analyser type signal display incorporating dual cursor readout in binary, hexadecimal or octal. Timing skews and glitches are displayed to a resolution of one picosecond in several days.

Pulsar will handle flip-flops, latches, monostables, and tri-state and open collector gates in addition to normal types.



Signal Generator patterns are defined on an interactive graphics screen, and may be connected to any point in the circuit.

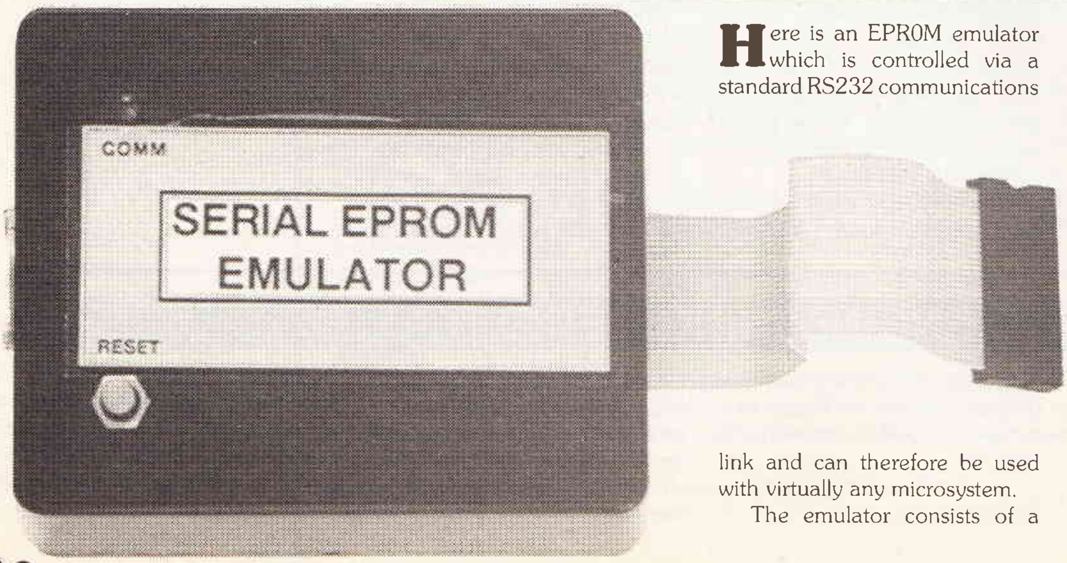
The new program features a full component library facility, allowing the user to add components, modules and sub-circuits to the full range of 74LS and 4000 series models supplied with the program. Component libraries for other logic families are available as options. Pulsar presents its output as a high-resolution logic analyser display, capable of being printed on either dot-matrix or laser printers.

It may be operated independently, entering and modifying circuit data through an interactive Netlist Editor, but it is also ready to link in with the forthcoming EASY-PC Professional Schematic Capture package and the Analyser III Linear Circuit Analyser, to form a completely integrated engineering design system.

Pulsar is priced at £195.00, complete with comprehensive manual and example circuit files. Pulsar is not copy protected and unlimited free telephone support is always available.

For further information, contact: Number One Systems Ltd, Telephone: St Ives (0480) 61778.

EPROM COPYCAT



Here is an EPROM emulator which is controlled via a standard RS232 communications link and can therefore be used with virtually any microsystem.

The emulator consists of a microcontroller which looks after the serial communications and the 32K bytes of emulation RAM and is housed in a practical ABS case measuring 98 x 114 x 45mm. The unit can emulate 2764 to 27256 EPROM types; a 28 way ribbon cable header is simply inserted into the target socket,whilst the data is sent via the RS232 communication link thus allowing remote programming. If the emulator was to be used in conjunction with a modem it could be possible for software to be upgraded remotely on site so eliminating costly service calls.

Further infomation contact JP Designs. Tel:0353 88325

POWER SCOUT

A new oscilloscope aimed at Plant Electricians and Maintenance Engineers is the Tektronix model 222 PS. The Power Scout is capable of measuring directly to 600V AC on both safe and fully isolated input channels. In addition, it has a 'Motor Trigger' function to facilitate AC variable frequency motor drive service. Other new benefits include field replaceable probes, increased battery operating time, a highly visible yellow case and an improved contrast green CRT filter for better viewing in high ambient light.

Standard features include fully automated operation, 10MHz bandwidth, digital storage capability with a 100ns glitch capture, continuous envelope mode, single shot storage and a 6kV surge rating for hunting out spikes and noise problems. All waveforms can be transferred via the RS 232C interface to a PC for storage, analysis and hard copy output. TIC supply this powerful tool in a rugged package weighing 2kg and meeting MIL-T-28000E standards for environment, shock and altitude.

Further information please contact Fred Hutchinson of Quiswood Ltd on (0756) 799737.

NEW PRODUCTION BOARD TESTER

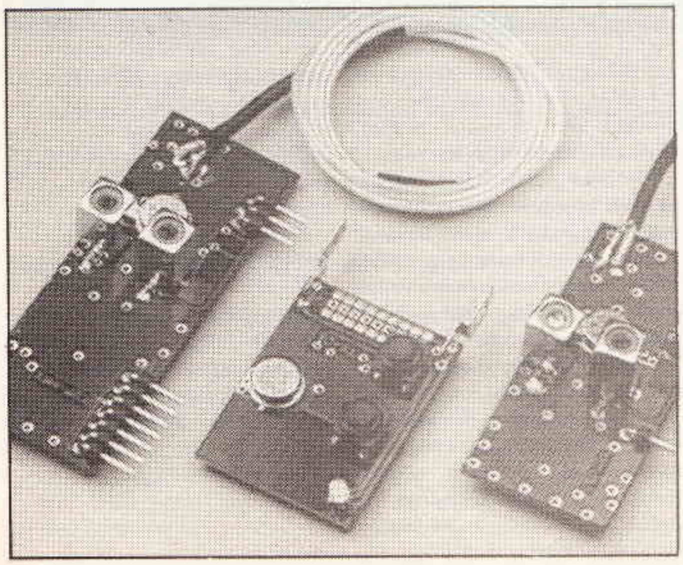
Schlumberger Technologies' ATE Systems Division has launched a 10MHz production test system — known as the S780 — uses the company's Computer-Aided Test Engineering (CATE) software and fully-integrated design-to-test links to significantly shorten in-circuit and cluster test program development times. The new system is specifically designed for easy integration with automated manufacturing systems, and forms part of Schlumberger's S700 range of ATE.

Schlumberger's CATE software was developed specifically to address the time-to-market issues facing electronics manufacturers. First introduced with the S790 tester just over a year ago, the software runs under Unix on a wide range of Sun computing platforms, and supports bi-directional links between design simulators and ATE systems to dramatically speed the development of high-quality test programs and diagnostic databases. The software can be used with Schlumberger's entire range of Series 700 ATE, and employs a colour graphical user interface with mouse-driven pop-up menus, icons and intuitive hierarchical structuring.

CATE software is already acknowledged as providing the fastest and most effective test program generation and management tools on the market.

Utility software will enable PCB schematics and board-layout diagrams to be imported direct from CAD/CAE systems over Ethenet.

CIRCUIT SECURITY



Seeing somebody securing their vehicle, locking doors and closing windows automatically by remote control is becoming quite commonplace.

European Security Products has developed a range of subminiature R/F switches for such remote controls suitable not only for vehicle entry systems but also for Plant machinery, Lighting systems, Commercial security and garage doors.

Surface Acoustic Wave (SAW) technology generates coded pulses over a narrow band of frequencies resulting in less sensitivity to surrounding radio interference. This is why the company incorporates the RFM-SAW devices in both transmitter and receiver. The transmitter sends a pulse width modulated at a carrier frequency of 418MHz to DTI and FCC standards, is powered by 12V and carries more than 20,000 codes with FIZ antiscan identification feature. Range is specified at 75 metres and models with a pre-amp stage specified at 200 metres, with a transmitter that can provide single or dual independent channels.

Clearly remote telemetry has become extremely significant with modern systems and is now dramatically enhanced with this cost effective system that complies with RF emissions limits without forfeit of performance and range.

For further information Tel: 0225 790730.

HHB'S NEW LISTENING ROOM

With the completion of a brand new Listening Room at the London headquarters of HHB Communications, customers can now audition and assess a wide range of professional audio products — using the full choice of monitoring systems from leading British manufacturer ATC.

The Listening Room has been optimised to provide the near-perfect environment for the critical evaluation of both active and passive models in ATC's SCM loudspeaker range.

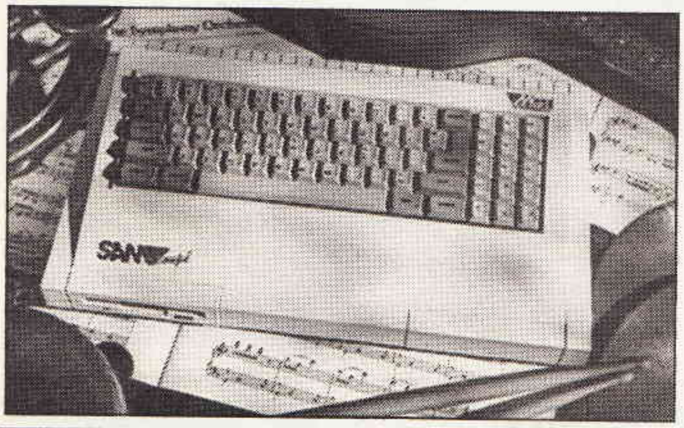
Also on demonstration is the RSS Sound Space processing system from Roland, as first seen on BBC's Tomorrow's World. FSS is a single-ended system, with separate Azimuth and Elevation dials for each of four independent processing channels. It requires no decoding circuitry to give the impression that sounds replayed through a conventional 2-speaker system are placed far outside the conventional stereo soundfield.

HHB Communications Sales Manager Steve Angel is understandably enthusiastic about the new Listening Room: "In spite of the advent of digital technology evaluation of audio products is as important now as it has ever been"

"The new Listening Room ensures that both we and our customers are better armed to make critical decisions about the performance of the latest in professional audio technology," he adds.

Further information contact Steve Angel, Tel: 081 960 2144.

PLAY IT SAM



The SAM Coupé is a music computer for less than £200.The Coupé contains one of the most capable synthesisers of any microcomputer. It has six channels across eight octaves with stereo. Additionally the Coupé is one of the very few computers fitted with MIDI (Musical Industry Digital Interface) as standard.

The SAM Coupé is attracting a lot of attention from third party developers. In music this has given rise to three new products:

A powerful MIDI sequencer, suitable for the home keyboard user costs £39.99 including MIDI cable.

A Sound sampler interface, microphone, control software and full documentation at £49.95 from Blue Alpha.

The Music Master is coming soon from Revelation. This software package drives the Coupés own synthesiser from its keyboard with full screen notation.

Further information contact Alan Miles, Tel: 0792 700300.

ELECTRONIC GLASS

Pilkington plc and the Toshiba Corporation, world specialists in glass and electronics, announced the development of the world's first virtual logic silicon chip. It is the first product arising from a major technical collaboration agreement in the field of semiconductor chips between the two companies in 1989.

The new silicon chip, launched at The Custom Integrated Circuits Conference in San Diego, California, is also the world's largest Field Programable Gate Array (FPGA) and marks a significant technological breakthrough.

The device is the first in a family of products planned by Toshiba using the unique Dynamically Programmable Logic Device (DPLD) technology developed and announced last year by the Pilkington subsidiary, Pilkington Micro-electronics Ltd.

Both companies believe the new technology will quickly become a world standard and they will continue their close technical collaboration to take advantage of the promising opportunities opened up by this new technology.

Pilkington, which has a long record in innovative technology, provided full technical data to develop the chip as well as its advanced design capabilities through its Pilkington Micro-electronics subsidiary. Toshiba developed the product and is manufacturing, marketing and selling it.

Toshiba plans to commence mass-production of the new chips in 1992 in order to meet demand initially in the rapidly growing FPGA market which is projected to grow at anywhere between 50 and 90% per annum.

Using CMOS 0.8μm, 3 layered metal process technology, the new device achieves the world's largest gate count in FPGA's and because of its dynamic reconfigurability can be considered a virtual logic device. With this development, Toshiba completely covers all aspects of application specific IC's (ASIC's), such as gate arrays, small scale PLD's and FPGA's. The DPLD technology will eventually impact into all of these sectors.

Pilkington Executive Director, Sir Robin Nicholson said: "We are delighted that Toshiba have launched this product which is the first practical outcome of the technical collaboration agreement between Toshiba and Pilkington which was signed two years ago.'

ETI NEWS stateside

Photovoltaic concentrator technology

The U.S. Department of Energy is supporting the development of photovoltaic-concentrator technology by distributing up to $12 million over four years among at least seven companies that now supply or are working on commercial, silicon-based solar panels. Sandia National Laboratories will manage the programme.

The DOE has set a goal of reducing the cost of photovoltaic power by 50% or more, from 25-30 cents/kwh today to 12-15 cents/kwh by 1995. Much of that reduction is expected to come from manufacturing efficiencies. The DOE progamme will support the development of mass-production techniques to help reach cost goals through economies of scale.

Several concentrator systems have been developed by the companies receiving contracts, but all are in the prototype stage. Sandia will not only manage the contracts but will also become an active participant by transferring production technology and providing design aid, testing materials and hardware, as well as access to its photovoltaic-testing, -fabrication and -evaluation laboratories.

Concentrators are solar cells onto which lenses concentrate sunlight. Because the cells received light is intensified, they tend to perform better and require less area than standard solar cells. Though the price per cell is high, it is expected that the concentrators' greater efficiency compared with standard cells will more than compensate for the cost.

On the other hand, concentrator photovoltaics are usually not as effective as standard cells when the skies are less than perfectly clear. They also usually need to be pointed directly at the sun, requiring that they be mounted on a tracking apparatus. Flat panels, by contrast, can operate in either direct or diffuse sun.

Technology goals for concentrator cells include increasing their efficieney; i.e. the ratio of the sunlight converting to electricity to the sunlight received.

There are two general categories of concentrator cells: linear focus and point focus. Linear-focus systems concentrate sunlight along a line. Their concentration levels are considered low, at 10 to 30 suns (10X to 30X the level of unconcentrated sunlight). But linear concentrator lenses can be made by relatively simple extrusion or rolling processes.

Point focus systems focus light on a point. Their concentration levels are considered intermediate, at 200 to 400 suns. Though they tend to provide higher efficiencies than linear focus systems, they can be more difficult to manufacture.

Commercial 20-sun cells are currently at about 15% to 17% efficiencies. The DOE wants to increase that to between 17% and 23%.

New approach to optical switching

A new approach to optical switching, based on diffraction gratings in which the index of refraction can be varied, is being developed at Physical Optics Corp. By using photopolymers that change their index of refraction when illuminated, it has been found possible to make diffraction gratings gradually deflect light from one direction to another. The process is ideal for building large, all-photonic crossbar switch arrays for fibreoptic applications. The continuous modulation of light also could be used to build optical neural networks.

Gratings are built by drawing parallel lines in holographic film with a laser. The laser acts to harden the film so that after chemical processing, a uniform grid of narrow channels remains on a substrate. This relief pattern is then spin-coated with a photopolymer, filling the space between the holographic film lines with a variable index medium.

When illuminated from the side with the grating at an angle to the beam, the system deflects light in proportion to the difference in index of refraction between the holographic film and the photopolymer. That difference is varied by illuminating the photopolymer from above. An optical switch has been demonstrated by building a grating at the intersection of two waveguides on a glass substrate.

Creating a super-conducting wire

Three U.S. organisations, Los Alamos National Laboratory, Sandia National Laboratories and Nuclear Metals Inc., are trying to create a super-conducting wire with a higher electrical current than is now possible with a manufacturing process patented by Sandia.

The wire is formed from a powder of yttrium, barium and copper oxide, encapsulated in a billet, and extruded through a die orifice under high pressure.

Sandia and Nuclear Metals have designed the billets and Nuclear metals will produce large-scale samples of the experimental wires.

Sandia will then perform small, laboratory-scale extrusions and mechanical tests to characterize the flow properties of the materials in the superconductors and billets. Los Alamos will determine the exact composition and properties of the components and the wire.

Los Alamos also may provide high-temperature superconducting bismuth compounds and compounds containing the metallic element thallium, if required safety measures can be put in place.

The participants, who are splitting the cost of the $800,000 three-year project, believe the first commercial superconducting wires could be in production in the near future. Nuclear Metals, of Concord, Massachusetts, will receive patent rights to the resulting wire.

Vehicle effect on EM fields

A 75-ft-diameter reflector with petals around the edge is helping the U.S.Army to measure the effect of vehicles on electromagnetic fields or patterns from antennas. Pattern disruptions can degrade antenna performance.

The reflector is part of a compact antenna range, which is test gear that picks up a wide band of electromagnetic frequencies at close distances. It allows testing of vehicles at frequencies that far-field ranges, which consist of two towers separated by large distances, cannot sense.

The petals dissipate sufficient electrical energy to create a quiet zone over about 66% of the compact-range refector. Patterns are stable in the quiet zone, permitting accurate measurements. Without proper dissipation, energy would create ripples and disrupt the patterns under study. Other compact ranges have quiet zones that are smaller than the one produced by the new design. This is because a large portion of the reflector must be left inactive to scatter electrical energy at the edges.

The new range consists of a 90-ton parabolic reflector and a positioner that elevates and rotates targets. The positioner can handle full-size vehicles up to 70 tons in weight and 50 ft in length, including the US Army's M-1 and M-60 tanks. The range is set up to test frequences from 6 to 40GHz. Previously, the Army could measure only frequencies less than 8GHz.

Software will use range data to generate a 3D plot of the antenna pattern. The plot will indicate which vehicles might have difficulty receiving some signals. Engineers can move the antenna or install a supplementary one to offset any deficiency.

The compact antenna range is located at the US Army Electronic Proving Grounds, Fort Huachuca, Arizona. It was designed by the Georgia Tech Research Institute, Atlanta.

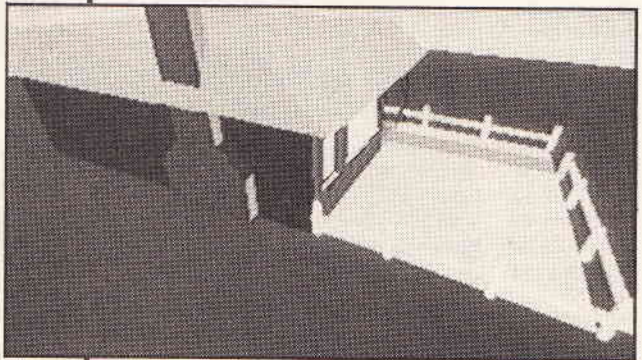
3

Towards Tomorrow

Virtual Reality

Virtual Reality is already here. But how will it affect our lives in the future once refinements have been made? Andrew Armstrong investigates.

Imagine you could reach out and pick up objects on a computer screen. If you have spent long hours working with advanced CAD or desktop publishing programs — both of which are notoriously difficult to learn — you have probably already experienced twitching in ~~your~~ fingers. Moving computer images manually is already possible to some extent, and will become more so, but this is only the beginning. Virtual reality is a concept which may in time make computers a complete window on reality or, at least, as complete as our perceptions can make it without total tactile feedback. At present, for instance, motional feedback can only be provided by mechanical systems, for instance, in a hydraulic flight simulator. That, in time, may change too.



Television and radio programmes has recently brought virtual reality to the attention of the public. It is not worth repeating all that these programmes have already said, but it is interesting to try to work out where this technology may be taking us in the future. In order to do this, it is helpful to trace some of the antecedents of virtual reality.

Many people use computers for tasks which would not otherwise be practical. Others play games, either realtime graphics games which are impossible without a computer, or games in which the computer is a fast replacement for pencil and paper.

All this is usually done with a flat display system. The realism of most '3D' graphics is limited, and the using of the system is often far from intuitive. There are some devices to make it less difficult for non-experts to use a computer effectively; joysticks for game playing, and GUIs (graphical user interfaces), such as Windows on PCs and their compatibles, or the Apple Mac operating system.

These make things easier for some purposes, but generally limit the choices available to the expert. Implemented thoughtfully, virtual reality could offer an environment which would be helpful to the lay user, and extend the reach of complex applications far beyond the present.

Reality-like environments can and do exist on computers in a two-dimensional format, but virtual reality requires a three-dimensional environment. The principles required for 3D display systems have long been known, and have occasionally been used in movies. All that is necessary to give the visual impression of three dimensions is to provide each eye with an image in the perspective which would be seen by that eye, viewing the scene in question.

When looking at reality, the focus of the eye must be constantly varied to accommodate objects at different focal distances. It is not necessary to provide this varying focal length for objects in a 3D display system.

In virtual reality, the images are supplied by two separate liquid crystal TV displays, with an optical system to project the images to the eyes at a reasonable focal length. The display is contained in a headset, which includes position sensors, so that the image can be adjusted to take account of head movements. This is makes it possible to look around, and walk around, a virtual room.

In order to interact with an image, a data glove is required. This senses the position of the hand and of each finger, allowing an image of the hand to pick up an image of an object. The principle is the same as that of dragging an object on screen using a mouse, but more naturally.

A dataglove can do much more than simply grasp: it's a convention in experimental virtual reality that, if you point the data glove, you 'fly' in the direction you are pointing. Your limitations are imposed only by the needs of the program: for instance, you can 'fly' through walls with impunity, but not, perhaps, in a flight simulation program. People who have experienced this ability to move at will have reported disappointment with actual reality.

The pointing and 'flying' could be applied to an object under your virtual control, as well as your own virtual movements.

Current two-dimensional graphical interfaces use a great deal of processing power. On, for example, a 12MHz 286 computer, many Windows 3 applications run very slowly. Generating three dimensional graphic shapes in real time demands very much more processing than 2D shapes, and until recently this rendered virtual reality too expensive for practical applications. Now however, virtual reality is penetrating those two most lucrative and advanced technological markets: industrial research, and games.

Applications

A present-day professional flight simulator for pilot training effectively consists of a real aircraft cockpit whose instruments are controlled by the simulation computer. High-resolution cockpit-view images are projected onto the windows, and the whole cockpit is tilted on computer-controlled hydraulic jacks to complete the illusion. Pilots can even forget that they are in a simulator. It is a very effective means of training people for a difficult and potentially dangerous job without putting lives or property at risk.

Virtual reality can provide all this, apart from the motion simulation, without a physical cockpit. At present, the image detail is not sufficient in reasonably-priced systems, but projecting computer cost/power relationships into the future, processors powerful enough to do the job will be cheap within a few years.

The lack of motional feedback may prevent virtual reality from replacing hydraulic flight simulators for a long time, if at all, but there are areas which are being investigated: the brain, for instance, can be persuaded to interpret certain kinds of visual feedback almost as positively as real movements. There remains a credibility gap at this point. However, virtual reality is already being used to accustom trained military pilots to combat environments.

Slightly less complex and accurate simulators provide a leap ahead in 'realism' in computer games. Virtual reality games systems are already with us, and it is quite likely that virtual reality combined with the already-popular type of mobile games chair will become the norm in a very few years. What then? Will motorbikes, hang gliding and funfairs eventually become relics of the past?

On a more prosaic level, one early application will be computer-aided design. Virtual reality is almost tailor-made for architectural modelling. An architect can construct an entire building, walk around the interior and exterior altering details and materials on the spot, or calling on the builder, surveyor or interior designer to join the inspection from their own virtual reality stations in any part of the world.

A more interesting use, perhaps, to scientists will be to design tailor-made molecules. Drug companies have for some time been using supercomputers and three-dimensional modelling techniques to help them to design drugs for specific purposes. The biological activity of a drug molecule depends largely on its shape. Using a computer programmed with information about what molecules are willing to bond to what others, bond strengths, bond angles, etc., biochemists are already able to examine chemical compounds in great detail. This approach has led to drugs which are highly effective for an intended task, and have few or no side-effects.

Virtual reality should allow a more thorough job to be done more easily. It will be practical to design more complex molecules with lower wastage and a better chance of practical successes.

When the manufacture of nanomachines becomes possible, the only practical way to design them is likely to be CAD using virtual reality. Nanomachines will probably be designed and built from a range of pre-defined molecule standard parts. The nanomechanical engineer will assemble virtual nanomachine parts into the structures required in a process rather like putting together Meccano. Using its data, the computer will then show the engineer a fairly accurate simulation of how the nanomachine would behave in use.

The simulation may not be perfectly accurate, but it will cut out a large part of the trial and error previously needed to develop drugs useful chemicals. An integrated CAD/CAM system will then provide instructions for computerised chemical systhesis equipment to produce the desired molecule.

Telepresence

Now comes the time to draw the distinction between virtual reality and its close relation telepresence. What is normally meant by virtual reality is a situation where scenes are provided by a computer either from stored images in memory, or from by calculations made by the computer on the spot from some predefined specification. For example, in a virtual office, you could be working with a complete digitised image of a desk, or on a set of instructions: "eight corners and a woodgrain finish" (and so on).

Telepresence, on the other hand, uses television cameras to provide the twin images for 3D viewing. This goes hand in hand with tele-operating, where the telepresent operator controls machinery, normally (at present) by using joysticks. It is likely that datagloves will take over from joysticks: using the dataglove to 'grasp' the image of an object would cause a remote robot arm to grasp the real object, for example.

At present, most remote control is done using cameras and a joystick, so that complex computer simulation is not required, but combination with virtual reality will allow a more natural and dextrous contact between the operator and the robot.

The need for control over machinery in remote or dangerous environments is likely to increase; another factor is social change. Factories could be run with a minimal human presence, allowing people to work away from heavy industrial sites and concentrate on jobs that make more creative use of human skills.

The applications in handling machinery in remote or hazardous areas will become ever more meaningful if mining and manufacturing moves into Space in the future, as many scientists expect. Indeed, as I write, UK astronaut Helen Sharman is heading for the Soviet space station to take part in experiments which are leading in this very direction.

She may be the only British astronaut, but very likely Britons will telework on Russian, American, Japanese, German or French space stations in future. The economic impact of this could be considerable, because it is likely that some of the highest value-added manufacturing will be done in space in the next century.

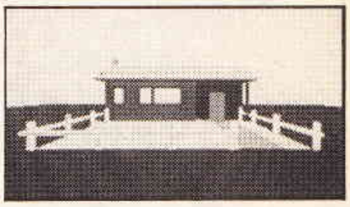
Just as state sponsored telecommuting in Sweden has prevented the need for mass migration from depressed areas, the same could apply to countries lacking physical access to space. Teleworkers could bring much needed foreign currency in to the economy.

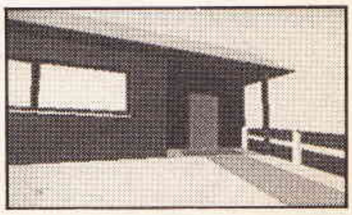
Later nanotechnological CAD may work partly by telepresence rather than only by theoretical simulation. A sealed nanotechnical laboratory containing raw materials and assemblers could be controlled by the computer so that as the designer moves groups of molecules in the virtual reality, equivalent actions are carried out in the nanotech laboratory. The computer simulation could then be adjusted to match what is actually happening in reality, giving a hybrid of virtual reality and telepresence, so that the designer is effectively telepresent at the molecular level.

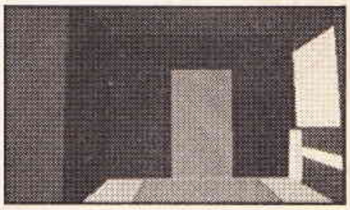
Mundane

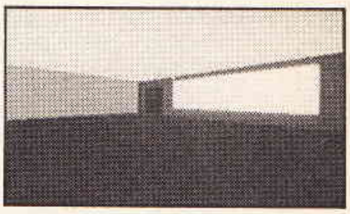
On a more day-to-day level, virtual reality will alter the way we see the computer in front of us. Extending the concepts embodied in flat screen graphical user interfaces, the data user could enter virtual reality, move around a stylised library block, be guided to a virtual filing cabinet, call up (quite literally: voice recognition is not far away) a virtual document folder, and examine the virtual documents. The combination of digital, visual and vocal interaction would give many of the benefits of physical action combined with the high speed and vast storage space conferred by the computer. Such a 'data stack' as I have visualised here would also combine facsimile document images with word-processed or DTP files. Little or no keyboard skill will be needed, and there may be less technophobia associated with virtual reality — claustrophobia, perhaps, could take over there.

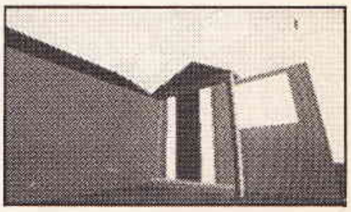
Taking the idea a step further, virtual reality may at last bring about the telecommuting revolution. Sitting in your office at home: you put on your virtual reality headset (by this time a smart pair of sunglasses, dis-











creetly linked by optical cable to your computer terminal). Your virtual office at HQ appears around you. You point your dataglove and move to your virtual desk, and your virtual in-tray appears. You confer with colleagues by entering their virtual offices, although it is more likely that you will call them up on a virtual teleconferencing screen within the virtual environment. Your virtual assistant appears in the corner (the door is optional) with an urgent and very real interruption — trouble at t'mill, 200 miles away. You switch to the virtual monitoring room at the machine shop and find that the robot assembler arms have been given oil without jam in it and are about to down tools. You reach for the virtual wall panel and punch it, bringing the virtual statutory maintenance down-time robot tea-trolley under your control, ready to run a diagnostic on the oil-delivery routine.

Having set the routine to run and reported back to head office, you remember that the emergency is over-running your own lunch hour. You quickly call up the virtual supermarket based at your corner shop, and scroll along the shelves — you could saunter, but today you are in a hurry — selecting the necessaries for your next few meals and, as an afterthought, some jam, enter your pin number at the virtual till. On a quieter day, you might choose to enter actual reality, jog down to the store, pick up a pack of milk, a sandwich and an actual newspaper, select the rest of your groceries from one of the virtual reality supermarket booths in the store, have a few friendly words with the storekeeper and jog back. Today you will have to make your own sandwich, and call up the paper or papers of your choice in your virtual document stack, but this is a small price to pay for not being at t'actual mill.

So virtual reality has two virtues: it can enable scientists, engineers and designers to undertake tasks of great complexity at remote distances; and it can provide a controlled environment for ordinary non-technical citizens to perform ordinary tasks: learning to drive, doing the month's shopping, visiting the bank manager, a business conference or dropping into the boss's office — from one place and with the benefit of immediate visual feedback.

Development of cheap, light virtual reality headsets will open up another possibility, that of 3D TV. While 3D displays can be viewed by several people simultaneously, they may prove difficult to design, there will be an incentive to use individual headsets for 3D viewing. Probably 3D videodisks and players will be around long before 3D TV is transmitted, just as stereo records were available long before stereo radio.

Real Effects

One of the most obvious potential problems of VIRTUAL REALITY is that people can confuse reality and simulation. Not a problem, you may think, in a flight simulator for pilot training, but the same is not true for computer games. Would it be safe to drive on the road after spending several hours playing a racing game in which, if you crash, you simply start on your next 'life'? Even a momentary sense of unreality could be fatal.

This possibility is not just speculation. Even with the low level of realism on present VIRTUAL REALITY systems, occasional momentary confusion has been reported. No doubt, if it becomes a problem, a law will be made to limit the realism of some types of game.

Another likely problem is that of computer games addiction. This problem is well known with flatscreen computer games, and is likely to be more severe and to aflict more people when VIRTUAL REALITY becomes widespread. There would seem no way to avoid this, which admittedly affects a small minority of people. It is simply an example of the unavoidable snags of every technological advance since the discovery of fire.

A good side effect of VIRTUAL REALITY, if it does encourage more telecommuting, would be the reduction of commuter traffic. With environmental concerns becoming more serious each year, any reduction of the need to drive around must be welcomed.

The Far Future

The idea of a direct link between brain and computer has been around for a long time, but it has never seemed very practical. Some years ago a blind person was enabled to see, after a fashion, by means of a television camera and an interface fitted inside the skull over the visual cortex. The person involved thought it much better than total blindness, but the idea has never caught on, partly, no doubt, because few people would be keen on such major surgery.

Despite its general unattractiveness, this experiment does show that some sort of direct brain interface is possible. It is probably not fundamentally impossible to generate a full colour image by direct brain stimulation. It may become practical if nanotech machines are used to build a microscopic interface on the brain without the need for actual surgery.

It may even become possible to get information directly out of the brain, though that may prove to be genuinely impossible. If it can be done, VIRTUAL REALITY could be made indistinguishable from actual reality, and even more possibilities are opened up.

If direct brain interfacing is possible, and is not rejected for reasons of distaste or social undesirability (eg computer addiction), then it will probably be done within the lifetimes of many of the people reading this article.

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8

HDTV

James Archer reports on the future prospects of a world standard for higher quality TV transmissions.

High Definition Television

Progress towards a world standard – the nineteen nineties

At the CCIR Plenary Assembly meeting in May 1990, what many considered the last chance to reach an agreement on a world standard for HDTV slipped by for another four years, as the decision was made to defer any agreement until the next CCIR study period, which runs from 1990 – 1994. We have been careful to distinguish between transmission standards and studio standards, but neither one of these has yet been achieved. Although many brave words about the importance of reaching an agreement on an HDTV standard were spoken, practical engineers can see that it now seems unlikely that there will be just one standard, and that for some considerable time ahead we are likely to see the Japanese 1125-lines/60 Hz standard competing with the European 1250-lines/50 Hz standard and an American standard perhaps based on 1050-lines/59.94 Hz. It is also important to remember that many other countries besides the USA and Japan currently use NTSC and therefore have an interest in an HDTV system that is NTSC compatible; during 1988 a group of thirteen countries using NTSC met to consider the wider implications that the adoption of an HDTV system would have. In spite of what the European engineers tell you, the Japanese 1125/60 system is currently something of a 'de-facto' HDTV studio production standard, with facilities houses in Europe and America making use of it, but this is mainly because there is no other HDTV equipment currently on sale. Test productions using the Sony High Definition Video System have been made, using equipment supplied (presumably on loan) by the manufacturers, by several European Broadcasters, including the BBC and HTV in the UK, RAI and Canale 5 in Italy, ORF in Austria, SRF in Switzerland, ZDF in Germany and RTVE in Spain. The EUREKA aim of promoting the 1250/60 system as a studio standard is likely to come to fruition as the project moves from the experimental stage and studio equipment becomes available for sale, but there are no indications that it will become *the* world studio standard – the Japanese system is unlikely to go away. Compounding the standardisation problems even further, the Russians have said that they do not favour any of the current proposals, and that they certainly do not intend to adopt the step by step approach based on MAC. They claim that such an approach would merely delay the onset of 'proper' HDTV. Similar sentiments have been expressed by the Australians, who feel that in the longer term revolutionary change is inevitable due to the coming of digital technology, and they feel that any approach to HDTV that has a heavy emphasis on backwards compatibility can at best provide only an interim solution. Australia advocates a digitally based single worldwide HDTV standard, but accepts that such a proposal must include a practical transitional path from existing systems to this new HDTV standard.

