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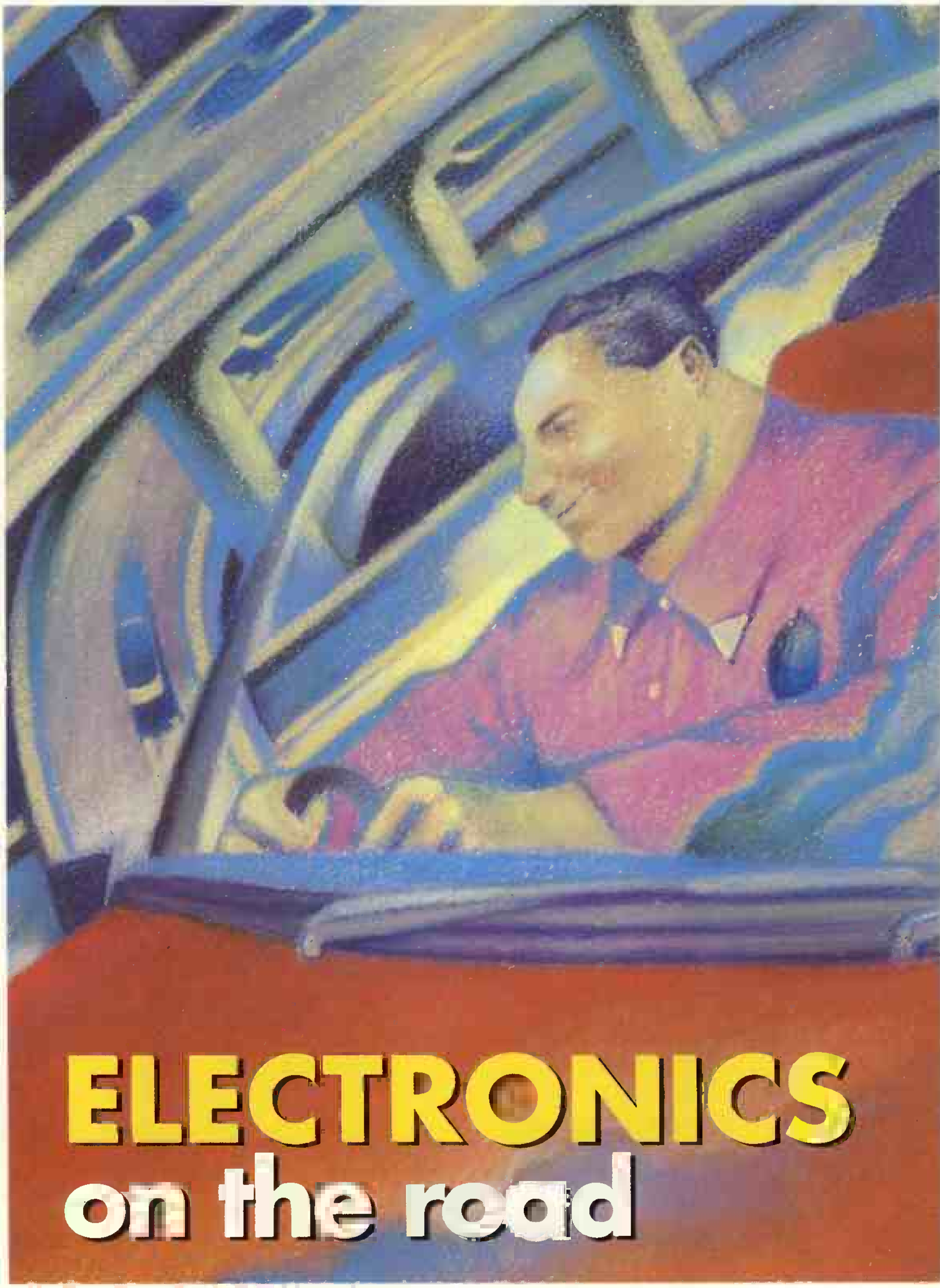

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Electronic systems keep this car going in a straight line on ice at 50km/h – page 372.

Cover Illustration Hashim Akib

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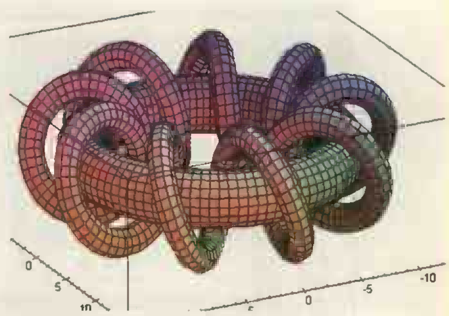

Mathematical modelling software Maple V even produces animation, which can help provide an insight into temporal behaviour. – page 379.

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Douglas Self presents a completely new amplifier concept, Steve Webb describes a low-cost video digitiser, Cyril Bateman explains Internet and Jeff Macaulay describes the microreflex loudspeaker that we were unable to publish last month.
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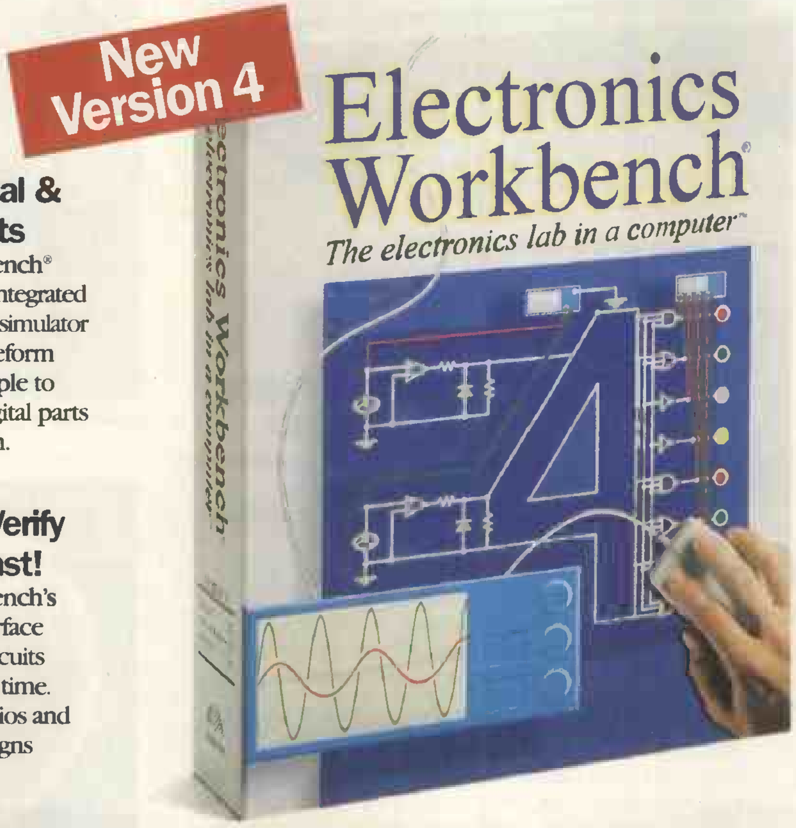

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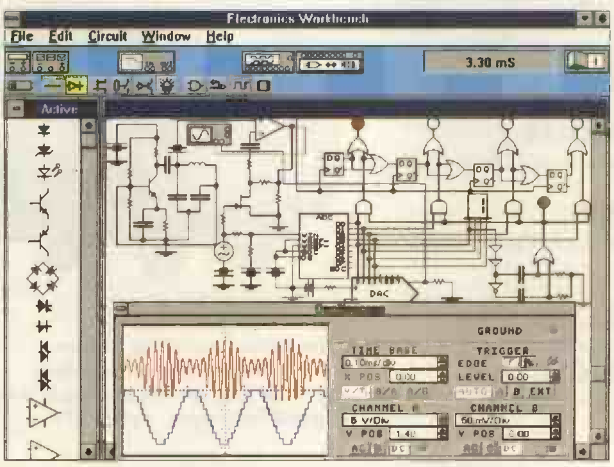

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A sorry foresight saga

Academic scientists have always had a disproportionate influence on the UK government's attitude to technology. That could be one reason why we have such a tiny microelectronics industry in the UK.

Earlier this month, the ITEC (Information Technology and Electronics) panel of the Government's Foresight programme looking at the UK's technological future, decided to write off the UK semiconductor industry.

As with the Alvey catch-up technology programme of the 1980s, the ITEC panel was dominated by academic scientists. Of the 25 man panel, 11 are working academics at universities, others are of an academic bent working on the boundaries of academia, and industry and not one of the 25 is a career semiconductor man.

The panel's principal microelectronics recommendation – that the UK needs a microelectronics R&D centre on the lines of the IMEC microelectronics research centre at the University of Leuven – will leave those people in the UK who struggle to make a living out of semiconductors, gasping for breath at its irrelevance.

The misdirection of government aid for the microelectronics industry has resulted in the UK having a chip industry made up mostly of design houses. These companies have world-class design skills – but they have nowhere in the UK to go to get leading-edge manufacturing services to turn their world-class designs into world-class products.

At a conference organised by the Federation of the Electronic Industry a couple of years back, delegates bemoaned the fact that there was no accessible, sympathetic British foundry facility where they could go for leading edge silicon – except for GEC Plessey Semiconductors (GPS). But now GPS has adopted a strategy of staying a year or two behind the leading technological edge, not even that exists.

But ITEC does not even purport to be aiming its microelectronics centre at helping the UK semiconductor industry – it is intending it as a support facility for inwardly investing foreign semiconductor companies. In effect, ITEC does not see the UK semiconductor industry as worth support and does not regard an indigenous capability to manufacture first-class silicon as being of any importance.

Instead, the scientists of ITEC are directing the Government's thinking to other spheres – how to use the rapidly accelerating power of computers and the Information Superhighway to deliver the UK's undoubted strength in media products to Britain and to the world.

This is proper work for scientists! Conceptual, theoretical, intellectual stuff on which papers can be written, conferences attended and jobs for more scientists created.

But will it deliver any useful, practical technology to help the many entrepreneurial UK design houses or encourage the start-up of new high tech businesses? As with Alvey and with all previous scientist-driven initiatives, one doubts it.

David Manners

Electronics World + Wireless World is published monthly. By post, current issue £2.25, back issues (if available) £2.50. Orders, payments and general correspondence to L333, **Electronics World + Wireless World, Quadrant House,** The **Quadrant, Sutton, Surrey SM2 5AS.** Tlx:892984 REED BP G. Cheques should be made payable to Reed Business Publishing Group.
Newstrade: Distributed by Marketforce (UK) Ltd, 247 Tottenham Court Road London W1P 0AU 0171 261-5108.
Subscriptions: Quadrant Subscription Services, Oakfield House, Perrymount Road, Haywards Heath, Sussex RH16 3DH. Telephone 01444 445566. Please notify change of address. Subscription rates 1 year (normal rate) £30 UK and £43 outside UK.
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Overseas advertising agents: France and Belgium: Pierre Mussard, 18-20 Place de la Madeleine, Paris 75008. United States of America: Ray Barnes, Reed Business Publishing Ltd, 205 E. 42nd Street, NY 10117. Telephone (212) 867-2080. Tlx 23827.
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Printed by BPCC Magazines (Carlisle) Ltd, Newtown Trading Estate, Carlisle. Cumbria, CA2 7NR
Typeset by Wace Publication Imaging 2-4 Powerscroft Road, Sidcup, Kent DA14 5DT

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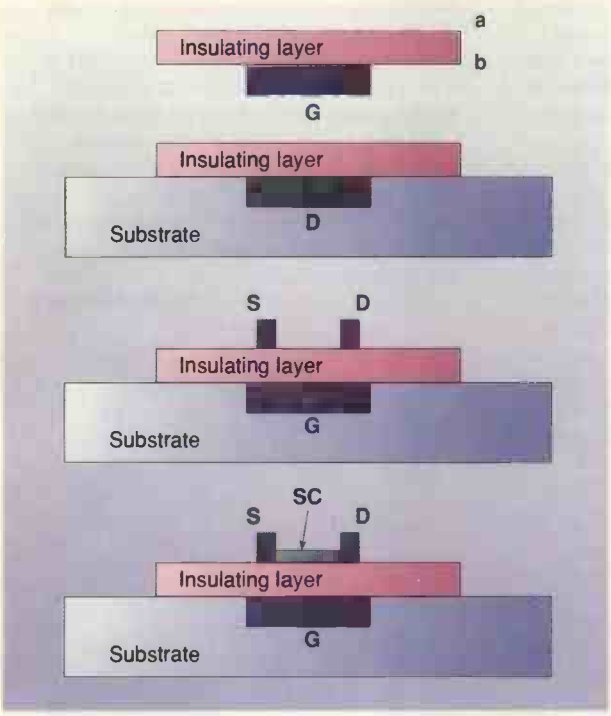
Focus on polymer transistors

With an all-polymer fet, it is easiest to begin with the insulating layer. This needs to have high homogeneity and good dielectric properties. Such fets could prove very useful for flat-panel display and smart-card type applications.



At least five major electronics firms are developing products based on all-polymer transistors, amid claims that the technology could eclipse amorphous silicon in applications such as flat panel displays and smart cards by the end of the century.

Japanese giants Matsushita and Mitsubishi, US-based Motorola and IBM and European firm Philips are working on all-polymer transistor systems. Matsushita and Mitsubishi have already published research papers on the subject, and Mitsubishi is rumoured to be very close to producing the world's first all-polymer-transistor based flat panel display type for laptops.

FLexible polymer transistors have been pioneered by a team of researchers at the CNRS centre in France, led by Francis Garnier. The team has been working on the devices for the last five years, but now the technology is being taken up by electronics giants worldwide.

The main advantage of polymer transistors over silicon ones is their flexibility, which may allow complete bending or rolling without affecting their electrical properties. They should also be cheap to make in volume, and the devices can be made transparent, suitable for windshield applications in planes and cars. "Organic semiconductors will be available at lower cost", insisted Garnier. "They can be applied with web printing techniques and this will open the field for cheap, flexible electronics".

At present, polymer transistors are slower, larger and have lower output current than silicon transistors but these characteristics are expected to be improved with further development. Garnier expects the first commercial products, probabLy in the form of displays for domestic appliances, as soon as 1996/7 and for these low-end applications to open the way for large-area, low-cost polymer electronics systems.

Unlike earlier work, where only the substrate was made of polymer, the latest transistors also have polymer-based electrodes made from graphite-based ink.

Svetlana Josifovska
Electronics Weekly

Video on the radio

Engineers at Racal Radio have developed a video compression technique said to be efficient and robust enough to transmit pictures reliably over a radio link. The technique, designed for immediate application in military surveillance systems, can transmit a real-time video stream over a 25kHz 16kbit/s radio link.

The compression algorithm used is a Racal-developed version of the lapped orthogonal transform, coupled to an error resistant entropy code. The combination is said to be able to recover from 20 percent data loss. For worse losses, rather than an image failure, there is a gradual degradation of the received image quality as the channel error rate increases.

Low cost route to silicon modelling

As feature sizes continue to shrink and devices become more complicated, chip designers may have to resort to virtual reality techniques in which they can literally immerse themselves in a 3D simulation of a chip, according to a top researcher.

Interactions between electrons and the edge of devices have become more important in determining chip performance. These require complex equations to model the effects, which is why the key to 3D simulations will be the development of very fast, cheap parallel computers capable of processing millions of equations.

Stanford University researchers, working with scientists at IBM, claim they have developed special algorithms that boost the performance of low cost parallel computer systems without the need to build specialised parallel computer systems costing tens of millions of dollars. The researchers have demonstrated the ability to solve 1.5 million equations at a speed of 9.5Gflops using an IBM Powerparallel SP-2 computer.

Robert Dutton, professor of electrical engineering and chief scientist at Stanford University's Center for Integrated Systems says that, "At these rates, 3D will take about the same time to run as current two-dimensional simulations".

The new algorithm has been incorporated into Pisces – a commercial program that simulates the behaviour of microscopic electronic elements in complex semiconductors.

Dutton said the algorithm could be ported to desktop workstations where it can speed up 2D chip modelling tasks. Stanford has said it will license its technology to other companies.

Philips/Sony fight back on high density CD

The chances of Philips and Sony conceding victory to Toshiba in the battle of high-density cd systems seem remote. Philips has been mounting a major information offensive in support of its system with demonstrations at CeBIT, the Audio Engineering Society convention in Paris and its home base, Philips Research Laboratories in Redhill.

Players using the single-sided dual-layer system will be on sale next year, Philips promises, whether the film industry supports it or not. Increasingly Philips/Sony are looking to the professional computer market – a potentially much larger user base – to back the system. "We do not believe this is a technology which is a mass market proposition that's just around the corner," said John Hawkins, world head of Philips Media Distribution, at Redhill.

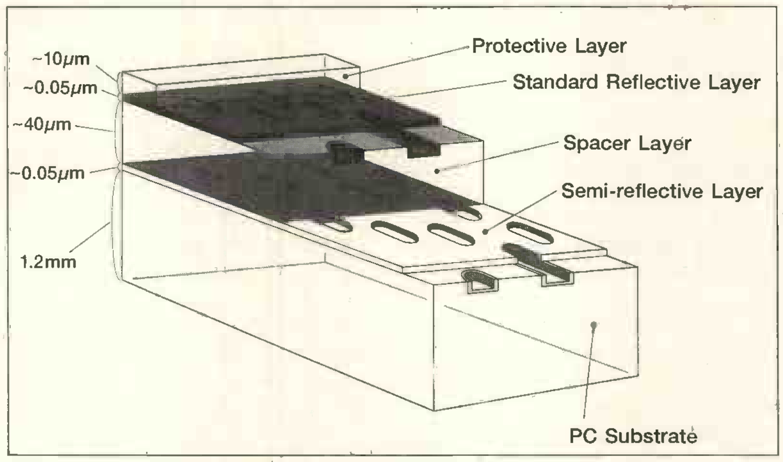
The demonstrations revealed some aspects of capability, such as the dual-layer system which was first used on Laserdiscs as far back as 1977, but also showed the complexity of the agenda which Philips is now grappling with. Although it needs to counter the Toshiba double-sided system, Philips also wants to create some space for the development of CDi, assisted by existing MPEG 1 CD Video. Hence its insistence on the high initial cost of high-density which, it contends, will preclude mass sales to begin with.

MPEG 2 will require four times as much memory as MPEG 1, and far greater processing complexity, to say nothing of the HD drive and new laser and optics. All of these combined will push the price of hardware up into the no-go area, well above £400.

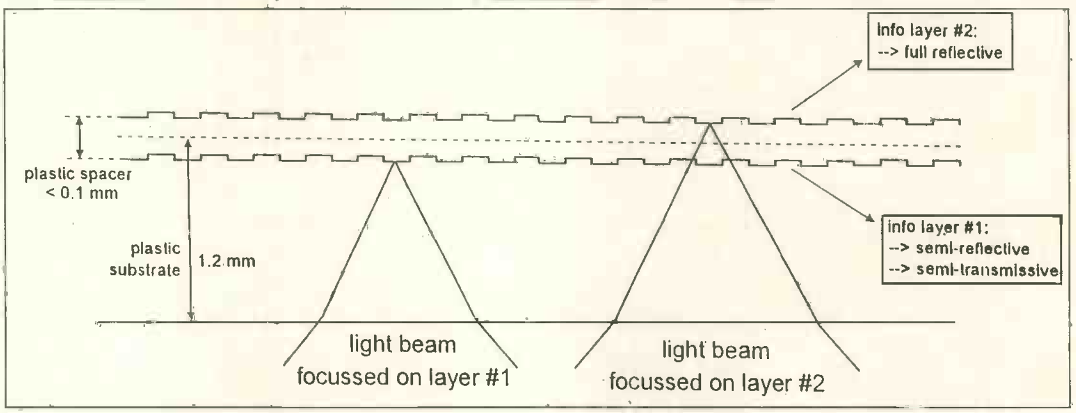
Thus, initial uptake of high density technology is likely to be by the computer, rather than consumer, community, where increased storage capacity is always in demand. Only after start-up costs have been amortised in that market, so the Philips argument runs, will high-density become affordable enough to go mass-market.

Both proposed high-density standards can carry more than ten times the current 650Mbyte capacity of CD-Rom. Philips/Sony will hold 7.4Gbyte in two layers; Toshiba, 10Gbyte, split between two sides. Both will use red laser technology with a wavelength of 635nm. Philips/Sony now promise backwards compatibility with existing formats. Apart from additional costs involved in accessing two sides of a disc, Toshiba has yet to work out where the label could be accommodated.