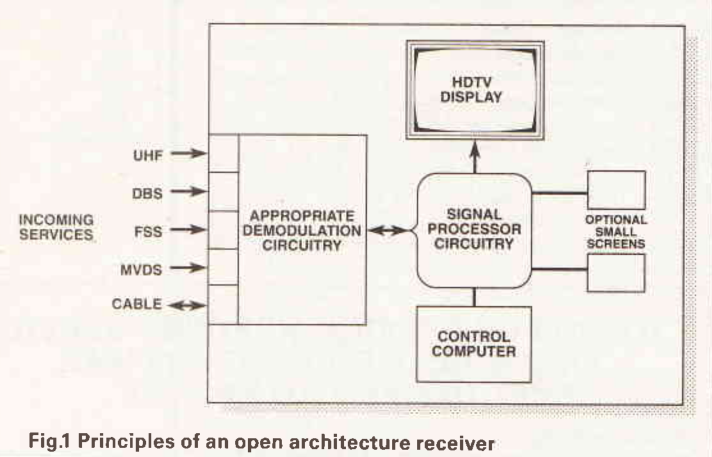


Fig.1 Principles of an open architecture receiver

Although many other engineers throughout the world would probably agree with these sentiments, it seems that to put these brave ideas into practice would delay the coming of HDTV for many years.

The groups of engineers working on the various HDTV projects have by no means given up their attempts at moving towards standardisation, however, and the currently fashionable idea is to try to reach agreement on some aspects of HDTV which can be regarded as common to all the existing systems, even though agreement on a complete system is unlikely to be reached. In other words, let us not worry about those things which we cannot agree on, but instead let us try to standardise those features of an HDTV system that could be common to all systems; as well as easing the path towards an eventual common standard this approach would make conversion between existing systems much simpler. The cynics say, with some truth, that the only parameter on which agreement has currently been reached is the aspect ratio; the whole world seems to agree that 16:9 could be acceptable, even if their currently favoured system actually uses something rather different. In fact there are agreements on a good many other basic characteristics as well, including things like the number of pixels per active line (1920) and the orthogonal arrangement of those pixels, and much work is currently being undertaken to try to reach mutual agreement on what are known as the 'Common Image Format' and the 'Common Data Rate' concept, the idea being to agree upon as many common parameters as possible; at the moment this work is mainly connected with the HDTV studio production field. The major remaining difference between the various systems is that of field rate, but so fundamental is this difference that it affects many of the other parameters of the HDTV signal.

Scanning: It seems to be generally agreed that progressive scanning would be the best long term option, but because of the complexities and the memory requirements when this is used for a full HDTV system, the various parties involved in trying to reach an agreed standard have recognised that 2:1 interlace is probably the most practical method of scanning in the near term. One manufacturer has suggested it might take as long as ten years to bring a 1000-line progressive scan camera onto the commercial marketplace.

Colorimetry: The CCIR expert going on colorimetry has accepted that in the long-term the agreed HDTV system should have colorimetric parameters which are in full agreement with the constant luminance principle, and which also allow for the representation of a wider range of colour than is at present possible. The experts are currently recommending this eventual goal should be achieved in two steps, first adopting an interim set of parameter values that can be put into practice with today's technology, leaving the final step to be taken after further discussion and development, — when practicable. Some engineers are unhappy with this approach because they feel it will be difficult to make changes to something as basic as the colorimetry of a system several years after its inception.

Common Image Format

The Common Image Format approach takes the long term view that television pictures may not always be synthesized by a scanning process, as at present, and that the best way to consider a television picture is as a large number of individual pixels positioned over the whole of the display screen. The desirable number of pixels per active line, i.e. that actually carry picture information on each line, has been agreed as 1920, but since the number of active picture lines has not yet been agreed, other parameters such as the shape of the picture elements cannot yet be agreed. One suggestion was to use 1080 vertical pixels per picture, i.e. 1080 active lines, since this would result in square pixels when a 16:9 display was used, and would provide a satisfactory number of visible lines for use with both 1125 and 1250 line systems. It would not, of course, be possible to use this number of lines with a 1050 line system. To illustrate that there is nothing 'magic' about the chosen numbers, an alternative suggestion, that has now been dismissed, was to have 1024 active lines and 1792 samples per line; this also gave square pixels, with an aspect ratio slightly different from 16:9.

The ideal 'common image' would have the same aspect ratio, number of active lines, number of pixels per active line and colorimetry irrespective of the frame rate or scanning method utilised. Many engineers like the 'common image' approach because it is rather like the electronic equivalent of film, where all the pictures are based on a single common image — the frame. If a common image approach could be agreed upon then standards conversion between the different HDTV systems would be simpler, since only temporal conversion would be needed. Although the 'common image' concept would mean that the active portions of the image, horizontal and vertical, would be the same for all systems, the blanking periods and total line periods and total numbers of lines could be quite different in different systems, which should enable HDTV to be introduced in a manner that is compatible with existing line and field rates that differ between different systems. The American ATSC favours the common image approach, and has said that it requires its HDTV production system to work at both 59:94 Hz and 60.00Hz, the former to maintain compatibility with existing transmissions, the latter for use in production centres where NTSC compatibility is not a consideration. Although such a dual frame rate approach could give rise to complications if attempts were made to edit between tapes using the different frame rates, the common image concept should be able to cope with he basic requirement of producing HDTV pictures at either of the two rates.

The Australians have a slightly different vision of what a common image format should include, and as well as a 'common image' of the type mentioned above they favour a 'common frame'. [N.B. It is important to notice here that the Australian use of the word 'frame' corresponds with the English word 'field'; two Australian frames make one complete picture.] The common frame would have the same total number of lines (active plus blanking), whatever the actual frame rate. This would provide for operation at different

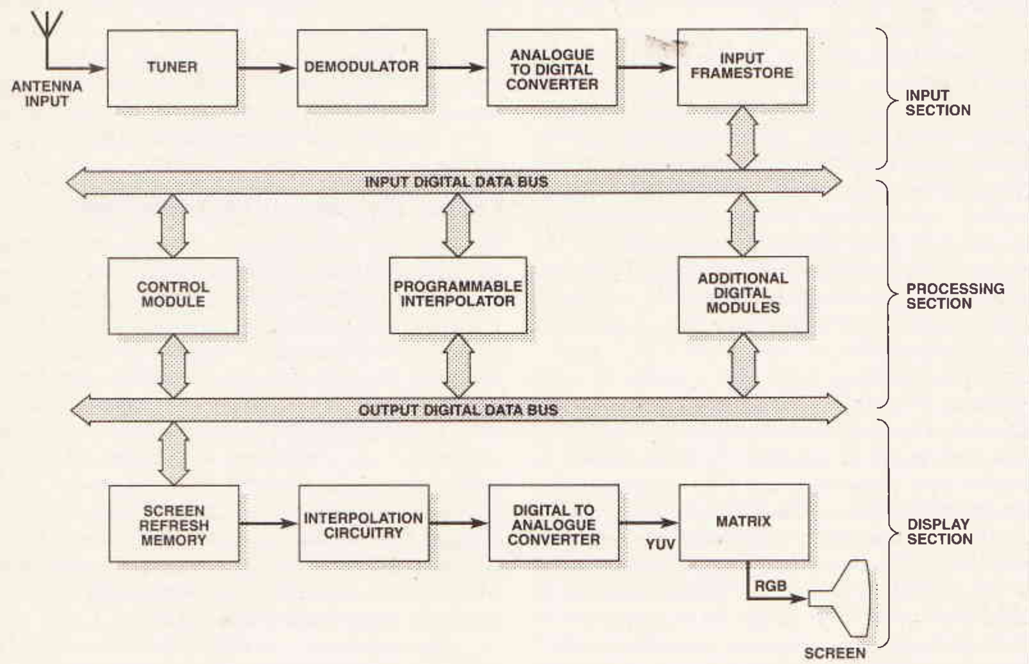


Fig.2 The MIT Smart Receiver — showing how 'open architecture' works.

frame rates, and the Australians favour a so-called 'agile receiver' which could cope with different incoming frame rates.

Whatever the small differences in the perception of the common image format, the idea can be seen to imply in essence a commonality of spatial characteristics for the active area of the picture, so that the number of samples per active line, the aspect ratio and the number of active lines is common, whereas the picture rate, the sampling frequency and the data rate could differ between systems.

Although the Common Image approach has much to commend it, the common image details cannot yet be agreed and could mean this approach will bring us no nearer to reaching a common standard than using any other approach, and could actually delay the final denouement.

The Common Data Rate

The world standard for digital television studio signals, CCIR Recommendation 601 has data rates for both 525 line/60Hz and 625 line/50Hz systems that are the same, adjustments being made to the number of samples carried in the blanking periods in order to achieve this. Effectively, Recommendation 601 is based upon a common sampling frequency, a common sampling mode, a common sampling structure, and a common number of pixels per active line for both 525/60 and 625/50 pictures. The 'common data format' for HDTV builds on the ideas of Recommendation 601, and is essentially a two-step 'dual-standard' approach to a single programme exchange standard.

The 'common data rate' approach uses techniques in which the sampling frequency and the data rate are the same for systems which have different picture rates; the aspect ratio and the number of samples per active line are also common. The luminance sampling rate for Recommendation 601 is 13.5MHz, with two colour difference signals sampled at half this rate, so that at eight bits per sample we end up with $8x(13.5 + 6.75) = 216$ Mbits per second. Although the first step would be to utilise HDTV standards that were based on the same rates as CCIR Recommendation 601 and therefore using a common data rate for both 525/60 and 625/50, the next step might be to use a higher common data rate, and 74.25 MHz (5.5×13.5MHz) is one rate that has been suggested. This would allow commonality between 1125/60Hz pictures and 1250/50 Hz pictures, and the mathematics shows that an even higher standards of 1375 lines at 50Hz would also fit into the set. Research engineers at the UKIBA have shown that other options are possible, whilst retaining a simple relationship with Recommendation 601, which is important for standards conversion to conventional standards:

1250/50 – 1050/59.94 1200/50 – 1001/59.94
1250/50 – 1125/60 1200/50 – 1000/60
1375/50 – 1125/60

Although any of these options could theoretically be used, the set with most of the advantages seems to be 1200/50 – 1050/59.94, both using progressive scan, since the relationship which this bears to the original 4:4:2 signal of Recommendation 601 corresponds to an increase by a factor of two in both horizontal and vertical directions, and the reader may remember that one of our aims in approaching HDTV was to double the resolution of the existing systems both horizontally and vertically. this scheme could be implemented with either an orthogonal sampling structure, or with the quincunxial structure that was discussed earlier in the series. The quincunx structure has the advantage of allowing us to retain the detail from a progressively scanned picture even when interlaced transmission is used, and this helps to improve the performance that can be obtained from standards conversion. It could also allow for interlaced scanning to be used as an initial step in the introduction of HDTV, with progressive scanning following later.

One scenario that has been discussed is that dual standard switchable equipment could be made for both studios and receivers, so that initially both standards could be used in appropriate countries, but leaving open the possibility that one day the overwhelming advantages of one of the systems would become so apparent that it would become the 'de facto' world standard. This argument ignores the probability that such receivers would be more expensive than single-standard equipment.

As might be expected, not everybody likes or supports the common data rate approach to HDTV. It is by its very nature a dual standard system, which means that some desirable combinations of other standards might not be practicable. The Canadians have done some work which suggests that when this type of approach is used it is inevitable that one of the standards must have a lower spatial resolution than the other, and they feel that this will delay the eventual implementation of a single standard.

Open architecture receivers

The idea of dual-standard receivers provides a reminder that in an earlier part of this series it was mentioned that the Massachusetts Institute of Technology (MIT) had suggested the adoption of so-called 'open architecture' (OAR) receivers, making the argument that if dual-standard receivers were being developed it might cost only a little more to develop OAR receivers that could decode lots of different standards, i.e. receivers that were basically independent of the transmission standard used. Such a receiver would use whatever information was presented to it, and somehow build up a suitable picture for display. Looking at this idea in a broader time frame we could envisage a television system using OARs that looked something like Figure 1.

Signals from a wide range of sources could be received in the home or at a cable head end and then fed by cable distribution systems to the home. The Open Architecture Receiver would consist of appropriate input circuitry to cope with the various incoming signals, some computer controlled signal processing circuitry, and a display of the highest quality that the customer chooses to buy. Whatever the standard of the incoming signals the computer circuitry associated with the OAR takes control of them and uses them to build the best high definition picture possible in the circumstances. Additional outputs from the OAR could feed other, small screen television receivers in the same house.

The MIT submission to the FCC included details of a possible configuration for a receiver of this type, which they christened 'The Smart Receiver'. Figure 2 shows the block diagram, from which it can be seen to consist of three basic sections.

The input section, shown along the top of the diagram, consists of the necessary tuner(s), RF and IF amplifiers, a demodulator, an analogue to digital converter, and a frame store. This section of the receiver is said to be 'tunable but not programmable'. Whatever the input signal, within the limits of what the tuner and input section can cope with, a complete picture frame is held in what is called the 'input frame store', although this is not necessarily in a form that could be used directly for display.

The central section of the diagram consists of input and output signal busses which provide the interfaces between the input and display sections and the processing section. The same digital bus lines can be used to connect digital input signals directly to the receiver, allowing it to synthesize a display from digital signals coming from a fibre optic cable, perhaps, or allowing for the connection of a digital video recorder or the input of computer data or graphics. The main function of this middle section of the receiver is to take the stored information in the input frame store and process it, perhaps rearranging the information corresponding to particular pixels and by carrying out the various interpolation processes that are needed to construct a high quality picture with the desired aspect ratio. The processing that is carried in this section is controlled by the microprocessor control module, which can be pre-programmed or which can accept messages from the remote control unit operated by the viewer. Effectively we have, in this central part of the smart receiver, a computer processing stage which could be very cheaply mass produced. The advantage of using such circuitry is that by a change in the programming, a picture can be constructed for whatever signal is presented to the receiver; without using complex convertor circuitry, the receiver can cope with PAL, NTSC, MAC, or wired inputs.

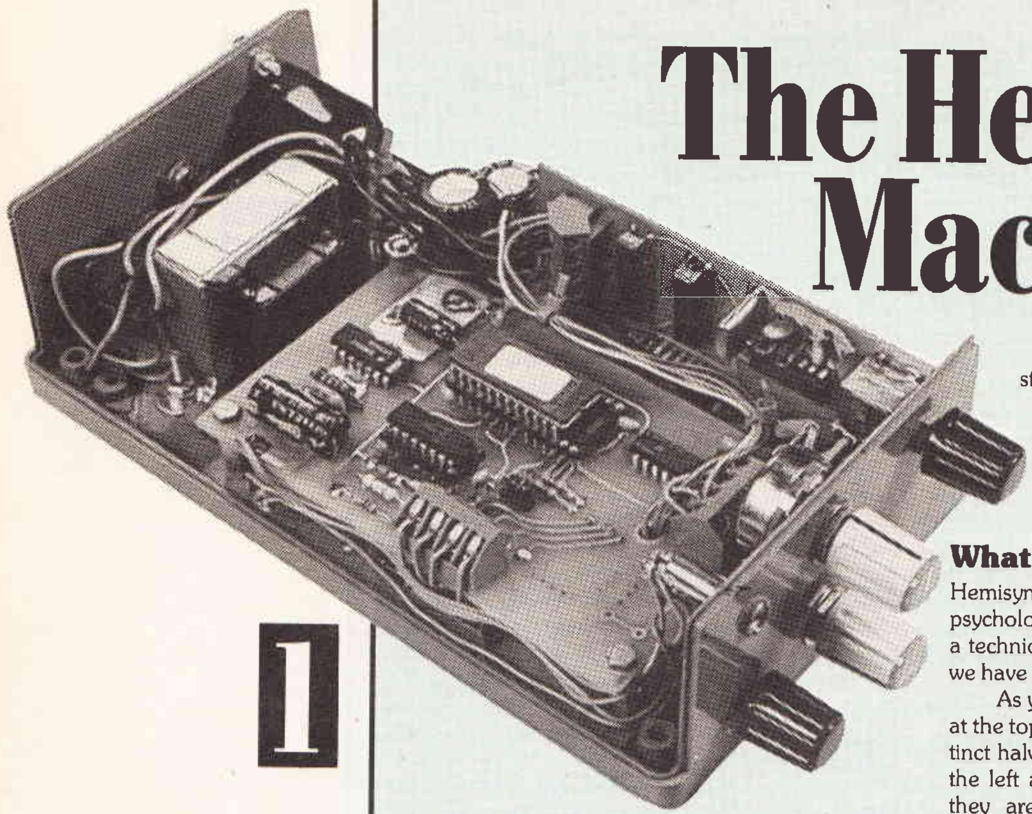
The display section, shown along the bottom of the diagram, takes its input from the central processing section and holds information from which an image can be recreated in the 'screen-refresh memory', at a line and frame rate suitable for display, but not necessarily bearing a direct relationship with the line and frame rates of the signals that were originally transmitted. It seems likely that this display information could be held in some compressed form. The output from this memory store could then be passed to interpolation circuits before being converted back to analogue form for final display. The display could be a high line rate, high frame rate HDTV format, but different versions of this basic receiver type could also be made available, each having a different type of display, according to the requirements and the depth of the pocket of the customer.

Such an open architecture receiver would, because it is controlled be a computer program, be easily adaptable to cope with the different types of television signal that will be available during the next few years, as the various steps towards HDTV are taken. It could even cope with new types of signal which were not thought of at the time of its construction — a change in the computer program would be all that would be necessary to allow it to deal with the novel signal.

Virtual Studio Standard

It is recognised by those involved in the long and arduous process of trying to achieve standardisation in the field of HDTV that in the longer term we are likely to develop digital HDTV systems, and it is in the digital domain the real key to the future of HDTV lies. Looking ahead to such times when the practical realisation of digital HDTV signals in both production and transmission might be practicable, the concept of a 'virtual studio standard' has been suggested. The kernel of this idea is that it should be possible to agree upon a single unique format for carrying the digital data representing an HDTV signal on a digital data bus, which could be used to transport HDTV signals between different pieces of equipment or between studio centres, and which could be used to record the signals. The actual standards used for the pictures and sound at the source and at the destination would be unimportant, as all the input and output signals would communicate with the universal bus by means of digital 'gateways', where the standards conversion to and from the universal bus standard would take place. Such a technique would allow broadcasters to exchange programmes made in a whole variety of different standards, but since the possibility of several standards conversions taking place between source and display would then be a real one, the 'virtual studio standard' will need to be of very high quality in order to ensure that it does not contribute any undesirable artifacts to the pictures.

It is generally accepted that using a digital system will provide the most flexibility and allow powerful computer processors to be used, but it will be necessary to ensure that the bit rates required for such a system are actually practicable; there would be no point in agreeing upon a theoretical system that did not permit equipment to be made at a reasonable price. In developing such a system, care must be taken to allow sufficient 'headroom' to cope with future developments that might arise. Up to the present time, the 'virtual studio standard' concept is nothing more than a concept; although much thought is being given as to how such ideas might be turned into something more concrete, and the 'common image format' and 'common data rate' could perhaps be regarded as steps along the way, it seems that we are as far away as ever from a single universal standard and inevitable that the next stage of development will see the introduction of at least three different HDTV/ATV systems to the different marketplaces of the world. Although this rather depressing scenario might be thought sufficient to dull the ardour of the keenest of research engineers, this is not the case, and in the final part of our HDTV series we take a longer term view, and find that once the present day technological restrictions have been overcome the prospects for the early part of the next century are really exciting.



The Hemisync Machine

1

Aubrey Scoon presents an audio project that could help you to exercise and encourage your brainwave patterns.

In recent years there has been a lot of public interest in the subject of 'brain improvement'. This has mostly taken the form of interest in biofeedback techniques and exotic forms of meditation. Whatever the technique, the emphasis has been on self discipline with results usually only occurring as the result of sustained and intense personal effort.

However, it is only comparatively recently that the public eye has turned to other methods, which promise the same kind of benefits as techniques such as biofeedback, but without the effort. These have been in the form of brain 'exercise' machines that operate on the premise that it is possible to induce meditative states and the like by an external stimulus. The ETI dream machine (November 1987 issue) is a simple example of the latter kind of device.

This project is another of that kind. It is called a Hemisync Machine.

What is Hemisync?

Hemisync is a term that was coined by the American psychological researcher Robert Monroe, to describe a technique he developed. To describe the workings, we have to examine the structure of the human brain.

As you probably know the cortex (the wrinkly bit at the top!) of the human brain is divided into two distinct halves, laterally. These two halves are known as the left and right hemispheres respectively because they are broadly hemispherical in shape. Much research has been done on the function of the hemispheres and it has been determined that each tends to assume a specialised role in the brain. The right hemisphere controls the left side of the body and is usually found to be responsible for the brain functions associated with spacial manipulation and creativity. The left hemisphere controls the right side of the body and is generally associated with logical, mathematical and verbal functions. Despite this specialisation in use, either side is capable of assuming functions of the other if necessary (i.e. if one hemisphere gets damaged).

The hemispheres, despite being separate structures are joined by a bridge of nerve fibres called the Corpus Callosum. This serves as a messaging network between the halves so they can keep track of what the other is doing. A few years ago a special kind of surgery was often performed to help epileptic patients which involved cutting the Corpus Callosum. The result was that the two halves of the brain in these patients started functioning independently, to the extent that in some

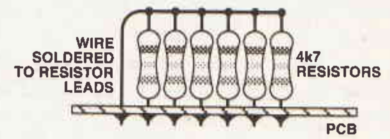


Fig.2 Front and rear panel dimensions

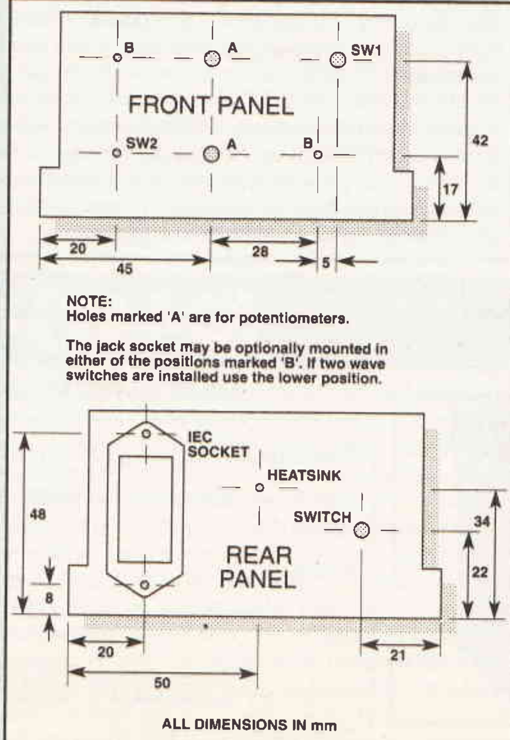
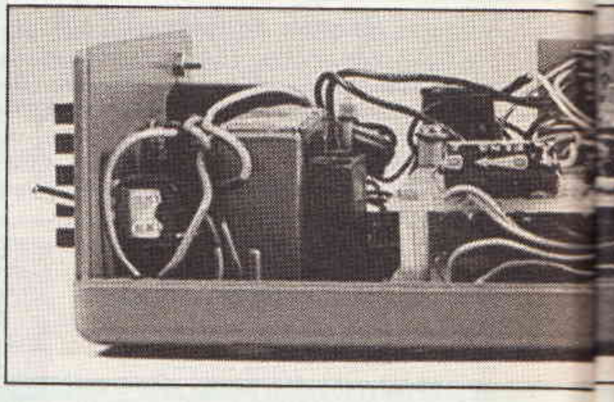


Fig.1 Alternative to SIL resistor network



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cases patients literally discovered that their left hemisphere didn't know what their left hand was doing! This resulted in interesting occurrences such as people being able to do something with their left hand yet being totally unable to describe it in words!

As a result of these and other studies, experimenters found increasing evidence that the brain normally performs an integration of information entering either hemisphere. If either hemisphere experiences a sensory input from its side of the body i.e. either hand or either ear (the eye connections are a bit more complicated) the net effect experienced by the whole brain of a normal person is usually comprised of a synthesis of the impulses from the two halves.

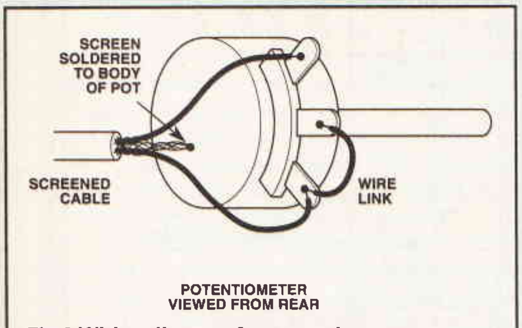
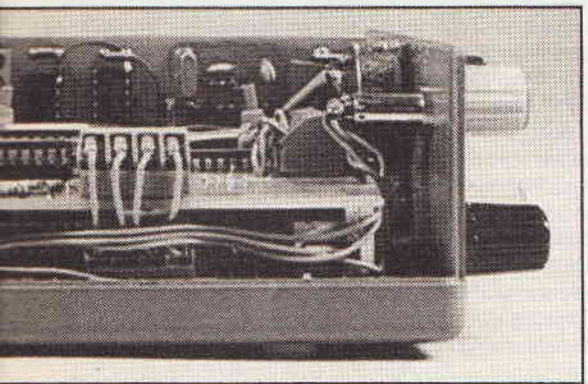


Fig.3 Wiring diagram for potentiometers

To give an example of this you can try an experiment. What you do is get three people together and get each of the first two to simultaneously ask the third person (the subject) a simple question, each addressing the subject from different sides (i.e. one to each ear). Very often (it works best when the subject isn't expecting it) the person questioned in this way will give a single composite answer to the two questions! For example if the first question is, "What is your name?" and the second question is, "How old are you?" and the subject's name is Fred say and he is 32 years old, his answer may well be "I am 32 Fred years old!" The best part is that the subject is often quite unaware that anything out of the ordinary has happened!

At this point I had better say that I accept no responsibility for the inevitable chaos that will ensue when ETI readers start going around confusing people by saying odd things into each ear!

Anyway, the hemisync machine works on a similar principle. The object of many people who dabble in biofeedback is to train their brains to produce a specific type of electrical activity pattern. This is usually the well known Alpha brain wave pattern (cyclical electrical waves of varying frequency between 8 and 12 Hertz). I won't go into a detailed discussion of the brain waves here as there are many good books on the subject. Suffice it to say that production of Alpha waves is associated with a relaxing meditative state, and the production of other wave patterns with other mental states, e.g. Theta waves (4 to 7 cycles per second) are associated with creative imagery.



The hemisync machine is essentially a highly accurate dual audio waveform generator. It generates two tones of slightly differing frequency. The separate tones are fed independently to each ear via headphones and this results in each tone being fed separately to the two different hemispheres. At this point the brain performs its integrating trick and generates a composite response pattern. The response in the case of two differing tones is usually a series of electrical impulses equal in frequency to the difference in frequency of the two tones.

This means that if we feed a tone say 200Hz to one ear and a tone of 210Hz to the other, the brain will start generating electrical pulses at 10Hz internally. The result: instant Alpha waves!

This is the idea behind Hemisync. If we can find a way of stably and accurately generating tones like this we can in theory at least cause the brain to generate any frequency of wave we like, within reason of course!

This idea has been (and still is!) the subject of much controversy in the medical community. Some researchers into brain function have been quick to point out that the waves induced by a Hemisync device are not in fact true brain waves. So they rightly point out that it is incorrect to say that we can create Alpha waves say, at will. The implication is that there is no benefit to doing so. It is certainly true to say that there is no evidence that inducing brain waves using external devices will result in the same psychological state that would be present when the brain is generating those same frequencies naturally.

Experimenters who have been testing Hemisync devices however have made varying allegations as to its practical effects. These range from the mundane claim that the devices act as aids to relaxation, to the fantastic Robert Monroe, the inventor of Hemisync claims that it can easily induce out of the body experiences and raise the operation of the brain to higher plane! Monroe has established centres for Hemisync experimenters. In one such centre he claims to have trained 'Heminauts', people capable of using Hemisync to transcend the limitations of time and space, these people in turn claim to have visited other times in an out of the body state! One such is said to have gone back in time to the Crucifixion of Christ!

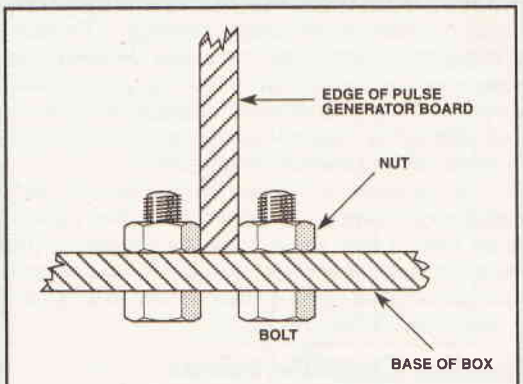


Fig.4 Securing the pulse generator board with two bolts

As a result of these and other claims, Hemisync is now big business. Recently there has been an influx of Hemisync devices from the United States and consortiums have even started to set up 'brain gyms' for people who want to go and tone up their grey matter with Hemisync! The commercial Hemisync machines are typically expensive (£300 upwards in general) and many use a combination of tones fed to the ears via headphones, and simultaneous pulses of light fed to the eyes via specially modified glasses that carry flashing light units. There is a danger however in the latter that this can cause seizures in people with epilepsy,

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and so many doctors are worried about the adoption of such devices. The design described in this article uses sound only and as such should be quite safe.

The connections to the eyes are not as simple as those to the ears in any event. In fact, half of each eye is connected to one hemisphere. So for example, the left halves of both eyes are connected to the right hemispheres and the right halves of both eyes to the left! This means that flashing light signals applied to each simultaneously do not affect the separate hemispheres in the same way the audio only version does. For this reason there is some doubt as to whether some visual versions of these machines are effective in the way they claim.

So what will the Hemisync machines do for you? The answer is nothing if you unfortunately happen to be deaf in one ear! For the rest of us it depends on both the frequency of the signals generated and the shape of the waveform that you use. This design will allow you to try 16 different frequencies of composite waves from 2 to 18Hz approximately, in 1Hz steps. This covers all the classical brain wave frequencies of Delta through to Beta waves. It also uses an EPROM with user definable data to generate one of 16 switchable waveforms. Additionally, the range of possible waves that the user can create by programming his or her own EPROM is virtually unlimited. If that isn't enough, each separate tone generator uses a different EPROM so you can experiment with sending different wave shapes to each ear simultaneously!

There are so many possibilities that its fair to say that many haven't even been tested yet! Having personally experimented with prototype machine I can say that I have found certain patterns to be very relaxing, and others to be stimulating. Whatever the reservations of the medical community, there is little doubt that the device can affect the metal state in some way, although perhaps not as simplistically as some of its more radical adherents would have it.

In any event, its certainly fun to play with, and even though I have yet to discover the correct pattern to go back in time and observe the Crucifixion (I'd rather go forward and see the result of tomorrow's races personally!) I have enjoyed experimenting with it, and hopefully you will too!

Design Considerations

At first sight it appears to be quite a simple problem to tackle, to generate two slightly different frequencies and feed them to a set of headphones. The problem is that the difference in frequencies has to be so small. There is little point in generating difference frequencies outside the normal operating range of the brain. This means that effectively all the frequencies of interest are below 20Hz. Consider also that the two tone generators have to maintain their frequency stability to within less than 1Hz and ideally also maintain a constant phase relationship and the problem becomes a bit more difficult.

My earliest prototypes of this circuit were analogue, however despite my best efforts even the most stable designs exhibited temperature related drift that exceeded the design limits. It became obvious that a digital approach was required. The problem was to generate two tones in the audio range such that each could preferably be easily generated by direct binary division of an input frequency. One channel could be fixed and the other variable. So a second consideration was that the variable channel ideally ought to use division factors that it would be easy to switch between with a minimum of circuitry. I decided on a target fixed frequency in the range of 100 to 300Hz since I personally find the lower frequencies preferable for extended listening. This design uses

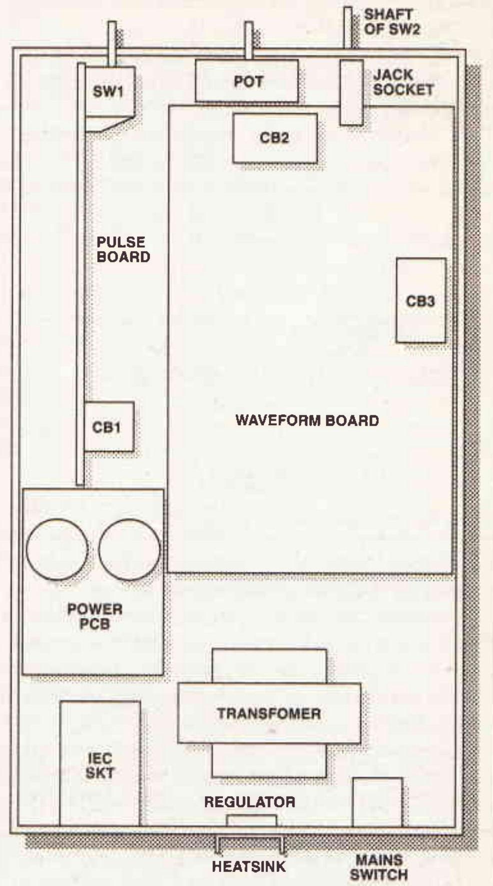

Fig.5 Layout of case

approximately 200Hz.