Peter Willis



Dual layer construction of Philips high-density CD system, whose complexity indicates initial take-up by the computer, not consumer, industry. Light beams will need to be focused separately on the two layers; each layers offers different read-out characteristics.



Silicon coils for even smarter cards

While smart cards may give the impression of being easy to use, they can give rise to problems, usually associated with the way they are made. The rigidity of the antenna coil, which is wrapped on a chip fixed on a flexible fixture like a plastic card, means that it is possible to break some of the connecting wires within the chip if the smart card is flexed.

Micro Sensys, a German-based radio identification specialist, has come up with a simple, low-cost way of building coils onto chips by growing them onto the silicon wafer, which avoids the traditional bonding processes. The monolithic microstructure employed is used in rf chips for contactless smart cards and other identification and access control applications. It integrates completely all of the analogue functions, a high-frequency rectifier, antenna coil and an EEPROM on a single chip.

In a conventional contactless smart card chip, the transceiver coil is applied using cmos metal layer technology. This method produces structures 1μm thick and below. These very thin layers introduce high surface resistance, inconsistent quality and inhibit the placement of active circuit elements (the logic gates, EEPROM and the transmitter) in the coil area. These drawbacks can be rectified by using thicker structures (around 100μm), produced by X-ray lithography, which although technically feasible is expensive.

Instead, Micro Sensys uses a modified straight wall bumping process. This process is normally used in tape-automated bonding for chips with many contacts (between 200 and 300). A single metal layer is applied to the silicon substrate in the form of 'bumps', leaving structures that look like tower-blocks behind. This is achieved by raising the metal layer higher than the silicon substrate; passivation-layer channels still run in between. The metal layer forms the coil between the bumps.

1Gbit DRAMs nearing production stage

Sony has combined two leading edge chip fabrication devices – one a quadrupole light source and the other a phase shift mask, to stretch optical lithography towards 0.18µm feature fabrication. This is the feature size that will be needed to make the first generation of 1Gbit DRAMs in production quantities.

The surface of a wafer is not flat, but deviates up to 1µm. The image of the production mask must be in focus for all 'altitudes' on the wafer surface, so the projection optics must have a minimum depth of field (DOF) of 1µm.

The size of image that can be clearly focused onto the surface of the wafer is proportional to the wavelength of light used. For 0.35µm lithography (current state-of-the-art for production), specially-developed krypton fluoride (KrF) excimer lasers are used that emit ultraviolet light at 248nm . For a given optical system, both the minimum image size and the depth of field are proportional to wavelength. These limitations restrict KrF lasers to feature sizes of 0.35µm.

Beyond the DOF, a circular spot projected on the wafer becomes a larger and larger circular blur. Sony has used a trick to reduce the effect of this problem by altering the characteristics of the laser beam.

Sony's modified optics split the laser beam in four, diverge the sub-beams using a prism array, then recombine them, creating a quadrupole light source. This replaces the normal circular light source with four smaller overlapping image ones. In sharp focus, the image looks like four spots but outside the DOF the blurred image has more energy in the centre and looks much more like a 'normal' focused spot.

This technique raises the effective DOF more than two times, allowing the optics to be changed and trading the increased DOF for smaller feature size.

If a feature size of 0.28µm is required, conventional illumination only gives a DOF of 0.77µm. The new source gives a 1.1µm DOF, suitable for production techniques of the near future.

The second feature Sony has incorporated is a phase shift mask. A normal mask has transmissive and non-transmissive regions. The sharp transitions between these regions result in diffraction patterns over the wafer surface around the image. Diffraction effects can be reduced by deliberately phase-shifting light by different amounts at different points in the mask.

There are some limitations to phase shift masks: not all image shapes can be made and there can be a strong secondary image net to the primary one. On their own, phase shift masks can improve image resolution, but the quadrupole light source can be optimised to suppress most of the secondary image. The new light source and mask together allow 0.22µm features with a 1µm depth of field.

Sony has demonstrated that its combination technology can produce 0.22µm features and claims it can be developed to make first generation 0.18µm chips using optical lithography.

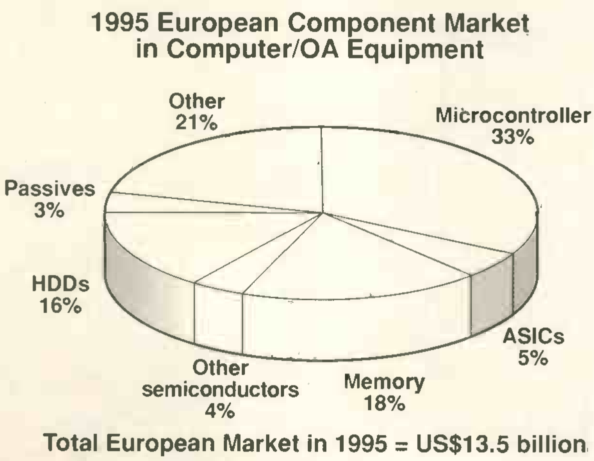
Steve Bush
Electronics Weekly

PCs fuel demand for electronic components

Industry analyst BIS Strategic Decisions reports that demand for electronic components continues to be fuelled by the booming markets for PCs, monitors and printers.

The BIS report, European Computer and Office Automation Equipment Production, expects the European computer market to be worth $13.5billion this year, up $3.3 billion since 1993. In 1993, $7.4 billion (around 72 percent) was accounted for by components in desktop and portable computers.

1995 European market for computer and office automation equipment.



Source: BIS Strategic Decisions

Low cost single-chip demodulator

A single chip digital tv demodulator based on the 64/256 QAM systems used in North America's Grand Alliance HDTV trials has been introduced by VLSI Technology. The quadrature amplitude modulation (QAM) system, which could also be the basis of European terrestrial digital tv transmissions, was developed by Californian developer Applied Signal Technology and integrated by VLSI Technology into its library of functional system blocks.

The quadrature down converter equaliser demodulator (QED) would be used in QAM cable tv set-top box receivers. It sits between the cable and the MPEG compression functions and extracts the digital video and audio data streams from the 64/256 QAM modulated signal on the cable tv network.

Operating at an IF of 43.75MHz, it supports symbol rates up to 5.4Mbaud and implements the Reed-Solomon forward error correction algorithm. The QAM protocol combines traditional amplitude modulation and quadrature phase shift keying (QPSK) to put the digitally coded tv signal on the carrier frequency.

An advantage of QAM is the relatively large number of phase and amplitude states, 64 and 256, used to represent the digital tv signal. As a result, QAM supports a high capacity data channel, equivalent to 40Mbit/s, by assigning 64 and 256 phase and amplitude states to represent the digital signal at 8 bits per symbol. The 40Mbit/s 256QAM digital channel can support up to five 8MHz PAL analogue tv signals or seven 6MHz US NTSC analogue television signals.

The QAM device is one of a number of chips VLSI is offering for low cost set-top box receiver designs. It is developing a separate QPSK demodulator with ComAtlas of France, and an MPEG-2 codec with US specialist, Mediamatics. ■

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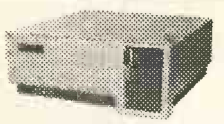

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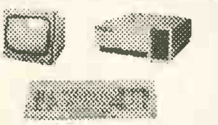

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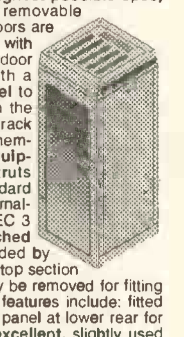

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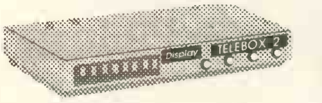

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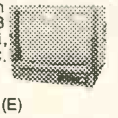

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CIRCLE NO. 105 ON REPLY CARD

Jonathan Campbell

Thin film cell packs a punch

Weight is so often a limiting factor in design of rechargeable batteries. But researchers at Tokyo University and Matsushita Electrical Industrial have announced development of a low cost solid state rechargeable battery that can store 50% more electrochemical energy in its electrodes than the best conventional technology available.

Key to performance of the new battery is an organic thin-film cathode. Organic materials have been proving particularly attractive to battery designers because they offer large theoretical energy storage capacity, combined with low weight and high strength.

The Tokyo cell is made up of a Dimercaptan (DMcT) and polyaniline (PAn) cathode with a lithium anode – compounds already known to have had a complementary effect on performance, though the precise chemistry of the reaction is not yet definitively agreed. However, cells fabricated along these lines have been reported before.

The advance made by the Japanese team has been to prepare a solution containing the electrode materials which can be printed or painted by conventional techniques. Not only does that make for easy manufacturing, but, importantly, it allows excellent molecular-level mixing of the DMcT and PAn, leading to much higher efficiencies than have been achieved before.

Gravimetric energy density of the composite cathode is reported to be >600Wh/kg cathode (Dimercaptan-polyaniline composite electrodes for lithium batteries with high energy density, N Oyama *et al* (*Nature*, 373, pp.598-600). This compares to a figure of 400Wh/kg for the cathode in one of best commercial lithium-ion cells. So energy density of the DMcT-PAn cathode is 1.5 times better.

No deterioration in capacity was observed in 30 cycles for the test cell, with the cathode charged at 4.5V and discharged at 0.1mA/cm^2 down to 2.25V. That compares with a loss of 15% in capacity by previous designs of this type of cathode.

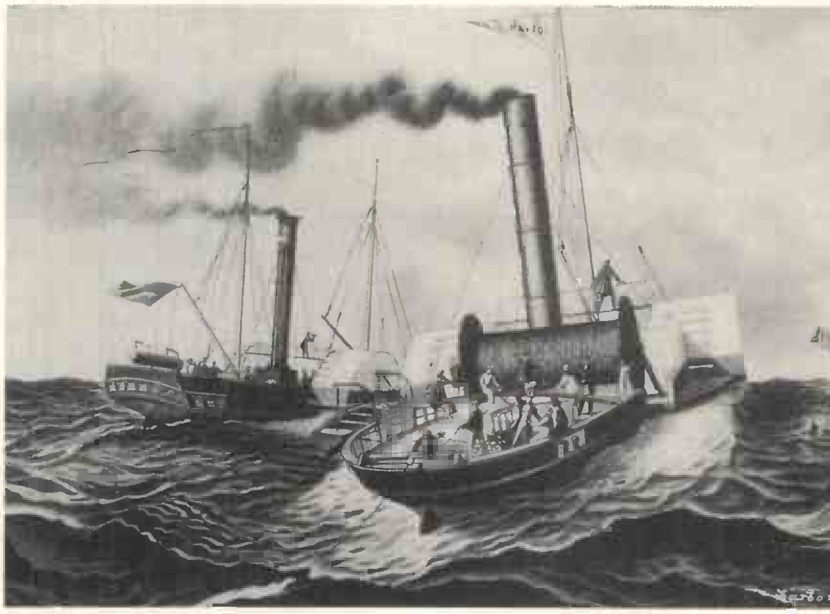
At present the maximum useful current density looks to be 0.1mA/cm^2 – which is undeniably small. But because the cathode is a film, a large electrode area can easily be obtained without weight penalty.

Expected applications will be in areas where weight rather than volume is the crucial factor, as high gravimetric density is offset by low physical density.

Deep conversations

Confidence in ultra-long-haul optical cable systems using cascaded erbium-doped fibre amplifiers has been boosted with news that Japanese workers have successfully made 5.3Gbit/s transmissions across 11,300km of installed submarine cable. This is the longest distance yet achieved using the technology. T Otyani *et al* (5.3Gbit/s 11,300km data transmission using actual submarine cables and repeaters, *Electronics Letters*, Vol 31, No 5, pp.380-381) from KDD Submarine Cable Systems, made use of two fibre pairs in a real cable 2850km long that had 48 repeaters and a repeater spacing of 60km. By joining the fibres together at their ends with optical attenuators, the researchers were able to create a 11,300km transmission line.

The long distance success of using a cable made up of dispersion-shifted optical fibres and erbium-doped amplifiers – designed to operate under the sea for at least 25 years – clearly demonstrates that the low-cost and high reliabilities of such a system



Exploiting the full potential of submarine cables already laid will be vital to the development of optical fibre comms.

Ultrasonics open up memory capacity

Development of a simple and convenient ultrasonic method for manufacturing very small cobalt particles – magnetic nanocluster – could have an immediate effect on high-density recording media.

The process, developed by Charles Gibson and Kathy Putzer at the University of Wisconsin (Syntheses and characterisation of anisometric cobalt nanoclusters, *Science*, 267, pp1338-1340) produces single magnetic domain particles with considerable shape- and magnetocrystalline anisotropy so that a preferred magnetic field orientation is adopted in the final product.

Relatively inexpensive reagents are used in the procedure and flocs of the suspended particles are stable for several days, so easing manufacturing flexibility.

The basis for the process is reduction of Co^{2+} with hydrazine. Low temperature reaction has been attempted before, but despite looking thermodynamically possible, the reduction has not previously been successful.

Now Gibson's and Putzer's use of ultrasound to initiate the chemistry has made the reaction practical – and economical.

The result is the birth of a simple technique that could have immense importance for the manufacture of magnetic recording media and permanent magnets.

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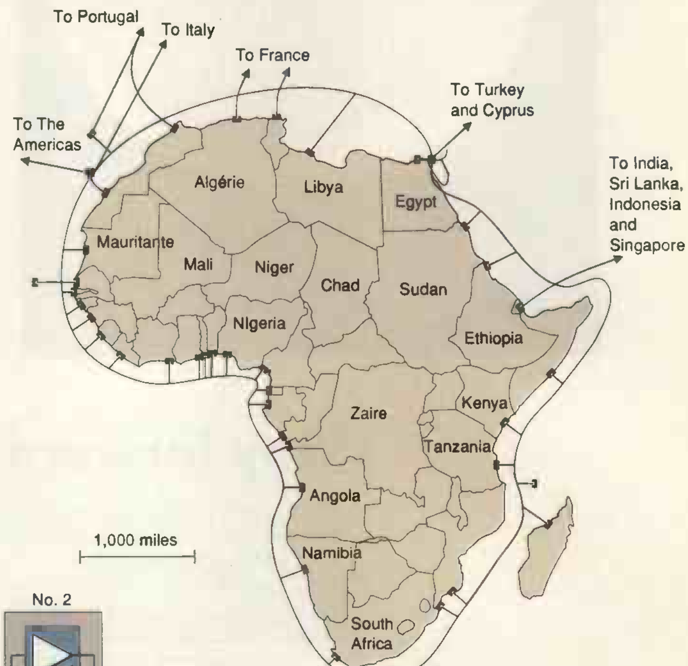
could be exploited in practice.

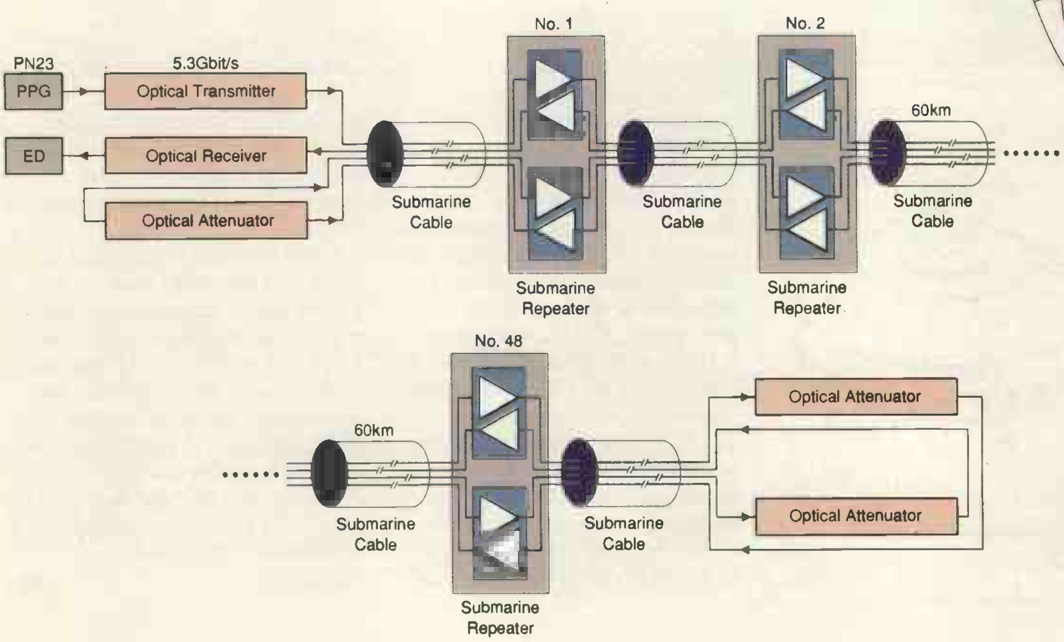
Other work currently going on is also helping to test the limits of undersea cables. For example, AT&T recently announced it had transmitted 10Gbit/s over a 2000km commercially installed undersea fibre-optic cable in the US. Normal operating limit for the cable was 2.5Gbit/s. AT&T achieved the increase through wavelength division multiplexing – the transmission of information on more than one wavelength of light on each fibre.

10Gbit+ transmission speeds greatly increase the capacity of undersea cable and AT&T says the test gives it the potential to upgrade installed fibre-optic communications systems without making adjustments to cable already sitting on the sea floor.

AT&T has already announced a proposal to build a 32,000km optical fibre ring around Africa, linking 40 countries. Practical architectures for such a project are still being considered though AT&T researchers say that experiment is demonstrating that such a large-scale all-optical network having many high speed channels is certainly possible.



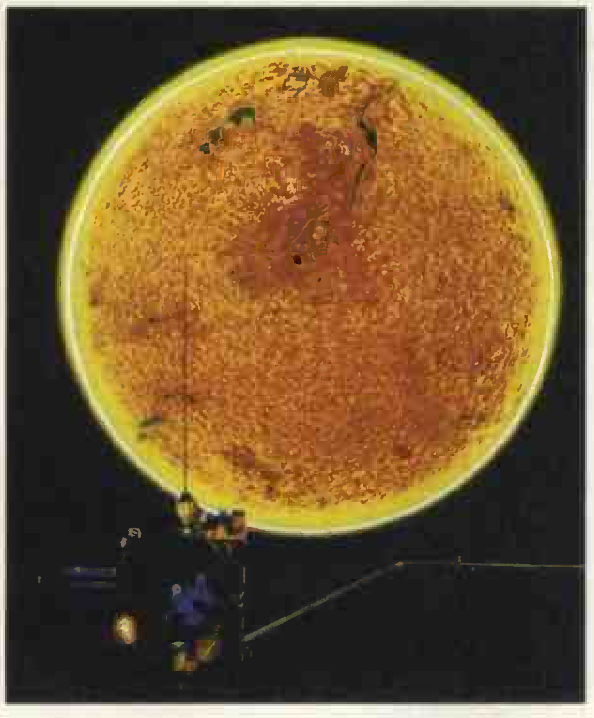
Continental drift: fibre optic technology is moving to make such projects as the 32,000km ring around Africa a reality.



11,300km is the longest distance yet for data transmission through commercial optical cable.

Getting the measure of solar wind

Ulysses on its mission to explore the heliosphere – the region of space dominated by the outward flowing solar wind. (Picture courtesy European Space Agency).



Quite apart from giving rise to the haunting northern lights, the million-mile-per-hour charged particles that make up the solar wind can degrade communications, disrupt power transmission grids, and damage satellites. Yet scientists are still unable to predict with any certainty when such activity is going to hit the earth. But data currently being processed from satellites belonging to the ISTP (International Solar Terrestrial Physics) programme could help change that.

ISTP involves coordinating experimentation aboard a number of space platforms, with different initiatives exploring key areas of geospace where the dynamics are controlled by Earth's magnetic field and its interaction with the solar wind.

For example Japan has been processing data from a satellite sitting in the magnetospheric tail formed by the solar wind as it rushes past the earth. Similarly, solar wind experiments (swe) aboard the 'Wind' satellite will measure properties of the solar stream before it reaches the Earth. Researchers are hopeful that Wind's location between the Earth and Sun could eventually give warning of magnetic storms.

Overall goal of the swe programme is to monitor how changes in the wind affect the environment around Earth, according to Alan J Lazarus, a senior research scientist in physics and head of the swe MIT team.

Since November, MIT's instruments have begun collecting samples of the charged particles that make up the solar wind, and measuring their speed, density, and other properties. Scientists from Nasa, the University of New Hampshire, and Boston University are cooperating on the swe project and six more experiments on the satellite are focusing on other phenomena associated with the solar wind.

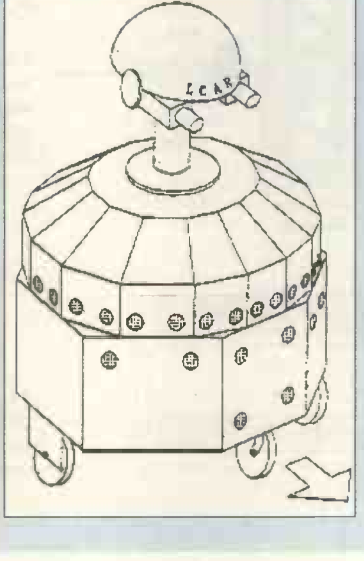
"There are efforts to return data in real time from this spacecraft, so we can report solar wind conditions to people who could be affected," says John T Steinberg, a research scientist at the Center for Space Research and also a member of the MIT team.

Ultimately, Wind will go into an orbit between the Earth and the Sun that will allow it to make continuous readings of the solar wind an hour before it reaches Earth.

The result would be that sensitive electronics on the spacecraft – which might otherwise be damaged – could be switched off. Varying magnetic fields can also have a serious effect on power grids, and have in the past caused massive power outages. One such incident occurred in Canada in 1989. With advance warning, power companies could make proper preparations for possible disruptions of their systems.

Way forward (or sideways) for robots?

Successfully negotiating our way around rooms full of furniture is a skill we learn as babies. For robots, the task is one some of them will never learn. But researchers at the Korea Advanced Institute of Science and Technology (Kaist) hope their work could lead to fewer bruised robot shins in the future.



Kaist's Lcar robot can switch between goal seeking behaviour and obstacle avoidance behaviour to negotiate obstacles in real time

A robot's navigational problem is that whenever it moves in an uncertain environment towards a goal, avoidance behaviour and goal-seeking behaviour always conflict. Avoidance behaviour is used to seek the goal position, until obstacles loom, when avoidance takes precedence, and goal-seeking behaviour is used to seek the goal irrespective of obstacle location.

Hee Rak Beom and Hyung Suck Cho at Kaist have been using fuzzy logic to describe both behaviours and have been working to develop a robot control system that switches to the best strategy based on the robot's local environment (A sensor-based navigation for a mobile robot using fuzzy logic and reinforcement learning, *IEEE Trans on systems, man and cybernetics*, 25, 3, pp.464-477).

Their Lcar robot has 26 ultrasonic sensors, stereo camera and sensors for dead reckoning.

Fuzzy logic is used to represent the mapping between the sensor input space and the mobile robot action space, with the correct mapping found by reinforcement learning.

So far the robot is managing to move around a 10 by 10m room packed full of obstacles towards its goal and is demonstrating an ability to adapt to unknown environments.

Importantly the small fuzzy-rule-base needed allows the method to be implemented in real time, while the reinforcement learning dispenses with the need to construct and tune the rule bases depending on the expert's knowledge. ■

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CIRCLE NO. 106 ON REPLY CARD

ELECTRONICS on the road

Eric Russell looks at innovations in electronic systems that automotive manufacturers are planning for the cars of tomorrow.

More vehicles come onto the roads each year and manufacturers are doing more and more to make them safer. The accent is moving away from mechanical developments towards electronic detection and control, with anti-collision radars, anti-skid systems and better anti-lock braking.

Aerospace technology has come down to road level, but the new technology is driving itself. More devices mean more wiring, which leads to intelligent harnesses, in turn resulting in more electronics. The automotive designer has to drive hard to keep up.

Driving on black ice

To be in full control while driving fast on black ice must be the ultimate motoring experience and it is promised for UK drivers this year by Mercedes-Benz.

Electronics is the key to this and other recent advances in automotive design in a trend which will shortly see more electronics than mechanics on the family saloon.

Mercedes-Benz calls its system Electronic Stability Program. It brings together traction control, intelligent brakes and aerospace technology to detect a car's direction of travel. ESP prevents skidding by braking individual wheels to maintain the car's balance. Control signals to the brakes derive from a computer which compares steering wheel position with the car's direction of travel.

When under- or over-steer is detected, the appropriate brakes are momentarily applied and engine torque is reduced. This brings the car back on line. The driver may not notice the system operating but a dashboard indicator illuminates, providing a warning.

Key to the system is a yaw detector. Housed under the rear seat of a car it gives an output signal proportional to the rate of rotation about a vertical axis.

Fig. 1. A car travelling on ice at 45mile/h is kept steerable and stable by the new Electronic Stability Program from Mercedes-Benz.

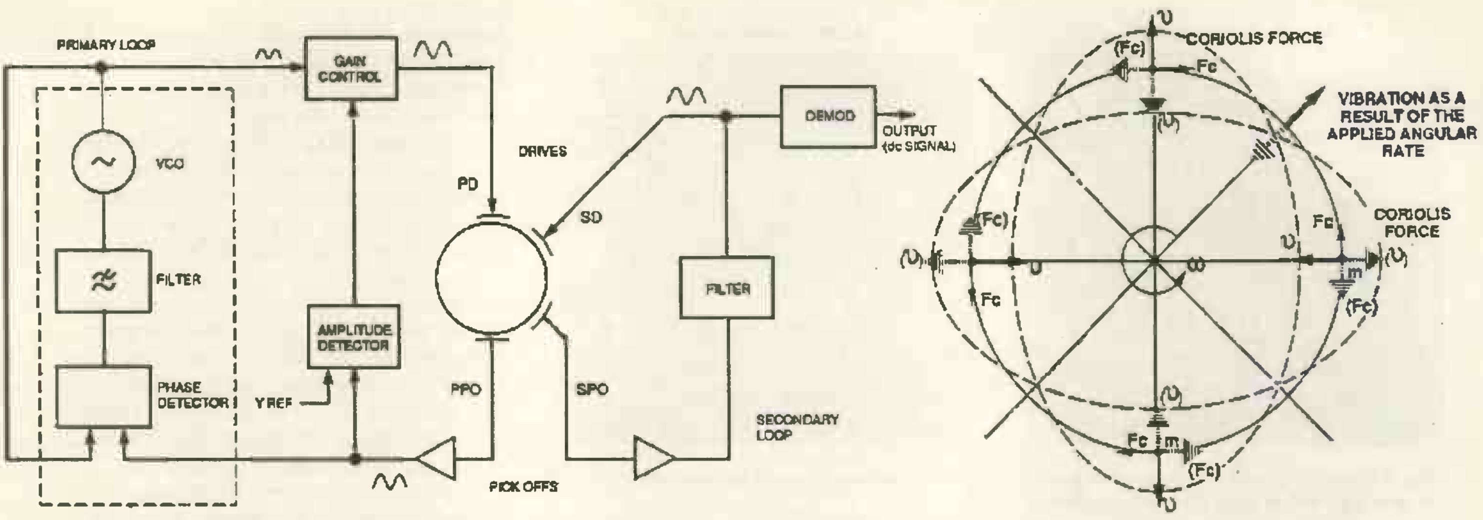

Fig. 2. Such a vibrating-structure gyroscope may be being used for yaw detection in Mercedes' electronic vehicle stabiliser. Output of the gyroscope is dc and proportional to the rate of rotation.

This data, together with steering wheel angle, individual wheel speeds, brake pressure and sideways acceleration are compared in a computer with a database which contains all the parameters for optimum stability.

The ESP control unit is linked to engine, automatic transmission, brakes, accelerator and sensors through a Controller Area Network data bus. The accelerator is electronically linked to the engine management system, bringing the new Mercedes close to drive-by-wire. A variable resistor is rotated as the accelerator is depressed to give a much finer control than with mechanical linkage.

ESP was recently demonstrated on a frozen lake in Sweden, Fig. 1. While a standard car was virtually uncontrollable at 30mile/h, the ESP car was steerable and stable at 45mile/h. Mercedes points out that such systems cannot beat the laws of physics and in unintended confirmation, a test driver promptly ploughed his vehicle into a snow bank.

The system was scheduled to become standard equipment in Germany in March on the *S600* coupe. The first cars for Britain are promised in the autumn – in time for our own snow. Details of the ESP system are not available, "Because the system is not yet in production," says a spokesman. But the key component, the yaw detector, could be similar to a unit produced by British Aerospace (Systems and Equipment) Ltd.

This is a solid state gyroscope using the piezo-electric principle and the coriolis effect. The sensing element is a cylinder of man-made ceramic, a lead zirconate titanate composite, which is electronically vibrated.

The coriolis effect refers to the distortion of an object's trajectory by the earth's rotation. The effect of the force can be seen when a person sits on a typist's chair holding a spinning bicycle wheel by the axle ends. If the person lifts their right hand, tilting the wheel, the chair will rotate towards the right.

A similar force can be generated when a vibrating object is rotated. In British Aerospace's Vibrating Structure Gyroscope the piezo-electric block is excited in one axis and electric output is taken from another axis. Output is dc and proportional to the rate of rotation, **Fig. 2**.

The solid state construction makes the VSG more robust than conventional mechanical gyroscopes with no maintenance requirement and minimal start-up time, which can be as low as 300ms. It can operate off a standard car power rail, **Fig. 3**.

At Lotus Engineering, the Active Technology Group uses vibrating-structure gyroscopes in active suspension designs. The company's system measures the load at the tyre contact patch once a millisecond and reacts to changes so a constant load is maintained. The VSG indicates when a road wheel is about to drop into a depression or rise over a bump and a hydraulic actuator is extended or retracted to keep the car body level.

This system is used in Arnold Schwarzenegger's Hummer, High Mobility Modular Wheeled Vehicle, but the price precludes its use in more popular cars. The servo valve on the actuator is an aerospace type, with an appropriate price tag, but if this could be manufactured in volume then active suspension would be seen on more vehicles.

Is ABS effective?

Research has shown that ABS is not often used in practice. Few drivers press the brake pedal hard enough to lock the wheels. In accident situations which demand hard braking drivers react in two stages: firstly a slightly harder than normal press of the pedal; then a heavier press when the situation is fully realised. Research also showed that if drivers reacted half a second earlier half of collisions would be avoided.

Advances in car control system

It is a development of ABS that forms part of Mercedes' ESP. A brake booster is activated when brakes need to be applied by the system and ABS prevents wheels locking up. When ABS is activated, brake fluid is taken out of the system, so reducing pressure on the brake

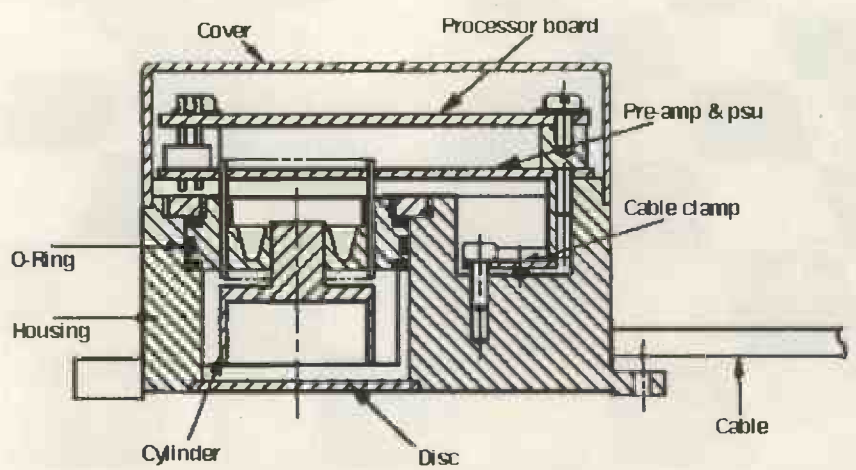

Fig. 3. Solid state construction makes the vibrating-structure gyroscope more robust than conventional mechanical types.

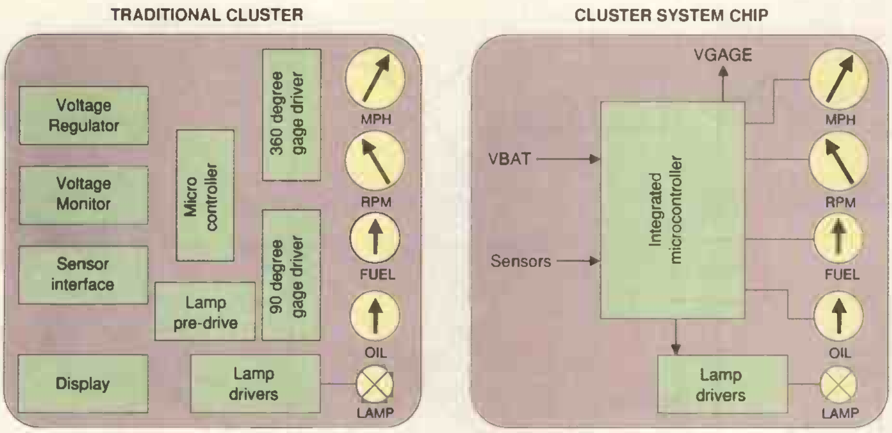

Fig. 4. Increasing microprocessor integration makes car electronics more reliable while improving compactness and maintainability.

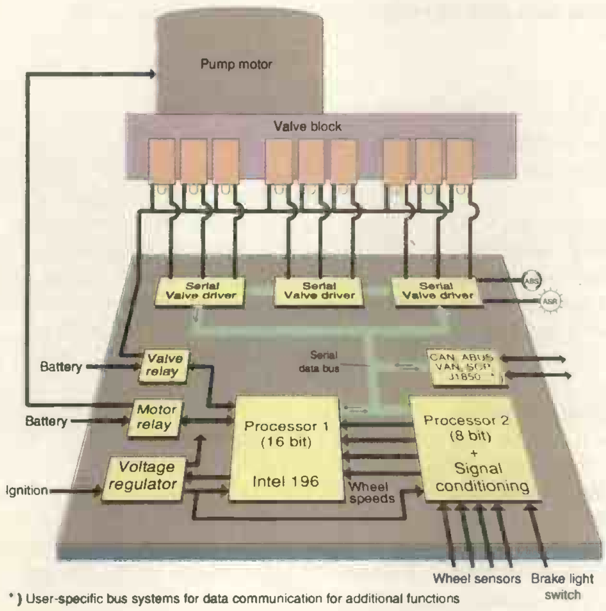

Fig. 5. In ITT's Teves Mk 20 ABS module, two processors – one of them 16 bits – work together, monitoring each other to eliminate the chance of a total loss of braking.

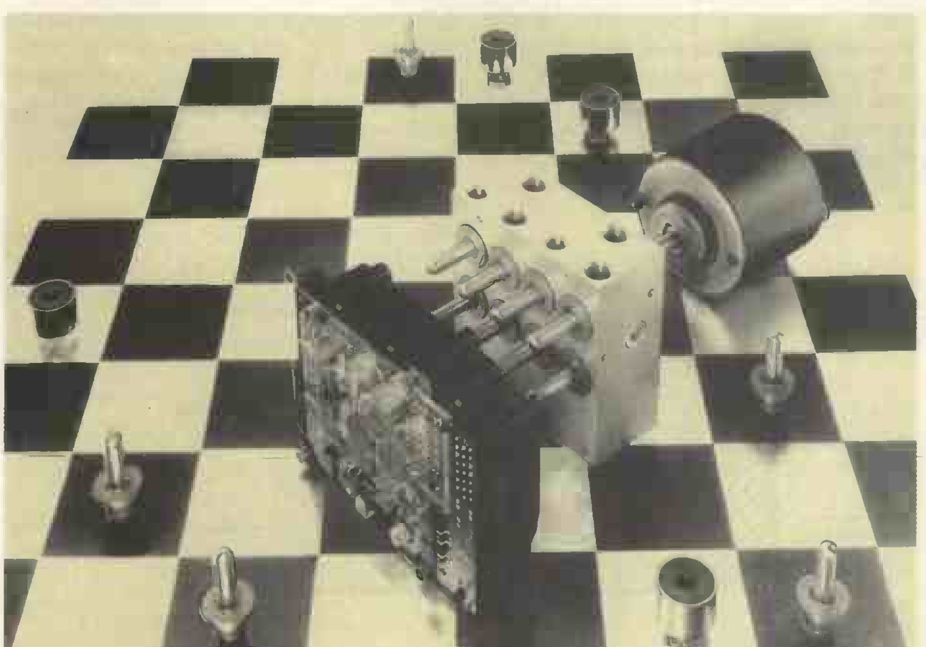

Fig. 6. ABS pump, electric motor, valves and a pcb containing two processors are all housed in a 16 by 10 by 10cm module – the Teves Mk 20 ABS system.

mechanism, be it disc or drum type. In an open system the brake fluid is returned into the master cylinder. In a closed system the fluid stays local to the wheel.

By the year 2000 ABS will be standard equipment on passenger cars according to a prediction from the Economist's Intelligence Unit. With 30% of cars fitted now, a compound growth for the technology of 22% per year is expected.

Against this background Texas Instruments recently announced a new customised microcontroller chip, the *cMCU370*. It will start to appear in a new design of ABS module from ITT subsidiary Alfred Teves, which is using some half dozen electronic subcontractors worldwide to assemble the modules.

TI has developed the microcontroller from the *TMS370* range of ICs. Sghaier Noury, TI's European Microcontroller Department Manager says: "It is part of a full product road map which includes many generations to come." The *cMCU370* has been designed under TI's Prism design methodology which evolved from a successful relationship with Delco Electronics. The principle of Prism is to steadily increase the number of functions that a chip can perform and to increase the different signal types it can handle, while using technology that has already been developed and proven, **Fig. 4**.

The *cMCU370* is an eight-bit device with a 16 bit version due next year and 32-bit architecture under development. At the launch of the new chip in Nice, TI also announced an agreement to supply ITT Automotive of Frankfurt with the product. The two companies have been co-operating for some six years using TI's knowledge of silicon and ITT's system experience. The *cMCU370* will be built into ITT's latest ABS module, the *Teves Mk 20*.

Under the agreement TI is expected to ship more than eight million microcontroller systems annually by 1997 rising to ten million by the year 2000. The first vehicles equipped with ABS using the new microcontrollers will be unveiled in 1996.

Teves' Mk 20 ABS module houses the electric motor, ABS pump, valves and pcb in a compact 16 by 10 by 10cm housing, **Figs 5, 6**. The system incorporates anti-skid control and electronic brake force proportioning. At the core of the hydraulic/electronic system is a lightweight aluminium block integrating the motor, pump and valves. Magnetic coils actuate the valves so there is no direct connection between controller and valve.

The pump conveys the brake fluid bled off by the ABS valves back to the master reservoir so the integration into one block saves installation time for the vehicle manufacturer.

Two microprocessor chips are carried on the pcb, a 16-bit Intel *196* and the Texas *cMCU370* 8-bit processor. These work together in 'asymmetrical redundancy' and monitor each other. This provides a high level of safety and protects against a failure which would open all the ABS valves, leaving the vehicle with no brakes.

Intel's chip processes the wheel speed and control algorithms. Complex mathematical formulae are written into the software, enabling the chip to calculate the best action to take from a given set of inputs. The TI chip simulates the calculations and then instructs the valve drivers. These are power semiconductors which replace the mechanical relays of previous designs and control current to the magnetic coils.

Within the pcb, the chips communicate via a serial data bus. This needs only three lines between each integrated circuit. The bits that make up each computer word are sent one after the other at a speed of two million bits per second. This communication system will link neatly into a vehicle's multiplexing harness whether the vehicle manufacturer has opted for CAN, ABUS, VAN, SCP or J1850 as the operating system.

Although both TI and ITT agree that multiplexing technology is both available and affordable, it awaits a change in outlook from the car manufacturers before being used regularly. There is also the consideration of higher after-care costs as a result of more complex systems.

The module could be a nucleus for the next project, a vehicle stability system. ITT Automotive anticipates its system arriving in the second half of the nineties.

More intelligence for ABS

Sensing the rotation of road wheels is a basic requirement of an ABS system and Siemens offers two sensor types – inductive and active. A toothed wheel is central to both systems. In the inductive version a magnet is fixed close to the wheel so as each tooth passes, the magnetic field is disturbed. These variations induce a current in a coil round the magnet

Fig. 7. Active speed sensor contains a highly sensitive inductive sensor combined with differential Hall IC to measure speeds almost down to zero. Output can be used for traction control, ABS and for driver information such as speed indication.