After some thought I worked out a relatively simple variable divider circuit but the final pulse streams were square waves. After experimenting with filtering to remove higher harmonics and produce sine waves I decided that it would be more flexible to use an EPROM to program the desired envelope of the wave. The pulse generator then could be used as an accurate clock to the digital waveform generator.

That then is the fundamental idea of the present circuit. Two digital divider channels provide clocking pulses to an 8 bit binary counter that in turn drives the address lines of an EPROM. The data in the EPROM is clocked out repetitively across 256 pulsed and fed to a digital to analogue converter which constructs the analogue voltages corresponding to the wave envelope. Two identical but separate waveform generator stages are used, one for each channel.

One of the earlier prototypes used a single EPROM operated in a time division multiplexed mode, feeding separate latching channels of a dual D/A. The problem with that design was that the multiplexing signals tended to generate spurious harmonics in the output waveform and there was a lot of crosstalk between channels. I decided that the dual generator approach was not much less economical (it didn't need all the multiplexing logic for a start) and offered more flexibility in the form of independently programmable waveforms on each channel. Additionally, the ZN559 is an excellent very low cost D/A converter and much cheaper than a dual unit.

Construction

The Hemisync machine requires 4 PCB's, the power supply, the pulse generator and 2 waveform generators. I designed the machine in modular fashion because I was experimenting with numerous different circuits. This became a useful design feature in the end, in that it allowed me to squeeze the whole circuit into a relatively compact box.

The pulse generator and waveform generator PCB's are double sided. I have designed them so that they can be constructed without the need for plated through holes. This is the reason for some of the otherwise redundant through hole wire links, LK1 through LK6. Although the two waveform generator boards are identical, unless you want independent control of separate waveforms on each channel, only one hex switch and set of associated pull up resistors is necessary. Of course if you do want that level of control then the extra switch and resistors may easily be installed. I would suggest though that for most constructors this isn't really necessary, I haven't done so on my prototype for example.

If you decide not to have independent waveform controls on each channel, then do not solder in SW2 or R5 through R8 on one of the boards. They must be present on the other though! If on the other hand you are going to add the independent switch controls to both boards then you don't actually need the connector block CB3 on either board.

None of the circuits are particularly critical or difficult to construct. When putting together the pulse generator remember that the leads on the analogue components should be kept as short as possible in order to minimise interference. The pulse generator board uses a 6 way SIL commoned resistor network as a pull-up for the hex switch inputs. I used it because I happened to have one in my component stock! If you have any difficulty in obtaining one it is relatively easy to substitute 6 ordinary resistors. These should be soldered vertically into the 6 holes furthest from the switch in the position of the resistor network. The hole nearest the switch is the common line and a wire should be taken from this point and soldered to the top leads of all 6 resistors adjacent to it. See Figure 1 for an example. An alternative would be to use a 7 or 8 way network which are easier to obtain and simply trim away the redundant leads.

Although the boards are double sided and not plated through, you can use sockets for the IC's. This can be a problem with non-plated through boards since you can't get to the connections on the upper side of the board under the socket. I usually use turned pin sockets for the IC's like this. Turned pin sockets are usually designed so that they stand off from the board by a small amount. This allows you to solder to the upper connections on the board on the component side under the lip of the socket, but it requires great care and a very fine iron so as not to damage the socket or create blobs of solder which will short out the circuit. If you can do this I would certainly recommend doing so at least for the EPROM socket if nothing else. If you do decide to do this then solder the socket on first, before you add any other components to the board. Otherwise you may find that the other components will get in the way of the iron when you are trying to reach into the small gap below the socket.

A compromise for the faint hearted (or those with huge irons!) would be to solder individual wire wrap socket pins in each hole of the IC position to construct a kind of home made socket. If you do decide to do this, plug an old IC into the pins while you are soldering them in place otherwise they will move around making it impossible to plug a chip in.

The LM380 audio amplifier IC should not be socketed. The reason being, the 3 most central pins on either side of the IC are connections to an internal heatsink and are designed to be soldered to an external heatsink in the form of an area of copper on the board. I have allowed just such a plane of copper on the waveform generator board as a heatsink although this is not strictly necessary given the normal operating conditions of the IC in this circuit.

The order of construction is unimportant, although I would recommend the standard practice of soldering passive components to the board first before adding the IC's. Construct all the PCB's first before attempting any interwiring, or trying to mount them.

I have designed the Hemisync machine to use a 2732 EPROM. Since each different wave cycle needs 256 bytes to define it, this allows 16 separate waveforms to be stored. Despite this some readers may find that larger EPROMs such as 2764's are both cheaper and easier to obtain since the 2732 is effectively obsolete. For that reason I have made allowances for the circuit to use any EPROM in the range 2732 through 27512. However, the circuit makes no allowances to use the additional address ranges of the larger EPROMs. If this is required the reader will have to make his own modifications to the circuit. I have provided a 28 pin socket on the PCB and a jumper. When a 24 pin 2732 EPROM is being used it

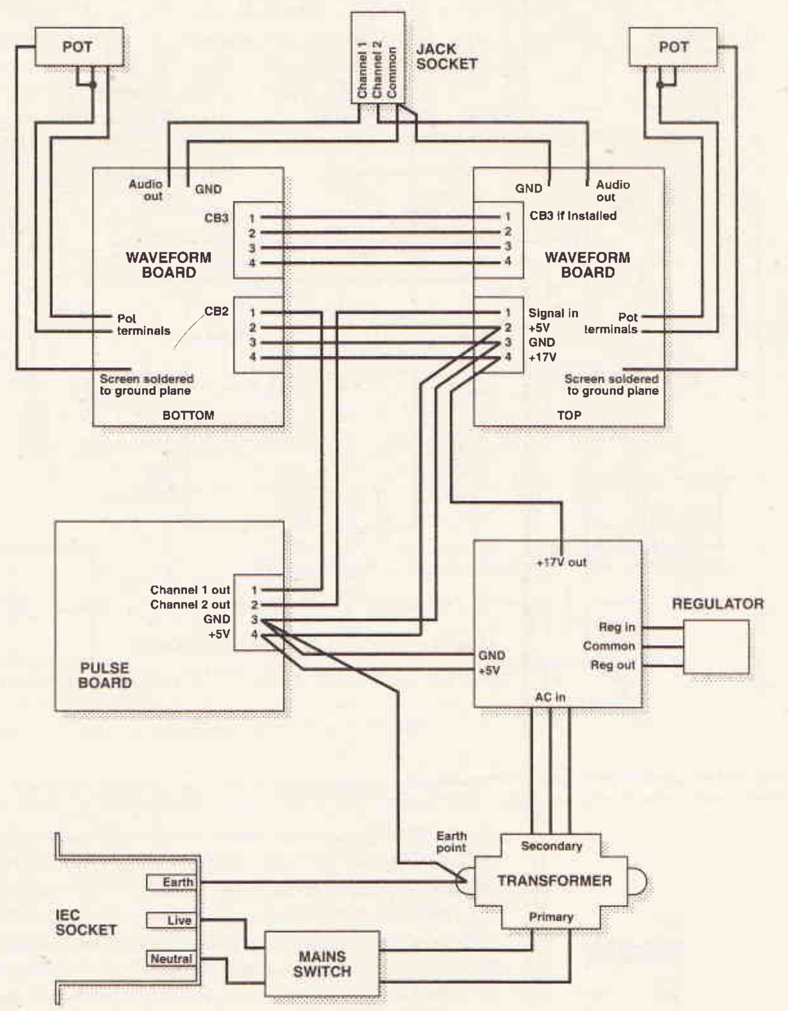

Fig.6 Board wiring schematic

will be necessary to seat this device in the lower 24 pins of the socket, i.e. pins 1,2,27 and 28 of the socket are not used. Since the power supply pin will move accordingly the jumper must be placed in the uppermost position (i.e with the EPROM pin 1 on your left, the jumper must connect the leftmost 2 pins of the jumper block). When any other type of EPROM is being used the jumper should be moved to the opposite position. When EPROMs larger than the 2732 are being used, pins 1 and 27 will be pulled high and pins 2 and 26 will be pulled low. This will result in a change in the active ranges of addresses. See Table 1 for a list of active address ranges for each EPROM type. If you can't be bothered to work out the active ranges for any given EPROM simply construct the patterns for the waves you want in the first 4 bytes and then repeat that pattern across the whole available address range of the EPROM you're using.

Another consideration for those readers preparing their own EPROMs is that the hex switch which selects between waveforms operates in a complementary mode, which means that as the switch is turned clockwise it will result in decreasing address ranges being selected. For this reason it will be necessary to program the first wave into the highest 256 bytes of the active address range, the next one in the 256 bytes below that and so on. Of course, there is no absolute reason why one waveform should come first on the switch before another so this is purely up to the preference of the circuit in any way.

EPROM	Active addresses in Hexadecimal
2732	0000-OFFF (whole device)
2764	0000-OFFF
27128	0000-OFFF
27256	4000-4FFF
27512	C000-CFFF

Table 1: Active address range for each EPROM type.

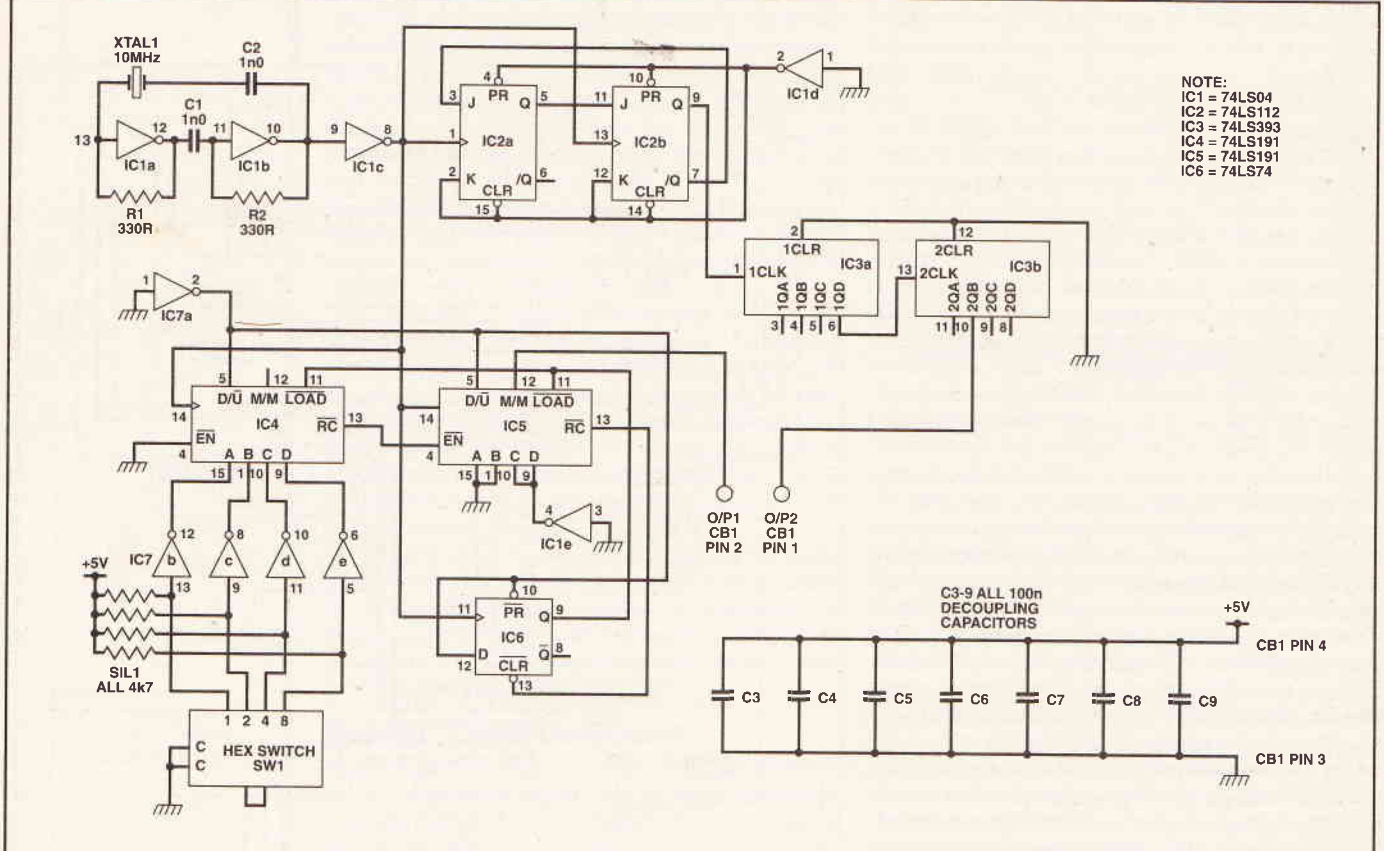

Fig.7 Hemisync Pulse generator circuit

One thing to watch out for is the Tantalum bead capacitor on the waveform board. Tantalum capacitors are polarised (although they are not always clearly marked). Make sure you insert this capacitor with the correct polarity or you will end up with a smoking heap of ash when you switch the power on!

Mechanical Construction

IMPORTANT:This project has been designed to squeeze into a compact box, the construction is quite complex and there is very little leeway for error in mounting any of the components. For this reason I strongly recommend that you read through all the construction details carefully making sure the right sequence is followed before starting on the construction.

The first thing to do is to drill the mounting holes in the front and rear panels of the case, see Figure 2 for dimensions. The large hole for the IEC mains socket is only necessary if you intend to use a removable IEC mains lead. Some readers may prefer to install a cable gland or grommet and a permanent mains lead wired in directly. There is no reason not to do this if you prefer. Cautious readers may also prefer to install an additional fuse, an option I have not allowed for. If so make sure that there is sufficient room in the final position you want to mount it in as the contents of the case are rather tightly packed!

When the main boards have been constructed, solder the leads for the pots to the waveform boards. These should be 2 core screened cable and the screen should be soldered to the ground plane (the heatsink) of the LM380 at one end of the cable, and to the case of the pot at the other. This is to ensure maximal shielding of the analogue input stage from the radio interference. The Hemisync machine will work better without Radio 1 on the audio channel! The actual wires to the pot terminals are interchangeable so they can go either way round. See Figure 3 for the rest of the wiring details for the pots. It is important to connect the wires to the pots before mounting any part of the circuit as it will be nearly impossible to access the connections to one of the pots when the boards and pots are mounted. After connecting the pots, attach the wires for the output connections to the board. These will go to the headphone socket, both grounds will go to the common terminal of the jack socket and each output from each waveform generator will go to one of the two stereo connections on the jack. Don't connect them to the jack at this stage.

At this point it will now be necessary to mark the mounting positions of the waveform boards in the case. The recommended Verobox has various plastic protrusions on the base of the case which will get in the way of the mounting pillars for the boards. These may need to be trimmed off with a sharp wood chisel. Alternatively if you have a mini drill and a suitable burr they can be removed in that way. Make sure that you do not damage the 4 main plastic mounting pillars at the corners of the box.

Place one waveform board (the one with the hex switch on if you have used only one switch, otherwise either will do) on the base of the box with the hex switch shaft forward. The shaft should go through the hole in the lower left hand corner of the front panel, viewing the box from the front. Slide the board forward in the case until the front edge is stopped by the main mounting pillar in the corner of the box. This is the final mounting position for the board, so now you must mark the base of the box through the 4 mounting holes at the corners of the board. Drill 4 holes into the base of the box at the marked points and trim back any protrusions on the base that may get in the way of the screws or cause the spacers which we will be mounting the board on, to stand unevenly.

The next stage is to wire together the two waveform generator boards. The 2 boards will be mounted in the box in piggyback fashion, using 4 spacers approximately 16mm in length to hold them apart.

The power connections to the two boards are common and so those on ~~the~~ lower board should be run to the connector on the upper board. A single set of connections from the upper board will run to the power supply and pulse generator. So you must wire the 17V, ground and 5V connections from CB2 on the lower board (which will be the one with the switch as mentioned above) to the corresponding terminals on the CB2 of the upper board with short wire lengths. The wire type isn't critical. The single input connection on CB2 of the lower board should be temporarily connected to a flying length of wire, sufficiently long to reach the pulse generator terminals once it is mounted. About 150mm of lead will do.

If you have used only one switch then you will have installed the connectors CB3 on the waveform boards. The purpose of this connector is to carry the common switch connections between the two boards. So you must now attach 4 short wire lengths to CB3 on the lower board and run them one to one to the corresponding terminals on CB3 of the top board.

Since the two boards will be sandwiched it will be impossible to reach the terminals on the lower board once the upper board is wired in, so attach all the necessary wires to the lower board first. The wires between the two CB3 connectors may be run around the side of the board nearest the connectors themselves, keep them as short as possible. The wires between the two CB2 connectors on the other hand must not be run around the front edge of the board. If they are they will get in the way of the pots. So run these wires around the side of the board opposite CB3 or alternatively, as I have done on the prototype, drill a large hole (6mm diameter) in the middle of the upper board between the tracks, just behind CB2. This will allow you to run the wires from the lower board to the upper through this hole.

Once you have attached the wires to the connectors on the lower board it is a good idea to temporarily bolt the two boards together with the spacers as they will be once they're mounted. This will allow you to trim all the interconnecting leads to the right length. You can now attach flying leads from the power connections on CB2 of the upper board and the upper input lead. This should leave you with 5 flying leads, the input leads for the upper and lower boards, and the 3 main power connections.

Put the waveform boards to one side and take the pulse generator board. This should be mounted vertically on its side, alongside the waveform boards. The hex switch should be at the top . Slide the pulse generator board into the case in this position and the switch shaft should run through the hole in the upper right hand corner of the case. The pulse generator board is supported by the switch mounting in this hole so the front edge should run right up against the front panel. Again you may find that protrusions on the base of the case prevent this in which case trim them until the board can be mounted in this position. Temporarily secure the PCB in place using the switch mounting. The board needs support at the other end to make it secure. In the prototype I bolted a small piece of ABS PCB mounting runner to the base of the case at the other end of the board. You can achieve a similar effect simply by marking two holes up against the board, on the base on either side and putting bolts through the holes. The nuts will hold the PCB in place against lateral movement (Figure 4). The power supply PCB will be mounted up against the rear edge of the pulse board and will provide additional support.

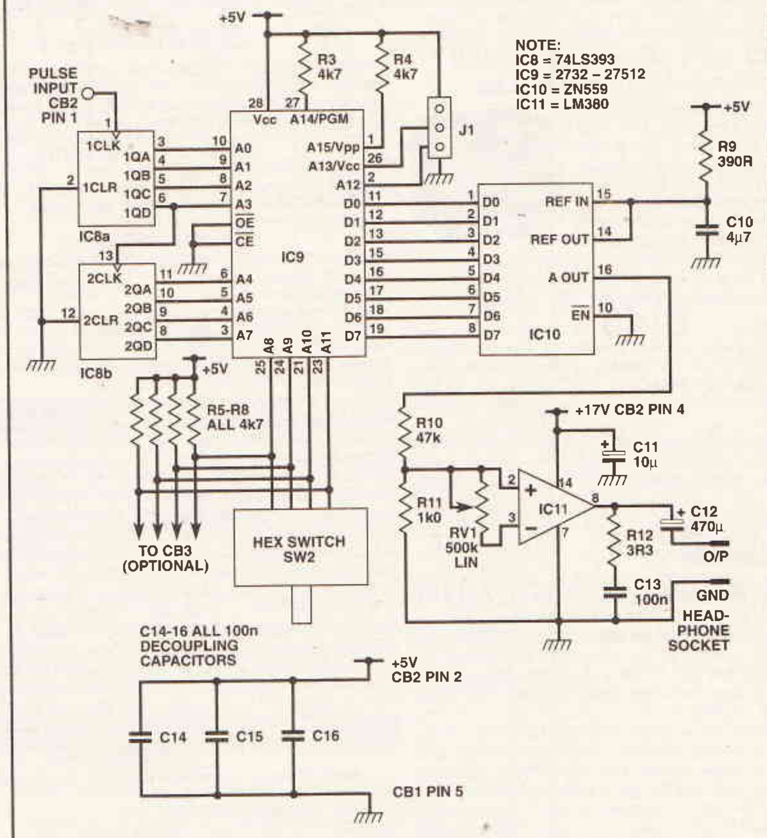

Fig.8 Hemisync waveform generator circuit

With the pulse board still in place, push the power supply PCB up against the rear edge of the pulse board and mark the 4 mounting holes required on the base of the case. The power supply PCB will be mounted on 5mm spacers, through these holes Remove both boards and drill the mounting holes for the pulse board securing bolts and the power supply PCB mounting. The only remaining holes required in the base of the case are the mounting holes for the transformer. The final position of the transformer will depend on the size of the switch used and so these should be left until after the switch has been mounted.

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Fault Finding In Electronic Equipment

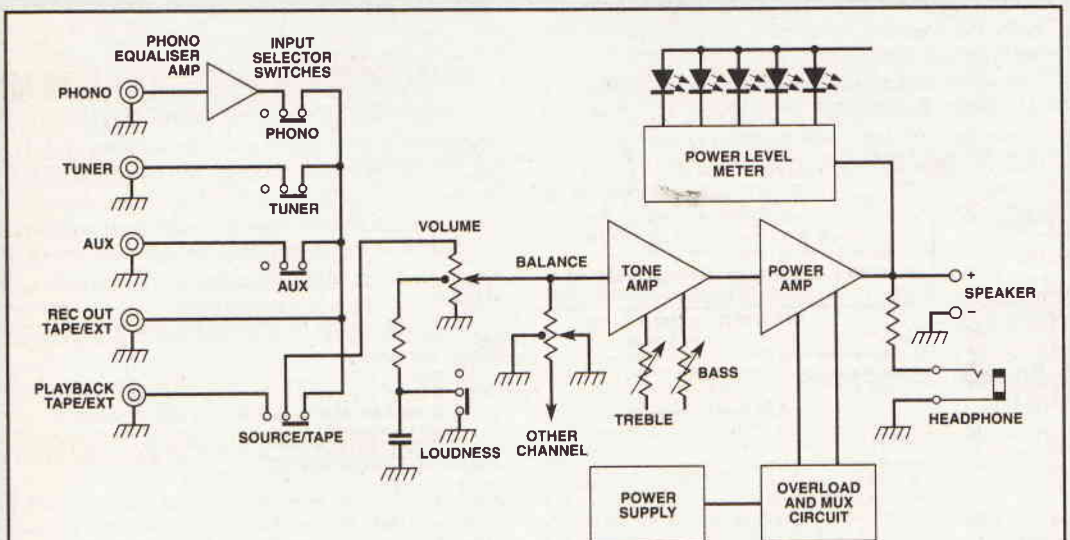

Fig.1 Block diagram of a typical audio amplifier

Why not try and repair that ever increasing pile of electronic scrap in the corner? Andrew Chadwick helps you find the solutions

Thomas Edison is reported to have said that genius is 1% inspiration and 99% perspiration. I'm sure many people feel the same way about fault-finding. However by applying a few simple principles and a little logical thought the percentage perspiration can be drastically reduced and fault-finding can become a very satisfying and straightforward procedure.

This article describes both the theory of fault-finding and the way this is put into practice. Wherever possible real-life faults have been used as examples. The article is restricted to fault-finding in electronic equipment although the principles involved can be applied to a range of activities from debugging computer software to fixing the car. The emphasis is on domestic equipment that the average enthusiast is likely to be called on to repair.

The first part of the article deals with various general subjects relevant to fault-finding. The second part begins by classifying the different types of fault and then goes on to describe the methods used to trace them. The third part describes how these methods were used to locate some real-life faults. Finally there is an excercise that will allow you to test your skills at fault-finding.

I have deliberately avoided describing the detailed theory of operation of the various types of equipment. The important thing to understand is the principles involved so that you can quickly decide whether a particular part of the circuit is performing as it should. If you are not familiar with these principles then I suggest that you read one of the many general electronics books which have a chapter on domestic electronic equipment. This should provide sufficient information for fault-finding. Remember you are only trying to repair the equipment not (hopefully) redesigning it!

I have also said very little about mechanical faults mainly because this is a magazine for electronics enthusiasts. In fact modern electronics, despite its complexity, is very reliable and many of the problems on domestic equipment are caused by mechanical failure or wear.

By the end of the article, I hope that you will have a more positive attitude towards fault-finding and approach it rather like a 'whodunnit' novel where the components are the suspects and the symptoms of the fault the clues. Your role is that of the sleuth who has to track down the culprit!

Philosophy

If you are not of a philosophic turn of mind then by all means skip the rest of this section and start on the first part of the article dealing with practical matters relating to fault-finding.

Having been involved in fault-finding for a number of years I feel that there are three important skills that are essential to efficient fault- finding but are not the sort of things that can easily be learnt from books. I have tried to summarise them in the following paragraphs.

Try not to become submerged in details. Block diagrams are very helpful in this respect and I intend to say a lot more about them later. Successful fault-finding relies on the ability to stand back (metaphorically!) and see through irrelevant detail to the underlying principles.

Human beings will always make mistakes. You cannot do anything about this but what you can and should do is to develop a way of working that shows up your mistakes before too much damage is done. Some tips are given in a section later on in the article but there are many others. If something seems unusual check it, don't accept it.

Don't jump to conclusions. The first possibility is not the only possibility. Try to think of all possible explanations then devise a test to identify the correct one.

Enough philosophy. I now want to look at some more practical matters.

Circuit Diagrams

A circuit diagram is essential for fault-finding on complex equipment and even on simple equipment it does make life a lot easier. Therefore its worth making an effort to obtain one.

If the equipment you are working on is a television or a radio or contains a radio section (eg a music centre), then try the public library. Most main libraries keep copies of Radio and Television Servicing. This is a useful book published annually containing circuits and servicing information for radios and televisions from many major manufacturers.

Alternatively you should be able to get a copy of the circuit diagram, or a full service manual from the spares department of the manufacturer of the equipment. However, they may make a charge for this.

Finally, there are companies specialising in the supply of technical information many of whom advertise in electronics magazines such as ETI.

Beware of errors on circuit diagrams. They do crop up quite frequently and can lead to a lot of confusion if not spotted.

Block Diagrams

Block diagrams are included in comprehensive service manuals and with constructional projects in the better enthusiast magazines. However, they are not as readily available as circuit diagrams.

Figure 1 shows a block diagram for a typical audio amplifier. Each block represents the function of part of the circuit. No details of the circuit or components are shown as it is the function that is important not the way this is implemented.

The lines connecting the blocks represent electrical signals or power supply lines. The arrows show the direction of information flow where necessary. Lines entering and leaving a block are called inputs and outputs respectively.

The function of a block is shown by means of words or a symbol. British Standard BS 3939 defines a number of symbols for use on block diagrams. A few common examples are shown in Figure 2.

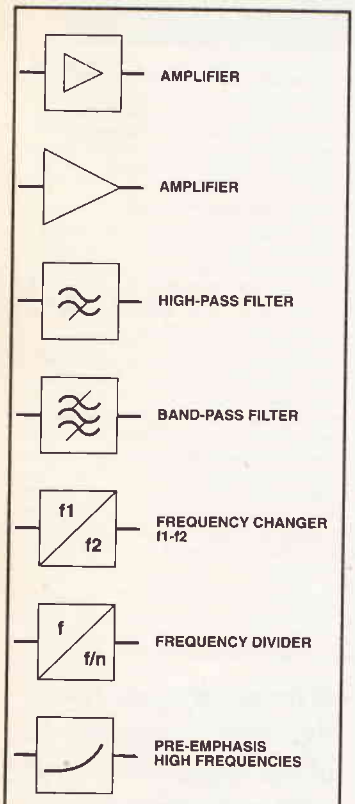

Fig.2 Examples of block diagram symbols from BS 3939 Part 10 1985

There are also various other conventions used by different manufacturers but they are usually fairly self-explanatory. Some manafacturers annotate the blocks with the references of the important components in the area of the circuit corresponding to the block. This is helpful when referring to the circuit diagram. Figure 3 shows an example of part of a block diagram for a telephone answering machine that uses this method. Q9, IC1 etc are transistor and integrated circuit references. To make things clearer the manufacturer has provided a separate block diagram for each mode of operation. Other manufacturers use a combination of blocks and circuit symbols so that the block diagram looks more like a simplified circuit diagram.

As has, I hope, already been made clear a block diagram is invaluable for fault-finding. Therefore if you don't have a block diagram its well worthwhile sketching out one based on the information on the circuit diagram. Most circuits can readily be divided into areas each performing a single function. Each of these areas is represented by a block on the block diagram. Once the blocks have been identified, the signals linking them will become apparent and can be added to the block diagram.

I have outlined and labelled the areas on the circuit diagram corresponding to each of the blocks. It is particularly important to note the points in the circuit corresponding to the inputs and outputs of the blocks as it is here that you will need to take measurements when fault-finding.

For simple domestic equipment the block diagram for each type of equipment (amplifier, cassette recorder, etc.) is very similar irrespective of the manufacturer. Therefore with experience you will find that you are able to visualise the block diagram without actually drawing it out on paper.

Fault-finding Charts

In addition to block diagrams and circuit diagrams you may also have a fault-finding chart or diagram. You've probably seen the sort of thing in connection with motor car maintenance:

Symptoms: Car will not start.
Possible Cause: No petrol.
Remedy: Catch a bus.

Joking aside I personally find fault-finding charts of little use both in motor car and electronic fault-finding. The problem is that only a few of the many possible faults can be fitted on the chart. In my experience those that are chosen seem to be the most unlikely. To be charitable this is probably because the charts are prepared at the design stage before the manufacturer has had any operating experience with the equipment. One major company has tackled this problem by providing an on-line service listing common faults and their symptoms based on customer experience. Maybe a computerised expert system is the answer.

Test Equipment

Most fault-finding does not require expensive equipment. As an electronics enthusiast you probably already own the basic tools such as a multimeter, either analogue or digital, soldering iron, screwdrivers, pliers and the like.

An oscilloscope is not absolutely essential but you will find yourself very restricted without one. It's a bit like trying to repair a car whilst blindfolded.

For audio equipment a signal source is useful. This only needs to be a fixed frequency, say 400 or 1000Hz sine or square wave. For cassette recorders a tape with a constant 400Hz sine wave recorded on both channels is adequate for fault-finding. However, for checking playback levels and frequency response and aligning the tape head, proper test-tapes are required which are expensive.

Any other equipment that you invest in will depend on how enthusiastic you are and how much fault-finding you intend to do. I have built some very useful equipment myself, including a telephone exchange simulator for testing answering machines and telephones and a power supply splitter for producing positive and negative supplies from a single 0-30V power supply.

For serious work a collection of test leads and audio connectors is essential. Most modern audio equipment uses phono sockets so it's worthwhile investing in cables terminated in phono plugs. For other types of sockets adaptors are available with the appropriate plug on one end and phono sockets on the other.

Dissassembly

Most fault-finding will involve a certain amount of dissassembly (commonly known as taking it to bits!). Some pieces of equipment have been designed with servicing in mind whilst others are, to use a colleagues phrase, "products of an unsound mind". With the benefit of experience, sometimes bitter, I offer you the following tips.

Place screws and small parts in a container as soon as they have been removed. I actually use empty margarine tubs! Don't leave them loose on the bench where they will get knocked off, lost or will short the underside of printed circuit boards. It is preferable to use a number of containers or one of the storage trays which are divided into compartments. Screws from separate parts of the equipment can then be kept together. A cynic would say that these precautions simply allow you to lose them all in one go when you knock the container off the bench!

As you remove each part examine it closely. Imagine you are reassembling the equipment and ask yourself whether it would be obvious how it fits together — in other words is it idiot proof! If not don't be afraid to make notes or a rough sketch. Look out for groups of screws where one or two are a different length from the others. Beware of unmarked multiway connectors where there are two or more with the same number of pins. A felt tip pen is useful for marking directly on metal parts or the circuit board.

Safety

Most mains operated equipment carries a warning about the danger of mains voltages when covers are removed. There are obviously mains voltages present but in most cases these are restricted to the circuitry on the primary side of the mains transformer. It is easy enough to trace this wiring and where it is not already adequately insulated or shrouded against accidental contact, it is worth applying a little insulating tape (with the mains disconnected!)

For maximum safety use one of the residual current circuit breakers, or earth leakage circuit breakers as they used to be called, which are available built into a plug or adaptor for around £20. In the event of current flowing to earth through you they will automatically disconnect the mains supply.

Special care needs to be taken with television sets. Here there are two dangers. Firstly, the chassis of the set is often at mains, or half mains potential. The only really safe way of working is to use a mains isolating transformer.

The other danger comes from the EHT voltage, applied to the anode of the tube. Treat connections and circuitry with great respect. The inner and outer surfaces of the tube are designed to act as a smoothing capacitor for the EHT. Sufficient charge remains to give a nasty shock even after the set has been off for some minutes.