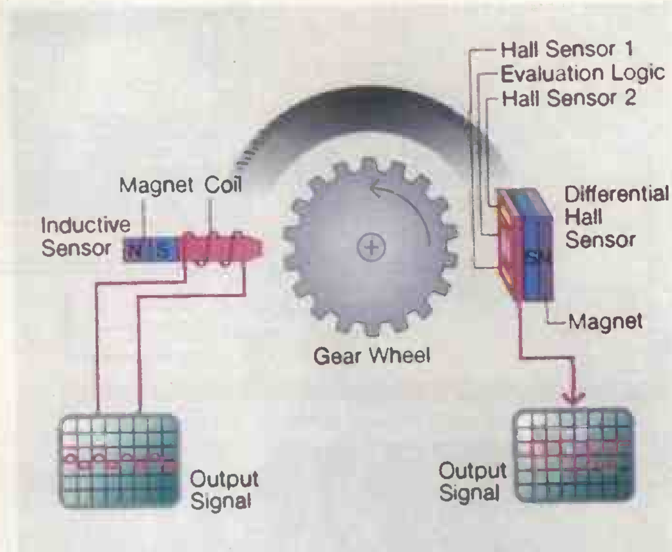

Fig. 8. One of the problems with ABS is that often, drivers only press the brake pedal hard enough to invoke ABS when it's too late. Lucas' new brake assistance system senses when the brake is pressed more rapidly than usual, and applies the brakes harder than would be the case if the pedal were depressed normally.

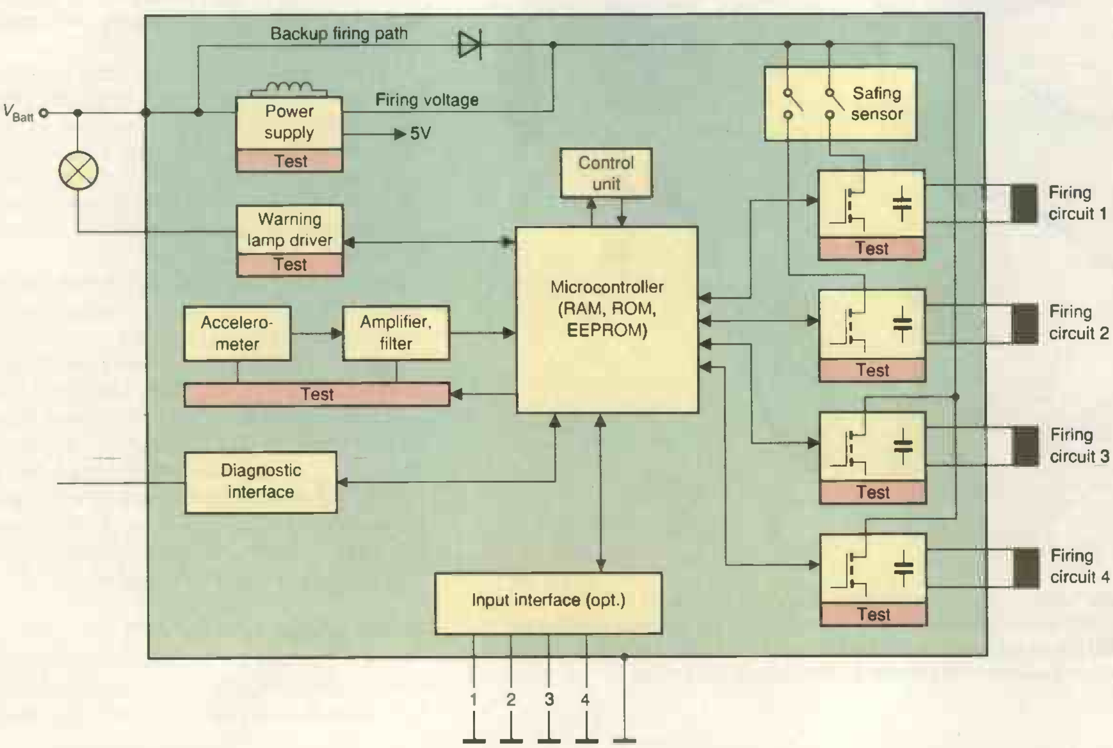

Fig. 9. Elements of a single-point sensing airbag electronic unit, courtesy Siemens. The system needs its own power supply in case the battery becomes disconnected due to the impact and there are multiple firing loops to cover for partial faults.

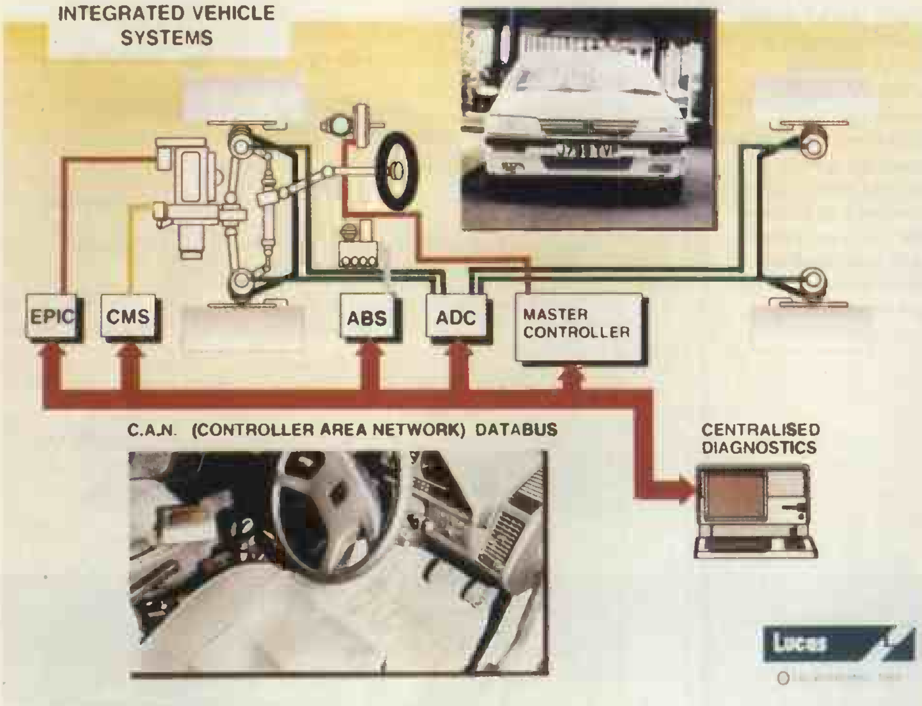

Fig. 10. Lucas's Advanced Prototype Vehicle, a Peugeot 605 turbo diesel, has completely integrated systems, controlled from a central processor via CANbus. EPIC is electronically programmed injection control and CMS is the clutch-management system.

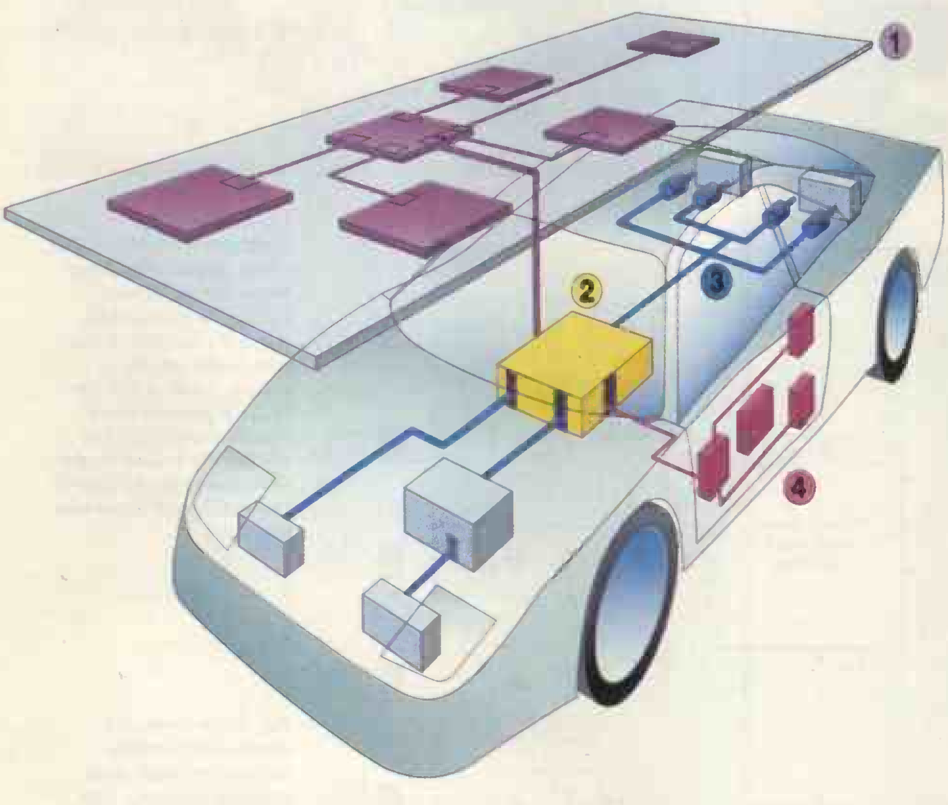

Fig. 11. With CANbus, cable harness requirements are greatly reduced since many switching and control signals can be multiplexed down one low-power bus. Conventional cabling for automatic windows, speakers, locking and mirror positioning means a lot of cabling between car and door, so this is one area where multiplexing is particularly attractive.

giving a sine wave output with each positive peak corresponding to a tooth on the wheel.

The active version, **Fig. 7**, uses a differential Hall sensor comprising two Hall switches and evaluation logic to provide a square wave output. In both systems the ABS computer counts the pulses and compares the result with time to provide an indication of road speed for the dashboard speedo and an indication of wheel lock to the ABS system.

Wheel bearing manufacturers are now producing intelligent bearings with on-board sensors and signal conditioning which reduces the effects of interference on the signal before it reaches the computer.

Grau's ABS system does not operate below 10km/h. This means that a stationary vehicle being held on a slope by the foot brake does not creep forward because the ABS system has detected an apparent wheel lock situation and reduces brake pressure.

To provide this extra margin needed to get round the drawbacks outlined in the ABS panel, Lucas is developing intelligent brakes. In an emergency, while the pedal may not be fully depressed, it is moved more quickly than normal. This can be detected and the signal used to operate an electronically controlled brake booster to apply the maximum servo force, **Fig. 8**. The controller compares pedal movements with the previous pattern of driver behaviour to assess an emergency situation. Operating the brake booster to its maximum invokes ABS, bringing the car to rest in the shortest possible distance.

This system could also work in conjunction with anti-collision radar, where microwaves or infra-red transmissions detect objects in front of a vehicle. The intelligence calculates when the distance is unsafe and, when intelligent cruise control is activated, reduces engine speed. Alternatively, the system can simply apply the brakes.

These electronic aids help when cars are well loaded with passengers or goods. The driver takes time to appreciate that longer braking is required in any given situation and may not have the space to stop in time. Intelligent brakes have an input from load sensors and the calculation includes the amount of load being carried.

Once all these functions are combined with a central computer, the brake holding system could also end hill start traumas.

Lucas's system has been developed within the Prometheus project. This concluded last year with a major demonstration of many new technologies at the Transport Research Laboratory. Prometheus – Programme for a European Traffic with Highest Efficiency and Unprecedented Safety – was a five year European initiative to develop automotive technology to a near-production state.

When it's too late for ABS

All these systems use electronics to help prevent accidents. When one does occur, the current spotlight is on airbags to protect the occupants. Basically, an accelerometer triggers the airbag inflation valve during abnormal deceleration. While a crash takes several seconds to complete, airbags react in milliseconds. Practically there are many considerations which demand that airbag systems are computer controlled, **Fig. 9**.

The system needs its own power supply in case the car battery becomes disconnected. This amounts to energy storage for a matter of seconds but the storage system needs topping up, measuring and checking.

The whole system must be self-checking on start-up with an output to warning lamps for system failure. Multiple firing loops provide redundancy in case of a single failure. A safing sensor disarms the system during safe situations, so while the accelerometer looks for crash signals, the safing sensor looks for non-crash signals. Seat belt status and passenger presence may be monitored and there could be a communications interface for external diagnostic testing.

Besides the physical considerations, the software has to be rugged. Like ABS, airbags are safety critical – causing danger when they fail or operate unexpectedly. Software has to reflect this. In conjunction with the British Standards Institute and others, the Society of Motor Manufacturers and Traders has just issued guidelines for the software that will be used increasingly on vehicles.

Linking it all together

Connecting all these systems is the car wiring harness. On a Mondeo there's 1.5km of wiring. It takes two people to lift the harness on some American models. In addition, harnesses can be a problem when many switches are mounted in doors and arm rests.

The simple version of dedicated point-to-point wiring is a two-wire ring main carrying serial information and a ring main carrying power. Operating an instrument switch sends an address followed by an instruction. All devices on the network listen to the address and the unit which recognises an address as its own will then act on the next set of pulses and operate as required.

The traditional way of providing a device with an address is a bit switch. The device compares the address pulses with the bit switch setting and enables the device when the two coincide.

A specification called Controller Area Network, CANbus, has been developed by Bosch for networking in automotive applications and this has been recognised by the International Standards Organisation. CAN protocol uses a multi-master, contention based bus configuration for transferring communication objects between nodes on the network. Multiple access raises the problem of collisions of data on the network. This is resolved in CAN by sensing a carrier denoting the network is carrying traffic.

A communication object consists of an identifier plus control data segments. The control segment contains all the information needed to transfer the message while the data segment contains up to eight bytes. Devices on the vehicle will only respond if their acceptance filter decides to receive a message. At each node the message identifier will have been set up in that controller's ram, **Fig. 10**.

The protocol can distinguish between permanent hardware failure and occasional soft errors. Defective nodes are switched off the bus, implementing a fail-safe procedure. To ensure robustness CAN uses non-return-to-zero bit coding. Ones and zeroes are indicated by a change in state, not the state itself. This produces fewer electromagnetic emissions at higher transfer rates than pulse width modulation or Manchester coding, which combine data and clock pulses.

One company manufacturing CAN control chips is NEC. Its *μPD72005* is a 52-pin flat package offering bi-directional two wire serial comms and two eight-bit i/o ports. Message memory space is 160 bytes and maximum data length is eight bytes – all of which highlights the relatively simple nature of car electronics compared with PCs.

Maximum transmission speed is 1Mbit/s. There are comprehensive error checking options including cyclic redundancy checking with a 15-bit crc generation polynomial, **Fig. 11**. The chip has been designed to fit into a large number of different networking configurations and the data book on it runs to some 96 pages.

Intel's CAN controller is the 44-pin *82527* fabricated in CHMOS III technology. Indicative of the harsh automotive environment, the *82527* copes with an ambient temperature range of –40 to +125°C.

In Russelsheim, Germany, Vauxhall says its car fitted with ISOTEC – Intelligent Safety and Orientation Technology – is currently being tested for reliability and suitability, before production sign-off. ISOTEC is a new research vehicle based on the recently launched Omega. On-board equipment includes distance radar, fog sensing, a night driving camera, and the latest navigation and guidance systems. Vauxhall says these are near-production electronic systems.

Distance measuring radar is connected to brakes, throttle and automatic transmission. The radar head is located behind the front bumper and detects other vehicles up to 140 metres ahead. Drivers can preselect a speed at which to travel and the distance radar will modify that according to the proximity of other vehicles. The required speed is selected on the indicator lever and a lamp in the speedometer indicates that speed.

When the Omega is too close to the vehicle in front, the distance controller first closes the throttle then applies the brakes. If the car reaches maximum automatic deceleration, an audible warning alerts the driver. Once the situation is stabilised the Omega automatically accelerates up to the preselected speed under guidance of the cruise control system.

Sensing obstacles by temperature

Infra-red is the technology used in the fog sensor. A beam of IR light from a black box mounted on top of the dashboard is reflected back by moisture droplets in the fog. The unit estimates the range of visibility, calculates a recommended speed and displays the figure on an led display once visibility falls below 200m. The fog sensor could be connected to the car's cruise control adjusting speed to visibility automatically.

An infra-red camera, located in the radiator grille of the Omega, records images of objects emitting heat. This applies to virtually all objects and the image is built up by making the screen brighter where more heat is being emitted. Should two objects be at the same temperature they will merge in the same way that similar tones merge in a conventional photograph, particularly when the scene is not well lit.

With infra-red systems it is possible to overlay the infra-red image with another taken by a conventional camera with light amplification. Combining the two technologies means that merged objects on one system will be separated on the other system. General Motors is assessing infra-red cameras in several highway patrol police cars in America at the moment.

Infra-red is also used on the ISOTEC to receive route navigation information. A sensor positioned behind the rear-view mirror picks up infra-red light from beacons at the side of the road. Vauxhall is using the Euro-Scout system. The driver programmes in the destination and direction symbols appear on the special dashboard information display during the journey.

In the case of collision avoidance, the computer in the distance measuring radar will have a choice of reducing speed by closing the throttle, operating the brake or selecting another ratio in the automatic gearbox. Its chosen course of action will depend on road speed and closing speed as the vehicles approach each other. This means a continuous set of calculations to cause least disturbance to the car's occupants and to keep the car stable.

Electronics are pervading cars in other areas that are near to production: automatic gearboxes and clutches, automatic lane keeping, speed limiters, side impact detection for airbag systems, blind spot detection systems, electronic deadlocks, solid state tachographs and electronic dashboard displays. This is in addition to navigation systems, route guidance, traffic warning systems, electronic tolling, satellite telephones and road side displays. Plus the electronics in 'red-light' cameras and automatic number-plate reading. Not forgetting in-car entertainment with a serial link between the cd holder and player in the boot and the dashboard radio. And the smart cards in your wallet, and the black box 'flight recorder' available from Mannesmann Kienzle. No wonder we need electronic pacemakers. ■

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Model software for *problem* solving

Allen Brown has been assessing the latest upgrade of a powerful modelling package capable – among other things – of solving equations analytically.

The low cost of powerful pcs hosting 486 or Pentium microprocessors, combined with highly visual graphics facilities, makes them very attractive tools for modelling applications. To match the performance of the pc, the engineer now has a variety of software modelling packages to choose from and one that merits consideration is *Maple V* from MathSoft of Massachusetts.

Now issued as Release 3, *Maple V* has over 2500 predefined operations and library functions, evokable as commands from the keyboard. These include such options as polynomial factorisation, equation solving, indefinite integrations and matrix manipulations. The package is capable of performing symbolic, numerical and graphical processing. In fact the 3D plotting is spectacular, and fast. *Maple* will work within dos or Windows although to access the full graphing features of the product a super-vga monitor, preferably with a graphics accelerator, is needed.

Maple V comprises three components: the kernel, the library and the interface. The kernel is the mathematical engine behind *Maple V*'s calculations. This is a compact, highly optimised set of routines written and compiled in the C programming language, and performs the large part of the basic computations done by the system.

Most of *Maple V*'s built-in procedures are written in the product's own programming language. Code written in *Maple V* is not compiled, but interpreted as it is read or entered, allowing users to create their own *Maple V* procedures interactively within the program. The interface is *Maple V*'s eyes to the world and defines, to a large extent, how the user interacts with the commands and procedures. In effect *Maple V* makes the whole discipline of mathematics more accessible for general usage such as engineering applications.

The method of entering instructions is by means of directly keying in commands. These commands form part of the native extensive command language. For example, to construct a sine function ranging from –π to + π, you would enter on the prompt symbol (>),

```
>        f(x) : = (sin(2*Pi*x), x=–Pi..Pi);
```

Maple would respond by writing,

> f(x) : = (sin(2πx),x=–π..πi);

All further operations on this function would refer direct-

```
> readlib(laplace);

  proc(expr,t,s) ... end

> dif1 := L11*diff(i1(t), t$1) + L12*diff(i2(t), t$1) + R11*i1(t) = E , L22*diff(i2(t), t$1
> ) + L12*diff(i1(t), t$1) +R22*i2(t) = 0 : fns := { i1(t),i2(t) } ;
```

$$fns := \{ \mathrm{i2}(t), \mathrm{i1}(t) \}$$

```
> dsolve( {dif1, i1(0) = 0, i2(0) = 0 }, fns ) ;
```

$$\Big\{ \mathrm{i2}(t) = -\frac{\%2\, e\, L12\, e^{\left(1/2 \frac{\%3\, t}{L12^2 - L11\, L22}\right)}}{\%4} + \frac{\%2\, e\, L12\, e^{\left(1/2 \frac{\%2\, t}{L12^2 - L11\, L22}\right)}}{\%4}$$

$$, \mathrm{i1}(t) = -4\, R22 \Big(e\, L12^2 - e\, L11\, L22 - \Big(2\, R11\, R22\, L12^2 + \frac{1}{2} L11^2\, R22^2 - \frac{1}{2}\sqrt{\%1}\, R22\, L11 + \frac{1}{2}\sqrt{\%1}\, R11\, L22 - L11\, R22\, R11\, L22 + \frac{1}{2} R11^2\, L22^2 \Big) \%2\, e\, L11\, L22\, e^{\left(1/2 \frac{\%3\, t}{L12^2 - L11\, L22}\right)} / \left(\%4 \sqrt{\%1}\right) - \Big(-2\, R11\, R22\, L12^2 - \frac{1}{2} L11^2\, R22^2 + \frac{1}{2}\sqrt{\%1}\, R22\, L11 - \frac{1}{2}\sqrt{\%1}\, R11\, L22 + L11\, R22\, R11\, L22 - \frac{1}{2} R11^2\, L22^2 \Big) \%2\, e\, L12^2\, e^{\left(1/2 \frac{\%3\, t}{L12^2 - L11\, L22}\right)} / \left(\%4 \sqrt{\%1}\right) + \%2\, e\, \big(-2\, L12^2\, R22 \sqrt{\%1} - R11\, L22^2 \sqrt{\%1} + L11\, R22\, L22 \sqrt{\%1} + 4\, R11\, R22\, L12^2\, L22 - 2\, L11\, R22\, R11\, L22^2 + L11^2\, R22^2\, L22 + R11^2\, L22^3 \big)\, e^{\left(1/2 \frac{\%2\, t}{L12^2 - L11\, L22}\right)} L11\, R11\, L22 / \%4^2 - \%2\, e\, L12^2 \big(-2\, L12^2\, R22 \sqrt{\%1} - R11\, L22^2 \sqrt{\%1} + L11\, R22\, L22 \sqrt{\%1} + 4\, R11\, R22\, L12^2\, L22 - 2\, L11\, R22\, R11\, L22^2 + L11^2\, R22^2\, L22 + R11^2\, L22^3 \big)\, e^{\left(1/2 \frac{\%2\, t}{L12^2 - L11\, L22}\right)} R11 / \%4^2 \Big) / (\%3\, \%2) \Big\}$$

$$\%1 := 4\, R11\, R22\, L12^2 - 2\, L11\, R22\, R11\, L22 + L11^2\, R22^2 + R11^2\, L22^2$$

$$\%2 := L11\, R22 + R11\, L22 - \sqrt{\%1}$$

$$\%3 := L11\, R22 + R11\, L22 + \sqrt{\%1}$$

$$\%4 := \sqrt{\%1}\, R22\, L11 - \sqrt{\%1}\, R11\, L22 + R11^2\, L22^2 + 4\, R11\, R22\, L12^2 - 2\, L11\, R22\, R11\, L22 + L11^2\, R22^2$$

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Listing 1. Maple also produces analytical solutions to differential equations. This example shows the solution from a model of a simple transformer.

GRANDATA LTD

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AC126	30p
AC127	30p
AC128K	40p
AC141K	45p
AC176	22p
ACY18	48p
ACY19	48p
AD149	60p
AF125	50p
AF139	30p
AF239	30p
BB105B	18p
BB205B	24p
BC107	8p
BC108	8p
BC109	8p
BC109C	10p
BC140	20p
BC142	20p
BC143	20p
BC147	8p
BC149	8p
BC159	8p
BC160	30p
BC171	10p
BC172	10p
BC177	14p
BC178	14p
BC179	14p
BC182	7p
BC182L	7p
BC183	7p
BC183L	7p
BC184	7p
BC184L	7p
BC212	7p
BC212L	7p
BC213	7p
BC213L	7p
BC214	7p
BC214L	7p
BC237	7p
BC238	7p
BC239	7p
BC300	20p
BC301	20p
BC302	20p
BC303	20p
BC304	25p
BC327	7p
BC328	7p
BC337	7p
BC338	7p
BC441	28p
BC446	8p
BC477	18p
BC516	22p
BC537	25p
BC546	8p
BC547	8p
BC548	8p
BC549	8p
BC550	8p
BC556	8p
BC557	7p
BC558	8p
BC559	8p
BC560	8p
BC637	20p
BC639	20p
BC640	20p
BCY33	200p
BCY34	200p
BCY70	16p
BCY71	16p
BCY72	16p
BD115	30p
BD124P	50p
BD131	25p
BD132	25p
BD133	50p
BD135	20p
BD136	20p
BD137	20p
BD138	20p
BD139	20p
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BD144	90p
BD157	38p
BD166	30p
BD175	30p
BD177	30p
BD179	32p
BD181	45p
BD182	60p
BD184	60p
BD187	30p
BD201	33p
BD202	38p
BD203	42p
BD204	42p
BD222	31p
BD225	31p
BD232	31p
BD233	30p
BD234	32p
BD235	28p
BD236	30p
BD237	21p
BD238	24p
BD239	30p
BD240	40p
BD241A	40p
BD243A	50p
BD244	50p
BD245	50p
BD246A	50p

Part	Price
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BD267	45p
BD269	45p
BD278	50p
BD311	100p
BD314	100p
BD315	150p
BD317	150p
BD331	40p
BD332	40p
BD361	60p
BD362	60p
BD370	30p
BD371	30p
BD410	50p
BD433	28p
BD434	30p
BD435	31p
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BD533	50p
BD534	38p
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BD828	50p
BD839	55p
BD897	50p
BD899	50p
BD977	50p
BDX33	60p
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BDW24	55p
BDW93	50p
BDW94	50p
BDY92	100p
BF137	35p
BF167	30p
BF181	18p
BF183	20p
BF195	7p
BF199	8p
BF200	16p
BF225	30p
BF240	16p
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BF259	18p
BF262	25p
BF270	18p
BF273	15p
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BF336	20p
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BF338	20p
BF362	30p
BF367	13p
BF371	17p
BF421	18p
BF422	21p
BF423	25p
BF455	12p
BF458	19p
BF462	50p
BF471	28p
BF472	28p
BF479	30p
BF494	16p
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BF595	16p
BF596	16p
BF615	30p
BF617	30p
BF760	40p
BF763	40p
BF870	22p
BF871	22p
BF960	38p
BF961	35p
BF964	38p
BFR90	85p
BFR91	99p
BFT43	30p
BFX29	28p
BFX84	20p
BFX85	20p
BFX87	15p
BFX88	15p
BFX89	60p
BFY50	14p
BFY51	14p
BFY52	14p
BFY56	25p
BFY64	25p

Part	Price
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BLY48	85p
BR100	14p
BR103	37p
BR303	85p
BSS74	33p
BSX20	15p
BT100A	70p
BT106	180p
BT109	90p
BT119	100p
BT146	99p
BTY79	140p
BU105	80p
BU108	100p
BU109	80p
BU110	90p
BU111	100p
BU124	60p
BU126	60p
BU180	100p
BU184	100p
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BU206	100p
BU208	70p
BU208A	75p
BU208AT	200p
BU208D	130p
BU209	90p
BU225	120p
BU226	120p
BU312	90p
BU325	55p
BU326A	75p
BU406	60p
BU406D	85p
BU407	55p
BU407D	75p
BU408	60p
BU408D	75p
BU409	85p
BU426A	70p
BU500	100p
BU505	90p
BU505D	90p
BU505DF	90p
BU506	100p
BU506D	70p
BU506DF	120p
BU508A	70p
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BU706F	150p
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BU807	60p
BU902	110p
BU903	110p
BU920	100p
BU922	110p
BU930	130p
BU2508A	130p
BU2508AF	130p
BU2508D	130p
BU2508DF	150p
BU2520AF	225p
BU2520DF	225p
BU2525AF	325p
BUH515	200p
BUT11AF	55p
BUT12	80p
BUT56A	75p
BU18	80p
BU18AF	80p
BUX10	150p
BUX11	200p
BUX12	150p
BUX20	350p
BUX21	450p
BUX22	450p
BUX37	220p
BUX40	210p
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BUX47A	220p
BUX48A	150p
BUXB0	180p
BUX84	50p
BUX85	50p
BUX86	50p
BUX87	50p
BUX98A	350p
BUY69A	200p
BUY71	250p
BUZ11	200p
BUZ71	75p
BUZ80	200p
BY44B	20p
BYT11	25p
C106D	20p
IRF630	150p
J174	38p
J300	50p
MJ900	200p
MJ1000	200p
MJ1001	200p
MJ10012	300p
MJ15003	250p
MJ15004	300p

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MJ2501	100p
MJ2955	55p
MJ3000	100p
MJ3001	100p
MJE29A	30p
MJE30A	30p
MJE340	25p
MJE350	80p
MJE520	30p
MP8112	45p
MPSA05	15p
MPSA06	15p
MPSA13	15p
MPSA20	15p
MPSA42	15p
MPSA43	15p
MPSA70	15p
MPSA92	20p
MPSA93	20p
MR510	35p
MR856	36p
OC28	350p
OC29	250p
OC35	350p
OC36	250p
OC45	50p
OC200	180p
R2008B	100p
R2010B	100p
S2000A3	175p
S2000AF	175p
S2055A	175p
S2055AF	200p
S2530A	100p
S2800M	72p
TIP29	15p
TIP29A	22p
TIP29C	25p
TIP29E	40p
TIP30	25p
TIP30C	25p
TIP31A	22p
TIP31C	27p
TIP32	24p
TIP32A	21p
TIP32C	28p
TIP33	50p
TIP33C	60p
TIP34	50p
TIP34C	60p
TIP35C	65p
TIP36C	65p
TIP41A	20p
TIP41C	20p
TIP42A	20p
TIP42C	22p
TIP47	40p
TIP48	40p
TIP50	60p
TIP51	80p
TIP52	80p
TIP54	85p
TIP105	65p
TIP106	65p
TIP107	65p
TIP110	40p
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TIP112	35p
TIP112H	50p
TIP115	30p
TIP116	30p
TIP117	30p
TIP120	37p
TIP121	35p
TIP122	30p
TIP125	30p
TIP126	40p
TIP127	35p
TIP130	30p
TIP131	30p
TIP132	30p
TIP141	65p
TIP142	75p
TIP145	50p
TIP146	70p
TIP147	80p
TIP150	90p
TIP151	60p
TIP2955	42p
TIP3055	42p
TIPL760	100p
TIPL763A	200p
TIPL791A	50p
TIS61	15p
TIS90	15p
TIS93	20p
ZTX107	11p
ZTX108	11p
ZTX109	12p
ZTX212	20p
ZTX300	10p
ZTX301	16p
ZTX302	10p
ZTX303	20p
ZTX304	10p
ZTX320	20p
ZTX501	13p
ZTX502	10p
ZTX503	18p
ZTX504	25p
2N696	26p
2N697	22p
2N698	40p
2N78	22p
2N914	28p
2N930	18p
2N1131	28p
2N1132	28p
2N1613	24p
2N1711	24p
2N1893	30p

Part	Price
2N2102	50p
2N2218A	24p
2N2219	24p
2N2221	23p
2N2222	23p
2N2369	15p
2N2484	15p
2N2646	40p
2N2904	20p
2N2905	20p
2N2906	18p
2N2907	18p
2N3019	28p
2N3053	18p
2N3054	40p
2N3055	38p
2N3055H	50p
2N3442	85p
2N3702	9p
2N3703	9p
2N3704	9p
2N3705	9p
2N3706	9p
2N3707	9p
2N3710	12p
2N3711	12p
2N3771	85p
2N3772	90p
2N3773	100p
2N3799	18p
2N3819	29p
2N3903	11p
2N3906	11p
2N4031	25p
2N4401	12p
2N4403	12p
2N5061	20p
2N5088	20p
2N5192	50p
2N5241	500p
2N5245	45p
2N5294	30p
2N5296	30p
2N5448	12p
2N6107	40p
2N6292	40p
2N6385	120p
2N6403	160p

RECTIFIER DIODES

Part	Price
BY127	8p
BY133	8p
BY164	40p
BY179	35p
BY184	32p
BY206	11p
BY207	9p
BY227	19p
BY228	28p
BY298	15p
BY299	18p
BY448	20p
BYX10	15p
BYX55/600	25p
BYX70/500	
OA47	10p
OA91	10p
OA202	10p
IN4001	3p
IN4002	3p
IN4003	3p
IN4004	3p
IN4005	3p
IN4006	3p
IN4007	4p
IN4148	2p
IN5400	9p
IN5401	8p
IN5402	8p
IN5403	8p
IN5404	8p
IN5405	11p
IN5406	12p
IN5407	12p
IN5408	12p
RGP15	25p
RGP30	16p
SKE4F2/06	60p
SKE4F2/08	80p
SKE4F2/10	100p
SR2M	60p

I.C. SOCKETS

Part	Price
8 PIN	5p
14PIN	6p
16PIN	7p
18PIN	10p
20PIN	12p
22PIN	13p
24PIN	14p
28PIN	16p
40PIN	18p

ZENERS

Part	Price
400 mWatts	
2V7 to 39V	5p
1.3 Watts	
2V7 to 39V	9p

VOLTAGE REGULATORS

Part	Price
7805	25p
7806	25p
7808	25p
7812	25p
7815	25p
7818	25p
7824	25p
7905	25p
7906	30p
7908	30p
7912	30p
7915	30p
7918	30p
7924	30p
78L05	24p
78L08	24p
78L12	24p
78L15	24p
78L18	24p
78L24	24p
79L05	35p
79L08	35p
79L12	35p
79L15	35p
LM309K	100p
LM317T	100p
LM323K	350p
78H08KC	800p
79H12KC	700p
79HGKC	800p

LEDs

Part	Price
3mm	
RED	5p
YELLOW	8p
GREEN	8p
5mm	
RED	5p
YELLOW	8p
GREEN	8p

RECTANGULAR LEDs

Part	Price
5mm × 2.5mm	
RED	5p
YELLOW	8p
GREEN	8p

OPTO COUPLERS

Part	Price
4N37	58p
4N38	68p

BRIDGE RECTIFIERS

Part	Price
W005	16p
1A/50V	
W01	18p
1A/100V	
W02	19p
1A/200V	
W04	21p
1A/400V	
W06	23p
1A/600V	
W08	28p
1A/800V	
BR81D	33p
2A/100V	
BR82D	33p
2A/200V	
BR84D	37p
2A/400V	
BR86D	43p
2A/600V	
BR88D	43p
2A/800V	
BR32	43p
2A/200V	
BR34	43p
2A/400V	
BR36	44p
2A/600V	
BR62	80p
6A/200V	
BR64	72p
6A/400V	
BR251	150p
25A/100V	
BR252	165p
25A/200V	
BR254	185p
25A/400V	
BR256	200p
25A/600V	
BR258	240p
25A/800V	
BR351	185p
35V/100V	
BR352	200p
35V/200V	
BR354	220p
35V/400V	
BR356	230p
35V/600V	
BR358	260p
35V/800V	
BY164	40p
1.5A/100V	
BY176	40p
1.5A/800V	

TRIACS

Part	Price
TIC206D	60p
4A/400V	
TIC225D	69p
6A/400V	
TIC226D	68p
8A/400V	
TIC236D	85p
12A/400V	
TIC246D	105p
16A/400V	
TIC253D	190p
20A/400V	
TIC263D	205p
25A/400V	

THYRISTORS

Part	Price
2N5061	20p
0.8A/60V	
TIC116C	59p
8A/300V	
TIC116D	70p
8A/400V	
TIC126D	75p
12A/400V	
TIC126M	90p
12A/600V	
C106D	28p
4A/400V	
BR103	37p
BR303	85p
BT106	180p
BT119	100p
17088	200p
17089	200p
17127	200p
15/80H	230p
15/85R	230p
SG264	800p
SG613	1500p

COMPUTER ICs

Part	Price
Z80ACPU	100p
Z80ADMA	200p
Z80ACTC	140p
Z80ASIO-1	210p
Z80ASIO-2	210p
75107	65p
75110	75p
75113	100p
75122	110p
75154	100p
75162	700p
75182	95p
75183	95p
75195	185p
2114	150p
2532	200p
2716	100p
2732	200p
2732A	220p
2764	150p
27C64	200p
27128	150p
27256-25	150p
27512	300p
4116	40p
4164-15	80p
4164-12	90p
41256-15	80p
41256-12	100p
41256-10	110p
41464-12	150p
6116	80p
6264-10	210p
62256-12	300p
6502A	360p
65C02	930p
6522	280p
6800	210p
6802	220p
680	500p
36808	500p
6809	500p
6810	150p
6818	380p
6821	130p
6840	290p
6845	200p
6850	90p
8085A	300p
8086	500p
8088	480p
8156	300p
8224	240p
8226	240p
8250	750p
8251	200p
8253	160p
8257	220p
8271	3400p
8279	270p
8283	400p
8284	440p
8287	260p
8288	650p
8748	700p
8755	800p
8T26	95p
8T28	110p

LINEAR ICs

Part	Price
AN203	210p
AN210	165p
AN214Q	170p
AN228	280p
AN252	150p
AN259	250p
AN262	140p
AN271	230p
AN274	250p
AN301	330p
AN303	250p
AN304	360p
AN315	210p
AN316	350p
AN360	100p
AN362	140p
AN366	150p
AN610	160p
AN3312	350p
AN3821K	600p
AN3822K	600p
AN3990K	300p
AN3991K	400p
AN5025	250p
AN5033	400p
AN5132	250p
AN5150	400p
AN5151	600p
AN5215	100p
AN5256	150p
AN5262	175p
AN5265	80p
AN5352	600p
AN5411	450p
AN5421	150p
AN5429	420p
AN5512	100p
AN5515	160p
AN5520	550p
AN5521	100p
AN5612	200p
AN5613	200p
AN5615	300p
AN5620	250p
AN5622	275p
AN5625	400p
AN5712	180p
AN5722	140p
AN5730	160p
AN5732	120p
AN5753	130p
AN5763	450p
AN5790	240p
AN5791	225p
AN5836	450p
AN5900	130p
AN6135	120p
AN6247	200p
AN6270	400p
AN6300	600p
AN6306	380p
AN6320	180p
AN6332	320p
AN6341	200p
AN6344	440p
AN6350	610p
AN6359	500p
AN6360	320p
AN6362	400p
AN6371	350p
AN6387	480p
AN6884	200p
AN7105	170p
AN7110	75p
AN7114	120p
AN7115	110p
AN7116	90p
AN7120	100p
AN7130	75p
AN7140	170p
AN7145	195p
AN7146	210p
AN7154	180p
AN7156	240p
AN7168	200p
AN7178	180p
AN7222	75p
AN7254	150p
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BA313	60p
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BA401	60p
BA402	50p
BA511	145p
BA514	160p
BA516	150p
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BA524	240p
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BA527	95p
BA532	100p
BA534	220p
BA536	150p
BA546	160p
BA612	120p
BA656	110p
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Part	Price
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BA6304	120p
BA6305	140p
BA6410	220p
BA6411	250p
BA6993	150p
BA7001	150p
BA7004	200p
BA7007	200p
BA7021	180p
BA7022	350p
BA7751LS	150p
BA7752	250p
BA7755	150p
BA7767AS	155p
CA3011	110p
CA3048	190p
CA3052	190p
CA3054	95p
CA3085	135p
CA3088E	200p
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CA3090O	250p
CA3130S	100p
CA3134E	280p
CA3140E	38p
CA3160	85p
CA3189E	230p
CA3193E	230p
CA3260E	170p
CA3290E	150p
CX108	950p
CX136	600p
CX139A	750p
CX141	750p
CX145	725p
CX150B	325p
CX175	325p
CX187	825p
CX804A	775p
CX867	575p
CX868	525p
CX877	300p
HA1125	120p
HA1197	130p
HA1199	130p
HA1319	200p
HA1338	300p
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HA1388	320p
HA1389	210p
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HA1394	170p
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LA4508	200p
LA4510	100p
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M50119P	525p
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M50786	500p
M50790	600p
M51161	300p
M51381P	200p
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M51544	150p
M51848	150p
M54523P	200p
M54563P	200p
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MB3715	250p
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NE558	80p
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ly to $f(x)$. For example if a plot was required then you would enter,

> plot(f(x));

The software responds by creating a 2D plot, autoscaled from $-\pi$ to $+\pi$. Alternatively by ending each line with a colon (:), you can effectively cascade a list of operations which are executed once the end semicolon (;) is reached.

All operations and functions are accessed in this way. However I must stress that the learning curve is quite steep. Owing to the low-level nature of *Maple V*'s command language, it is unforgiving and will require a fair amount of time and patience to master its rigid syntax.