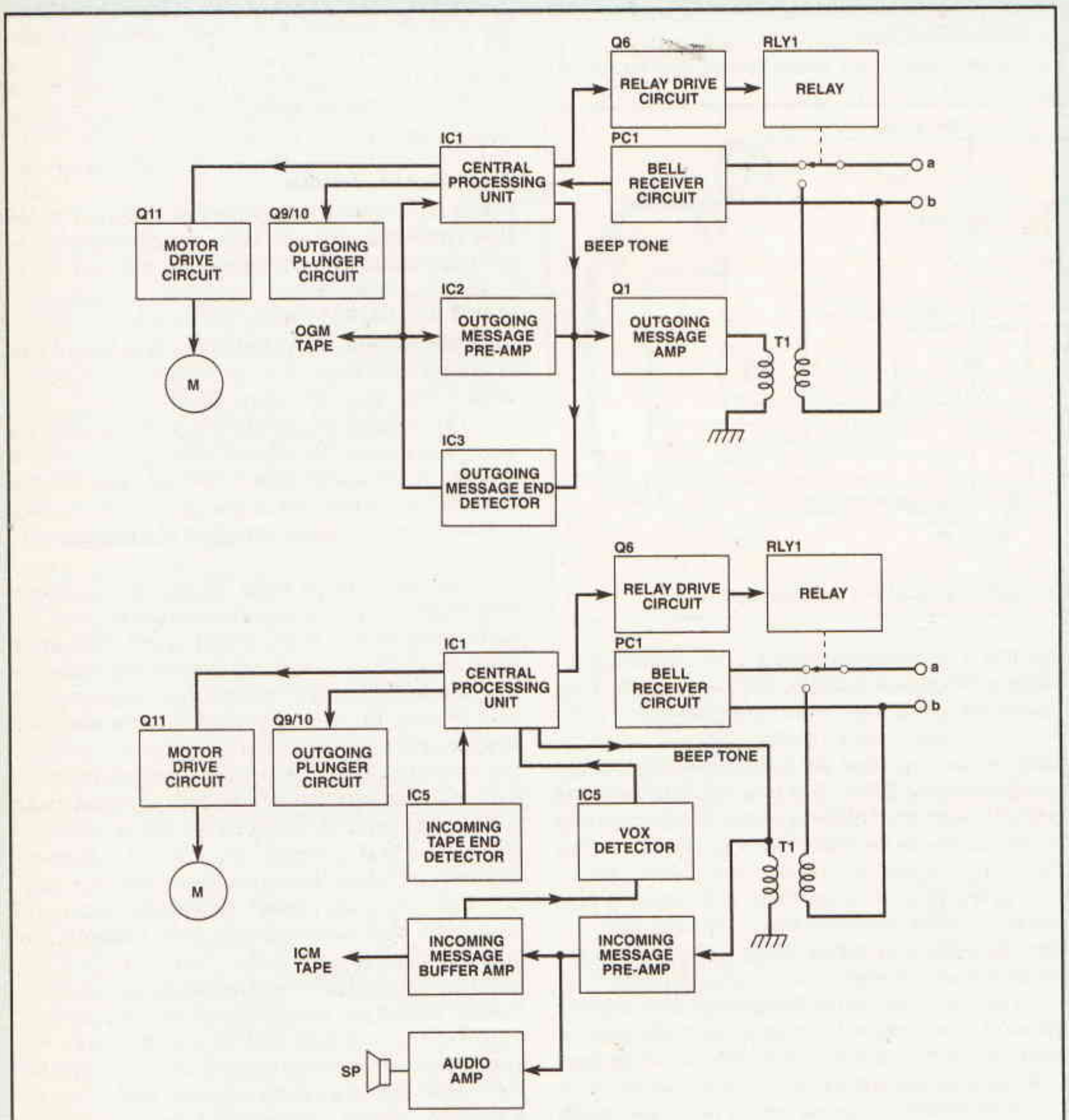

Fig.3 Part of block diagram for a telephone answering machine

Keep a magnet handy to magnetise your screwdrivers. Removing screws from awkward corners is then very easy. However avoid using a magnetised screwdriver near tape heads or, if you do, demagnetise the heads when you have finished.

Small Philips screws can sometimes be virtually immovable. Try a pair of pliers on the handle of the screwdriver to give a better grip. If this fails you can often cut a slot in the head with a junior hacksaw blade and then use a larger flat-bladed screwdriver.

Grounding

Contact between metal work sometimes forms the common return for parts of the circuit as, for instance, between a cassette mechanism and the chassis. If the equipment is tested whilst it is partly dismantled the required contact may no longer be present. This can produce very strange symptoms. Use a short lead with crocodile clips either end to restore the return path.

When making measurements whether with a 'scope or a multimeter you need to identify the common or 0V line to which the measurements are referred. If you possess a circuit diagram this should be no problem. If not then you will need to make an intelligent guess. The screen connection of inputs, the common of a centre tapped transformer, screening cans and grounding leads are some of the things usually connected to the circuit common. However the metal case is not necessarily connected.

If there is no convenient component lead on which to clip test leads solder a short piece of bare wire to the common track on the circuit board.

When attaching a 'scope ground lead remember that this is normally connected to the chassis of the scope which is connected to the mains earth. If the equipment under test has an earth conductor in the mains lead check either by inspection or resistance measurement, whether this is connected to the low voltage circuitry. If it is , it is essential that the scope ground is connected to the same place, otherwise part of the circuit will be effectively short-circuited. (See Figure 4) This also applies to other test equipment such as signal generators where one output is connected to earth. Most modern equipment does not have an earth connection to the mains and so the problem does not arise.

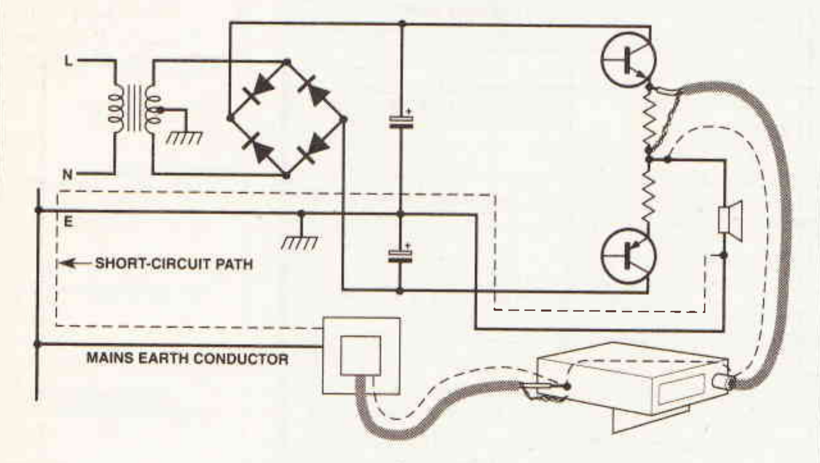

Fig.4 Example of a short circuit caused by an earthed oscilloscope

For low voltage or high frequency measurements the short grounding lead on the scope probe must be used and connected to the circuit close to where measurements are being taken. Otherwise it is often more convenient to use a separate longer return wire to the 'scope itself.

Hints On Making Measurements

Insulate all but the very tip of multimeter test prods with sleeving or tape. This way there is less chance of short-circuits when the prod slips. The tip of the prod should be sharpened. As well as making it less likely to slip, this also helps penetrate oxide and varnish layers on conductors.

When attaching spring loaded test leads turn the power off first. The extra few seconds it takes to do this is nothing compared to the time it takes to repair the damage causes by an accidental short.

Beware of the loading effect of an analogue meter even on fairly low impedance circuits. Figure 5 shows how the voltage in the circuit changes when the meter is connected. Even with the usual 10M input impedance of a digital voltmeter the impedance of the circuit being measured needs to be less than 100k to achieve a 1% accuracy.

Finally four silly mistakes that wouldn't seem worth mentioning apart from the fact that I'm still regularly guilty of them. If there appears to be no voltages anywhere check that the other lead of your meter is still attached to the circuit common.

Before measuring resistances touch the two test leads together. This confirms that your meter is working and that the two leads you have in your hand are connected to the meter and not just lying on the bench.

If a digital meter kicks up when first connected then settles to zero, you're probably trying to measure AC on a DC range.

Before making the first measurement after turning on your 'scope touch the probe with your finger. You should get a nice picture of mains hum. If not you're switched to the wrong channel, or the probe you're holding isn't plugged in or the zero switch on the scope is still on.

Types Of Fault

Before dealing with fault-finding procedures I would like to discuss the types of fault that you may meet as this has a bearing on the procedures that you use to tackle them. I have divided faults into four categories.

The first category is the complete failure. Surprisingly this is often the simplest kind of fault to deal with as the problem must lie in an area common to the whole circuit, often the power supply.

The second category is the partial failure. An example is a stereo amplifier which only works on one channel or a cassete deck which will play but not record. The fact that part of the system is functioning allows you to eliminate a number of areas immediately.

The most difficult faults fall into the third category. These are normally partial failures but with the added problem that they are intermittent. With some faults simply placing the equipment on a work bench and face to face with a battery of test equipment is often enough to frighten it away. It's only when the equipment has been returned to the owner that the fault reappears. Even if you manage to catch the equipment misbehaving on the work bench you can be sure that the first touch of a test prod on the circuit board will clear the fault. However, don't despair — there are hints later on in the article on tackling this kind of fault.

The previous three categories apply to equipment that was definitely once working and therefore the problem is likely to be a single fault or a few related faults. I have reserved the final category for faults in equipment that has been built from scratch. Here there may be a number of unrelated faults and even faults such as wrong connections that would not occur with the other three types of fault. The one advantage with this type of fault is that you normally have far more information at hand, particularly if you have designed the circuit yourself.

I now want to look at fault-finding procedures in detail. Figure 7 is a logical flow diagram that summarises the procedures described in the following sections and shows how they are applied to the different categories of fault.

Fault Symptoms

If you have not experienced the fault yourself then obtain as much information as possible about the symptoms of the fault from the person who has. The type of questions to ask are:

Is the fault intermittent?
Does it affect one channel only?
Does it affect one function only?
Has the fault appeared suddenly or has there been a gradual deterioration?

This kind of information will save a lot of time later. I often have to put up with equipment sent to me for repair with such cryptic descriptions as 'no go' or 'faulty'.

Mains Plugs

The first job on any mains operated equipment is to check the mains plug. Typically 80% of the equipment I come across has a wrongly fitted plug. Amongst the commonest faults are the flex grip gripping only the inner conductors rather than the sheath of the mains cable, loose terminal screws and fuses of the wrong rating fitted.

I find it absurd that manufacturers make great efforts to design a safe piece of equipment and then leave one vital part to the whim of an unqualified householder. As the majority of houses now have sockets conforming to BS 1362 it would be far more sensible to use a moulded-on plug with appropriate fuse already fitted.

Controls

Before moving any controls make a mental note of their positions. Its surprising how often a so-called fault is actually caused by incorrect positioning of controls. One example that I experienced was in a car radio where the balance control was operated by pushing in the volume control and turning it. Presumably as the owner had turned the radio off he had slightly depressed the volume control and managed to turn the balance control fully one way. As there was no indication of the position of the balance control it appeared at first sight as if one channel was not working.

Function Checks

If the equipment is completely dead you can do very little without removing covers. If the equipment is partly working check all the functions and controls before dismantling anything. For example in the case of a typical amplifier you would connect a signal to each of the inputs (phono, aux, tape etc) in turn and check that the controls (volume bass, treble etc) and indicators (VU meters, pilot lamps etc) were working.

The reason for the above is twofold. Firstly using the block diagram and the results of the function tests you will often find that a large part of the circuitry can be eliminated at once and the fault isolated to one area. Secondly you may well notice other minor problems that weren't brought to your attention such as noisy switches, potentiometer and bulbs that don't work. Its very frustrating to cure the reported fault, reassemble the equipment and then find for instance that the stereo indicator lamp doesn't light!

As an example of what can be deduced simply from the function test let's suppose that the fault is on an amplifier on which the left channel phono input doesn't work. Refer again to the block diagram of a typical amplifier shown in Figure 1. The function tests show that the amplifier works satisfactorily on both channels using the aux input but only on the left-hand channel using the phono input. A little thought will show that the fault must lie in the phono input pre-amplifier. Thus without using any test equipment you have eliminated 90% of the possible causes. To track down the fault further you need to look more closely at the phono amplifier circuit.

Visual Checks

Having done as much investigation as possible with the equipment in one piece you probably need to remove the cover to gain further access. It is not feasible to give detailed instructions on disassembly for every type of equipment. However with the help of the general hints discussed previously and a bit of common sense you shouldn't have any difficulties. If you have a service manual you may find it contains disassembly instructions.

With the covers off don't dive in with test equipment. Look for obvious problems such as blown fuses, blackened components and discoloured printed circuit board which could be a result of overheating. I once discovered two electrolytic capacitors whose outer cans had blown off, leaving the remains attached to the board. However don't expect all faults to be so obvious!

Keep an eye open for "foreign bodies" ranging from spilt beer stains to paper clips and staples and

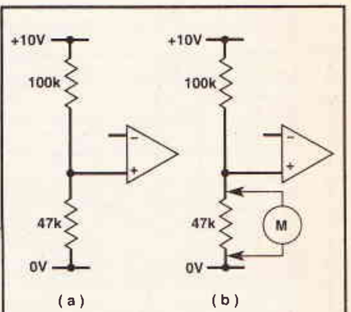

Fig.5 Effect of meter impedance. the multimeter has sensitivity of 20k/V and is on the 0-10v range

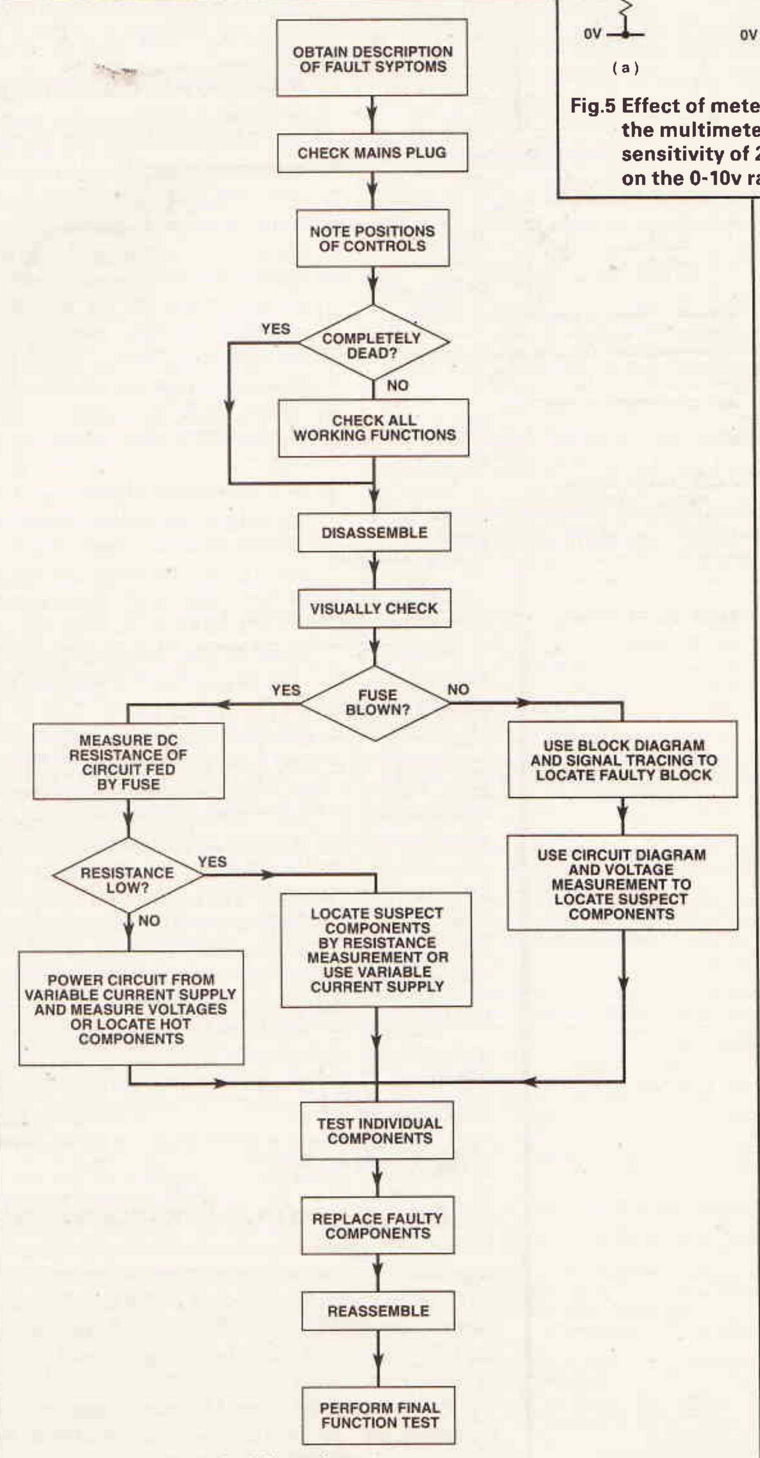

Fig.6 Fault finding logical flow diagram

even leaves. The latter I found in a video cassette recorder which was giving a very noisy picture. Foolishly I didn't at first link them with the fault. Eventually I found that one of the video heads was broken and can only assume it had caught on a leaf.

Take note of indications of repairs in the past such as components that don't match the corresponding components in the other channel and flux left round soldered joints. Missing screws are a sure sign that a bodger has been at work.

If you discover a blown fuse whilst examining the equipment then you can be fairly sure this has something to do with the fault. The procedures to follow in this case are described in the section entitled blown fuses. The information in the next three sections dealing with fault-finding theory, signal tracing and voltage measurement will not apply.

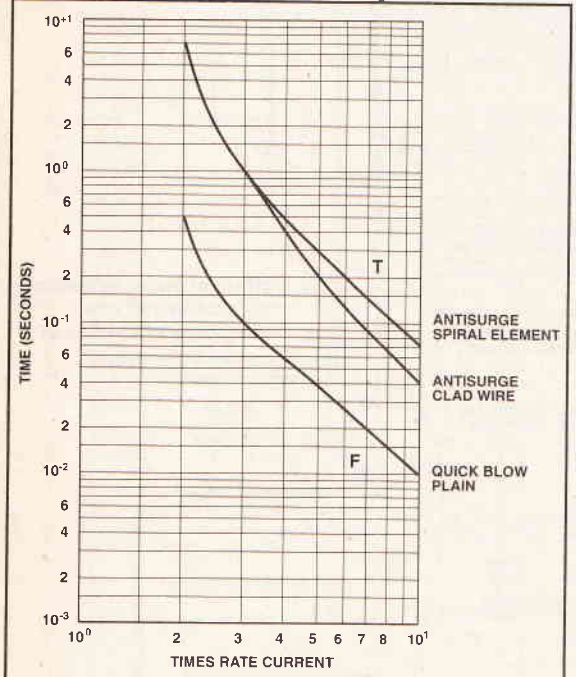

Fig.7 Graph showing block characteristics for quick blow and two forms of anti surge fuses

Fault-finding theory

At this stage you may already have a good idea as to the general area where the fault lies either through your initial function check or as a result of visual evidence. The professional service engineer gets to know certain standard faults on particular models of equipment and can therefore often pinpoint the fault straightaway. However in general the best approach is to locate the fault by isolating it to a smaller and smaller area of the circuit.

The most efficient way to do this is by using the block diagram. Take each block in turn and check that it is receiving acceptable inputs. If it is look at the output of the block. If this is also satisfactory then the block is working and you have effectively checked all the components that the block represents. If the output is not satisfactory then the block is faulty.

Once the faulty block has been identified the corresponding area of the circuit can be examined in more detail. In the case of an audio amplifier for instance you would probably look at the circuit diagram for that area. In a more complex circuit you might use a more detailed block diagram to pinpoint the fault even further before moving to the circuit diagram. Once at the circuit diagram level the fault can be isolated to one or two suspect components. A final test should then confirm which component is responsible.

Although by no means always the case, the faulty block is often identified by some form of signal tracing and the faulty components located by voltage measurements. These two methods are described in the following sections.

Signal Tracing

As has already been discussed all circuits can be broken down into a number of areas or blocks. Each block is intended to perform a certain function. A block will have inputs and outputs connecting it to other blocks. When functioning correctly a block should produce a certain output when its inputs (if any) are within their expected ranges.

Signal tracing simply involves checking that each block is receiving the correct form of inputs and producing the correct output. When you find a block producing no output or a distorted output despite receiving the correct inputs, then the fault will lie in that block. Don't forget that power supplies are in effect inputs to most blocks although they are not usually shown on the block diagram.

For certain blocks you may need to provide an input signal from a suitable source. This should have as simple and constant characteristics as are consistent with the equipment being repaired. It should also be repetitive so that it can be displayed on an oscilloscope. For audio equipment a fixed frequency sine or square wave is used. For video equipment the colour bar signal is common.

With digital circuits involving microprocessors signals are often highly complex, particularly on address and data buses. Things can frequently be made easier by writing a short program consisting of a continuous loop within which the part of the circuitry you are interested in is activated. This produces simple repetitive signals in the equipment which can be viewed on an oscilloscope. This idea is described in more detail in Example 1 later on.

The form of the output signals from a block is often obvious. However in video equipment in particular, signals can be complex and often typical signal waveforms at various points in the circuit are shown in the service manual as an aid to fault-finding. If you are working on stereo equipment in which one channel is operating correctly you have a complete set of typical waveform available! Signals in the faulty channel can be very easily compared with those in the good channel.

When looking at complex waveforms on an oscilloscope don't forget that the 'scope can often be triggered far more reliably using the EXT trigger input connected to a suitable point in the circuit rather than triggering directly from the signal itself.

Voltage Measurement

Measurements of voltages in the circuit are normally taken when the fault has been isolated by signal tracing to as small an area of circuitry as possible. Voltages can be measured on a voltmeter or an oscilloscope. Beware of the averaging effect of a voltmeter. A reading of 2.5V could be a steady DC signal or a 5V square wave. With a 'scope there is no ambiguity. Example 2 illustrates this point very well.

As with signal tracing it's necessary to know the voltage that should be present before you can decide whether there is a fault. Typical voltages are often marked on a circuit diagram. Note that these are measured with the equipment in a certain mode, for instance playback in the case of a cassette recorder, so make sure you are in the same mode before comparing voltages. There can also be a difference of generally at least ±10% between the voltage measured in the circuit and that marked on the diagram. As with signal tracing you may be able to compare voltages between a faulty and a working channel.

There are a few general rules that apply when no values are given. NPN transistors when operating linearly should have the base 0.5-0.7V positive with respect to the emitter. The collector should be at some positive value with respect to the emitter. For PNP transistors the polarities of the above voltages are reversed.

Operational amplifiers in the linear mode should have both non- inverting and inverting inputs at the same voltage within a few millivolts. The output should be somewhere between the power supply limits normally at least 1-2V from either power supply.

CMOS logic outputs should swing to within a few tenths of a volt of the power supply rails unless driving a low impedance load.

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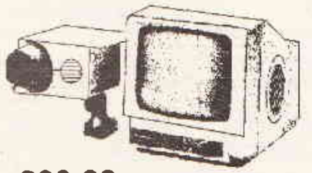

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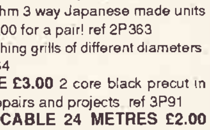

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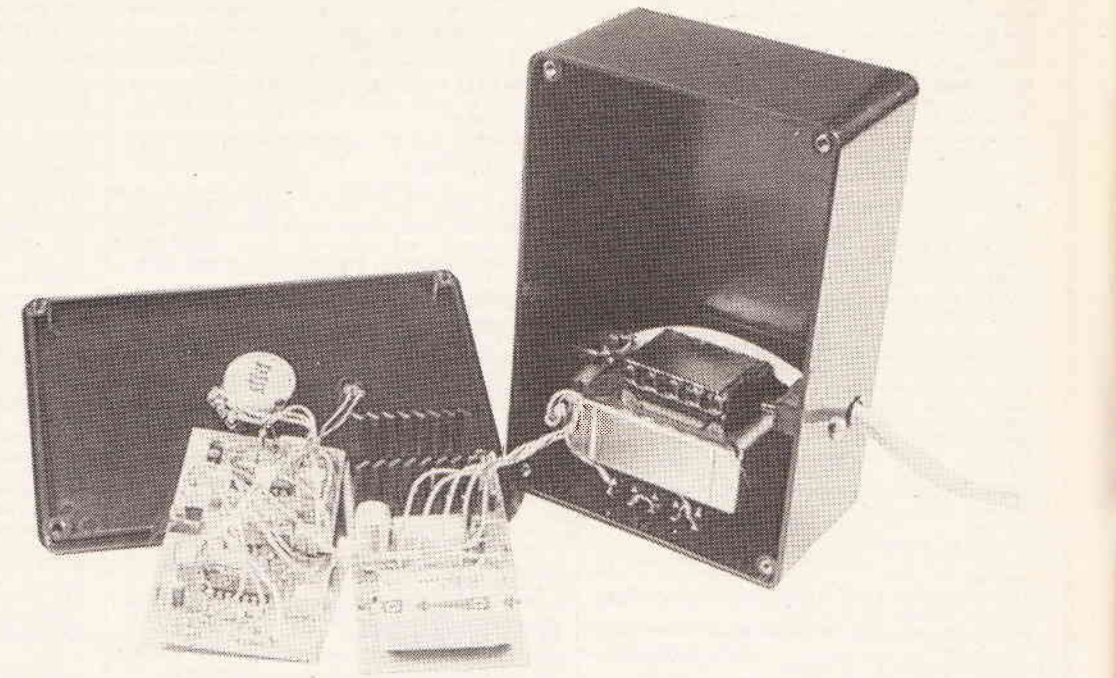


Model Railway Speed Controller

Andrew Chadwick constructs a smooth control for your railway.

The motor speed controller circuit to be described was developed for use with OO gauge model railway engines. However it can be easily modified to control any other small 12V DC motor such as a in a mini-drill. The circuit achieves 'closed loop' control of motor speed by measuring the back-EMF of the motor. This gives excellent speed regulation at all speeds and greatly reduces 'stiction' when starting. A single potentiometer controls both speed and direction. Alternatively a speed control and separate reversing switch can be incorporated. The controller has latching overload protection.

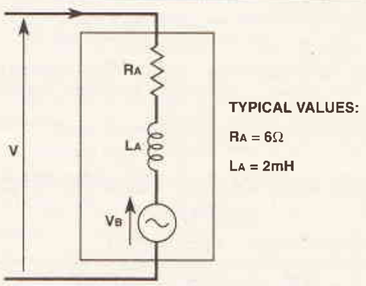


Fig.1 Equivalent circuit of DC Motor

Motor Basics

The electrical characteristics of a simple permanent magnet motor can be modelled fairly accurately by the equivalent circuit shown in Figure 1. I is the armature current, R_A and L_A the resistance and inductance of the armature respectively and V_B the back-EMF of the motor. The torque produced by the motor is proportional to the current, whilst the back-EMF is proportional to the speed.

If the motor is running at a constant speed with an applied voltage V then we can say that electrically:

$$V = V_B + IR_A \quad \ldots\ldots (1)$$

Mechanically the motor torque due to the current I is balanced by the resisting torque of the load on the motor. If the load is increased then the motor torque must increase to again achieve a balance. An increase in torque can only be produced by an increase in armature current I. In the simplest form of control V is held constant. Equation 1 then shows that I can only increase if the speed of the motor, and hence V_B, drops.

Ideally only a small drop in speed should produce a large increase in torque, or in other words a small drop in V_B should produce a large increase in I. If the applied voltage V is held constant then it can be seen from Equation 1 that the increase in current for a given drop in V_B is determined by the armature resistance R_A which for the best speed regulation should be as low as possible. Unfortunately R_A is fixed by the design of the motor and cannot be changed. It is possible to effectively reduce R_A by arranging that the controller voltage increases with increasing current. However, the controller then needs to be adjusted to suit a particular motor and good control is only achieved over a limited speed range.

The approach adopted in the present circuit is to measure the back-EMF V_B directly, compare it with a desired value and adjust the motor voltage accordingly.

Figure 2 is the block diagram of the controller and Figure 3 the full circuit diagram. Referring to the block diagram, a conventional linear controller tries to maintain the voltage applied to the motor equal to the voltage at its setpoint input. This setpoint voltage is normally equal to the output of the speed controller but periodically it is forced negative by an analogue switch controlled by an oscillator. This turns the voltage controller off and the motor free runs. The voltage across its terminals is therefore the back-EMF. This is stored in the sample and hold circuit which has also been enabled by the oscillator. This switching cycle is repeated every 30ms. The relevant waveforms are shown in Figure 4.

The voltage from the sample and hold circuit represents the actual speed of the motor. It is compared with the desired value or setpoint in the speed controller, whose output is the setpoint of the voltage controller. If the measured speed is less than the setpoint then the output increases so increasing the voltage applied to the motor. If the speed increases the opposite occurs.

The speed setpoint is derived from a single potentiometer which also controls the direction of the motor by means of a relay. At mid position speed is zero. Rotating the potentiometer clockwise or anticlockwise increases the speed in the forward or reverse direction.

Excess current through the motor trips a latching RC filter during the sample period. The sample period can be increased by increasing the cycle time but too long a cycle time causes undue motor vibration. The fraction of the cycle during which the back-EMF is sampled cannot be increased too far otherwise an unduly high supply voltage would be required and problems of overheating would arise. The values of 30ms and 6ms chosen are therefore, as always, a compromise.

Control Facilities

A single potentiometer controlling forward and reverse speed was felt to be more convenient than a potentiometer and reversing switch. The cost of a relay is not much more than a switch and one less hole needs to be drilled in the front panel! The potentiometer circuit gives a parabolic speed versus rotation characteristic but this is probably advantageous as it gives greater control at low speeds. A conventional speed control and reversing switch can be used if preferred by modifying the circuit as described later.

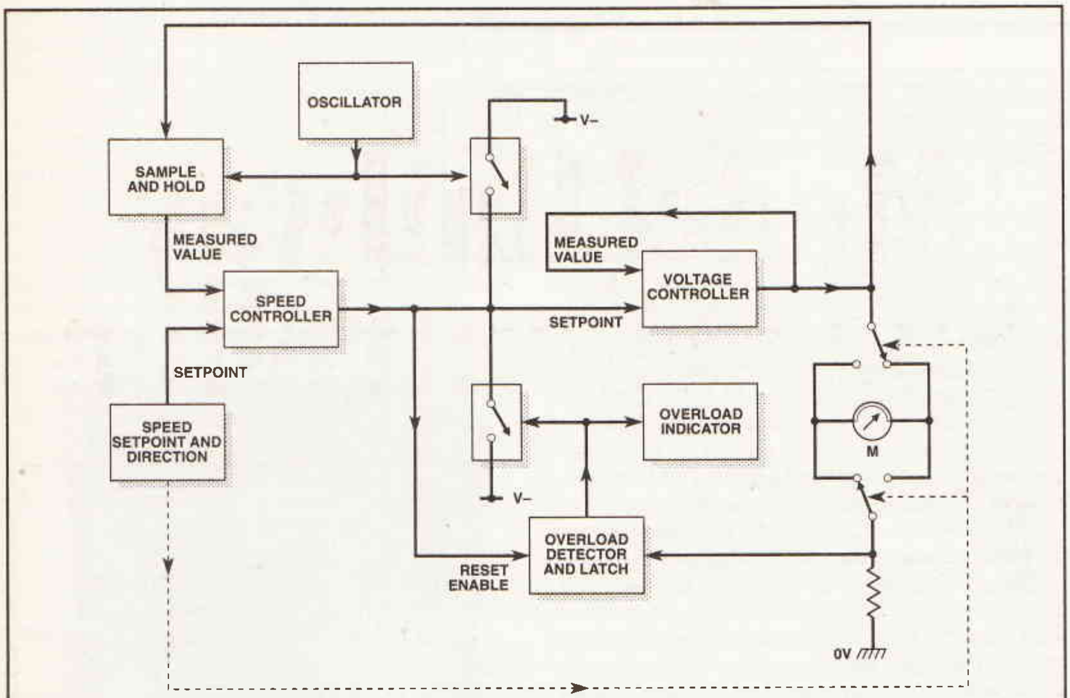


Fig.2 Block diagram of controller

overload circuit which clamps the output to zero. The overload circuit is automatically reset when the speed potentiometer is turned to the off position. Operation of the overload is indicated by a bicolour LED changing from green to red.

Back-EMF Sampling

The back-EMF is by no means a steady DC potential but contains a significant AC component and impulsive noise as evident from Figure 4. The AC component is due to the interaction of the magnetic field and the armature windings, and has a frequency of 6 times the rotational frequency for a 3 pole armature. The peak-to-peak amplitude of this component varies depending on the construction of the motor but with an inexpensive model engine motor was about one third of the DC level.

To avoid problems of aliasing, the back-EMF should in theory be sampled at a frequency at least twice that of the AC component. This is unfortunately not feasible as it would require a sample period that would be too short to allow the negative voltage transient due to the motor inductance to decay.

Instead the sampling period has been made as long as possible and the back-EMF is averaged by an

Power Supply

Although the LM324 is described as a single supply operational amplifier in practice its performance is limited when the output approaches ground. Hence a negative power supply was required which was obtained from the voltage drop across two diodes feeding the main reservoir capacitor. This is cheaper than connecting the transformer in its centre-tapped mode as the rating of the transformer would then have to be doubled with a consequent increase in cost and size.

The average current taken by a typical model engine is about 0.5A although when starting this may rise considerably. Therefore although the transformer is rated at 1A the overload circuit does not operate until 1.5A.

Construction

The general layout of the controller is shown in Figure 5. Most of the components are mounted on two PCB's which are fitted vertically in slots in the side of the case. In the prototype, space was deliberately left at the front for a possible sound effects PCB.