Symbolic processing

It has often been said how useful it would be if computers could solve equations analytically, performing differentiations and integrations. Well, this software is able to perform just that. No matter how complex the equation, *Maple V* will find a solution – of sorts. It is very effective at expanding expressions, **Fig. 1**, and generating series terms, or for that matter factorising expressions.

With a package like this, one wonders why it is necessary to learn integration and differentiation techniques when the pc can find the answer in a fraction of the time. No more looking up tables to perform Laplace transforms and their inverse; *Maple V* performs these operations quite comfortably. However on occasions the answers do not agree with tabulated versions and it is difficult to know if there is an error or just an ambiguity. As expected, *Maple V* also performs numerical evaluations of equations and is particularly strong on the numerical evaluation of integrals and series.

Procedures

Maple V allows procedures to be created. These comprise a sequence of instructions. Like any other programming language, *Maple V*'s procedures incorporate conditionals, loops and exit loop conditions. The syntax is not too dissimilar to that of programming language Pascal.

An example of *Maple V* procedure is shown in **Fig. 2**. It calculates the transfer functions of different order low pass Chebychev filters. The iterative procedure shown for calculating the Chebychev coefficients from the recurrence relation is,

$$T_{n+1}(x) = 2x\,T_n(x) - T_{n-1}(x)$$

with starting conditions $T_0(0) = 1$ and $T_1(x) = x$. Although the procedures can be quite powerful they do have quite a steep learning curve associated with them and the syntax is very precise. However there are thousands of functions in the *Maple V* libraries which can be used within the procedure framework.

Solving differential equations

Maple V is quite effective for solving differential equations of any order. It will also solve coupled differential equations analytically, however the answer may appear to be somewhat unwieldy as illustrated in **Fig. 3** which is a printout of the solution of circuit with mutual conductance – whoever said that transformer design was simple?

In line 2 *difl* defines the coupled equations and line 3 performs the evaluation with the boundary conditions (no initial current in either the primary or secondary). Although not an immediately useful solution it does illustrate the analytical capability of *Maple V*. However by attaching numbers to the L, R and E values, numerical solutions will be produced. *Maple V* does not like nonlinear coupled differential equations to solve, in fact in several instances it refuses to do any processing on them.

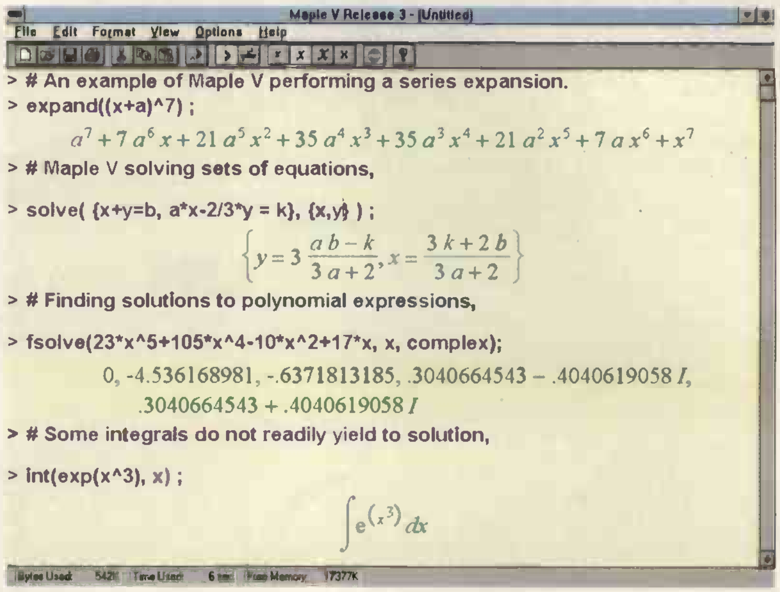


Fig. 1. Maple V is very effective at expanding expressions and generating series. In fact it performs many of the operations that an engineering student toils for hours over.

Old hacks at differential equations will know that there are several ways of solving them and *Maple V* offers the user the choice of a solution method. Electronics engineers would probably opt for using the Laplace Transform method for finding a solution and this is requested by augmenting the dsolve instruction by,

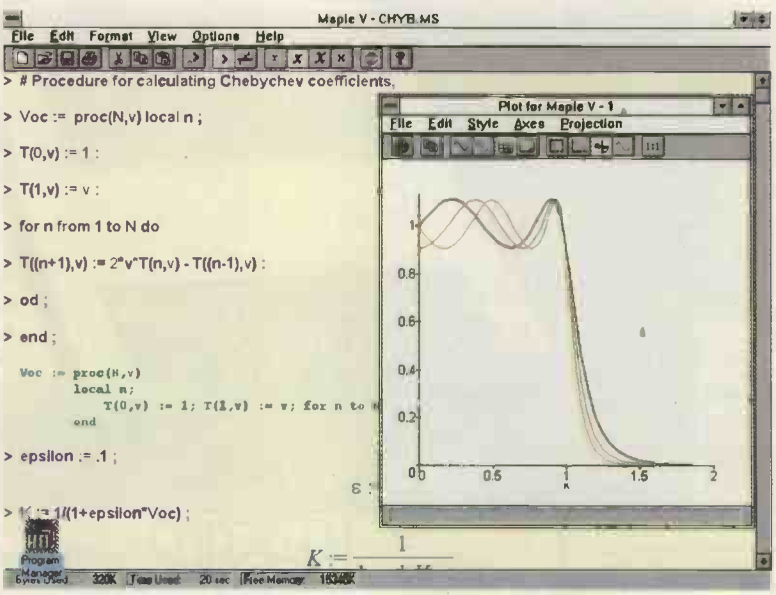
dsolve(diff_eq, y(x), method=laplace) ;

Although *Maple V* seems to tackle linear differential equations quite well, like a number of other maths software packages, nonlinear maths usually proves to be a little too testing and solutions are not always provided.

2D graphics

An essential aspect of any mathematical modelling package is its ability to generate graphs. These days such a task is no big deal as most numerical software can generate 2D graphs. An example of the 2D output from *Maple V* is shown in Fig. 2, displaying the Chebychev filter transfer functions with their characteristic ripples in the pass band. It is relatively easy to overlay several plots on the same graph and the scaling is performed automatically.

Fig. 2. Modelling performance of a Chebychev analogue filter is easy with Maple V. As seen in this example, increasing the number of poles improves the roll-off of the filter.



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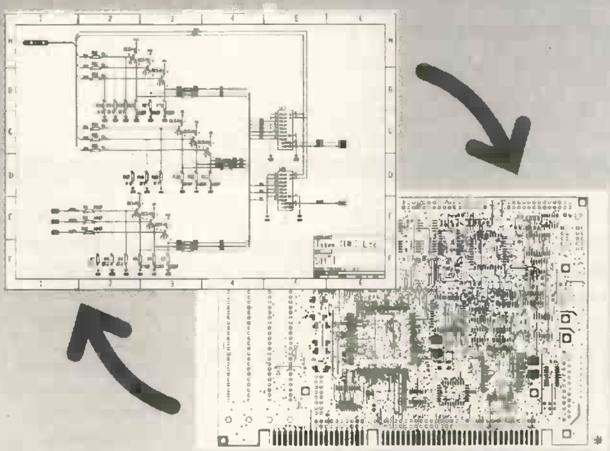

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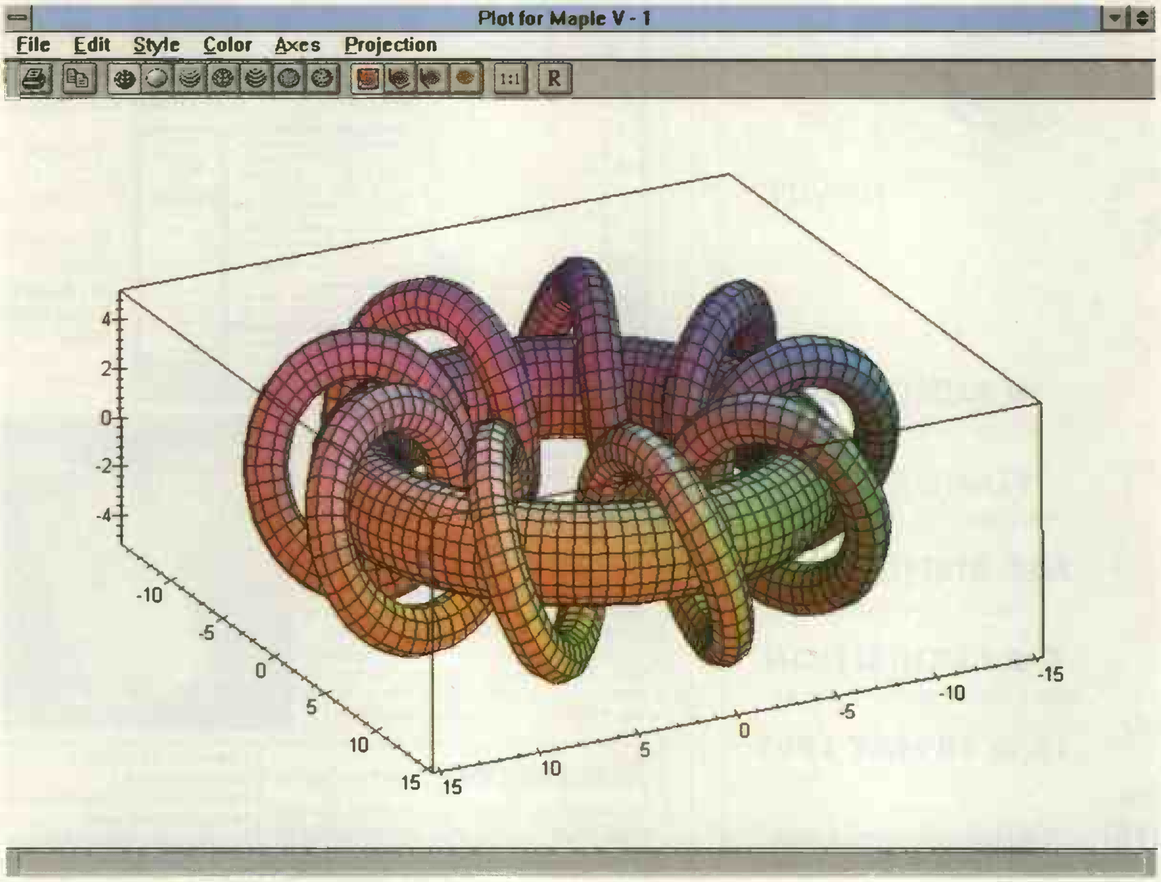

Fig. 4. 3D plot generation with Maple V can produce some fascinating solid modelling. Animation can also be added to the modelling to give an insight into temporal behaviour.

Provisions are available for plotting in cylindrical coordinates and performing contour plots. It would however be helpful if more control could be exercised on the plotting features, axis definition and labelling for example as it is likely that you will require a printing of 2D plots.

3D graphics

Features for performing the now commonplace function of 3D plotting are available in *Maple V*. But one of the extraordinary features of *Maple V* is its ability to plot in a variety of coordinate systems – spherical coordinates for example. This allows true solid modelling to be realised. For example, the complex mode structures in graded index optical fibres can be represented pictorially. They involve a lot of unfriendly Bessel functions, however with *Maple V* they can become somewhat more accessible and easier to work with.

There is an impressive range of 3D plotting features but it does require a push of the imagination to realise their usage. The 3D surfaces also have a variety of colour shading as can be seen from the example given in **Fig. 4**; although pretty to look at, it is not terribly useful.

However if there was a need to model the 200MHz pulse propagation along pcb tracking, then *Maple V* could be used to determine the 3D impedance profiles along the length of the tracking (including reflections). Being able to visualise solutions such as these must be one of the main benefits of using modelling packages like *Maple V*.

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Conclusion

There are very few areas of engineering where *Maple V* would not prove useful. Although the package is very powerful and undoubtedly applicable to a variety of modelling purposes a word of caution must be expressed.

New users must be prepared to spend a lot of time learning how to use the package proficiently. It will probably be several hours before they will be in a position to apply *Maple V*. A number of manuals are provided to help the learning process, including the Reference Manual and a Tutorial Introduction.

The Tutorial presents many examples, which are necessary for a package with such rigid syntax rules. Working through these manuals is an absolute must. There is also a well-designed screen-based tutorial which should prove helpful to the new user. Also available for *Maple V* are a number of text books written by third parties. It is certainly pleasing to know that if you have a pc on which you want to perform complex mathematical operations, *Maple V* will certainly put it through its paces and uses all of its memory and calculating power. ■

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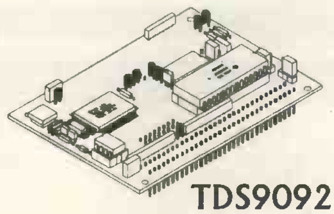

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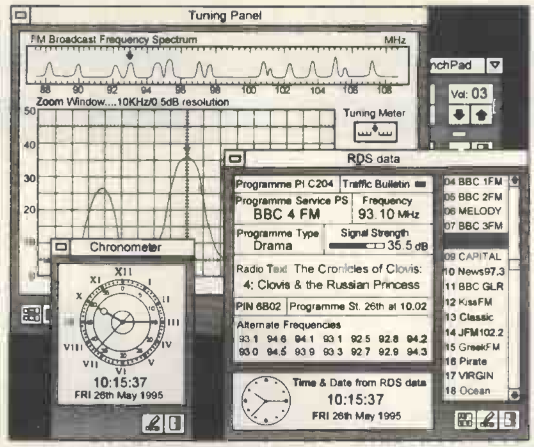

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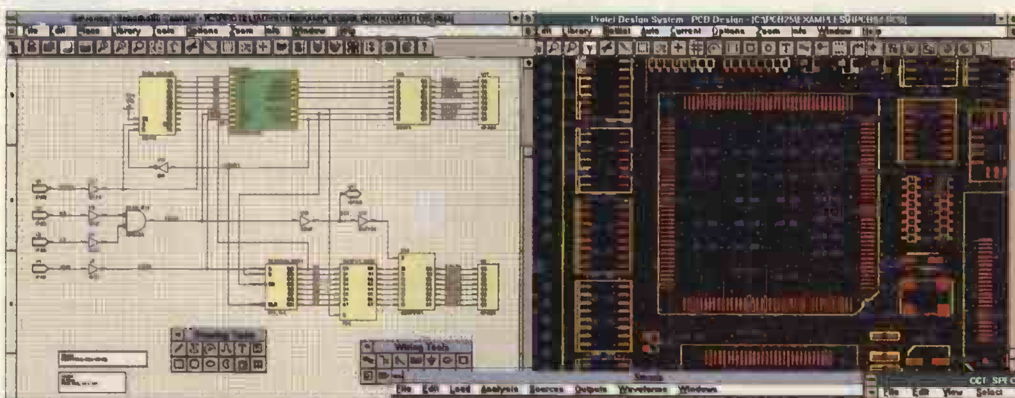

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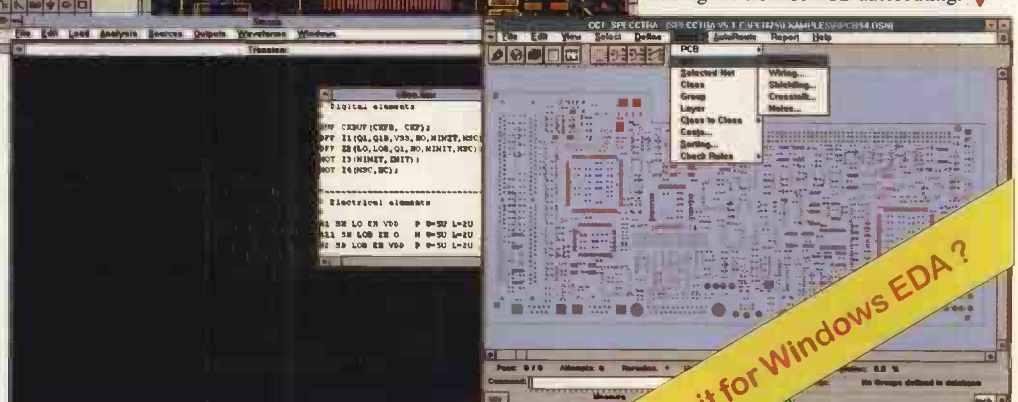

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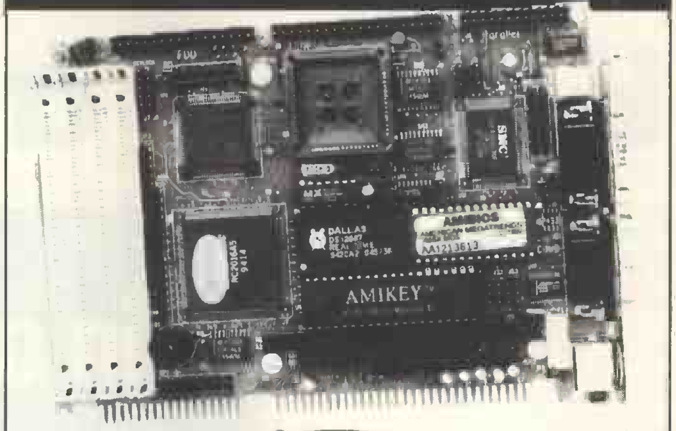

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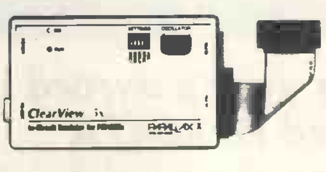

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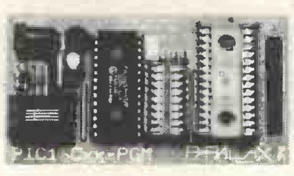

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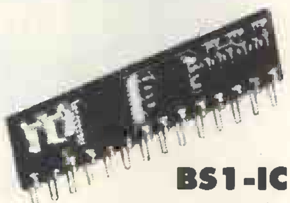

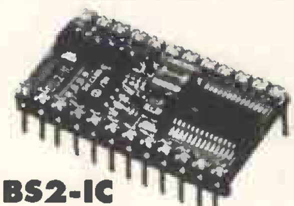

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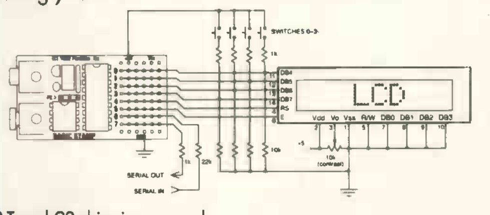

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CIRCLE NO. 116 ON REPLY CARD

Fets versus bjts
the linearity competition

"Had bipolar transistors been invented before power mosfets, they would have been heralded as a major step forward in components for power amplification," suggests Douglas Self.

There has been much debate recently as to whether power fets or bipolar junction transistors (bjts) are superior in power amplifier output stages. Reference 1 is a good example. It has often been asserted that power fets are more linear than bjts, usually in tones that suggest that only the truly benighted are unaware of this.

In audio electronics it is a good rule of thumb that if an apparent fact is repeated times without number, but also without any supporting data, it needs to be looked at very carefully indeed. I therefore present my own view of the situation here, in the hope that the resulting heat may generate some light.

I suggest that it is now well-established that power fets, when used in conventional Class-B output stages, are a good deal less linear than bjts.[2] Gain deviations around the crossover region are far more severe for fets than the relatively modest wobbles of correctly biased bjts, and the shape of the fet gain-plot is inherently jagged, due to the way in which two square-law devices overlap.

The incremental gain range of a simple fet output stage is 0.84 to 0.79, range 0.05, and this is actually much greater than for the bipolar stages in Reference 2; the emitter-follower stage gives 0.965 to 0.972 into 8Ω, with a range of 0.007, and the complementary feedback pair gives 0.967 to 0.970 with a range of 0.003. The smaller ranges of gain-variation are reflected in the much lower thd figures when PSpice data is subjected to Fourier analysis.

However, the most important difference may be that the bipolar gain variations are gentle wobbles, while all fet plots seem to have abrupt changes. These are much harder to linearise with negative feedback that must decline with rising frequency. The basically exponential I_c/V_{be} characteristics of two bjts approach much more closely the ideal of conjugate mathematical functions, – ie always adding up to 1. This is the root cause of the much lower crossover distortion.

Close-up examination of the way in which the two types of device begin conducting as their input voltages increase shows that fets move abruptly into the square-law part of their characteristic, while the exponential behaviour of bipolar devices actually gives a much slower and smoother start to conduction.

Similarly, recent work* shows that less conventional approaches, such as the common-collector/common-emitter configuration of Bengt Olsson, also suffer from the non-conjugate nature of fets. They also show sharp changes in gain. Gevel[3] shows that this holds for both versions of the stage proposed by Olsson, using both N and P-channel drivers. There are always sharp gain-changes.

Class A stage

It occurred to me that the idea that fets are more linear was based not on Class-B power-amplifier applications, but on the behaviour of a single device in Class-A. You might argue that the roughly square-law nature of a fet's I_d/V_{gs} law is intuitively more 'linear' than the exponential I_c/V_{be} law of a bjt, but it is difficult to know quite how to define 'linear' in this context. Certainly a square-law device will generate predominantly low-order harmonics, but this says nothing about the relative amounts produced.

In truth the bjt/fet contest is a comparison between apples and aardvarks, the main problem being is that the raw transconductance (g_m) of a bjt is far higher than for any power fet. **Figure 1** illustrates the conceptual test circuit; both a TO3 bjt *MJ802* and an *IRF240* power fet have an increasing dc voltage, V_{in}, applied to their base/gate, and the resulting collector and drain currents from PSpice simulation are plotted in **Fig. 2**.

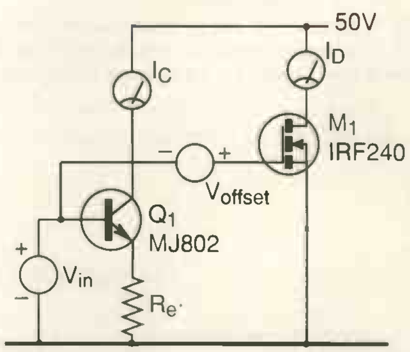


Fig. 1. Linearity test circuit. Voltage V_{offset} adds 3V to the dc level applied to the fet gate, purely to keep the current curves helpfully adjacent on a graph.

Voltage V_{offset} is used to increase the voltage applied to fet M_1 by 3.0V because nothing much happens below a V_{gs} of 4V, and it is helpful to have the curves on roughly the same axis. Curve A, for the bjt, goes almost vertically skywards, as a result of its far higher g_m. To make the comparison meaningful, a small amount of local negative feedback is added to Q_1 by R_e. As this emitter degeneration is increased from 0.01 to 0.1Ω, the I_c curves become closer in slope to the I_d curve.

Because of the curved nature of the fet I_d plot, it is not possible to pick an R_e value that allows very close gm equivalence; a value of 0.1Ω was chosen for R_e, this being a reasonable approximation; see Curve B. However, the important point is that I think no-one could argue that the fet I_d characteristic is more linear than Curve B.

This is made clearer by **Fig. 3**, which directly plots transconductance against input voltage. There is no question that fet transconductance increases in a beautifully linear

* The subject of an article by Douglas to be published in *EW+WW* in the near future – Ed.

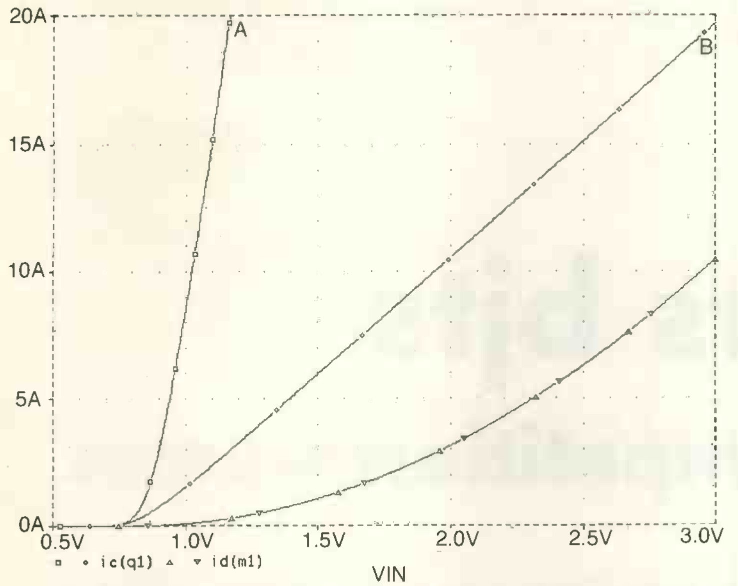


Fig. 2. Graph of I_c and I_d for the bjt and the FET. Curve A shows Ic for the bjt alone, while Curve B is the result for R_e=100mΩ. The curved line is the I_d result for a power fet without any degeneration.

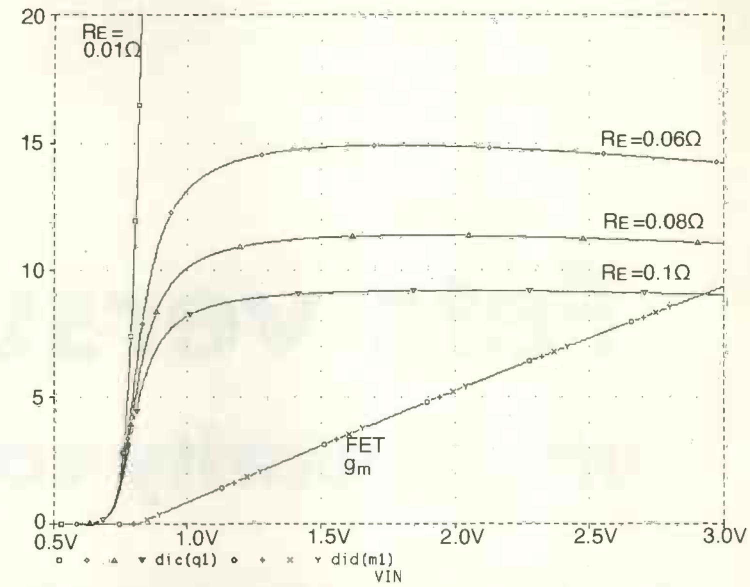
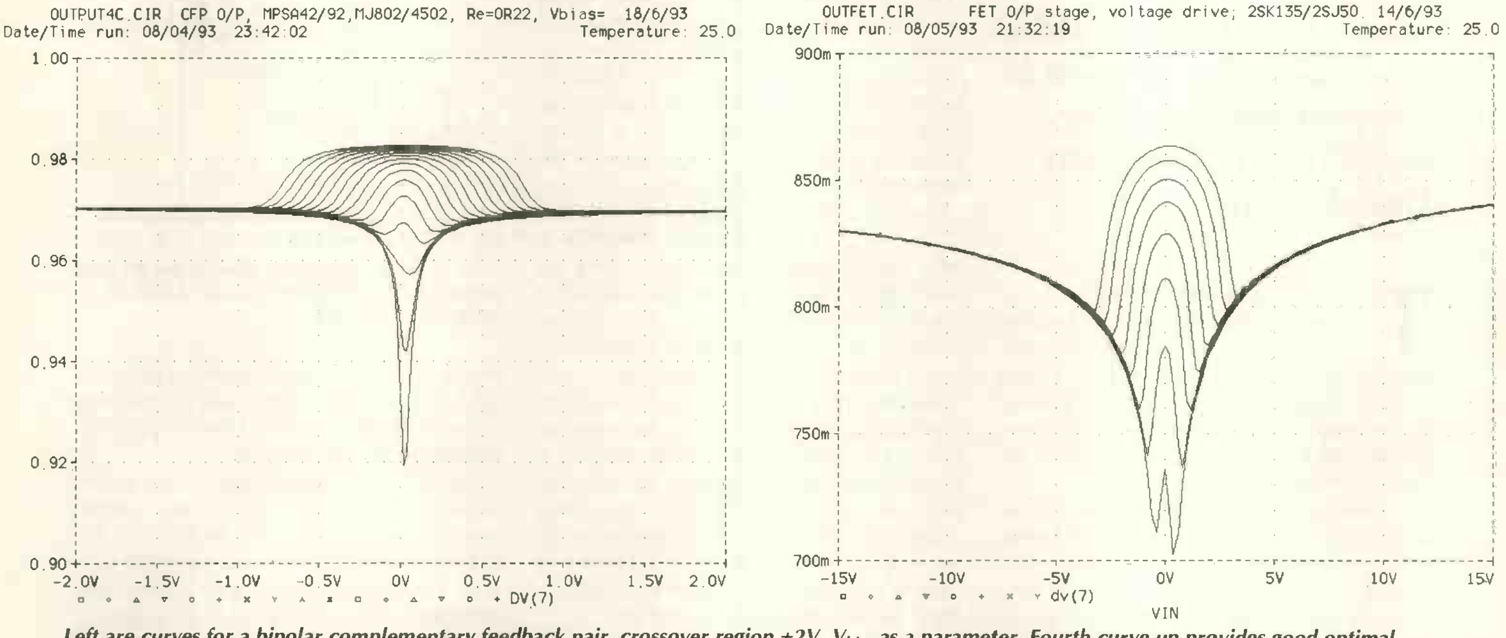


Fig. 3. Graph of transconductance versus input voltage for bjt and fet. The near-horizontal lines are bjt g_m for various R_E values.



Left are curves for a bipolar complementary feedback pair, crossover region ±2V, V_{bias} as a parameter. Fourth curve up provides good optimal setting – compare with curves on the right, for a fet source follower crossover region with ±15V range.

manner- but this 'linearity' is what results in a square-law I_d increase. The near-constant g_m lines for the bjt are a much more promising basis for the design of a linear amplifier.

To forestall any objections that this comparison is nonsense because a bjt is a current-operated device, I add here a small reminder that this is untrue. The bjt is a voltage operated device, and the base current that flows is merely an inconvenient side-effect of the collector current induced by said base voltage. This is why beta varies more than most bjt parameters; the base current is an unavoidable error rather than the basis of transistor operation.

The PSpice simulation shown was checked against manufacturers' curves for the devices, and the agreement was very good – almost unnervingly so. It therefore seems reasonable to rely on simulator output for these kind of studies; it is certainly infinitely quicker than doing the real measurements. In addition, the comprehensive power-fet component libraries that are part of PSpice allow the testing to be generalised over a huge number of component types without you needing to buy them.

To conclude, I think it is probably irrelevant to simply compare a naked bjt with a naked fet. Perhaps the vital point is that a bipolar device has much more raw transconductance gain to begin with, and this can be handily converted into better linearity by local feedback, ie adding a little emitter degeneration.

If the transconductance is thus brought down roughly to fet levels, the bipolar has far superior large-signal linearity. I must admit to a sneaking feeling that if practical power bjts had come along after fets, they would have been seized upon with glee as a major step forward in power amplification. ■

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1. Hawtin, V., Letters, *EW+WW* Dec 1994, p.1037.
2. Self D., 'Distortion In Power Amplifiers', Part 4, *EW+WW*, Nov 1993, pp 932-934.
3. Gevel M., Private Communication, Jan 1995.

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120	21.54	15.08	11.35	8.39	8.15	7.89
150	25.98	18.19	13.70	10.12	9.82	9.53
160	23.83	16.68	12.56	9.28	9.00	8.73
225	30.10	21.07	15.87	11.73	11.39	11.04
300	34.32	24.02	18.09	13.38	12.98	12.58
400	46.19	32.32	24.35	17.99	17.47	16.94
500	50.48	35.34	26.61	19.67	19.09	18.51
625	53.09	41.36	31.14	23.02	21.24	20.57
750	58.39	44.23	33.30	24.62	23.89	23.17
1000	78.80	55.16	41.54	30.70	29.80	28.89
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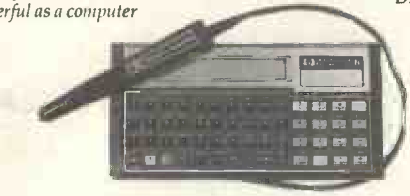

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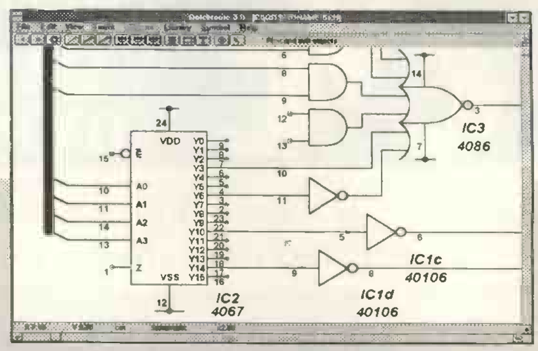

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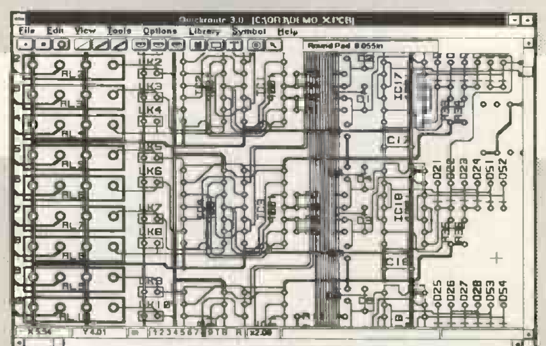

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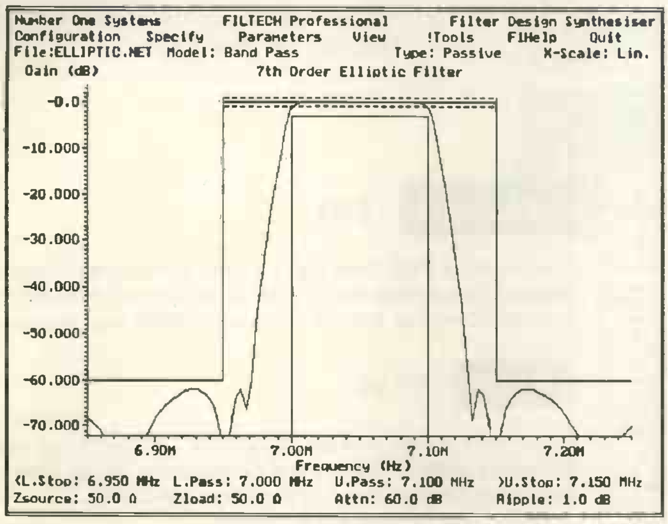

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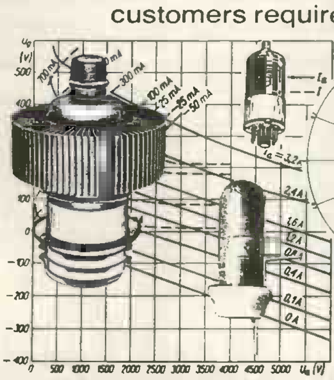

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CIRCLE NO. 122 ON REPLY CARD

Delayed audio signals

Too many audio designs are deeply flawed in the bass, says Ben Duncan, recalling recent work of Douglas Self and Edward Cherry. Here Duncan uses simulation to explain the reasons and ramifications for the entire audio chain.

Dependence of the quality of reproduced sound on the number of components through which it is passed still seems to be doubted by some commentators[1]. But how many have actually bothered to examine exactly what happens to a given signal between the mic terminals – via multitrack recording process and recording media - and its emergence from a domestic power amplifier?

A realistic record-to-reproduction path could include six gain stages with dc blocking in input and feedback paths; three high pass (–12 and –18dB/octave) filters; and 52 other dc blocking capacitors, **Fig. 1**. In a typical consumer grade path, capacitor values for assorted random f_{3L}s ($\omega_{low}/2\pi$) will be centered around 4-6Hz, and up to 16Hz. In fact this is a specification that is becoming increasingly prevalent even in supposedly professional equipment.

Analysing the frequency responses of 50 of these paths, **Fig. 2**, at different points shows the gain stages, high pass filters and buffers to range from –3dB, at from below 3Hz, up to 63Hz in the worst case. Uncorrected response at the end of the chain is –3dB at 45-200Hz.

This doesn't mean that bass is absent by so much: it is compensated for during the recording production process. But compensatory equalisation means the real path experiences even more phase corruption.

The figures nonetheless suggest the kind of roll-off commensurate with the delay and waveform distortion existing.

Delay problems can be appreciated by examining the contribution of a solo gain stage, **Fig. 3**. Just this one type of stage clearly exhibits more delay than the 52 buffers (otherwise the sum would exceed the upper plots in Fig. 3).

The effect of this aurally significant delay is mistiming of

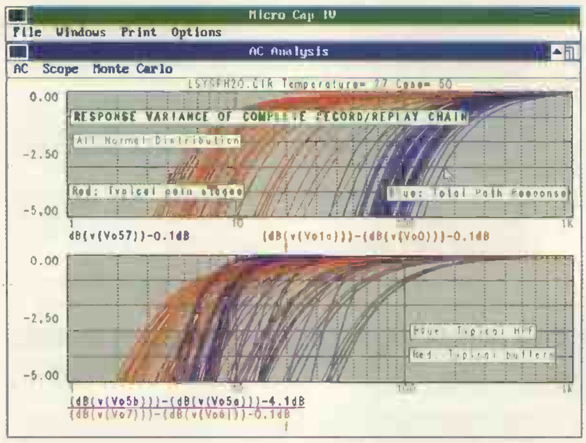
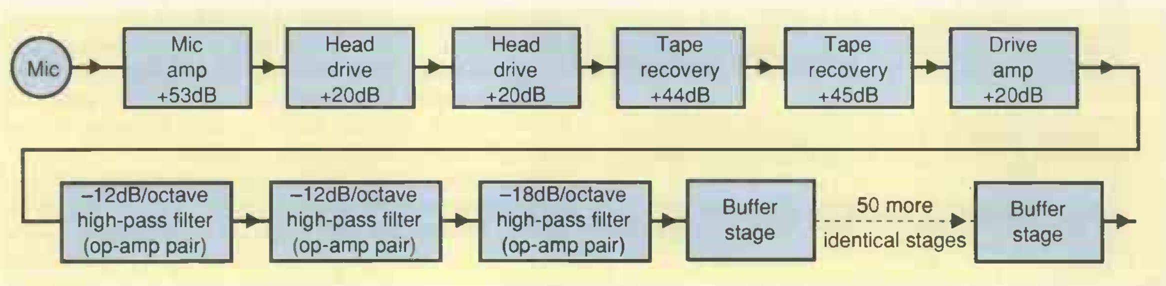


Fig. 2. Unequalised frequency responses of a possible complete consumer-grade audio reproduction path (upper panel, blue plots). Upper panel red plots, and blue and red lower panel plots, show typical responses of constituent gain stages, high-pass filters and buffers. Each Monte Carlo run represents myriad design differences, as nearly all audio chains are made from effectively random equipment assemblies. There are no standards for f_{3L}. Y axis is decibels.

Fig. 1. Over 70 cascaded RC high-pass elements model a complete (electronic portion of an) audio record-to-reproduction path. Capacitor tolerances are engaged to simulate random equipment combinations, as well as tolerance, temperature and drift variables.



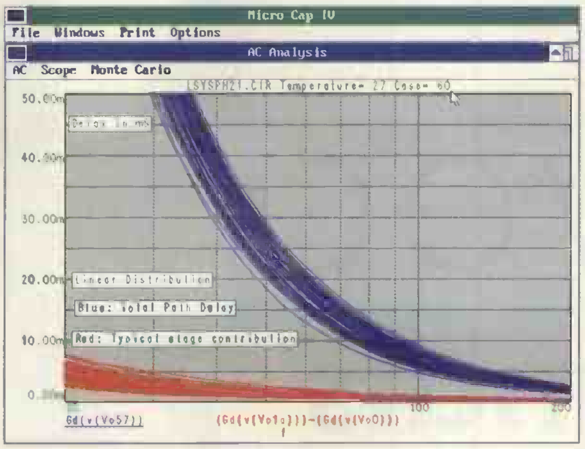


Fig. 3. Group delay vs frequency, individual and total, for a complete, consumer-grade reproduction path. Note the convergence on linearity only at extreme frequencies. Y-axis is milliseconds of delay.

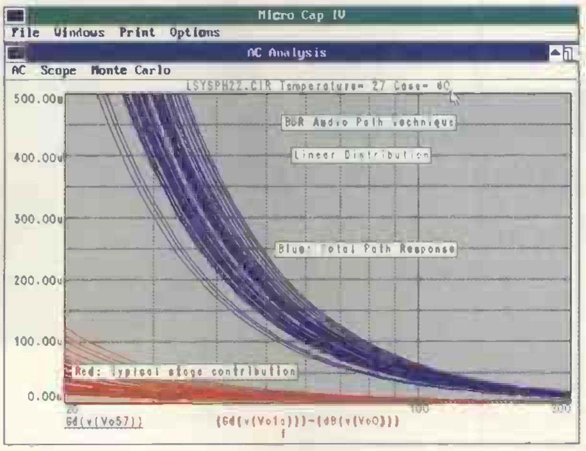


Fig. 4. The BDR method: like Fig. 2, but with 100 times less signal delay. Note Y-axis scale change.