Install components on the PCBs according to the

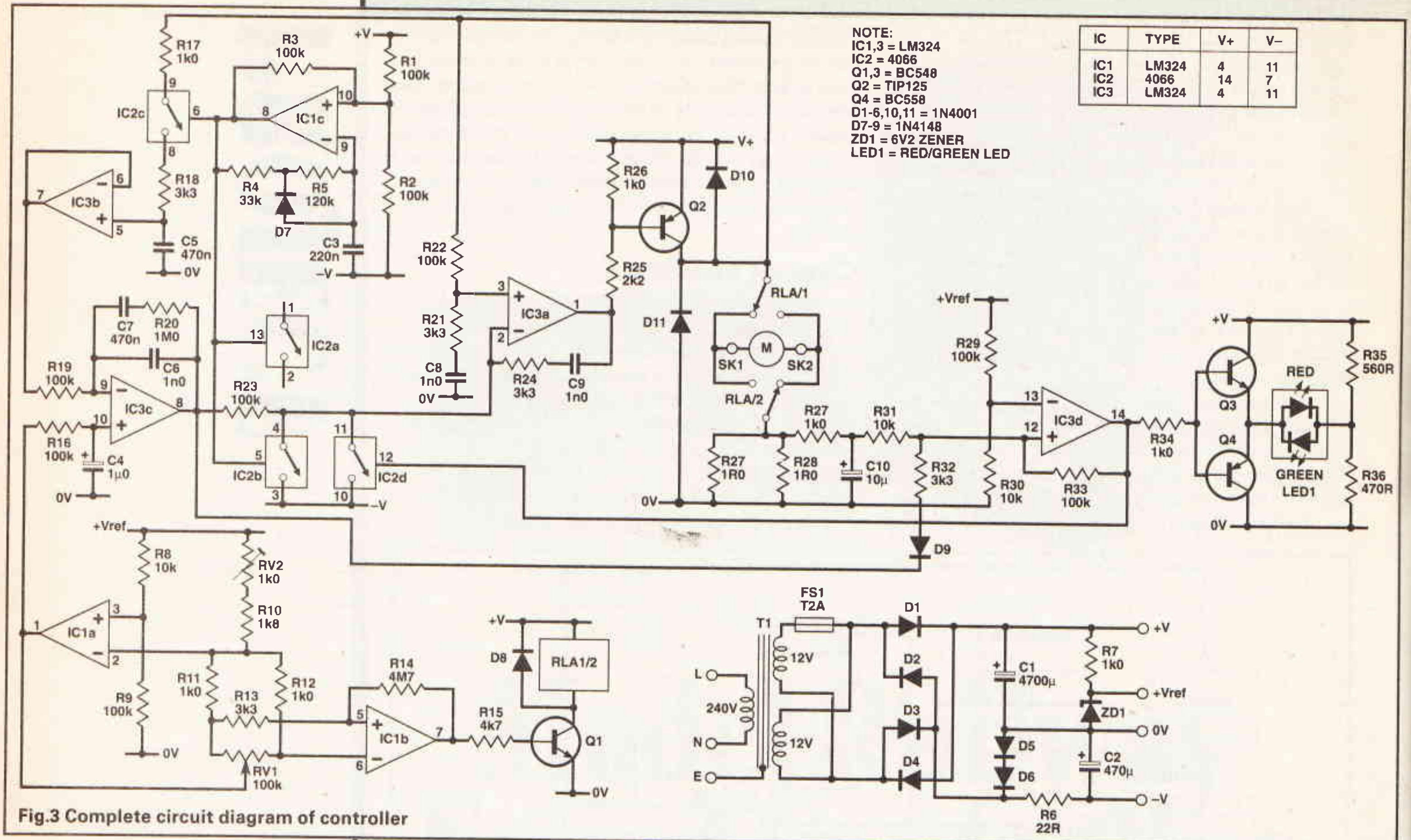


Fig.3 Complete circuit diagram of controller

overlay shown in Figure 6 beginning with the lowest profile components first. However leave the CMOS IC to last and observe static precautions when fitting it. I do not personally recommend sockets for any IC as I think they are expensive and a source of unreliable contacts. However, if you feel happier, then use them.

Mount the transformer, cable clamp and output sockets in the base of the case and RV1 and D12 in the lid. (See the section on modifications if a handheld unit is preferred). A little care is necessary when doing this. Fit the transformer as far back as possible using countersunk bolts and nuts from below. On the prototype the wiring tags were bent up to make more room. Before drilling holes for the other items slide in the two PCBs and check that the sockets, cable clamp and D12 will clear the transformer and that RV1 will fit between the two PCBs without fouling any components.

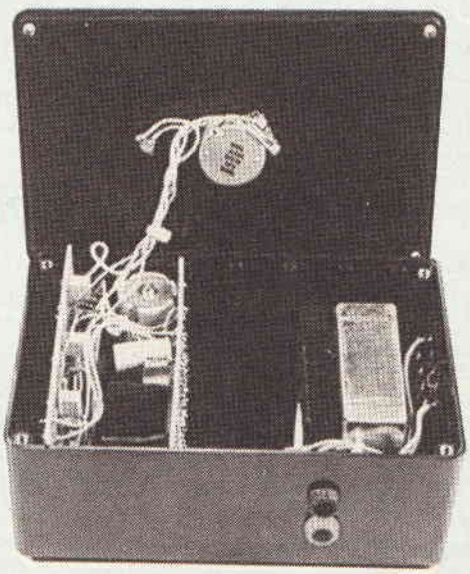
Remove the transformer and PCBs from the case and make the necessary interwiring. Lay the two PCBs component side up with their bottom edges about 20 m apart. Locate corresponding connecting points on the PCBs (marked A to G on the overlay) and cut wires roughly to length so that a neat loom is obtained. Do the same for the connections to RV1/D12 and the transformer/output sockets. Leave sufficient length so that the boards can be removed from the case without also having to remove the transformer.

Leave the sheath on the mains flex for as far as possible for additional safety. The earth wire should be connected to the transformer core by means of a solder tag on one of the mounting bolts.

Fit four self-adhesive feet and a suitable knob. Use a 2A fuse in the mains plug.

Testing

If possible use a variable current-limiting power supply for initial testing. Connect the positive output to D1 cathode and the negative to D4 anode. Temporarily connect a 1k resistor across the controller output. Set the current limit to 100 mA and gradually increase the output to 15V. If the current limit operates before you reach 15V then something is wrong. If a variable power supply is not available check thoroughly then simply plug in to the mains and switch on (with fingers crossed).



All being well D12 should be glowing green. Check that there is approximately 6.3V at ZD1 cathode, −1.5V on the negative supply and +13 to +15V on the positive supply.

Monitor IC1 pin 1 whilst turning RV1. The voltage should fall to a minimum at the midpoint of RV1. Adjust RV2 so that this minimum voltage is about −0.3V. As RV1 is rotated from one end to the other, IC1 pin 1 should start at about 5V, fall to −0.3V at midposition then rise to 5V again. As RV1 passes through the midposition RLA1 should operate with an audible click.

Check IC1(c) output with a voltmeter or preferably a 'scope. There should be a squarewave signal of period 30ms, high time of 6ms and amptitude about 14V present. A voltmeter should read about 1.8V. Measure the voltage at the output terminals across the dummy load resistor. With RV1 in midposition this should be zero. Turning RV1 either way should cause the voltage to ramp up to about 13V. Note that you will not be able to control this voltage at any intermediate value due to the lack of back-EMF feedback. Replace the resistor with a motor and it should be possible to vary the speed over the full range. If the motor is unloaded it may hunt slightly but should otherwise be stable. If the motor is accessible set it to run fairly slowly then grip the shaft with the fingers. You should feel an increase in torque and the motor speed will stay constant. Briefly gripping, then releasing the shaft should cause a slight oscillation of speed which is quickly damped. If the motor behaves sluggishly or is unstable see the section on modification of controller response.

The overload circuit can be checked by monitoring the voltage across a low value high power resistor connected to the output. The overload should operate when the voltage reaches a value of 0.8 x I xR where I is the overload current (1.5A for the standard circuit) and R is the value of the resistor. For the standard circuit R should be between 2 and 6 ohms. Carefully turn RV1 whilst measuring the voltage across the resistor. The voltage should increase to the calculated value and then drop to zero as the overload operates. At the same time D12 should change to red. Turning RV1 back to mid position should reset the overload and D12 should change to green.

RV2 may need slight readjustment when the controller is put into service. If turned too far one way the motor will never turn off completely and it will not be possible to reset the overload circuit. If turned too far in the opposite direction there will be a wide 'deadband' around the centre position of RV1.

Use

The main enemy to the smooth control of a model railway engine is poor electrical contact caused by dirt and oxidation on track and wheels. No amount of electronics can be effective if current simply cannot flow. Therefore to achieve the best performance from the controller give the track and rolling stock a thorough clean. I have found fine emery paper followed by a wipe with a rag moistened with contact cleaner to be effective on badly oxidised track.

Modifications

The following paragraphs describe possible modifications to the basic circuit.

Single Direction Control

If a single potentiometer giving 0 to 100% speed with a separate switch for forward and reverse is preferred then replace the setpoint circuit IC1(a), IC1(b), Q1 and RLA1 with the components shown in Figure 7(a) and 7(b). If the motor is only required to rotate in one direction as in a mini-drill, then the switch may be omitted as shown in Figure 7(c).

Speed Range

With the circuit as described the speed setpoint varies from 0 to about 6V. This gives a fairly high top speed. To reduce the speed range connect a resistor in parallel with C4. A value of 100k should halve the

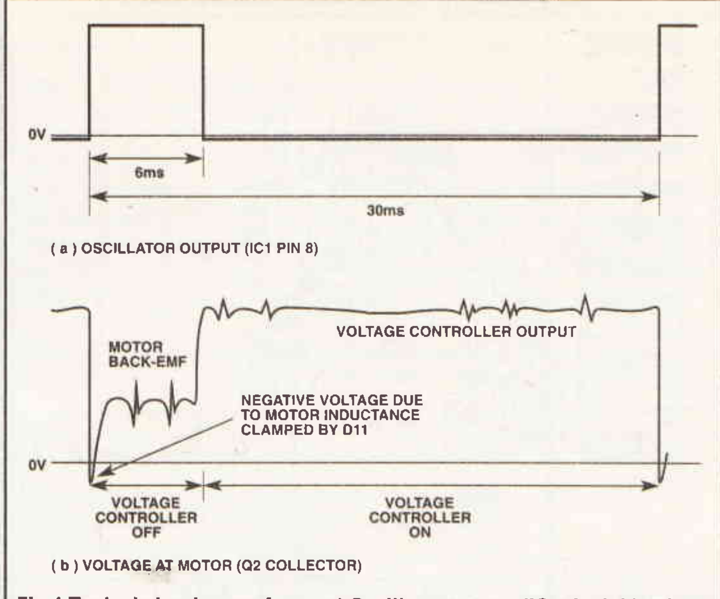


Fig.4 Typical circuit waveforms a) Oscillator output (IC1pin8); b) voltage at motor (Q2 collector)

range. With low values of resistance, C4 may have to be increased slightly otherwise the controller will react too sharply to changes in setpoint. RV2 will also require adjustment.

Hand-held Control

It may be more convenient to mount RV1 and D12 in a separate small hand-held box connected to the controller by a flying lead. This allows you to move around to change points and uncouple wagons whilst still being able to control the engine.

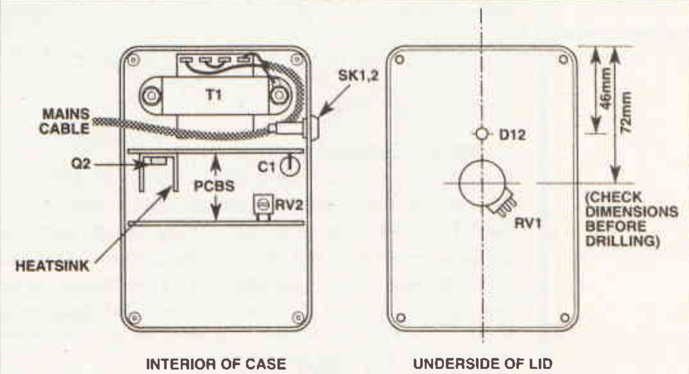


Fig.5 General layout of the controller

Speed Signal

The voltage at IC3 pin 7, is the motor back-EMF and so is proportional to actual engine speed. It could be used to operate a speedometer or to control a sound effects circuit giving increasing chuff rate with speed.

Uprating

For use as a mini drill controller a greater current output will probably be required. Suggested modifications necessary to give a controller with 3A output are as follows:

Uprate T1 to 48VA
Change FS1 to T5A
Change D1-D6 to 1N5401
Change C1 to 10000µ
Change R27, R28 to a 0R22 2.5W resistor or equivalent combination of resistors
Decrease the thermal resistance of the heatsink for Q2. The size of case and general layout will have to be modified to suit the increased size of T1, C1 and the heatsink.

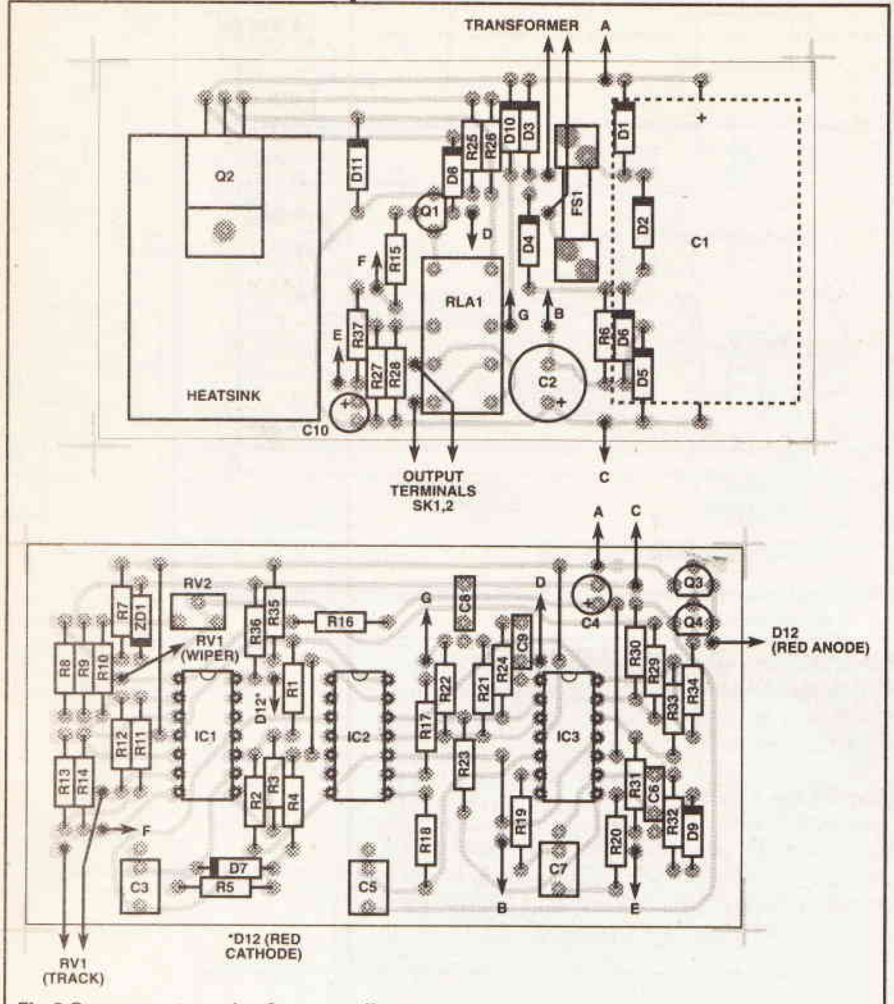


Fig.6 Component overlay for controller

oscillation during the time that the controller is on, try increasing the value of both C8 and C9 to 2n2 or 3n3. Don't worry about random noise and spikes as these are normal.

To tune the speed controller temporarily short C7 and with the motor running at a medium speed vary R19. As the resistance is lowered the motor will become more unstable until finally oscillations break out. Roughly estimate the period of these oscillations. Select a value for R19 that is two to three times the value that provokes oscillations. C7 should be selected so that R20 x C7 is approximately equal to the oscillation period.

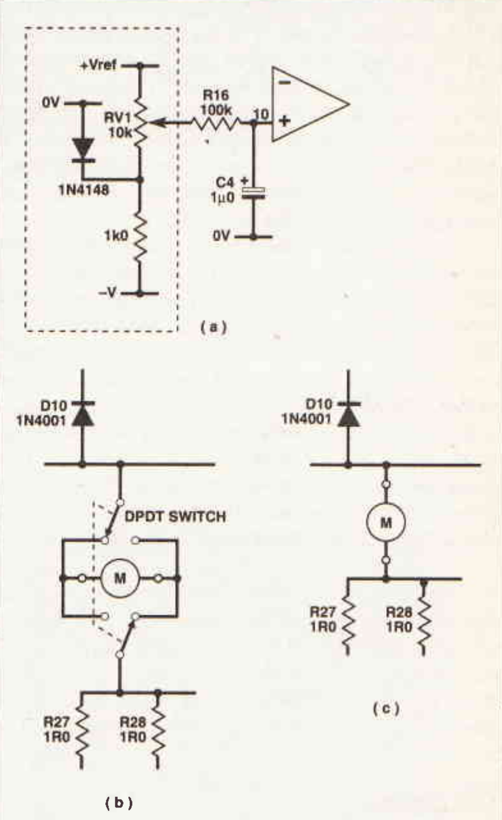


Fig.7 Modifications to speed setpoint and direction circuit

Control Characteristics

If satisfactory speed regulation cannot be achieved and you are sure that there are no faults in construction then try tuning the controller. First check that the voltage controller is stable by monitoring the voltage at Q2 collector on an oscilloscope. This should look similar to Figure 4. If there is any high frequency

PROJECT

HOW IT WORKS

Voltage Control

IC3(a) and Q2 form the motor voltage controller. The voltage across the motor is fed back via R22 and compared with the desired voltage fed from pin 8 of IC3(c) via R23. Any difference between the two causes the output of IC3(a) to vary the current through Q2 and hence correct the difference. R22, R21, C8 and R23, R24, C9 provide frequency compensation to give stable control even with a fairly inductive load such as a motor. D10 clamps any positive going spikes.

Back-EMF Sampling

IC1(c) is a conventional op amp astable which produces a square wave output of period 30ms and 'high' time of 6ms.

During the 'high' time analogue switches IC2(b) and IC2(c) are switched on. IC2(b) forces the desired motor voltage to a negative value causing IC3(a) output to rise and switch off Q2. As the motor has significant inductance the voltage at the collector of Q2 swings negative until diode D11 begins to conduct. Current in the motor then decays and the voltage rises to the value of the back-EMF as shown in Figure 4. The back-EMF is fed via R17, the now open switch IC2(c) and R18 to capacitor C5. R18 and C5 form a filter which averages the back-EMF during the sample period.

At the end of the sample period the output of IC1(c) goes low opening switches IC2(b) and IC2(c). The voltage controller IC3(a)/Q2 is enabled again and the voltage across the motor is restored.

Speed Control

The sampled back-EMF held on capacitor C5 is buffered by IC3(b) and fed to the speed controller IC3(c) via R19. The desired speed signal is fed from IC1(a) output via R16. IC3(c) compares the two and increases or decreases its output accordingly thus raising or lowering the desired voltage fed to the voltage controller.

In control engineering terms this is a cascade loop. IC3(c) is what is known as a proportional plus integral controller. At medium frequencies its gain is set at about ten by R20/R19, C7 having little effect. At low frequencies C7 has more and more effect so that gain rises to infinity at DC. This is the integral effect and means that over a reasonably long period of time the average difference between actual and desired speed must be zero. R16/C4 gives a smooth response to changes in desired speed.

Speed Setpoint

Like all good op amps IC1(a) tries to maintain the voltage at its non-inverting input, pin 3, equal to that at the inverting input, pin 2, by adjusting its output. Pin 3 voltage is a fixed value derived from the

PARTS LIST

RESISTORS (¼W unless stated)

R1-3,9,16,19,22,23,29,33	100k
R4,18	33k
R5	120k
R6	22R
R7,11,12,17,26,34,37	1k
R8,30,31	10k
R10	1k8
R13,21,24,32	3k3
R14	4M7
R15	4k7
R20	1M
R25	2k2
R27-28	1R 0.6W
R35	560 0.6W
R36	470 0.6W
RV1	100k LIN
RV2	1k Vert Preset

CAPACITORS

C1	4700µ 25V
C2	470µ16V
C3	220n
C4	1µ 63V
C5,7	470n
C6,8,9	1n
C10	10µ 16V

SEMI CONDUCTORS

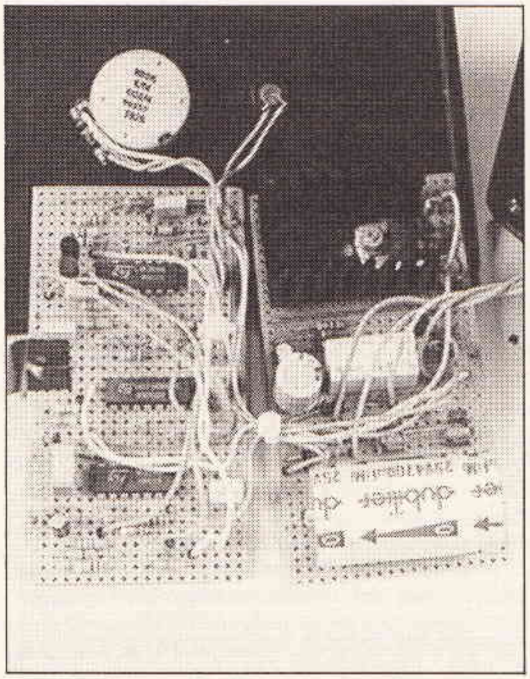
D1-6	IN4001
D7-9	IN4148
D10-11	IN4001
D12	Red/Green Bi-colour LED
ED1	6V2 400mV
Q1	BC548
Q2	TIP125
Q3	BC548
Q4	BC558
IC1	LM324
IC2	4066
IC3	LM324

MISCELLANEOUS

RLA1	12V 280R DPCO contacts
T1	12VA 12½% regulation
Case	MB5 150×100×60 ext
Knob	
LED clip	
Flex clamp	
SK1,2	4mm Sockets
Fuse clips or holder	
Heatsink 'Twisted Vane' type 9.9°C/W	
Feet	
PCB's	

BUYLINES

A kit of parts (excluding the PCB's) is available from Newland Engineering, 36 Ella Street, Hull HU5 3AY. Price £26.00 including p&p. PCBs are obtainable from the ETI PCB Service.



reference voltage by potential divider R8/R9. The voltage at pin 2 is set by a divider consisting of RV2 and R10 in the top arm and R11, R12 and RV1, the speed potentiometer, in the bottom arm. Ignoring R13 and IC1(b), when RV1 is at midposition, the resistance in the lower arm is at its maximum. RV2 is adjusted so that the output of IC1(a) must be roughly zero to make the voltage at pin 2 equal that at pin 3. If RV1 is rotated either way the resistance in the lower arm decreases and so IC1(a) output rises to maintain balance. The output is not linearly related to potentiometer rotation but this doesn't matter and in fact is an advantage giving better control at low speeds.

Motor Direction

IC1(b) acts as a comparator with hysteresis set by R14. When RV1 is rotated in one direction away from the midpoint current through R11 will decrease and current through R12 will increase. This will cause a difference in voltage at the comparator inputs and cause the output to go high, switching on Q1. This transistor operates RLA1 whose contacts reverse the direction of current to the motor. Rotating RV1 in the opposite direction will turn off Q1 and release RLA1.

Overload Protection

Motor current passes through R27 and R28 and the resultant voltage is smoothed by R37 and C10 and compared by IC3(d) with a voltage of roughly 0.7V set by R29 and R30. If this value is exceeded the output of IC3(d) goes high and turns on switch IC2(d) which forces the desired value of the voltage controller negative and hence turns Q2 off.

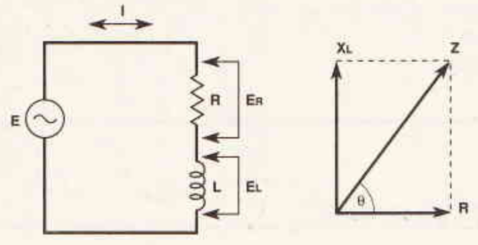
In normal operation the voltage of IC3(c) pin 8 reverse-biases D9 and so R32 has no effect. R33 and R31 then provide sufficient hysteresis to latch IC3(d) output in the high state even when the voltage across R27/R28 falls to zero due to Q2 turning off. The latch can only be reset when IC3(c) output falls below zero and draws current through R32. This can be achieved simply by rotating the speed potentiometer RV1 to the centre off position.

The output of IC3(d) also drives Q3 and Q4 which operate a bicolour LED D12. When conditions are normal IC3(d) output is low, Q4 is on and the LED glows green. If an overload occurs IC3(d) output goes high Q3 turns on and the LED changes to red until the overload is reset.

Power Supply

D1-4 form a conventional bridge rectifier but the rectified current to the negative side of the reservoir capacitor C1 passes through D5 and D6. The voltage drop across these diodes provides a negative supply of about 1.5V which is smoothed by R6, C2. R7, ZD1 provide a simple reference voltage.

Back To Basics



$X_L = 2\pi fL$

$E_R = IR$

$E_L + IX_L$

$E = IZ$

$Z = \sqrt{R^2 + X_L^2}$

$E = \sqrt{E_R^2 + E_L^2}$

$\sin\theta = \frac{X_L}{Z}$

$\cos\theta = \frac{R}{Z}$

$\tan\theta = \frac{X_L}{Z}$

$\text{POWER FACTOR} = \frac{\text{TRUE POWER (W)}}{\text{APPARENT POWER (VA)}} = \frac{R}{Z}$

WHEN $\theta = 0°$, p.f. = 1

WHEN $\theta = 90°$, P.F. = 0 (i.e. NO POWER CONSUMED)

Fig.1 Simple RL circuit

Paul Coxwell includes Capacitive reactance in his description of AC circuits.

Last month we examined some very important concepts regarding phase, vector diagrams, and the relationship between resistance, reactance, and impedance. Figure 1 summarizes the most important points, and you should fully understand how each formula was derived before attempting to continue.

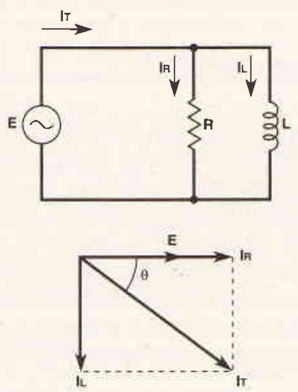
Parallel RL Circuits

You have seen that in a parallel circuit the same voltage appears across each of the components. Figure 2 shows a parallel resistive-inductive circuit.

As the resistor and inductor are in parallel, the voltage across each must be in phase with the supply voltage. In the resistive part of the circuit, current varies in direct proportion to applied voltage, so I_R is in phase with E. An inductive circuit current lags the applied voltage by 90 degrees, so I_L lags I_R and E, as shown in the vector diagram.

Vector addition, by way of Pythagoras' Theorem, must be used to calculate the total impedance of a parallel resistive-inductive circuit. As parallel connection reduces overall impedance, it is necessary to use the reciprocal of resistance and reactance in the formula and then take the reciprocal of the answer. The way in which the formula is derived is shown in Figure 2, along with its final algebraic re-arrangement.

When drawing a vector diagram to represent resistance, reactance, and impedance, remember that it is the reciprocal values that must be used. This extra step makes impedance vector diagrams for parallel RL circuits less common than current vector diagrams.



$I_T = \sqrt{I_R^2 + I_L^2}$

FROM OHM'S LAW:

$I_R = E/R \quad I_L = E/X_L \quad \text{AND} \quad I_T = E/Z$

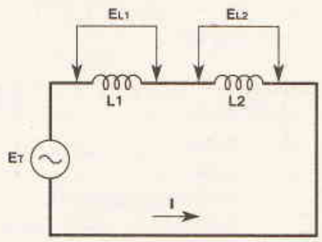
BY SUBSTITUTION:

$E/Z = \sqrt{(E/R)^2 + (E/X_L)^2}$

SO:

$1/Z = \sqrt{(1/R)^2 + (1/X_L)^2} \quad \text{OR} \quad Z = \frac{RX_L}{\sqrt{R^2 + X_L^2}}$

Fig.2 Parallel RL Circuit



$L_T = L1 + L2$

$X_{LT} = X_{L1} + X_{L2}$

DERIVATION OF FORMULAE:

SINCE THERE IS NO RESISTANCE, E_T, E_{L1}, AND E_{L2} ARE ALL IN PHASE, SO:

$E_T = E_{L1} + E_{L2}$

FROM OHM'S LAW:

$E_T = IX_T$ (WHERE X_T IS THE TOTAL INDUCTIVE REACTANCE)

$E_{L1} = IX_{L1}$

$E_{L2} = IX_{L2}$

SO, BY SUBSTITUTION:

$IX_T = IX_{L1} + IX_{L2}$

WHICH GIVES $X_T = X_{L1} + X_{L2}$

SINCE $X_L = 2\pi f$, IT FOLLOWS THAT

$I(2\pi fL_T) = I(2\pi fL1) + I(2\pi fL2)$

AND $(2\pi fI)L_T = 2\pi fI(L1 + L2)$

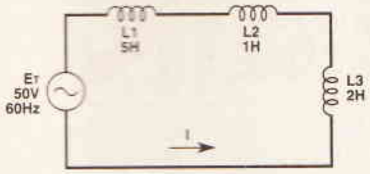
THEREFORE $L_T = L1 + L2$

Fig.3 Series inductors

Notice that the total current, I_T, is out of phase with both I_R and I_L. Compare this arrangement with that for a series RL circuit, where current is the same in all parts of the circuit but the three voltages are out of phase. The phase angle of the parallel circuit can be calculated by using any trigonometrical function, just as in the series circuit.

Series And Parallel Inductors

Figure 3 shows a simple inductive circuit with two coils connected in series. There is no resistance in the circuit, so there is a simple 90° phase shift between current and voltage. This implies that E_T, E_{L1}, and E_{L2} are all in phase, so the voltages can be added directly. Simple substitution from Ohm's Law and the inductive reactance formula lead to the conclusion that total reactance is equal to the sum of the individual react-



CALCULATE THE TOTAL INDUCTANCE, THE TOTAL REACTANCE, AND THE CURRENT FLOWING IN THE CIRCUIT.

$L_T = L1 + L2 = 5 + 1 + 2 = 8H$

$X_L = 2\pi fL = 2 \times 3.14 \times 60 \times 8 = 3{,}014\Omega$

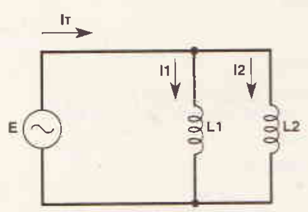
$I = E/X_L = 50/3{,}014 = 16.6mA$

Fig.4 Simple series inductive circuit

ances and total inductance is equal to the sum of the individual inductances.

Figure 4 shows a simple circuit with some values applied to it. The inductance of each coil is given, so it is a simple matter to determine the total inductance. The inductive reactance formula can then be applied to calculate the total reactance (which in this circuit, having no resistance, is also the total impedance). It would also be possible to work out the inductive reactance of each coil separately, then add the reactances together, but this method is far more complex than need be to solve the problem as stated.

In a parallel inductive circuit, the voltage across each coil is identical and in phase, and the current through each coil varies with the reactance of the coil (see Figure 5). Because the current in each coil lags the applied voltage by 90°, the two coil currents, I_1 and I_2, are in phase with each other, allowing a simple addition to obtain total current, I_T. Substitution from Ohm's Law leads to a parallel reactance formula of the same



$I_T = I1 + I2$

FROM OHM'S LAW

$I_T = E/X_T \quad I1 = E/X1 \quad$ AND $\quad I2 = E/X2$

SO: $E/X_T = E/X1 + E/X2$

OR $1/X_T = 1/X1 + 1/X2$

BY SUBSTITUTION FROM $X_L = 2\pi fL$:

$1/L_T = 1/L1 + 1/L2$

Fig.5 Parallel inductors

form as that used for parallel resistance, but with X in place of R.

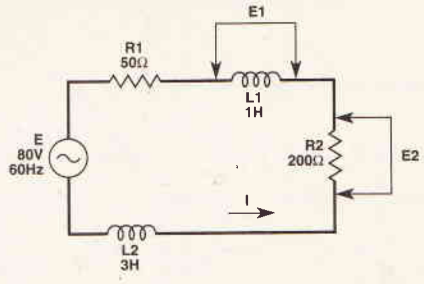
By way of revision, Figure 6 presents a series circuit with resistance and inductance. Try to calculate the values listed then check your answers with those shown. For some calculations there is more than one way to obtain the correct answer, so if you used a different method it is not important so long as you arrived at the same result.

Capacitance

You have seen how inductance causes a delay in the build-up of current in a DC circuit and sets up impedance to current flow in an AC circuit.

There is another electrical property which is very important to understand: capacitance. Inductance is the property that causes an opposition to a change in current. An inductor opposes current change by setting up a counter EMF. Capacitance attempts to prevent a change in circuit voltage.

Figure 7 shows the construction of a simple capacitor, which is also sometimes called a condenser. Notice that there are two plates, placed close together but not touching. Many practical capacitors are made with alternate layers of aluminium foil and insulating material, wound into a spiral. This allows the largest



CALCULATE:

I, TOTAL IMPEDANCE (Z), E1, AND E2, THE PHASE SHIFT AND POWER FACTOR, AND THE POWER CONSUMED.

$R_T = R1 + R2 = 50 + 200 = 250\Omega$

$X1 = 2\pi fL1 = 2 \times 3.14 \times 60 \times 1 = 376.8\Omega$

$X2 = 2\pi fL2 = 2 \times 3.14 \times 60 \times 3 = 1{,}130.4\Omega$

$XT = X1 + X2 = 376.8 + 1{,}130.4 = 1{,}507.2\Omega$

$Z = \sqrt{R_T^2 + X_T^2} = \sqrt{250^2 + 1{,}507.2^2} = 1{,}528\Omega$

$I = E/Z = 80/1{,}528 = 52.3mA$

$E1 = IX1 = 0.0523 \times 376.8 = 19.7V$

$E2 = IR2 = 0.0523 \times 200 = 10.46V$

PHASE ANGLE = Tan^{-1} XL/R = TAN^{-1} 1,507.2/250 = 80.6°

p.f. = R/Z = 250/1,528 = 0.164

POWER = E x I x p.f.. = 80 x 0.523 x 0.164 = 0.686W

Fig.6 Example RL circuit

area of metal plate to be packed into the smallest space possible. The insulating material of a capacitor is called the dielectric, and may be air, paper, mica, porcelain, or even glass.

Figure 8 shows a capacitor connected in series with a battery and switch. When the switch is closed, electrons from the upper plate of the capacitor are attracted to the positive pole of the battery, which has a deficiency of electrons. This leaves the upper plate of the capacitor with a positive charge. At the same time, electrons from the negative pole of the battery move to

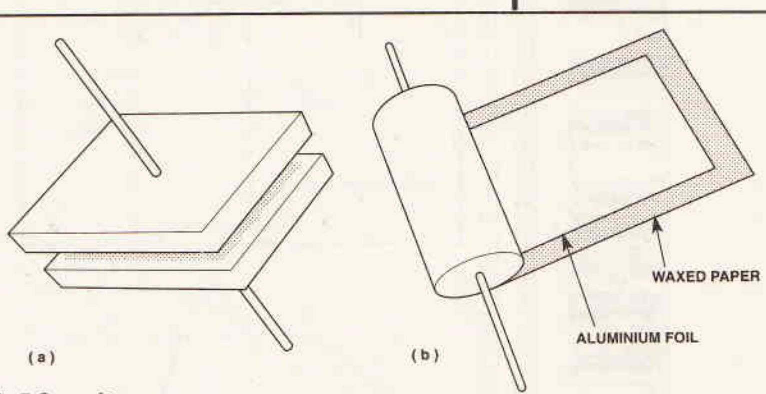


Fig.7 Capacitors

the lower plate of the capacitor. The positive charge on one plate helps to attract electrons to the other, and vice versa.

The result is a very brief flow of current in the circuit until the plates of the capacitor have acquired all the charge that they can hold. The capacitor is then said to be charged. If the switch is then opened, the positive and negative charges on the capacitor have

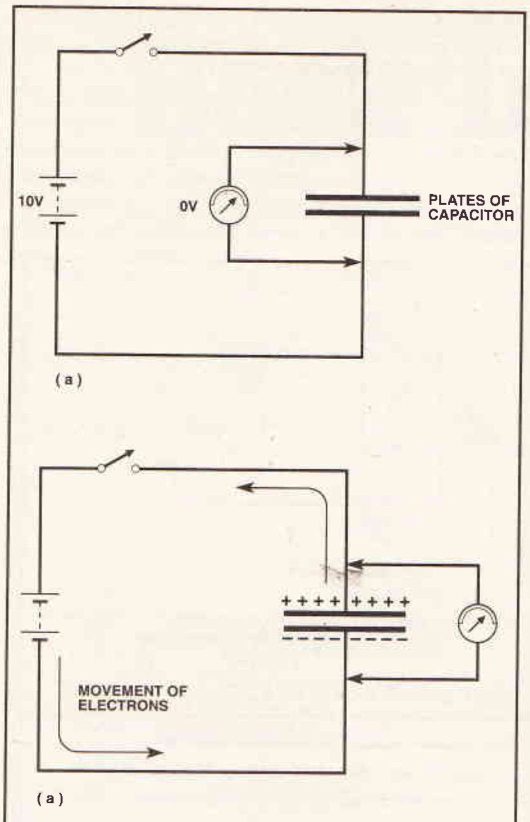


Fig.8 Charging a capacitor

nowhere to go, so the capacitor retains its charge, just as two objects charged with static electricity retain their charge until a discharge path is completed.

In our examination of inductors, we saw that current through a coil increases gradually when a voltage is applied. The graph of capacitor voltage against time in Figure 9 should look familiar, for the curve follows the same pattern. When the switch is moved to connect the capacitor to the battery via R_{R1}, current flows through the circuit to charge the capacitor. As the voltage across the capacitor plates rises, so the current decreases. When the capacitor voltage equals the battery voltage, current is zero. A similar decay of voltage occurs when the switch is moved so as to connect R_{R2} across the capacitor. There is an initial surge of current which gradually decreases as the capacitor voltage drops.

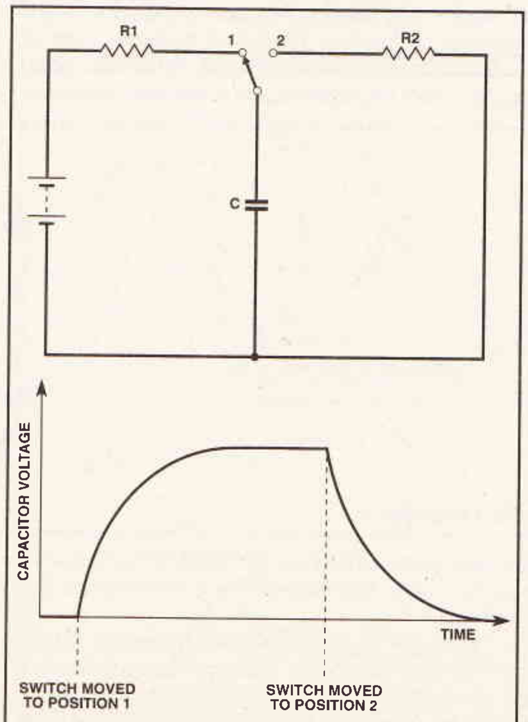


Fig.9 Charge/discharge of a capacitor

In the first part of this series it was shown that the quantity of an electric charge is measured in coulombs, one coulomb being a charge equivalent to billions of electrons. Any given size of capacitor plate can only hold or give up so many electrons, so the size of the plate in a capacitor affects how well it can store a charge. The larger the area of the plates, the greater the charge that can be stored.

The measurement of a capacitor's ability to store a charge is called its capacity or capacitance, and is measured in Farads (see Figure 10). A simple formula relates capacitance to charge (in coulombs) and voltage, but it is seldom required in most electronics work. The farad is an extremely large unit of capacitance, and represents the size of capacitor that holds a charge of 1 coulomb when an EMF of 1 volt is applied.

For most electronics work capacitance is measured in microfarads or picofarads, abbreviated as µF and pF respectively.

The area of the plates in a capacitor affects its capacitance. The larger the area of the plates, the greater the capacitance. The spacing between the plates also has a direct effect on capacitance. If the plates are brought closer together, the negative charge on one plate repels more electrons from the other, and vice versa, so a greater charge can be accommodated on each plate. As the distance between the plates increases, therefore, the capacitance decreases.

LET C = CAPACITANCE, E = VOLTAGE AND Q = CHARGE

$C = Q/E$

THEREFORE

$Q = C \times E$

AND $E = Q/C$

CAPACITANCE IS MEASURED IN FARADS (F), MICROFARADS (µF), AND PICOFARADS (pF).

1F = 1,000,000µF

1µF = 1,000,000pF

EXAMPLES:

0.001µF = 1,000pF

2,200pF = 0.0022µF

2,000µF = 0.002F

Fig.10 Capacitance measurement

A third factor which affects capacitance is the type of dielectric used. Certain materials placed between the plates of a capacitor increase its value by many times. Mica, for example, usually increases capacitance by a factor of between 4 and 8, compared to the same plates separated by air.

Capacitive Time Constant

When examining inductance we saw that the current through the circuit rises according to a special rule, and we saw that the length of time taken for the current to reach 63.2% of its full value is called the time constant.

A similar calculation can be applied to a resistor and capacitor combination, but this time the time constant is the length of time taken for the voltage across the capacitor's plates to each 63.2% of its final, maximum value. The time constant is dependent upon both the value of capacitance and the circuit's resistance (see Figure 11). As with inductance, after five time constants the voltage will have reached its maximum value.

Capacitance In AC Circuits

When a capacitor is connected across an AC voltage source, a phase shift occurs between current and voltage, just as with an inductor.

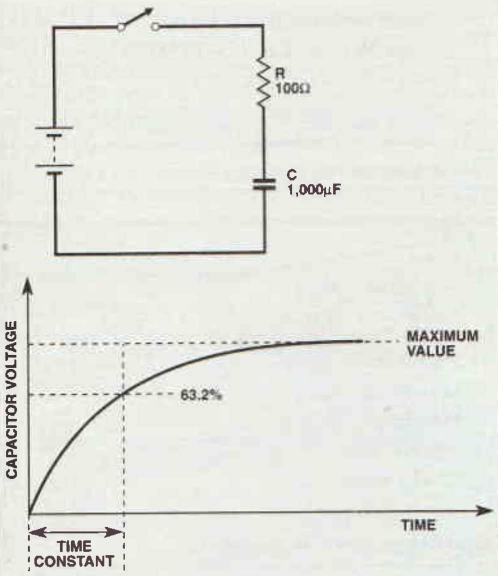
Consider the simple DC circuit presented earlier. At the moment the switch is closed the voltage across the capacitor is zero and the charging current is maximum. As the capacitor charges the current decreases and the capacitor voltage increases. When the capacitor is fully charged, current drops to zero and the voltage across the plates reaches its maximum level.

In an AC circuit the voltage does not have time to reach its peak before the current starts to drop toward zero again. As a result, the capacitor is continually charging and discharging, which allows current to flow in the rest of the circuit. No electrons actually cross the gap between the plates of the capacitor; it is the charge and discharge effect that causes them to flow in the external circuit. The result is that in a capacitive circuit the voltage lags the current by 90° (or the current leads the voltage, if you prefer). Notice that this is the complete opposite to an inductive circuit in which current lags voltage. You will see that inductance and capacitance are opposites in many ways, and used in combination they provide us with many useful electronic circuits.

Figure 12 shows the relationship between current, voltage, and power in a capacitive circuit. Compare it to the inductive circuit shown in part 5 of this series. Notice that the power curve is centred on the zero line; as with pure inductance, a pure capacitance does not consume any power. The energy taken from the circuit to charge the capacitor is returned to the circuit when the capacitor discharges, giving an average power of zero.

The charging and discharging action of the capacitor impedes the flow of current in the circuit, and the impedance is called capacitive reactance. Like inductive reactance, it is measured in ohms and can be related to voltage and current by Ohm's Law (Figure 13). Capacitive reactance is abbreviated as X_C.

Capacitive reactance is dependent upon the value of capacitance and the frequency of the applied AC voltage. As the value of capacitance increases so



t = R x C

(R in ohms, C in farads)

IN THE ABOVE CIRCUIT

t = RC = 100 x 0.001 = 0.1 SECOND

Fig.11 Capacitance time constant

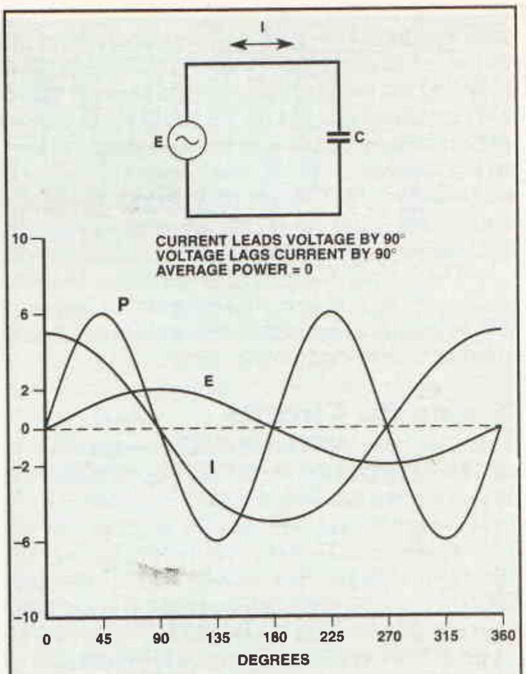


Fig.12 Capacitance in an AC circuit

OHM'S LAW FOR REACTANCE:

I = E/X THEREFORE E = IX AND X = E/I

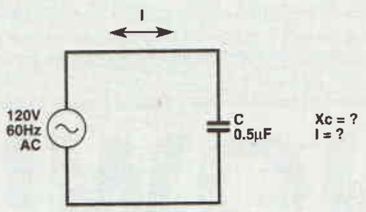
X = REACTANCE

Xc = CAPACITIVE REACTANCE

Xc = 1/2πfC

WHERE C = CAPACITANCE IN FARADS AND f = FREQUENCY

EXAMPLE:



Xc = 1/2πfC = 1/(2x3.14x60x0.0000005) = 5,308Ω

I = E/Xc = 120V/5308Ω = 22.6mA

Fig.13 Capacitive reactance

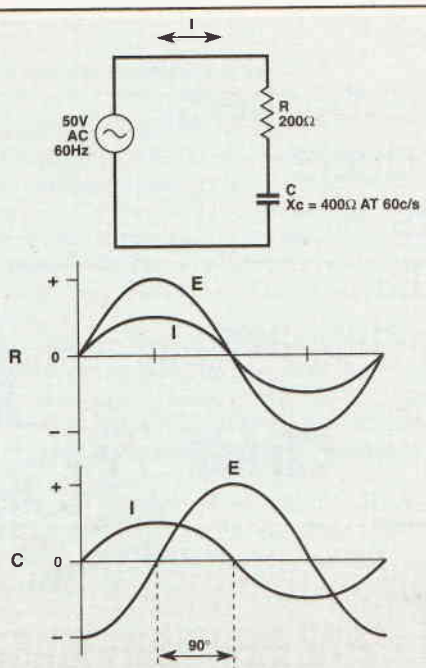
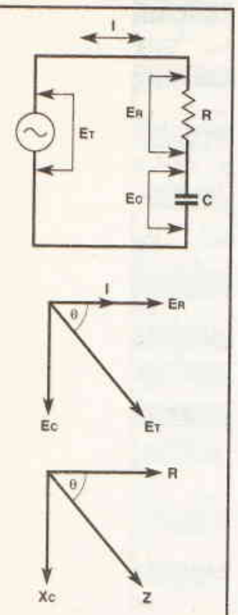


Fig.14 RC series circuits



$Z = \sqrt{R^2 + X_C^2}$

FROM OHM'S LAW:

$E_R = IR$

$E_C = IX_C$

$E_T = IZ$

Fig.15 Vector diagram for a series RC circuit

does the time constant for the circuit. That means that current will flow for much longer during each half cycle of AC, which means the capacitor offers less impedance to current flow. As the frequency of the applied AC increases, each half cycle becomes shorter in time, so that compared to the time constant a half cycle becomes very short. This also results in an increase in average current, which means that the reactance has decreased.

The formula for capacitive reactance, therefore, shows that X_C is inversely proportional to frequency and capacitance. Compare this formula to that for calculating inductive reactance.

Series RC Circuits

Figure 14 shows a simple series resistive-capacitive circuit. As with any series circuit, the current is the same at all points in the circuit. In the resistive portion, the voltage varies directly with current, as shown. In the capacitive portion, voltage lags current by 90°. The result is that the capacitor voltage is out of phase with both the resistor voltage and the supply voltage. Compare this diagram with the similar one presented for series RL circuits and notice that only the direction of phase shift in the inductor is different.

Figure 15 shows the now familiar vector diagram for the circuit. Current, I, and resistive voltage, E_R, are in phase and shown as the zero-degree reference. Capacitive voltage, E_C, lags current by 90°, and is drawn downward from the centre point. Pythagoras' Theorem can be applied to calculate the total applied voltage, E_T, or the total circuit impedance, Z. Similarly, the three trigonometrical functions can be applied to the vector diagram to calculate the phase angle and power factor of the circuit.

As with inductance, the power factor will vary between one for a purely resistive circuit and zero for a purely capacitive circuit. Refer back to the formulae presented in earlier installments if you are unsure about these calculations.

To finish off this month, try some calculations from the circuit shown in Figure 14. Calculate the total impedance of the circuit, the current flowing in the circuit, the voltage that appears across each component, the phase angle, and the power dissipated. When you have finished, check your answers against those shown in Figure 16.

Next month's installment continues our look at capacitance.

R =2000Ω

Xc = 400Ω

$Z = \sqrt{R^2 + Xc} = \sqrt{200^2 + 400^2} = 447\Omega$

$I = E_T/Z = 50/447 = 111.8mA$

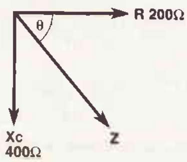
VOLTAGE ACROSS R:

$E_R = IR = 0.118 \times 200 = 23.6V$

VOLTAGE ACROSS C:

$E_C = IX_C = 0.118 \times 400 = 47.2V$

PHASE ANGLE:



Tan θ Xc/R = 400/200 = 0.5

SO θ = 63.4°

POWER FACTOR = Cos θ = R/Z = 0.447

APPARENT POWER = E_T x I = 50 x 0.1118 = 5.59VA

TRUE POWER = 5.59VA x 0.447 = 2.5W

TRUE POWER CAN ALSO BE CALCULATED BY USING $P = I^2R$, SINCE ONLY THE RESISTIVE PORTIONS OF THE CIRCUIT CONSUMES ANY POWER

Fig.16 Solution to problem

Pulsed Width Train Controller

PROJECT

David Silvester describes a different approach to controlling your model railways.

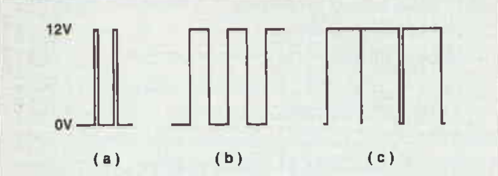


Fig.1 Pulsed width control

Last Christmas I bought my son a train set. Very few men have a problem with this since it is all too easy for them to want to play trains themselves but it did bring back memories of the problems that I had had over the low speed running of the engines when trying to shunt trucks. Although the set I had purchased seemed reasonable at low speed running, a friend had problems in this area especially with some old engines that he had obtained. With a long standing interest in electronics it seemed a good opportunity to try to build a train controller that would allow all of the engines to run as we wanted. The project initially started as a single controller to back up the one included in the set but since the unit could be made with two isolated controls without much extra effort then the prototype was built in this form.

Circuit Overview

The control circuit is based on a principal of pulse width modulation to provide a supply that has an average voltage that is suitable for operating the train. Consider the earlier system where the train is operated with current from a 12V DC supply via a high power resistor (a rheostat). We find that if we wish the train to start up slowly then the speed characteristics of the DC motors used tends to prevent good slow speed starting since they require a lot more power to get them going than to maintain the speed and the model train seems to jump into fast forward rather than start in a realistic way. The problem can be overcome if we supply the low average current as a series of voltage pulses. Consider for a moment Figure 1. We have here a pulse train (sorry about that but it is the usual term) of fixed frequency but with times in the high and low states that vary. In Figure 1a the current pulse is very short and although at it's peak it presents the full supply of 12V across the motor winding the average voltage and current are low. The voltage spike tends to prompt the motor into turning but the short duration of the pulse prevents it moving too far. As such the motor steps forward at each pulse and this creates the slow start and running. Higher power is given by increasing the time that the full supply voltage is applied. Figure 1b shows about half power with equal on and off timing whilst Figure 1c shows the high power setting where the output of the supply remains high for most of the time. It should be noted that there is no time when the instantaneous voltage to the motor is at half potential, it is either 'full on' or 'cut off'.

Since this is the case in the 'on' state the controlling device will have very little voltage across it although it will be passing a high current and in the 'off' state little current but the full 12 volts across it. In either case the power it dissipates is minimal. However the addition of current protection complicates matters as we shall see later.

This pulse width switching effect can be achieved by comparing a reference voltage (proportional to the power input to the required train) to a triangular waveform that carries out the switching timing. Consider Figure 2 where we have the triangular waveform and the reference. If we arrange that the switched output to the train is allowed when the triangular wave voltage is below that of the reference then if the reference is set at a low voltage the turn on time will be short.

Construction

The train supply can be built either as a single unit with one output or as a multiple unit with as many outputs as desired. The prototype was built as a dual unit so that two trains could be run on two tracks at the same time. To prevent problems with places where crossovers occur in the layout it was decided that the two supplies would have to be isolated from each-other and from earth. Thus Figure 4 shows one half of supply, the other half being identical and separate although on the same PCB. The transformer options have been discussed earlier and the description and parts lists that follow are for a single supply. R3 may

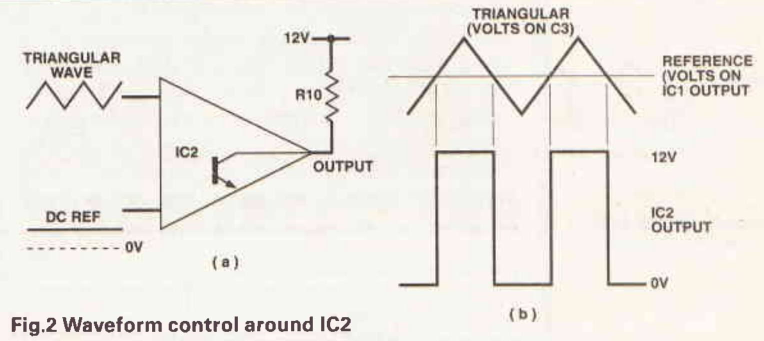


Fig.2 Waveform control around IC2

cause some readers difficulty since we require 11k to get the correct voltages out of the reference circuit. The author purchased these from Verospeed in Eastleigh, Hampshire (0703— 644555) but they only come in packs of 50. You may decide to substitute a 10k and a 1k in series for the single component. For the dual supply you just add another set of components to put in the case.

By following Figures 3 and 4 and the parts list the main PCB can be built and if required duplicated for the second supply. I have always found it easier to insert sockets for the ICs at first as this helps in orientation. Be careful when soldering as they all have tracks passing close to one of the pins and a short could cause serious problems. Then add the resistors and capacitors, watching out for the diode orientation. Lastly solder in the transistors but leave the ICs out of their sockets at the moment. Add a wire to each of the pads.

The pads marked P1 to P12 on the PCB drawing are mirrored on the circuit diagram as connections to

HOW IT WORKS

I shall describe the controller as a single unit since even if a second is included in the same case the two are electrically isolated although on the same printed circuit board.

240V AC mains input passes through a mains transformer giving 12V AC output and providing safety isolation. The difference between the transformer for the single and dual units is that for the single, the transformer has a pair of secondary windings rated at 2A by 6V whilst for the double unit this becomes two windings of 2A by 12V. During the construction the two windings of the 6V transformer are placed in series to give 12V as the input to a single rectifier. For the double unit the two windings feed separate rectifier circuits. The transformer is over rated on current to assist with regulation problems.

Let us consider the single control unit shown in Figure 3. 12V AC is applied to the bridge rectifier BR1 which charges the reservoir capacitor C4. This provides a DC voltage. Whilst not stabilised, it is sufficiently stable to run the op-amp and comparators used. The voltage across the capacitor is about 17V but the switch mode circuit never turns on for the whole of the cycle so the average voltage is kept below this level. The reservoir capacitor and bridge are not on the main PCB but mounted into the case directly as we shall see later. The unstabilised voltage is supplied to the board through connections P11 and P12.

IC3 is a voltage comparator which, whilst drawn in a very similar manner to an op-amp, actually has an transistor collector output that can be switched on or off depending on the voltage difference between it's input pins. Unlike an op-amp it is designed for switching operation rather than linear amplification. In this circuit the comparator IC3 forms a triangular wave oscillator with an output voltage of 5.6 to 11.3V (1/3 to 2/3 of supply voltage) above ground across C3 when the voltage at the slider of RV1 is at half the supply voltage. The oscillator has a fixed frequency of about 150Hz. By varying the voltage at the slider of RV1 the trigger points of IC3 can be shifted to allow for offsets in the ICs to be corrected.

In operation, the voltage at the output (pin7) of IC3 can be either 0V or supply voltage depending on whether the output transistor is either on or off. When the voltage at pin7 is high the voltage at the non-inverting input (pin2) is set at 11.3V by the values of R15, R12 and by the voltage at the slider of RV1. In this condition C3 charges through R16, and the voltage at pin 3 rises. When the voltage at pin3 of IC3 just exceeds that at pin2 then the output transistor in IC3 switches on and the voltage at the output pin7 drops to zero. Under these conditions the voltage at pin2 drops to 5.6V reinforcing the error condition that caused the initial switch. This is a Schmidt trigger action. With the voltage at the R14 end of R16 low, C2 begins to discharge through R16 until such time that the voltage at pin3 of IC1 drops below 5.6V at which time the circuit re-switches to the original condition with the output at high voltage. The voltage across C2 approximates to a triangular wave although being part of a CR charge/discharge curve a distinct non-linearity can be seen on an oscilloscope but this does not affect the circuit operation in this case. Since C3 charges and discharges through R16 the triangular wave output will have the same rise and fall times.

The train speed reference voltage comes from the potentiometer RV2. To give some lifelike characteristics to the model train it was decided to add electronic inertia and braking to the system. If the output voltage at the slider of RV2 rises sharply then C1 is charged via R4 but the time constant of the circuit causes the voltage across C1 to rise slowly so that the train appears to accelerate over a few seconds rather than jump to the new speed. Equally when slowing down the time constant of C1 with R7 allows the train to decelerate more realistically. Current flow through R4 during deceleration is prevented by D1. During braking extra current flow is provided by R1 and transistor Q1. Switch SW1 is part of a combined switch-pot where at the full anticlockwise end of rotation the switch is open circuit and closed for the rest of the pot travel. When SW1 is closed the gate of Q1 is held at ground and no current flows through R1 except for a very small leakage current. When SW1 is open Q1 turns on and provides the extra current sink for the charge on C1. Braking cannot be achieved unless the train is already decelerating. IC1 provides DC buffering to prevent loading affecting the operation of this high impedance circuit. The values of the components in this circuit are arranged so that the output of IC1 can be between 5.6 and 10.7V depending on the position of RV2 and with SW1 on.

Thus we have the reference and triangular waveforms to input to the control circuit since they now cover the same voltage ranges but with the reference slightly less so that the output is never 'on' for 100% of the time. The control unit is a second comparator arranged so that when the input from the triangular wave on pin2 is below that from the reference on pin3 the output transistor in the comparator is on and this turns on the main output control transistor Q3. When the triangular wave is higher in voltage than the reference then resistor R10 pulls the output high and Q3 turns off. Thus Q3 switches the supply on and off at high speed to give the required pulse power to the train's motor.

However mistakes can be made when using such a unit so protection has been built in to protect the supply. In normal operation the current demanded by the external circuit causes a small voltage to be developed across R11. Normally this is insufficient to turn on Q2, but under problem conditions, say by a short circuit across the rails then at a current of 600mA Q2 turns on and robs Q3 of drive, preventing high currents flowing and protecting the supply. The difficulty is that whilst Q3 dissipates very little power in normal switching operation in the limiting mode the power that normally is dissipated in the train is used to heat Q3. Thus under worst case conditions Q3 may be called on to dissipate 10.6 watts and therefore needs to be on a heatsink. To protect Q3 from spikes and high voltage feedback from the motor components C2 and D2 are included.

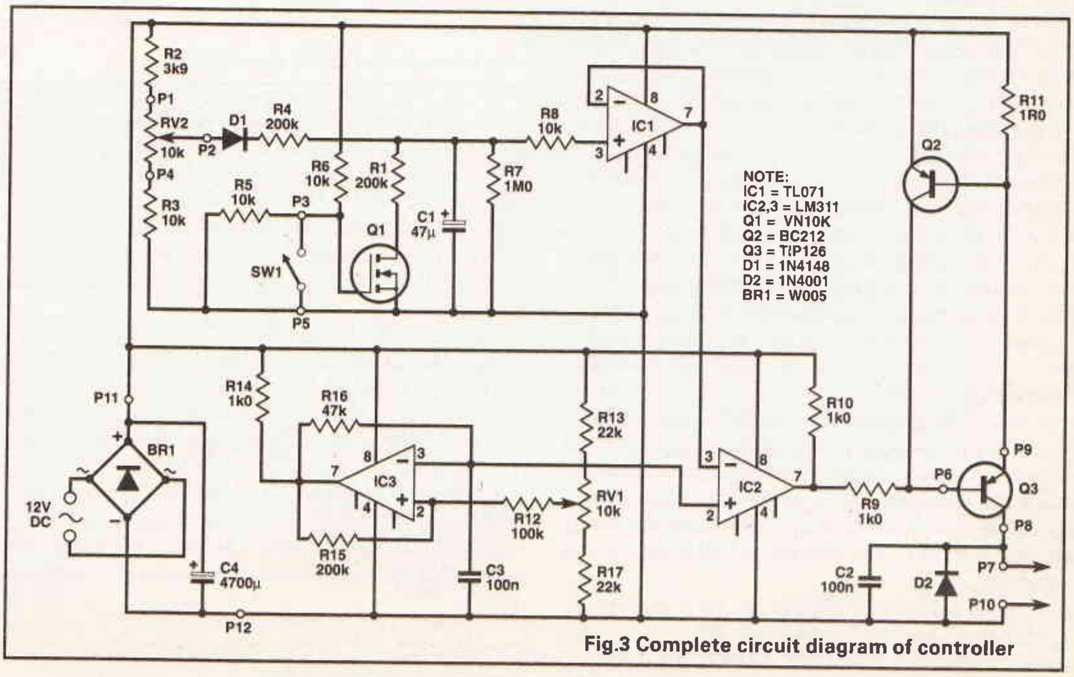


Fig.3 Complete circuit diagram of controller

the off board components, RV1 with SW1, Q3 and the input and output voltages.

Remember during construction that your sons and daughters will use the unit so take particular care over safety.

Take the box and position the switch-pot where required on the sloping front, then lay out the other items ensuring that they can all fit in without touching. Drill holes as necessary including one for the mains input cable which is secured by a locking grommet. Fit the mains lead, bare back the insulation, solder the blue neutral wire to the transformer and the brown live wire to the top of the fuseholder. Thus with the fuse removed you have to deliberately push something into the holder to make contact with mains voltages. Take another wire from the other fuse contact to the remaining input on the transformer. The careful constructor

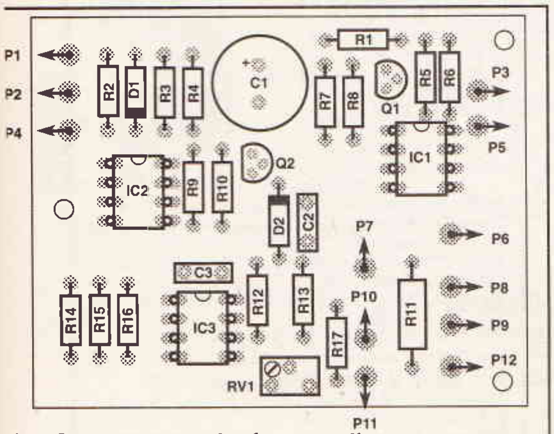


Fig.4 Component overlay for controller

now inserts a fuse, plugs in and checks for 12V AC on the transformer output. If all is OK unplug and cover all of the exposed connections with a thick layer of insulating tape. From now on we are away from mains voltages so it is much safer. As yet we have not made any provision for the earth lead in the mains input. As we have noted we cannot connect the earth to one of the supply lines as during use it will be possible for the unit to be shorted out within itself. The case used has a metal cover although the main part of the case is plastic so a solder tag was attached to the earth wire so that at the final stage the cover would be grounded with the tag between the cover and the main case.

The bridge rectifier is attached directly to capacitor C4 with wires to the transformer. Build this part of the circuit and check for about 17V across C4. Now install all of the rest of the components in the box with the PCB sitting on stand-offs. Connect the wires to the capacitor C4, pot RV2, switch SW1 and the transistor Q3 following Figure 3. Since we want the train to be able to go backwards and forwards the output at pads P7 and P10 goes to a switch that crosses over the connections to the output sockets (See Figure 5). Although written in a few words and because of the number of connections, especially with the double unit, wire colours will have to be used more than once. This stage should be taken very carefully. The appearance of the final unit depends on the care in this wiring.

Testing

If you have an oscilloscope it is interesting to look at the waveforms for the circuit using the oscillator as the trigger, but it is in no way necessary to set up the unit. There is only one pot to adjust. To protect the trainset use a 47R wire wound resistor as a load for the circuit during initial tests. Turn RV2 the speed control anticlockwise as far as it will go before the switch operates as when SW1 opens Q1 turns on reducing the voltage on C1. We need to adjust RV1 so that at the lowest normal output of IC1 the lowest voltage of the triangular wave is above this value and IC2 never triggers. Measure the voltage across the 47R resistor with a multimeter set initially on a 20V or greater range. Measure the voltage, if any, with the pot at the anticlockwise end of it's travel, then turn up slowly and see if the voltage rises. Remember there is a built in delay so the voltage will not snap up and down as you turn the pot. Check you can see the acceleration delay by turning the pot up quickly and the voltage at the output follows slowly and if turned back down, the voltage at the output falls slowly. Test the full anticlockwise 'brake' position of the pot. If you cannot get these tests to work there is probably an error in the construction. Set RV2 at the most anticlockwise position and with the switch on, turn RV1 up and down slowly. The output voltage should rise to a low value. Set the multimeter to it's most sensitive voltage range and turn RV1 so that the output just reaches zero. Repeat for the second channel if used. Set up the trainset and connect the supply. We can hear the very narrow power spikes as a buzzing in the train motor. With RV2 at it's lowest point adjust RV1 so the buzzing stops. Leave for a few moments and re-adjust if necessary.

Fathers will no doubt find this project an excellent excuse to interest their sons in electronics and at the same time play trains.

PARTS LIST

RESISTORS	
R1,4,15	200k
R2	3k9
R3	11k see text if not available locally
R5,6,8	10k
R7	1M0
R9,10,14	1k0
R11	1R0
R12	100k
R13,17	22k
R16	47k
Extra	47R 3W Wire wound for testing only
RV1	Spectrol 64Y Type 10k
RV2	10k lin pot with switch SW1
CAPACITORS	
C1	47µ electrolytic 25V
C2,3	100n ceramic
C4	4700µ electrolytic 25V with clip
SEMI CONDUCTORS	
IC1	TL071, CA3140, LF351 or equivalent
IC2,3	LM311
Q1	VN10KM, BS170 or equivalent MOSFET
Q2	BC212, BC213, BC557 or equivalent
Q3	TIP126 or any PNP power darlington
D1	1N4148, 1N914
D2	1N4001 or any equivalent
BR1	WO1 or equivalent 100V by 1A bridge

MISCELLANEOUS

Transformer 6 or 12 volt x 2 amp see text for details
Sloping Front Case Maplin LH67 used
Pot Knob Large Maplin YX04 used
Miniature DPDT switch for train direction (See Text)
PCB Standoffs
4mm plugs and sockets
Fuseholders and Fuses 250mA Slow Blow for Transformer input
1A Fast blow for supply outputs
Input cable and locking grommet
Solder tag for earthing front panel
Small cable tyes and sticky cable supports
Heatsink Redpoint 2W-1
Screws nuts and washers

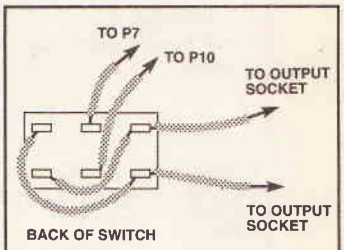


Fig.5 Switch detail

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BP024	2	2 Right angle, PCB mounting rotary switch, 4 pole, 3 way rotary switch *UK made by LORLIN*
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BP033	2	FM stereo decoder modules with diagram *UK made by PHILIPS*
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BP033A	3	6"x⅜" High grade Ferrite rod *UK made*
BP034	2	AM IF modules with diagram *PHILIPS UK MADE*
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BP049	10	OC44 transistors. Remove paint from top and it becomes a photo-electric cell (ORP 12). *UK made by MULLARD*
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BP051	6	14 watt output transistors. 3 complimentary pairs in TO66 case. *(Ideal replacement for AD161 and 162s)*
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Field Programmable Gate Arrays

Xilinx – Pronounced 'Zy – links'

Anthony Williams describes the exciting new developments taking place in silicon integrated circuit technology.

Have you ever heard of a company called Xilinx? If you have than you are probably familiar with a new range of digital ICs called Field Programmable Gate Arrays (or FPGAs for short.)

If Xilinx is a new name to you then I suspect that you will be hearing a lot about them shortly because Xilinx's FPGAs are revolutionising the way in which digital electronic circuits are designed.

The FPGA concept is quite straight forward. A designer sits at his computer terminal and enters his electronic design using a Computer Aided Design package. Once he is confident that his circuit will perform the desired function, he lets the Xilinx software (called XACT) take over. XACT examines the design and performs various operations upon it which gradually transform it into a 'bit-stream'. This bit-stream is a large amount of serial data, which when loaded into

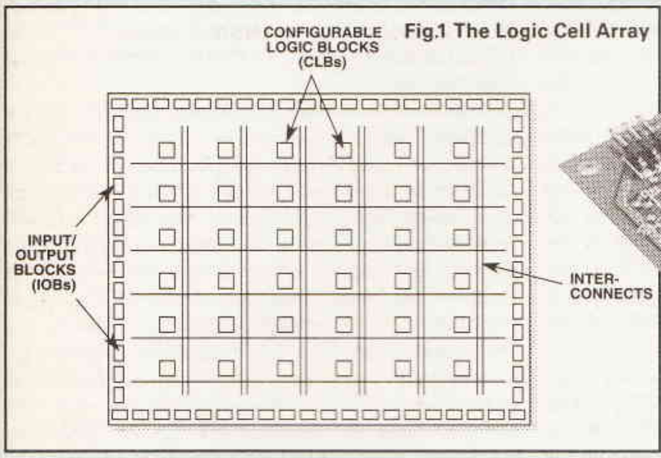
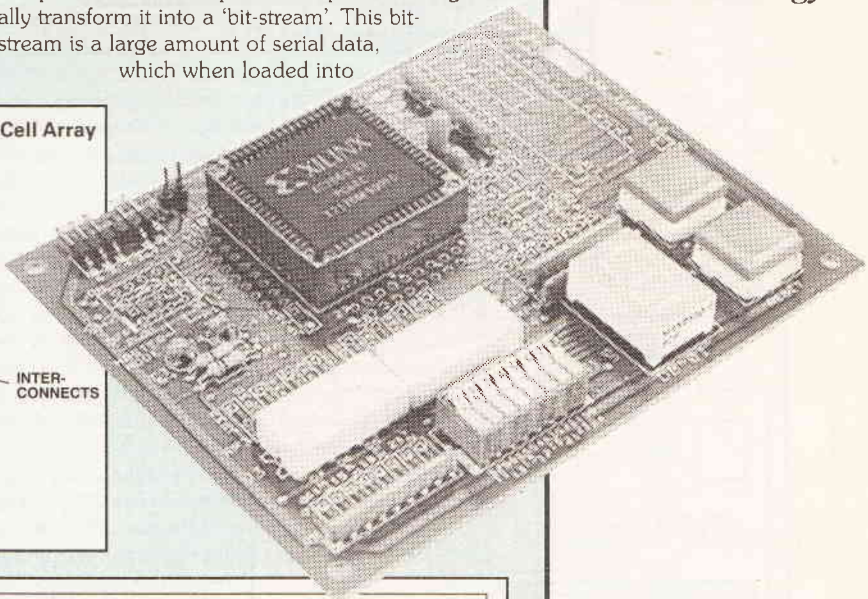


Fig.1 The Logic Cell Array



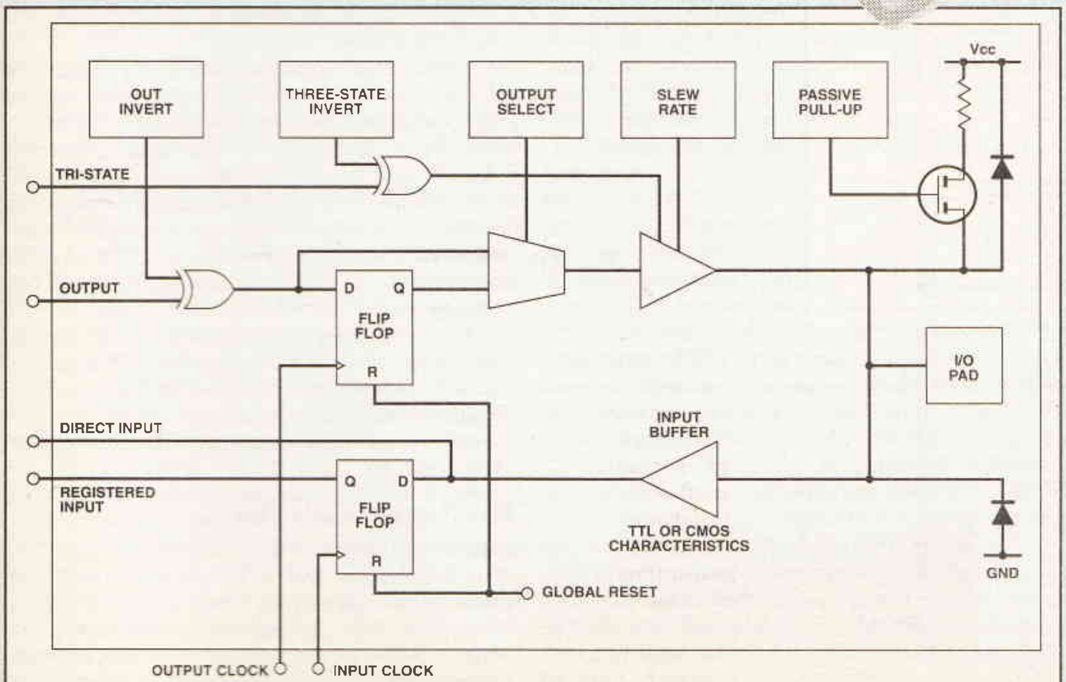


Fig.2 Input/Output Block

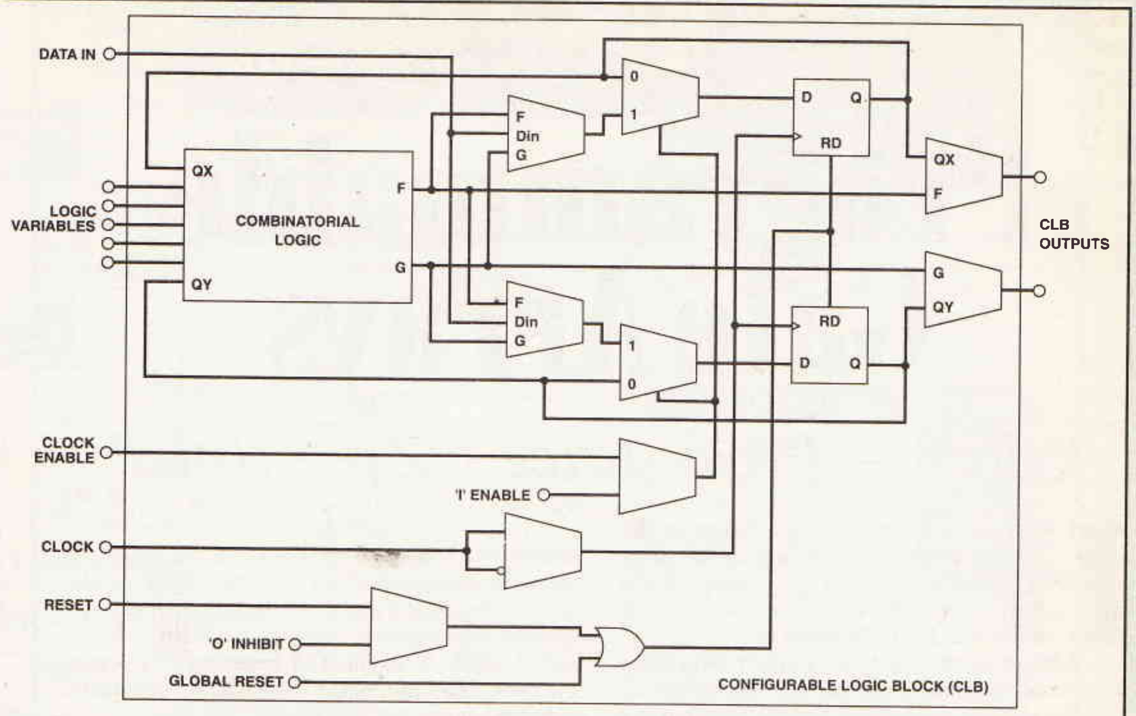


Fig.3 Configurable Logic Block (CLB)

the FPGA will organise its internal logic such that it takes on the function of the designer's circuit. Input and output connections are made via pins on the package, allowing the device to interface with the other components in the system. The whole process is (usually) performed automatically and can take between a few minutes and a few hours — depending on the size of the design.

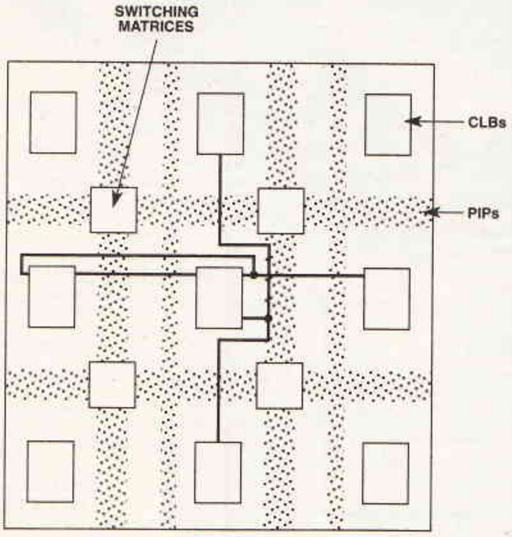


Fig.4 Direct Interconnect

The beauty of the Xilinx system is that the FPGA holds the bit-stream within itself in a large static-RAM where each memory location corresponds with the function of one small part of the circuit. This means that by just interrupting the FPGA's power you can start your design all over again with a clean slate — you don't even have to take the device out of its socket. Of course this also means that the FPGA has to be reprogrammed every time it is switched on and there are two methods of achieving this. The first method involves attaching a non-volatile, serial or parallel ROM to specific pins on the FPGA. During power-up, the FPGA copies the contents of the ROM into itself and takes up its new function — the ROM is then no-longer needed. When this method is chosen, it is more common to find serial ROMs being used, since they are small, inexpensive and require fewer connections to the FPGA.

The second method involves a direct link to a computer, allowing the designer to program the FPGA directly without having to go to the trouble of reprogramming any PROMs. (In this instance the computer would act as a serial ROM). Using this approach, the FPGA logic in an experimental system can be altered, at the whim of the designer, by simply making the required changes to the circuit diagrams on the screen of his computer. Consequently, working with Xilinx FPGAs is convenient and efficient, simple and relatively painless.

Several features of the Xilinx design process are explained here. For example, the ability of the XACT software to take a design, produce a bit stream from it and then work backwards to calculate all the propagation delays that will occur when the circuit is implemented within an FPGA. This timing information can then be used in the simulation of the circuit so that the designer can be as certain as possible that his circuit will work once it is loaded into the target device.

Another feature of the FPGA is the possibility for the designer to 'read-back' the contents of the RAM to verify that the bit stream was loaded correctly. The designer however, may choose to prevent read-back altogether, allow only a single read-back or allow any number of read-backs. This gives rise to two important considerations:-

Firstly, if the security of the design is critical — as in a data encryption system — then the system may be programmed and supplied with a battery back-up arrangement to maintain the bit stream within the FPGA. Then if anyone tampers with the device the contents of the FPGA will be lost leaving no trace of its function. To recover the system once it has been tampered with, all that is required is to re-insert the ROM containing the original bit stream and let the FPGA reprogram itself.

Secondly, during a read-back, not only is the bit-stream read back but so is the state of each of the flip-flops within the device. This allows the function of the FPGA to be verified in— circuit without the need for painstaking test-vector generation or 'design-for-test' methodologies.

The Logic Cell Array

Xilinx have implemented an architecture called the 'Logic Cell Array' in their FPGAs — see Figure 1. This consists of an outer ring of I/O interface blocks (IOBs) surrounding an inner matrix of Configurable Logic Blocks (CLBs). Occupying the rows and columns between these are the interconnection resources — metal tracks that run the length and breadth of the chip allowing signals to be transported from a source to a destination. The CLBs provide the main functional elements from which the user's circuit is constructed and the XACT software allocates small portions of the user's logic to each CLB. The IOBs also contain a small amount of configurable logic but this takes the form of either input/output latches, invertors, tri-state buffers or passive pull-up resistors.

The internal structure of an IOB (found in the X3000 family of FPGAs) is shown in Figure 2. The role of the IOB is to provide an interface between the external package pin and the internal user logic. Each I/O block may be configured as an input, output or bi-directional line between the outside world and the internal logic. Inputs and outputs can be direct or latched and inverted as required. Other options allow (a) the outputs to be driven into a high-impedance 'tri-state' condition, (b) for a passive pull-up resistor to be applied and, (c) for the slew rate of the output pin to be either high or low. (A high slew rate is required for high speed signals but can be an unnecessary power drain on any non-critical signals.) The characteristics of the IOBs may be altered globally to suit a TTL or CMOS environment and all inputs and outputs are protected from static electricity and sudden power surges that might 'crash' the FPGA.

The internal structure of a CLB (found in the X3000 family of FPGAs) is shown in Figure 3. The combinatorial logic section consists of a static RAM arranged with 32 entries of 1 bit and forms a look-up table which is used to generate the small portion of logic allocated to each CLB. Of its seven inputs only five can be used at once and these include five inputs from other CLBs or IOBs plus two inputs from the two accompanying flip-flops. The logic may be implemented in a variety of ways allowing two functions of up to seven variables. The flip-flops can be entirely separated from the logic within the CLB or they can be used to latch the logic block's output. Each CLB has 9 inputs and 2 outputs — any of which may be connected to the inputs or outputs of other CLBs or IOBs.

Note that Xilinx FPGAs can come in a variety of package types and that not all packages have the same number of pins as the chip has IOBs. Consequently there may be IOBs on the chip which have no function as they are not connected externally. However, rather than allow this silicon to go to waste Xilinx permit the designer to make use of the flip-flops, invertors and tri-state buffers in his own design. This also applies to IOBs that the designer simply has not needed to use. In this way an IOB may be used as a limited type of CLB.

Connections between the IOBs and CLBs are made using the interconnection resources that lie on the surface of the chip between the logic and I/O blocks. Three types of interconnect exist. The first is the General Purpose Interconnect (see Figure 4) which consists of short lengths of metal track that extend away from the outputs of each block into the vicinity of the adjacent block's inputs. Connections between these (and all other types of interconnect) are made via programmable interconnect points (PIPs) which are represented by the small dots on the diagram. (PIPs may be turned on or off thus making or breaking a connection between two metal tracks.)

The next type of interconnect is the Direct Interconnect (see Figure 5) which spreads across the entire surface of the chip in a grid consisting of five metal tracks. At the intersections of these tracks lie switching matrices — crosspoint switches that allow tracks to be connected together, jump over each other or cross from a horizontal to a vertical limb of the grid. All of these tracks cross at least one of the General Purpose Interconnects associated with each CLB/IOB making it easy to route large busses around the FPGA. Again PIPs are used to make connections between these and other interconnects.

The last type of interconnects are called long-lines (see Figure 6) which are single, long tracks of metal which traverse the chip in horizontal and vertical directions. There are three vertical and two horizontal long-lines for each CLB plus two long-lines which run around the extremities of the chip specifically for the IOBs. These lines are ideal for supplying the same signal to a large number of CLB/IOBs simultaneously without introducing any skew or time delays and are typically used for clock lines.

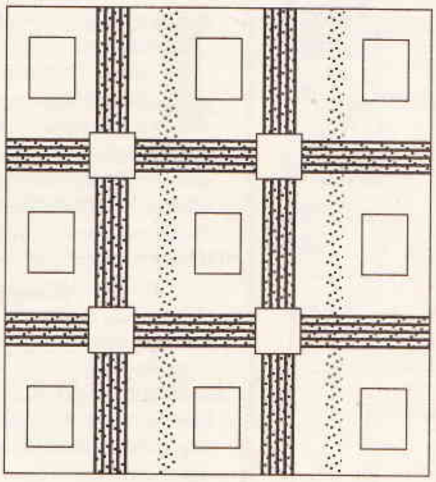


Fig.5 General Purpose Interconnect

Finally, for each CLB/IOB there are two tri-state buffers and for each long-line there are two passive pull-up resistors. Together these allow multiplexers and wired-AND functions to be generated within the FPGA without using up any of the valuable logic resources. In addition, an on-chip crystal oscillator is provided if an internal clock is required. This can be distributed around the entire FPGA by its own set of dedicated long-lines.

The bit stream that I mentioned earlier is generated automatically by computer from the circuit diagram entered by the designer. It contains the bit patterns that should be loaded into the CLB look-up tables, it contains details of which PIPs should be turned on or off, which connections should be made in the switching matrices and details of how the IOBs should be configured. The XACT software includes the XACT Design Editor which gives a pictorial representation of the Logic Cell Array and indicates which tracks are used and which are not, which PIPs are on or off, which connections have been made in the switching matrices and how the CLBs have been arranged internally. The XACT software usually makes all these decisions for you but sometimes it may fail to fit the entire design into the limited space of the FPGA or the resulting 'routed' design may not meet the speed requirements dictated by the specification. In these instances the designer would turn to the Xilinx Design Editor to make the fine adjustments to the 'routing' that will give the desired performance.

Overall, the Xilinx design system is easy to use and quick to learn with the automated tools taking 99% of the work out of the hands of the designer. The incredibly short turnaround on going from a 'paper' design to a finished working device has to be seen to be believed and the ability to accurately model a design on the Xilinx simulator leaves the designer with unprecedented levels of enthusiasm and confidence in his design.

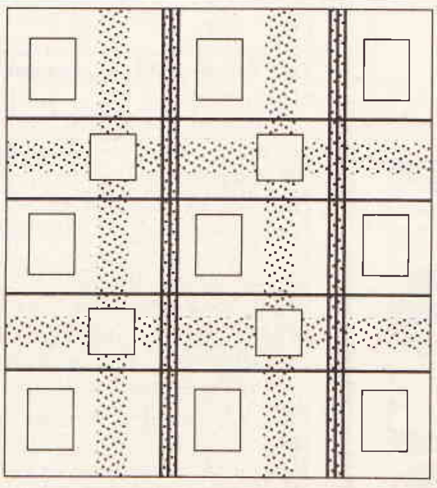


Fig.6 Long Lines

Loudspeaker Damping

Jeff Macaulay discusses the problem of loudspeaker resonances.

In the March edition of ETI a circuit in 'Blueprint' was given to increase damping in speaker systems. This was of great interest to me since I have been experimenting with this idea for some months and have come to some, I hope, interesting conclusions. First before delving more deeply into the theory it may be of interest that the original circuit was due to Clemments and published in 'Audio engineering', a now defunct American publication of 1950! [1],[2],[3]

In the original text the output impedance of a valve amplifier was reduced by sampling the current through the speaker and feeding this back into the amplifier. Unfortunately the only way to make this work is to use positive feedback which increases non linearity in the power amp. However, if excessive negative feedback is used to linearise the amp, this is not a problem.

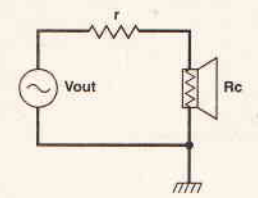


Fig.1 Simplified circuit of amp/loudspeaker combination

To illustrate what happens look at the circuit of Figure 1. This shows a simplified model of the loudspeaker as seen by the amplifier. The series resistance R can be made negative cancelling part or all of the voice coil resistance R_C. This will provide much better damping of the speaker than simply feeding it from a zero impedance source. When this has been done, an oscilloscope connected across the speaker terminals will show that the amplifier will generate a correcting voltage if the cone is gently tapped. Try this with a conventional amplifier and the output stage does nothing at all.

almost impossible to determine what instrument is being played.[4]

Most of the power supplied by an amplifier to a speaker is simply used to heat up the voice coil. If there were prizes for inefficient machines the average driver would be a good contender.

If you can stretch your mind back to the original speaker design articles in ETI (July-Aug '89) you will recall that there are three main speaker parameters, f_s, Q_{ts} and V_{as} is the base resonant frequency of the driver, measured in free air, usually in the range of 20 to 100Hz for your average driver. Qts is the 'Q' of this resonant peak considering both the electrical and mechanical Q's. Finally Vas is the volume of air whose compliance equals the compliance of the surround.

The efficiency of a driver is,

no.= $(2.7 \times 10^{-8} \times fs^3 \times Vas)/Qes$

Q_{es} is the electrical Q of the driver and it's value should be supplied in the driver data sheet. To take an example lets consider the KEF B200A, an old but venerable design! Q_{es} is quoted at 0.57, fs is 25Hz and V_{as} is 4.6 cu ft. Putting this into the equation above gives us no.=.003427. To find the percentage efficiency multiply by 100 = 0.3427%! To convert this to something more useful the sound pressure level (spl) at 1m for 1 watt input is,

spl = 112+10log10(no.) = 87.35 db/W/m, where no. is expressed as a decimal.

Now, as mentioned earlier, Q_{ts} is not a simple parameter it's made up from two others, Q_{ms} and Q_{es}. Q_{ms} is the mechanical Q and Q_{es} the electrical. They are related to one another by,

$1/Q_{ts} = 1/Q_{ms} + 1/Q_{es}$ (Just like parallel resistors).

r (ohms)	Qes1	Qts1	no.%	SPL,1W at 1m	db down at fc.	F3,Hz
0	0.790	0.707	0.26	86.0	-3.0	35.0
-1	0.670	0.607	0.32	87.0	-4.34	41.7
-2	0.567	0.521	0.37	87.7	-5.66	51.3
-3	0.456	0.426	0.46	88.5	-7.41	68.0
-4	0.345	0.328	0.59	89.7	-9.68	95.4
-5	0.234	0.226	0.86	91.3	-12.92	146.9
-6	0.112	0.119	0.16	94.0	-18.3	282.6
-7	0.011	0.012	1.00	102.0	-39.2	3210.0

Fig.2 The effect of negative output impedance on speaker damping and low frequency performance

Reading the original articles is interesting. From our vantage point of 40 years on, the explanation for the observed behaviour of the circuit is fairly obvious. But then we have the advantage of Theille/Small theory to fall back on. The main subjective effects of greater damping is a tighter sound, bass loss and some apparent loss of efficiency. When I wrote the articles on Theille/Small theory last year I didn't get into the area of efficiency. To understand what's happening it's necessary to do some simple maths.

The tighter sound quality is easily explained by the improvement of transient response gained by Q reduction. Transient response is a vitally important factor in the perception of harmonic structure within music. If the starting transients are removed from recordings of familiar musical instruments it becomes

Q_{es} depends on the amount of resistance in the circuit and can be altered by adding or subcontracting series resistance. In fact,

$Q_{es}=Q_{es}\ (R_c+r)/r_c$

Where r_c is the voice coil resistance. So you can see that altering r will alter both Q_{ts} and the efficiency no. Furthermore if you mount your driver in a sealed box or reflex enclosure adding negative resistance will reduce the Q_{tc} of the system. A useful trick of the trade is that the relative efficiency of a speaker mounted in a closed box at it's fundamental resonance f_c will be,

db = $20\log10(Q_{tc})$

Where Q_{tc} is the Q of the driver when mounted in an enclosed cabinet. Strictly speaking Q_{ts} is the system Q_{tc} of an infinite volume box. Also you will recall that both the resonant frequency and Q_{tc} are increased by box mounting. This equation applies to both mounted and unmounted drivers. Taking the B200A as an example. When mounted in a closed box of 1.56 cu ft the resonant frequency rises to 34.65Hz at a Q_{tc} of 0.707. With this Q_{tc} the $-$3db point, F3, is equal to fc. Lets see what happens as the output impedance of the driving amplifier is made negative by degrees. Rc, the voice coil resistance for the B200 is 7.1 ohms.

One way of visualising whats going on is to consider an analogy. The resonant frequency of a driver can be likened to a mass suspended on a spring. If you pull the weight downward and then let go it will oscillate before coming to rest. This is analogous to an underdamped resonant circuit. If you were to repeat the experiment with the apparatus under water you might well be able to achieve a system which rapidly reaches it's final position without overshoot. A overdamped system would be like performing the above experiment in a bath of molasses! The weight will take an extremely long time to reach it's final position. This is shown graphically in Figure 3. The best transient response is only obtained with a system Q of 0.5. The critically damped condition. Note also the way in which F3, the -3db point gets higher with decreasing Q.

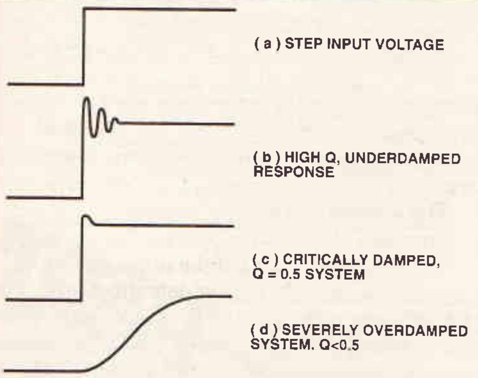


Fig.3 Effects of damping on a loudspeaker

Now if you look at Figure 2 you can see what happens is that the output at f_c falls, F3 the -3db point in the bass, goes up and the midband efficiency also goes up. No free lunch though, the extra efficiency is at the expense of more current from the power amp.

What then can be learned from Figure 2 and has the technique any real value? I think so. In Clemment's original article he pointed out that any speaker system which possessed a resonant frequency will have that resonance excited by any signals of higher frequency than the resonance. Once excited the speaker will ring at the resonant frequency producing colouration. If you think for a moment what this means. Every note reproduced by the speaker will excite the bass resonance producing colouration.

As Q_{tc} is lowered the amount of ringing decreases. Surprisingly a tuned circuit or speaker will not ring if the Q is equal or less than 0.5. This condition is known as critical damping. The reason that Hi Fi shops aren't filled with critically damped speaker systems is the penalty to be paid is a loss in bass output compared to a Q_{tc} of 0.7.

Translated into practical terms our test speaker will have it's -3db point shifted up to 63Hz instead of 35Hz at Q_{tc} = 0.5. Considering the bass loss penalty it's probably not advisable to reduce Q_{tc} to below this value in any event.

It's a sad fact of life that most people confronted with the choice between well damped speakers and bassy ones opt or the bass. Still, a small amount of Q reduction can be a positive advantage.

For example you could manipulate the Q_{ts} of a driver to fit a given cabinet size when reflexing for example. The low rate of rolloff could be useful in matching the bass response of an existing system to take advantage of the bass enhancement due to room reflections. Lastly if your existing speaker booms in the bass, a little judiciously applied negative resistance would cure it. The circuit shown in Blueprint would be most suitable. Where the circuit would fail is in a specifically designed speaker/filter system such as the Flatmate, ETI May 1990. Here the result will be an irregular, to say the least, bass response due to upsetting the delicate balance between parameters achieved in this design.

Finally a circuit that I have used intermitantly since I first developed it in 1982 [5], Figure 4. This is a useful alternative to negative output impedance and has the advantage of not reducing Q_{tc}. Here the speaker is connected directly into the feedback loop of the power amplifier. This is done by wiring a low value resistor in series and taking the junction back to the feedback point. Because of the low impedance of R1 and Rs they effectively swamp the existing feedback components, R1 and R2.

Also since a moving coil driver looks like an inductance in series with R_c a Zobel network has been placed in parallel, R3 and C1. If this is excluded the circuit will exhibit a rising response with frequency. The values suggested are starter ones. Adjust them for the best sound.

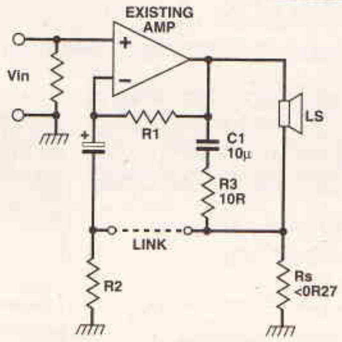


Fig.4 Speaker in feedback loop of power amplifier

This circuit shows some unusual effects. Again if the speaker cone is tapped the amplifier generates a correcting voltage. The top range is also extended. I've used a B200 with this circuit and got very usable output to above 10kHz! Admitted the treble beamed a bit on axis but the unit sounded as good as many woofer/tweeter combinations I've tried and it has the advantage of no interdriver phase shifts or crossover network! This might well work OK with the Flatmate (ETI May '90) but I admit to not having tried it. I am after all now doing my listening on son of Flatmate!

References

1) 'A New Approach to Loudspeaker Damping' by Warner Clemments*
2) 'Dynamic Negative Feedback' by Ulric J. Childs*
3) 'It's Positive Feedback' by Warner Clemments*
4) 'Identifying Musical Sounds' by Vivian Capel. HFN&RR Feb 1971
5) 'Active Speaker Systems' by J. P. Macaulay. Practical Electronics July 1982
*These articles are available in the 'Audio Anthology', Vol 2 published by AUDIO AMATEUR PUBLICATIONS, $16.95 available from 'OLD COLONY SOUND LAB', POST OFFICE BOX 243, PETERBOROUGH, NEW HAMPSHIRE, 03458-0243 USA. Please write to them first for UK price etc.

Medical Laser Systems

A look at the latest developments and uses for Lasers in the medical world by Douglas Clarkson.

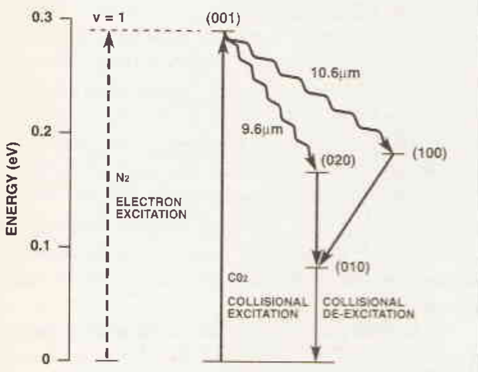


Fig.1 Vibrational states of CO_2 molecule. The favoured 10.6 micron transition represents the release of energy from one mode of vibration to another of reduced energy

The use of laser systems in medicine began around the early 1970's when carbon dioxide systems were introduced. Since then numerous other types have been developed. After a period of relative stability, the field of medical lasers is witnessing the implementation of a range of new techniques and systems. In describing the uses made of medical lasers, it is appropriate to consider each of the specific laser types and outline the range of clinical applications for which they are used.

The Carbon Dioxide Laser

The carbon dioxide laser is primarily used as a tool in general surgery where its heating effect is used to cut/destroy selected areas of tissue. This laser radiation has a relatively long wavelength (10600nm:10.6 microns) in the infra red region which is readily absorbed by moisture-containing tissue.

The carbon dioxide molecule can undertake three main types of vibrational motion, each of which is associated with so called quantum levels of energy. When a molecule changes from a higher vibrational level to a lower one, it releases a 'bundle' or quantum of energy.

In the CO_2 laser, the gas is ionised so that ionised molecules can receive energy by colliding with electrons in the gas plasma. In order to improve the efficiency of the energising of the CO_2 gas, Nitrogen gas is added. This is because an ionised Nitrogen molecule can excite a CO_2 molecule from the ground state up to a high vibrational state as shown in Figure 1. Decay to an intermediate level releases the 10.6 micron photon. Helium is added to the gas mixture to promote release of excited molecules to the ground state. Typical gas mixtures used are in the ratio 4.5%: 13.5%: 82% of CO_2: N_2: He respectively.

The gas in the discharge tends to become depleted due to the formation of carbon monoxide. It is normal practice to allow the gas mixture to pass along the laser resonator at low pressure of between 10 to 30 Torr. New designs of tube now use sealed systems, which allow the gas to regenerate.

The main advantage of the CO_2 laser is its high lasing efficiency. Values as high as 20% can be achieved. This means that power requirements are not excessive and cooling is easily implemented.

The design of the laser tube of a CO_2 system as shown in Figure 2. A pair of mirrors, one of which is partially reflecting, establishes the lasing cavity. Radiation transmitted through the partially reflecting mirror is directed outwards into the articulated arm system for clinical use. Cooling is provided by a water jacket surrounding the inner laser resonator. The gas discharge can be maintained by a DC voltage of several thousand volts or an oscillation driven by capacitance discharge at around 20MHz.

The output of a CO_2 laser still requires to be directed to the site of application by means of an articulated arm. This resembles a multijointed periscope with 6 or 7 sections.

The radiation at 10.6 microns cannot be seen by the human eye and so a visible aiming beam is required which is aligned with the main treatment beam. Low power He-Ne lasers are widely used for this purpose. One reason why laser diode devices have not yet replaced He-Ne lasers in this role is the excellent visibility of He-Ne at 633nm relative to 'deep red' laser diodes at around 670nm. It is assumed the treatment beam is exactly aligned with the aiming beam, otherwise the operator will irradiate the wrong area of tissue. Usually the output of the CO_2 laser is directed through an operating microscope as shown in Figure 3.

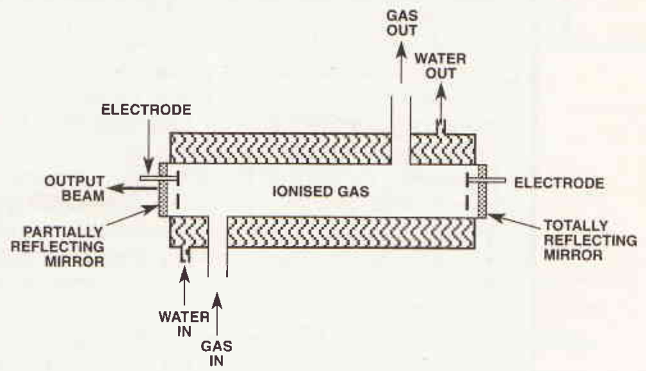


Fig.2 Design of typical medical CO_2 laser tube. Gas is continuously introduced into the tube at a low pressure. Output power is allowed to escape through a partially transmitting mirror

A lot is left up to the skill of the operator to apply the correct power density at the treatment site. Moving away from the focal plane the power density decreases. Typical power levels used, for example for treating cancer of the cervix, range between 20 to 50 watts.

The carbon dioxide laser has been established for nearly 20 years and in that time has proved a valuable tool in a broad range of procedures. One disadvantage, of such a system is energy has to be directed 'through air' to the site of application. Surgeons prefer to use tools which obtain 'tactile feedback', ie feel as they cut. Newer types of laser at wavelengths for optical fibre cables are being implemented to provide this feature.

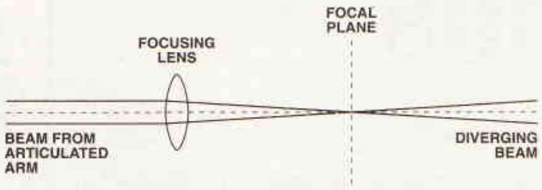


Fig.3 Typical application of energy from CO_2 laser system through lens of operating microscope. In the focal plane, the power density can be high

Argon And Krypton Lasers

The Argon laser was discovered by two independent groups in 1964. The output of the laser is a series of blue/green visible lines, principally at 488nm (blue) and 514.5nm (green). Argon atoms/ions are excited by collisions with electrons in the laser cavity. Initially an argon atom is excited to an ionised state and a subsequent excitation increases its energy to higher levels from which laser energy can be released. Because of the two stage nature of the excitation and the significant release of energy as ultraviolet radiation at a wavelength of 72.3nm, the efficiency of the Argon laser is low, around 0.1%. So in order to achieve 1W of output power from the laser tube, at least 1kW of power has to be supplied to the lasing system. Figure 4 illustrates the energy transitions which are responsible for the output lines of the Argon laser.

Figure 5 shows the key features of the Argon laser tube, where the high DC voltage (around 250 to 400V) is established across the laser at low pressure (0.2-0.7 Torr). Initially a much higher voltage 'spike' of around 5kV is applied to the tube to initialise ionisation, analagous to striking of a flourescent tube.

Typical maximum currents of 30 Amps flowing through the ionised gas are usually required. There is therefore, considerable need for cooling of the laser tube, and this is achieved by means of water flowing in a jacket around the core of the tube. Typically 2 to 3 gallons per minute are required from an external water supply. Also, the power to supply the laser is typically 3 phase. The design of an Argon laser system tends to be more complex than that of a CO_2 system because of a number of factors. Also, the alignment of the laser components such as the lasing mirrors, tends to be more critical than that of a CO_2 system.

To improve the efficiency of the Argon laser, Brewster Windows are used at the ends of the laser tube as shown. The windows cause light to be polarised (E vector) in a vertical plane and allows such light to be efficiently coupled from within the laser tube to the external mirror system and beyond. The Argon tube is a very harsh environment, with high temperature, ion bombardment and high levels of ultra violet light.

It is necessary to clean the Brewster windows as a maintenance procedure at appropriate intervals, since even though the windows are held in a sealed environment, contamination of their surfaces invariably occurs. In general, new designs of Argon laser tube have more effective air tight seals.

Once the beam has left the 'laser power generation system' (Figure 6), the so called 'delivery system' takes over. The narrow beam of laser energy is usually delivered into a beam splitter device in which a small percentage (eg 0.5%) of the beam energy is split from the main beam and sensed by a photodiode. This sensor is normally used to provide an indication of the level of power on the control console which the laser is able to deliver. There is often, a significant difference between the level of power which directly leaves the laser tube and that which is used for treatment at the patient. This is due to various losses, as much as 50%, which invariably occur in the 'delivery system'.

The next component in the delivery system is usually the shutter assembly, a mechanical arrangement which effectively blocks the main treatment beam except when the operator activates the footswitch. Normally exposure times of around 0.1 second are used for treatment of the retina.

An 'aiming beam' is required to allow the operator to aim the beam to a specific location requiring treatment. An aiming beam can be readily produced by securing a filter element in place which attenuates the main beam by a fixed amount. Typical fixed filters have absorbtion factors of 10,000, 5000, 2000 and 1000. Some laser systems use a rotating polaroid filter in association with a fixed filter. Because of the anxiety about even low levels of 'blue' light of argon lasers for operators, fixed filter elements in more recent systems pass only the 'green' lines. The newest generation of Argon lasers tends to have been safer He-Ne aiming beams.

A range of different levels of aiming beam is required since there is in practice a considerable variation in the degree of transmission of light within the eye, details of which are shown in Figure 7. Older patients with cataracts present specific problems in achieving good visibility of the areas of the retina requiring treatment.

After the shutter stage, the light energy is coupled into an optical fibre in the 'beam steering unit'. Precise optical alignment is required in order to launch the beam efficiently into the fibre. The beam is focused onto the acceptor window of the fibre by means of a

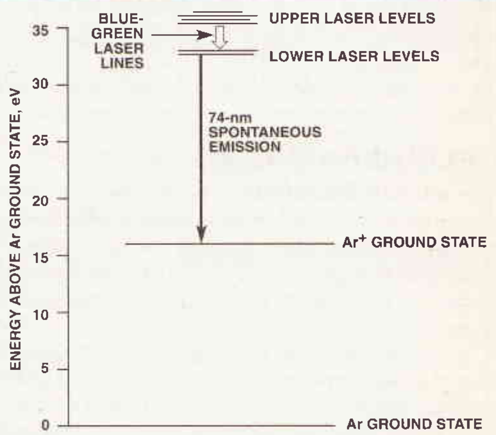


Fig.4 Energy transitions responsible for blue/green lines of the Argon laser

single lens. The focusing lens has to be at the correct distance from the aperture of the fibre in order to ensure a 'sharp' focus on the fibre window.

After the laser energy is coupled into the fibre, the energy is delivered to the patient by means of a slit lamp. This device allows the operator to observe the aiming beam on the surface of the retina and so direct the main treatment beam of the laser. A typical treatment can consist of several hundred short bursts of energy directed skillfully by the laser operator.

The Argon laser is principally used to treat diabetic retinopathy, a condition where blood vessels in the retina tend to invade into the vitreous of the eye and reduce visibility. After a long period of experimentation, the most effective treatment is now considered to be that of treating the pigment epithelium, a layer of cells within the retinal structure and not directly the meshwork of small blood vessels present in the retina. Where the retina has begun to become detached from the choroid, the Argon laser can be used to 'spot weld' it back into position.

Probably more patients are treated using Argon lasers than any other medical laser system. Also, while lasers in other specialties such as general surgery may have rival technologies such as surgical diathermy (radio frequency heating of tissues), this is certainly not the case with the Argon laser. The Argon laser can also be used in dermatology for the removal of 'port wine stain' skin markings. The Argon wavelengths are strongly absorbed by haemoglobin within blood vessels in such areas of skin.

Krypton lasers have also been developed to complement the use of Argon systems. The output of such systems occurs principally at 647nm and passes deeper into retinal structures compared with Argon. Also, the Krypton wavelengths are poorly absorbed by blood, so the risk of accidental damage to blood vessels is reduced. Argon lasers are the preferred option and Krypton systems are used less frequently.

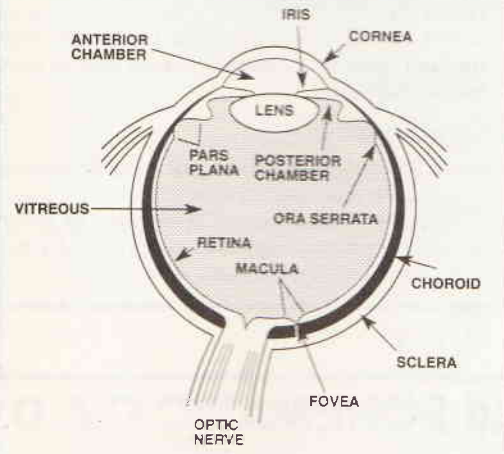


Fig.7 Diagram showing structure of the human eye

Pulsed Nd:YAG In Ophthalmology

The pulsed Nd:YAG laser releases energy over very short time scales into minute volumes. This leads to very high localised power densities — sufficient when directed in the anterior chamber of the eye to cut and disrupt tissue. The Nd:YAG laser is excited by a Xenon flash lamp which focuses the energy onto a Nd:YAG crystal. The resulting pulse width is typically 10ns with single energy pulses up to 20mJ. Typically as many as 5 individual pulses, separated typically 0.1s apart can be fired in a burst.

The ideal pulsed laser of this type delivers a set amount of energy in as small a volume in as short a time period as possible. It is important the energy coupled in the Nd:YAG crystal is released in one sharp pulse and not as a sequence of pulses of diminishing amplitude as can occur with poorer quality crystals. When the laser is energised in air at sufficiently high output levels, the air will be ionised at the focal spot and 'breakdown' can be heard as a click and seen as a minute blue flash of light. When the laser is used in the anterior chamber of the eye, the shock waves from the production of plasma (ultra hot gases) at the focal spot results in disruption of tissue in close proximity. This provides an ideal tool for non-invasive treatment of many conditions which would otherwise require a surgical procedure.

A He-Ne alignment beam is necessary in order to direct the treatment beam to the appropriate treatment site. This aiming beam can be implemented as two red spots which at the correct focus become coincident. It is very important, that the alignment between the two beams is highly accurate, otherwise then delicate structures within the eye can be unintentionally damaged with subsequent risk to vision.

The main use of the pulse Nd;YAG laser is in the management of complications following eye surgery.

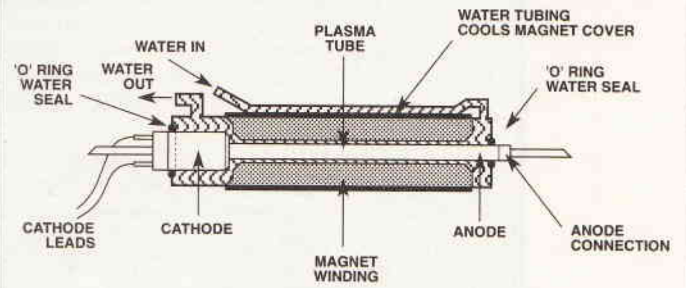


Fig.5 Key features of Argon laser tube

Where for example, a cataract is removed and the posterior (rear) capsule (skin) of the lens is retained in place to provide structural strength, the capsule can become opacified. The Nd:YAG laser can be employed to punch a hole in the capsule and thus restore vision. This avoids the need for an additional surgical procedure with all the associated risks of infection and additional complications.

Also, where after eye surgery, the iris adheres to a strand of capsule or the lens surface, the pulsed Nd:YAG laser can free the iris and relieve a painful condition with otherwise serious complications. One advantage of using the pulsed laser technique is that tissues do not require pulling or traction as would be required with conventional methods.

Although the Nd:YAG laser is used less frequently than the Argon, the equipment allows many conditions to be treated during short out-patient appointments rather than by means of an in-patient procedure requiring surgery.

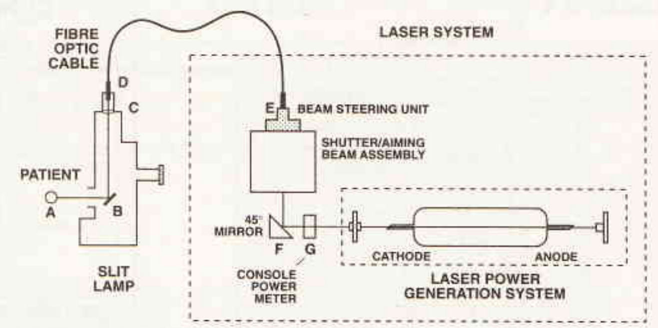


Fig.6 Outline of Argon laser system used in Ophthalmology

Optical Fibre Based Surgical Laser Systems

While CO_2 laser systems have found specific application in a number of areas, there is increasing use of laser systems which use optical fibres to deliver their energy. This provides the operator of such systems with 'tactile feedback' and also the advantage of much reduced 'smoke/plume' production as tissue is cut and vapourised.

There are a number of rival technologies used to provide such 'laser scalpel' systems. Within the UK, the most popular system appears to be the product of SLT (Surgical Laser Technologies) where a continuous Nd:YAG output at 1.06 micron wavelength is channelled down a fibre optic cable to a small sapphire tip.

The energy is absorbed by the sapphire tip which attains temperatures around 1500°C as it contacts tissue and 'cuts' it. In this way the laser is simply providing an ultra hot tip for cutting tissue. Little if any radiation is radiated out into tissue. If the tip was energised without any contact with tissue, it would simply be vapourised. Sapphire tips are expensive and though can be used for a number of procedures, they invariably have to be replaced. There is claimed to be some overlap between such techniques of 'laser scalpels' and cheaper conventional surgical diathermy systems. The most frequently undertaken procedure using sapphire tip technology is 'laporoscopic cholestectomy' or the removal of the gall bladder using 'keyhole surgery' in the abdominal cavity.

In orthopaedic surgery a range of laser systems have been investigated for so-called arthoscopic procedures in which a joint cavity such as a knee is examined through a small aperture and treatment such as removal or repairing of cartilidge undertaken. While CO_2 lasers have been used for this application, they tend to leave deposits which have to be carefully removed to prevent subsequent inflammation. Also, sapphire tip systems have not proved ideal since the tip tends to adhere to the tissue surfaces.

The Holmium: YAG laser delivering an output of 2.1 microns, has been found particularly useful in such procedures and interest is growing among orthopaedic surgeons in its application. Arthoscopic procedures are generally undertaken in a fluid environment, and a Holmium : YAG can efficiently deliver the energy through fluid and cut tissue with minimum bleeding and subsequent inflammation of tissue.

The Holmium YAG typically has a variable pulse rate of between 5 to 20 pulses per second with a maximum pulse energy of 2 Joules per pulse. The duration of each pulse is typically 350 micro seconds. It can be imagined how a laser tip can access structures more conveniently than can conventional cutting devices, thus extending the range of procedures which can be undertaken.

It is no secret that the Holmium YAG laser was developed primarily to treat joint injuries of American football players. Hopefully now, the benefits of such technology will be more widely used.

Photodynamic Therapy

The interest in medical lasers is primarily in relation to surgical cutting procedures. The Copper-vapour dye laser is being developed as a means of cancer treatment using the technique of photodynamic therapy. Light energy developed by gas discharge stimulates a specific radiation in a circulating dye liquid.

In this process, tumours which have absorbed a photosensitive drug, are irradiated with light derived from a Copper vapour laser. Cyto toxic (cell killing) products are released in the tumour as the light interacts with the drug, resulting in destruction of the tumour. While the treatment has been shown to be effective, there are naturally problems in accessing tumours which are deep in the body. The Copper vapour dye laser has output lines at 511nm and 578nm and has a high lasing efficiency. The use of a dye laser however, requires increased level of service and maintenance.

Conclusion

Lasers have played a valuable part in the development of medical technology but they seem to be poised to provide even greater service to mankind as systems become increasingly cost effective and a greater range of wavelengths become available.

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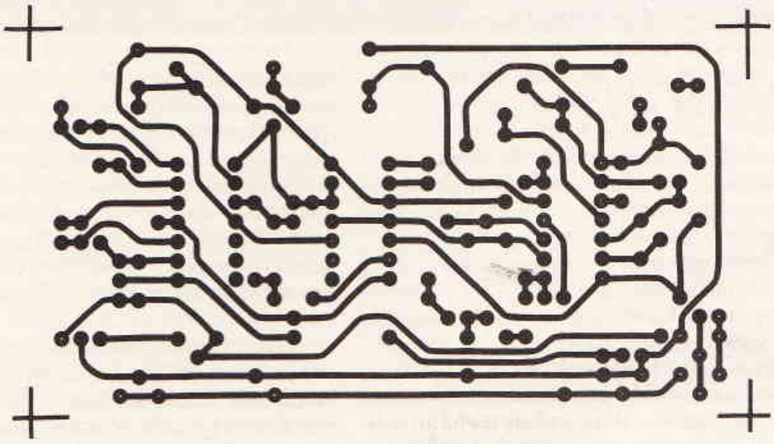
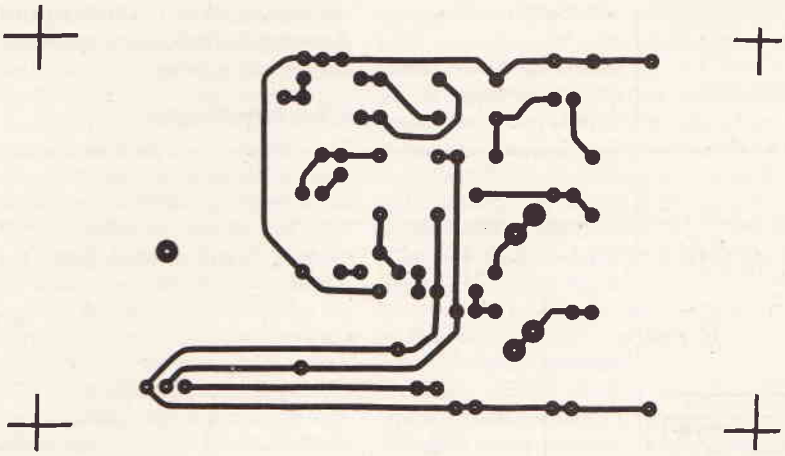


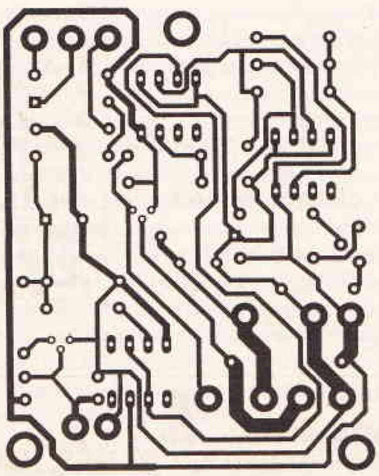
Model Railway Speed Control — Main Board



Model Railway Speed Control — Power Supply

Frequency Plotter (May 91)
R12 and R13 should swap places in Figure 1, the circuit diagram and in Figure 7, the component overlay. In Figure 1 the X and Y plate output labelling should be reversed.

Arienne's Lights (March 91)
Arienne's lights project should have a pull-up resistor network on the data/address bus lines. The result of not fitting it could mean that the unit will only select one sequence whatever the switch is set to. It is intended that new software will be written to increase the range of effects later on in the year.



Pulsed Width Train Controller Foil

3

Fire Detection Systems

Positioning of fire detecting circuits is this month's topic by Vivian Capel.

Locations

In the last article we saw how the detectors are wired, and fire compartments defined so as to be served by single zones. Now we go on to see where the detectors should be located.

Heat and smoke travel up to the highest point, which in most cases is the ceiling. This then is the most effective place for siting detectors. On reaching the ceiling from a point immediately above a fire, the heat and smoke spread sideways. This spread enables a detector to be actuated that is located some way from the actual fire. So a detector can guard an area around it as well as that immediately beneath.

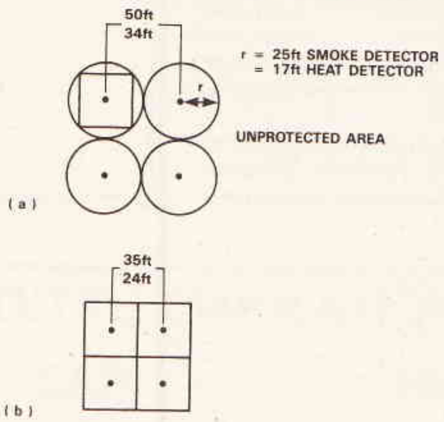


Fig 1a For a row of detectors in a narrow area, the spacing is twice the radius of its area of coverage. For a matrix in a large area, this spacing leaves unprotected gaps.
b Inscribed squares in the circles are moved in together to indicate the required spacing.

The spread causes the heat or smoke layer to thin out at ceiling level, although it thickens as the fire increases. The inlet vents of the detector should therefore be as high as possible to avoid being below that layer. If this is not so, the detector could be affected only when the layer had deepened down to the vents, that is when the fire is well advanced.

The vents of a heat detector should not be more than 6-inches (150mm) being ceiling level, or more than 2ft (600mm) in the case of a smoke detector. This means in most cases mounting actually on the ceiling rather than girders or beams although these may seem to offer a more convenient mounting and wiring prospect. Thin ceiling struts that do not lower the vents more than the above amounts could be used.

There is also a tendency for smoke and heat to dissipate as they rise, so that with very high ceilings the concentration is too low for a quick response. This becomes a problem with ceilings higher than 30 ft (9 m), but there are not very many at that height.

In the case of pitched roofs or those having north lights, the detectors should be fitted into the apex of each as these are the highest points. If there is any variation in ceiling level which is less than the above dimensions, such as a very shallow pitch, the variations can be ignored, and the ceiling can be considered flat.

Coverage

The sideways spread of heat and smoke allows the detectors to be mounted well apart and yet give adequate protection. There are though maximum spacings which should not be exceeded. No point in the building should be further than 25ft (7.5m) from a smoke detector, or 17ft (5.3m) from a heat sensor. So, for a flat ceiling, it would seem that smoke detectors can be up to 50ft (15m) apart in rows that are also up to 50ft apart. If the area is long and narrow, being less than 50ft wide, a single row mounted centrally would be sufficient. In the case of heat detectors, the spacing would appear to be up to 34ft (10.6m) apart in rows of the same pitch.

The total area covered by a single smoke detector is thus a circular 1,963ft^2 (182m^2), and 908ft^2 (84m^2) in the case of a heat sensor. However, any group of non-overlapping circles leaves spaces in between, so the actual coverage of each of a group of detectors, is that of a square inscribed in the above circular area (figure 1). The areas thus become 1,250ft^2 (116m^2), and 578ft^2 (54m^2) respectively and the sides of the squares are 35 ft (10.7m), and 24ft (7.3m) These dimensions are therefore the true spacings between detectors in a group.

Obstructions

These figures hold good for flat ceilings but must be modified if beams or other obstructions could restrict the sideways spread of smoke or heat. The rule in such cases is a simple one, add the total path around the obstruction and subtract it from the normal spacing between the affected detectors (Figure 2). For example, if there is a beam that is 9-inches deep between two rows of detectors, the path around it has been increased by 1½ft. So, instead of a maximum 34ft spacing, it would be reduced to 32½ft.

There is though a proviso that the depth of the obstruction should not exceed one tenth of the height of the ceiling. If it does, the obstruction must be regarded as a complete wall and the areas on either side as separate rooms.

Alarm bells

While any form of sounder such as a siren can be used, the bell is probably associated with fire more so than any other warning sound, and so is generally preferred. As with the rest of the system, 24V models are the standard as distinct from the 12V of the intruder alarm.

Apart from the very small installation, quite a number of bells are usually required to be audible in all parts of the protected building. The sound level must not be below 65dB anywhere. This is not all that loud, being about the level of a normal conversation at 3ft (1m) distance. Again there is a distinction between the fire alarm and that of the intruder system. The object is not to frighten, but to clearly warn all those in a limited area, whereas the purpose of the intruder alarm is to panic the intruders and to inform all over a wide area that help is needed.

The 65dB level which is specified in the BS 5839 is sufficient for the purpose, but of course this is the minimum at any point, at those areas nearer the bells it will be much louder.

In some situations a higher sound level will be required. Where there is background noise that could persist for more than 30 seconds, the level must be at least 5dB higher than the noise. If it may be necessary to wake sleeping persons such as in a hotel, or clinic, the sound level must be no less than 75dB at the bed-head. As this is after possible penetration of closed bedroom doors, and is 10dB (three times) higher to start with, it is evident that many bells would be needed and carefully located to achieve the required levels.

Where heavy and noisy machinery is running, recourse may have to be made to large mains-powered bells with high output. These can be controlled from the fire alarm system via a main relay. If desired, the mains supply could be switched by the same switch that operates the machinery (or one phase of it if three phase), so that the mains bells only function when the machinery is running. At other times, warning would be given by the normal system bells.

Rated sound levels

Bells, and all sounders, have a sound level rating specified by the makers. These though are not all the same. Some are rated at 1m distance, which others are rated at 3m. Obviously the 1m rating looks better than the 3m, you have to be sure which distance is being quoted.

The sound pressure level drops 6dB for each doubling of distance, and 10dB for each trebling. This makes it easy to compare bells having different specifications as the 1m rating will be 10dB higher than that of the 3m. This can also be used to calculate the levels at various distances. For example, 90ft (27m) is nine times or twice treble the 3m distance, so there will be a drop of 10dB × 2 = 20dB. For the required 65dB the output of the bell must thus be 85dB at 3m, or 95dB at 1m.

These figures hold good for a sound source in free air, but in buildings various factors influence the result. If the sound must penetrate doors or other solid barriers, it will be attenuated. (Note: a door with air gaps transmits much more sound than one that is effectively draught-proofed).

On the other hand, a bell sounding in an enclosed area such as a room or corridor will travel further with smaller reduction because of the reflections from walls and ceilings. Heavy furnishing and carpetting though can absorb and reduce sound down almost to the free air figures.

Bells should be located in positions to optimise their coverage, that is to give the required sound levels with the minimum number of units. One position to be avoided though is near the telephone. Cases are known where the fire brigade have not been able to hear the telephone call because of a nearby bell. Some instances have even been reported in which the telephone exchange dialling tone recognition circuits have been confused by frequencies in the alarm sound.

Alarm tones

Sound frequencies generated by the bells should be between 500Hz and 1kHz, according to BS 5839, but can be outside that band if there are ambient noise frequencies of similar frequencies which could mask them.

Coded signals may be considered a good idea such as single rings for the first floor and two rings for the second, but these could be confused or misunderstood and so are banned in the British Standard. However, it is permissible to have two-stage soundings. That is a first sounding confined to the immediate vicinity of the fire, in the same fire compartment or above it, and a second one in all other areas. If it is evident that the fire has not been brought under control or is likely to spread. This saves evacuating large premises for a small fire that poses no danger outside its own compartment.

Another permitted concession, is that the alarm may be sounded only in staff areas if it is considered that panic may result from a full alarm. A nursing or old people's home are possible examples of this situation. The condition is that there is always an adequate number of staff available to supervise an orderly evacuation if required.

Whatever type of sounder is used, bell or siren, it must have a distinctive sound that cannot be mistaken for any other type of signal. Everyone in the premises except visiting members of the public, should be familiar with the sound due to occasional fire drills. Some sirens have switched multi-toned effects such as warble, oscillation, and fixed tone. One of these could be used to give a time signal for an end of shift, and also a fire alarm, as long as the sounds are quite different.

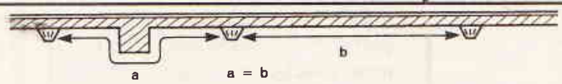


Fig 2 If an obstruction such as a beam intervenes between two detectors, the path around it must not exceed that maximum spacing requirement.

Control panel

The control panel has certain similarities with the intruder alarm panel, but also many differences. Like the intruder system, small single-zone or multi-zone models are obtainable. Furthermore, each zone latches on when activated and a visible indication of the affected zone is given.

There are no separate anti-tamper loops or power supplies for active detectors. Detection monitoring and power are all achieved with a two-wire circuit as described in the last article, and can be used only with the specified fire sensors and manual call points, although different types can be mixed on each zone. There are no exit circuits or key-operated switch because the system is on all the time. Some models though have a lockable glass panel door, so that the indicators can be seen but nothing interfered with by non-authorised personnel.

The bell circuit supply is different from the intruder alarm in that a reversed polarity monitoring voltage is always present when the system is on guard. A short or open circuit is indicated on the panel. As mentioned before, the operating voltage is 24V, although sometimes 48V is used for large systems.

Unlike the intruder panel, the fire alarm control should be mounted in a conspicuous position. This enables the fire-fighters to quickly trace the source and extent of a fire by the state of the indicators. The main entrance will in most cases be the most practical position. To facilitate rapid source location, a chart should be mounted by the box giving the areas covered by each zone.

The power supply should not be from an ordinary plug and socket, as someone will surely sooner or later use the socket for something else. It should be by means of a switched box to which the control panel is permanently connected. The box should be painted red and labelled "Fire Alarm, Do Not Switch Off".

Standby batteries should be of the rechargeable type having a minimum life of four years. They should have sufficient capacity to operate the system for at least 24 hours, and the charger should be capable of recharging them in less than 24 hours. The BS 5839 prohibits car batteries for this task but does not explain why.

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Mark Webb

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NEXT MONTH

ETI presents The Nightfighter,the ultimate in disco lighting technology. This major project puts all other light controllers into the dark ages. This modularised system produces a multitude of different configurations and has the flexibility of upgrade or expansion at any time in the future.

We also continue with the hemisync machine, a machine for encouraging brain wave patterns for relaxation or creativity.

In these days of environmental concern, it is handy to have a pocket radiation detector. Not that you have radio-active pockets but we thought you might like to have a Gieger counter in your kit bag to have an increased awareness of radiation hazards.

We know ETI readers like to keep abreast of the latest consumer products so we bring you a 'How it works' feature on the Sony Pocket Record/Play disc system that is to emerge on the European market within the next two years.

These are just some of the tantalising features to sample next month.

In your shops Friday 2nd August- Don't miss it!

The above articles are in preparation but circumstances may prevent publication

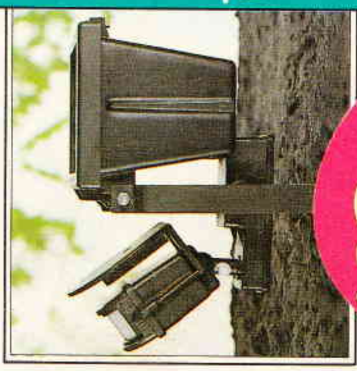
LAST MONTH

The July issue contained:

- The Consort, an active loudspeaker system
- Laser Diodes
- Amateur Microwave Equipment
- The Foot-tapper, electronic volume control
- Versatile temperature controller
- Four-track cassette recorder update

ADVERTISERS' INDEX

BRITAIN'S BEST VALUE FLOODLIGHT SECURITY SYSTEM
GUARANTEED!



UNBEATABLE VALUE!

£29.95

YMS01

(*500 watt halogen tube YMS02 £3.75 not included in this price)

HELPS YOU PROTECT YOUR HOME AND YOUR FAMILY!

HIGH DEMAND
Because of high demand for our security products and our increased buying power, Maplin Electronics can now offer this exclusive lamp at Britain's lowest price, guaranteed!

GUARANTEE
We guarantee you can't find better value, or all your money back. Absolutely no risk to you.

QUALITY CONFIDENCE
Every detector purchased comes with a FULL MONEY-BACK, NO QUIBBLE GUARANTEE.

YOUR TOP TEN FEATURES
★ Automatic infra-red sensor, lights up *500 watt tube, when people approach your property
★ Adjustable 'on time' ★ Easy installation
★ Full 15m detection range
★ Fireproof ultraviolet material
★ Water resistant and weatherproof
★ Approved to international standards
★ Automatic on/off and manual override
★ Heavy duty zinc alloy body
★ 110 degree detection angle

The Detector Security Floodlight has the latest infra-red technology that detects movement over your chosen area and illuminates it with a 500 Watt Halogen lamp for up to approx 12 minutes which gives you time to park your car, unload the shopping, find your keys, greet your guests or avoid obstructions.

With 500 watts of halogen lighting beaming down on them, any potential burglar becomes clearly visible – so visible it could well be daylight!

Feel safer, more confident with the Maplin security floodlight. Economical – the system automatically switches off in the daytime to save power.

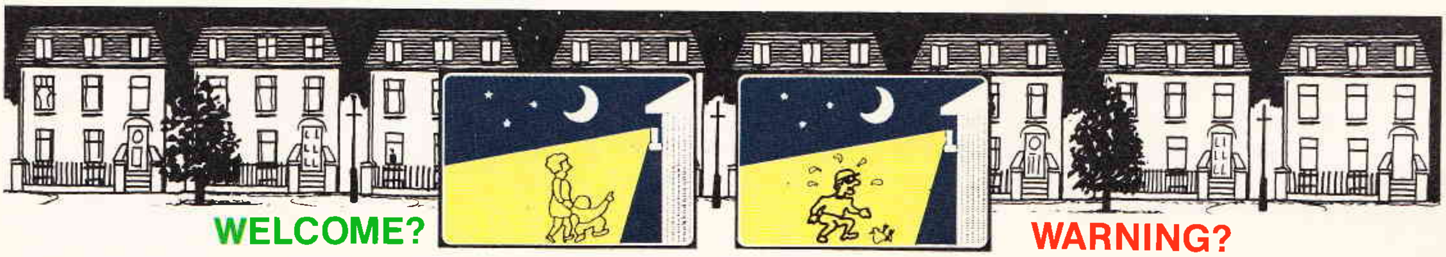
For your enjoyment the Detector can be permanently switched on, for EVENING BARBEQUES etc, by turning the main light switch on, off and on again within 2 seconds.

The range of the Detector is such that it is ideal for both residential and commercial use.

COMPARISON WITH SIMILAR SECURITY SYSTEMS

SE Essex Branch	Heavy Duty	500 Watt Power	Weather-proof	Automatic Infra-red	Adjustable Timer	Complete with Halogen Tube	Cost of 500W Halogen Tube	Cost of Security System
DO-IT-ALL	•	•	•	•	•	•	£4.15	£69.99
HOMEBASE	•	•	•	•	•	•	£7.99	£69.95
TEXAS	•	•	•	•	•	•	£5.99	£59.99
ARGOS	•	•	•	•	•	•	Not supplied	£46.99
PAYLESS	•	•	•	•	•	•	£7.59	£74.99
B&Q	•	•	•	•	•	•	£3.95	£79.99
MAPLIN	•	•	•	•	•		£3.75	£29.95

(Survey conducted on 21st February 1991)



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Quantity	Description	Code	Price	Total
	Infra-red detector	YMS01	£29.95	
	500 watt halogen tube	YMS02	£3.75	
			Carriage for 1	£3.75
			Add further £1.25 if more than 1 YMS01	
			Handling	£1.00
			Total	

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ETI7

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Although this unit may deter intruders, no warranty is given or implied that the unit will provide security or prevent illegal entry.