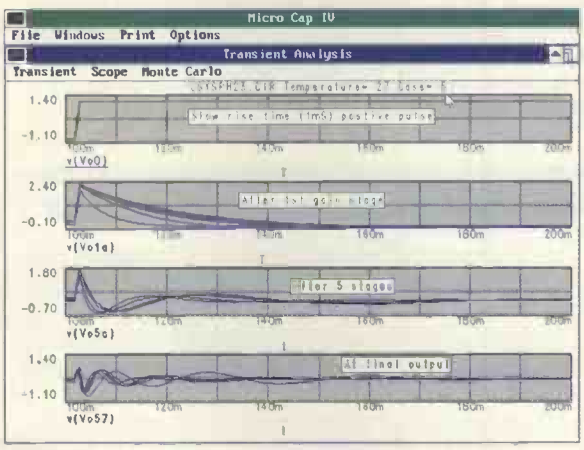


Fig. 5. Complete consumer path again. A pulse goes down the chain, with just five Monte Carlo runs for clarity. The emerging wave should not seem 'suitable for its intended purpose'. Fortunately, music productions only occasionally comprise such waveforms and 'data corruption' to the ears may be less fundamental than it appears to the eyes. Y-axis is volts.

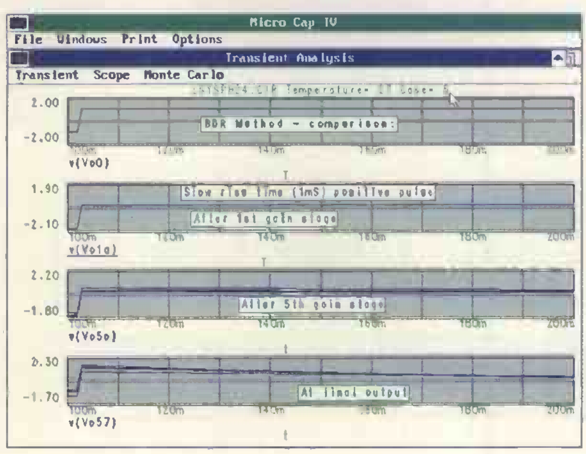


Fig. 6. Keeping the pulse. How bdr handles a pulse – something that looks very like the input pulse emerges at the output (lowermost).

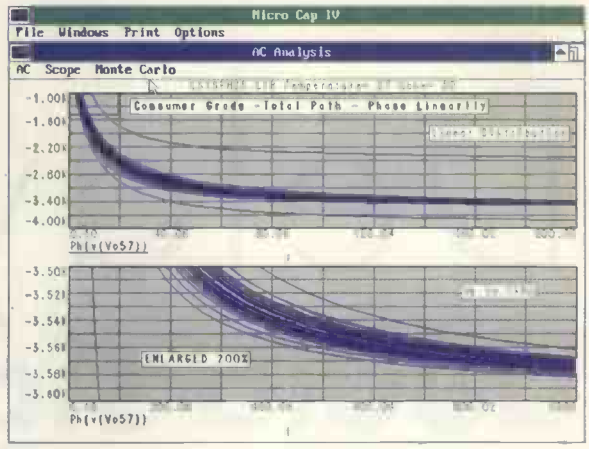


Fig. 7. Phase disaster at path output. With consumer values, the phase response of the whole path is truly non-linear, and the rate of phase shift changes at hundreds of degrees every few Hz around 40Hz. In the lower panel, the phase change rate (enlarged x30) isn't even linear by 1kHz. Note also the wild singleton – a disparate of excess phase. Y-axis is degrees.

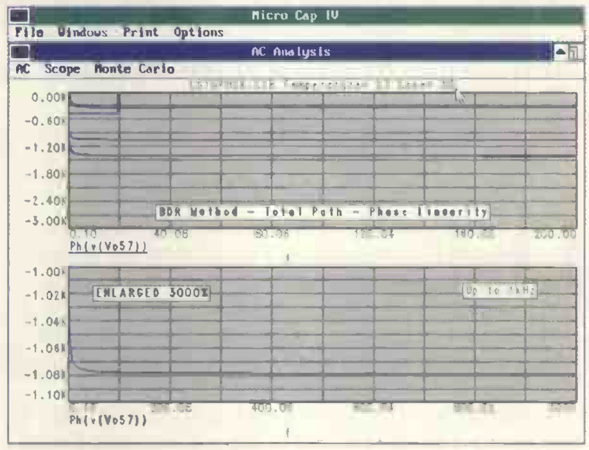


Fig. 8. Attaining global phase linearity. With bdr, the rate of change of phase is far, far less at the end of a full audio reproduction chain. In the lower panel, even x30 enlargement fails to reveal any visible curvature above 100Hz.

the music – here as much as 43ms at 40Hz – while the higher harmonics of a note at this frequency can have periods many times shorter than this.

Clearly, the music is playing out of step with itself, and any *RC* components that add hp filtration will compound this delay. The real test of a design is to measure delay after passing a signal through seventy (of Douglas Self's 'blameless') power amplifiers – with appropriate interstage attenuation.

Distortion suffered by wideband audio waveforms (10Hz to 20-100kHz, Fig. 3) resulting from this delay is horrific: 'smeared' is a fair description.

Phase compensation suggested by Cherry[2] ought to help, but will it? Compensation must be in use in not just one stage, but throughout a fair fraction of – if not all – the audio chain. Plainly this would prove unworkable as each stage's inevitable xdB of subsonic gain would accumulate, soon eating up headroom. Also, any compensatory equalisation circuit would require further critically-toleranced *RC* parts, and its own phase relations and tolerance deviations would destroy Cherry's compensation's benefits.

The problems of the consumer approach are self-inflicted. To demonstrate what would happen if the bdr (see panel, **BDR *vs* Cherry and Self**) approach were used throughout the audio path, the capacitor values can simply be increased by ×167.

Effect on group delay is to make it 100 times smaller, **Fig. 4** and contribution of the solo gain stage also ranges higher.

So what would be the fate of a simple positive pulse as it passes through the chain, **Fig. 5**? After the 57th high-pass function, the edge reduces to something like a damped oscillation. But using the bdr method, **Fig. 6**, although the final output may be a little tilted, at least it's recognisable and quite faithful.

Similarly, phase linearity for the consumer path is a disaster at all frequencies below 1kHz, **Fig. 7**, with the rate of change of phase per hertz accelerating. This can be compared with the bdr method, **Fig. 8**, which demonstrates an almost text book model of phase linearity. No significant curvature is visible above 100Hz.

Ironically, without the expense of hindreds of volts of lf headroom extension, Cherry's phase compensation scheme can in practice only be used once or twice. It is only in this almost phase-linear environment that it would have significant objective effect. Yet, in ordinary signal chains the effect would readily be heard as an improvement. But the same phase correction of just one stage in 60+ would be nearly invisible in any objective measurement of the whole chain due to phase jitter.

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Ben vs Self and Cherry: simulated contest

Ben Duncan wonders if he's the only designer left who really cares about the effects of phase and group delay on bass response.

Simulation of the Ben Duncan Research (bdr) simple and low-compromise approach to low frequency reproduction accuracy[3] can quickly provide a straightforward picture of phase and group delay, audio aspects of which are evidently still only foggily understood by some. Simulation also allows the design to be compared with those of Douglas Self[4] and Edward Cherry[2].

First step is to enter the three circuits into *MicroCap IV* to compare different approaches to low frequency reproduction (**Fig. I**). In the bdr approach, topology is minimal and f_{3L} (alias $\omega_{low}/2\pi$) is made extremely low, typically <0.1Hz.

The "consumer grade" version of the same topology, has lean *hp* capacitors to save pennies (eg Self[4], though to be fair, far worse examples are extant) and f_{3L} is typically 3-10Hz. In this and the bdr circuit, the main resistive arm values have been scaled to be identical to those specified by Cherry so like is being compared with like.

In practice, I would use a 1000µF – not 3300µF – lower arm capacitor, and scale the associated *R* values by a factor of three. In Cherry's circuit, extra parts have been introduced, apparently to compensate for having used too lean a principal elcap value in the first place. One practical problem with Cherry's method is that an exact ratio of three between electrolytics requires some messy paralleling when only E3 series values (10, 22, 47, 100µF etc) are available, as is often the case.

Plotting lf frequency response and phase using conventional log frequency scale (**Fig. II**, upper panel) for the three circuits does not give meaningfully view of phase behaviour for reproduction errors. In *MicroCap*, while simultaneously plotting by frequency, the scale for the phase data can be set to linear with 0Hz ('dc') as the origin, **Fig. III**. This will remove the delay[5] independent of frequency,

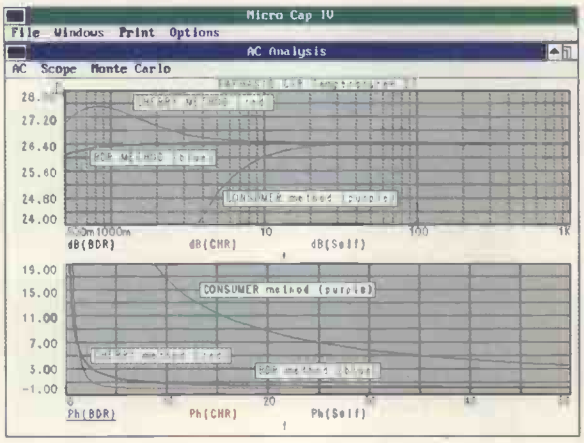


Fig. II. Frequency responses (upper panel) of the three contrasted circuits all provide negligible roll-off in the audio band >20Hz, but with true, frequency-dependent phase shift visible for a change (lower panel), the consumer/Self circuitry commits phase crime well within the ear's most sensitive domain.

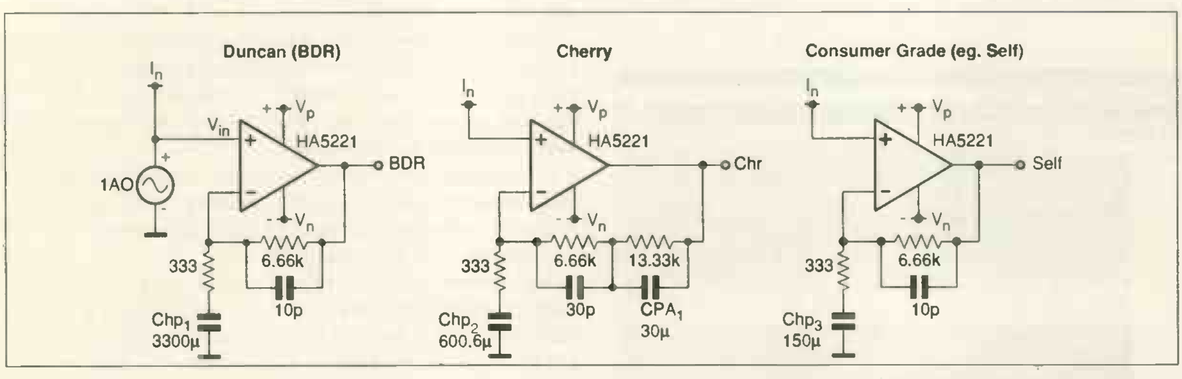


Fig. I. Three bass response approaches compared. Centre is Prof Cherry's "phase compensation" scheme. Note ac test source (left) drives all three. Measurements are referred to node labels; nodal numbering in MicroCap is automatic and transparent. Left and right circuits vary only in their elcap size. The Harris HA5221 IC model parameters are Level 1 for speed, and have been over tweaked but these factors have no appreciable effect on simulation accuracy or validity in our strictly lf arena.

Fig. III. MicroCap's ac analysis prolog screen. Note the frequency range origin is set at 1mHz, not quite dc but near enough, to speed up plotting. Also, the the decibel and phase plots are set logarithmically and linearly, respectively. Y-axis is milliseconds of delay.

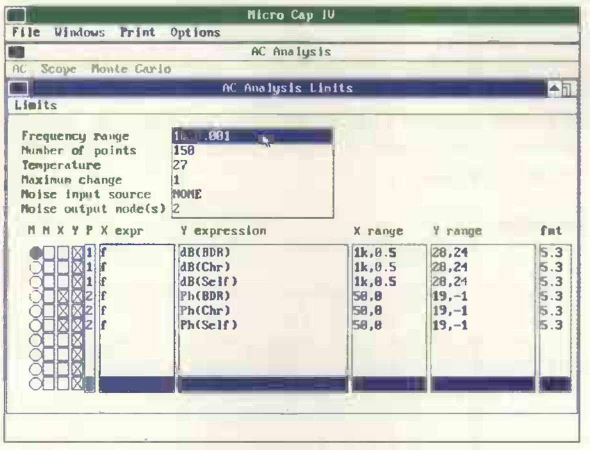


Fig. IV. Square wave responses compared. Upper panel shows all three. Lower panel magnifies the positive pedestal and abstracts it in time too, to clarify the differences between the Cherry (convex) and bdr (near-linear) methods. Y-axis is volts.

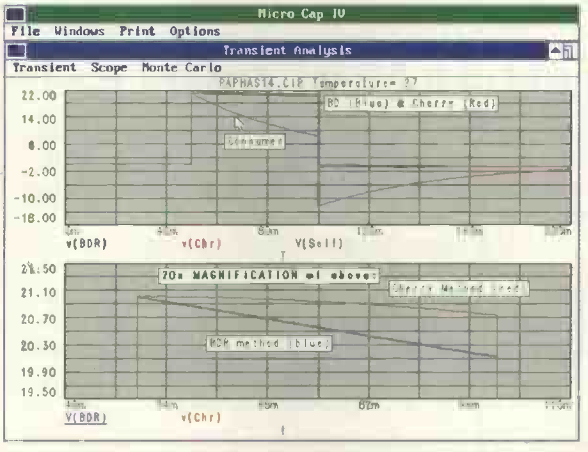


Fig. V. Mass frequency responses. Upper graph covers half the amplitude of the lower. The Monte Carlo linear run shows what could occur in a real population. Y-axis is decibels.

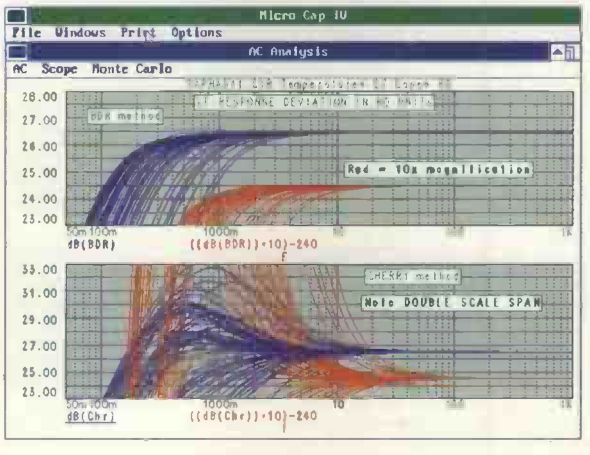
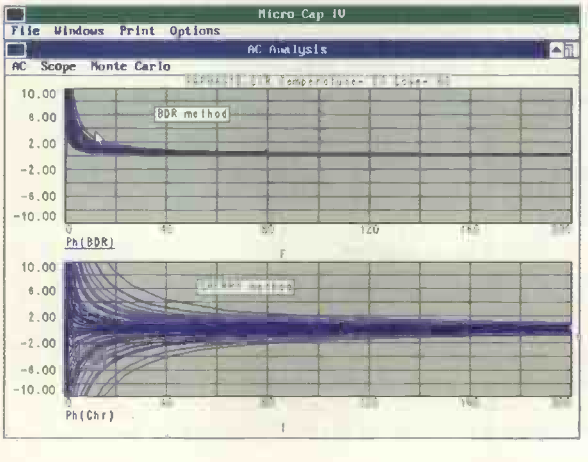


Fig. VI. Cherry's phase disaster: A Monte Carlo run showing true phase response after Jensen, in a production population. Note linear frequency scale. The vertical step just discernible in the origin of the upper plot is because frequency was set to begin at 0.1Hz rather than 0Hz. This speeds the run. Y-axis is degrees.



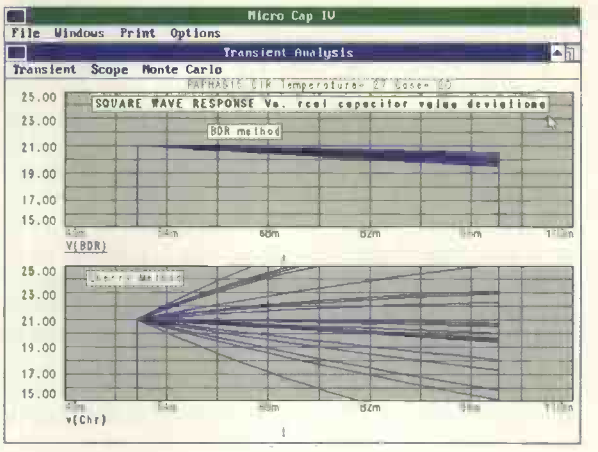


Fig. VII. Effect on the two square waves shown in the lower panel of Fig. IV when capacitor values are stepped over real world tolerances. The lower set of plots shows how – with most variations – Cherry's method fails to achieve the flat top that is its goal. The bdr method is clearly much less sensitive to part tolerance, though with more than 20 plots (a limit imposed for visual clarity) a few 'wild' plots will occur. Y-axis is volts.

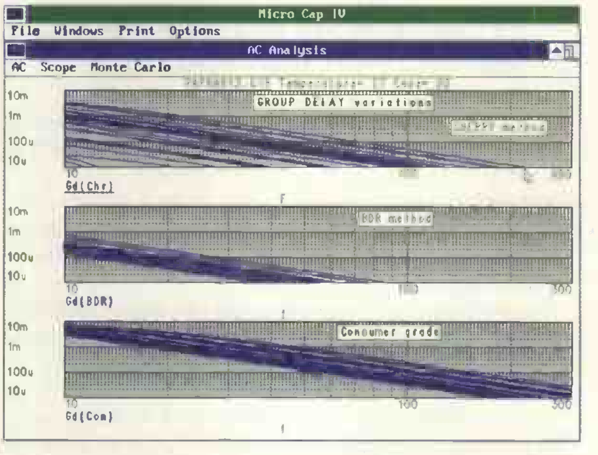


Fig. VIII. Three signal delay patterns. Group delay is plotted with the 'Gd' operator. For clarity with the three, smaller, scales and because smooth Gd plotting demands slower runs than phase or amplitude, the number of Monte Carlo runs has been reduced from 60 to 30.

revealing true phase linearity so that a straight line on this linear scale, whether sloping or level, indicates absence of waveform distortion. Anything bending is slurring the signal with respect to frequency.

Using this technique, both the Cherry and bdr methods can be seen to have (Fig. II, lower panel) audio band, to 20Hz, true phase linearity well within 1°. But the consumer approach shows almost 4.5° of tilt at 42Hz – the lowest fundamental from a bass guitar.

Cherry is certainly more linear at sub-sonic frequencies than bdr, and that would improve the accuracy of say, an earthquake or explosion (for hi-fi video entertainment). But we must ask: "Is it really worth it?"

Square-wave responses, **Fig. IV,** show a major tilt in the consumer approach, while a 20 times magnification is needed to see that the BDR method tilts more than Cherry's and the slope is almost linear. A sign of Cherry's phase compensation can be seen in the slightly convex curvature, whereas the consumer tilt is concave.

The lower arm dc blocking capacitor is inevitably electrolytic – Douglas Self agrees[1] – even if for sonic reasons a far smaller valued polypropylene capacitor is shunted across. Scaling *R* up and *C* down is just not practical on grounds of noise, microphony and increased electrostatic/EMI sensitivity[3].

Electrolytic tolerances may have improved greatly over the years, but they are still commonly as poor as ±30% and most are ±20% at best. Electrolytics also have the poorest temperature coefficients of any capacitor type. Typically the value will change from that at switch on by at least +10%, and possibly to over 50%, after the unit's internal temperature has risen by 35°C. Equally, faradic value could drift by 25% with time.

Taking the midpoints of these, we have 25% + 30% + 25%. So in real use the two elcap values on which Cherry's scheme depends may realistically and independently vary by ±80% (ie from ×0.2 to ×1.8). To reflect this, all capacitors definition statements for the simulation (Fig. I) have been appended with `LOT=80%`. For clarity, resistor values are assumed to be invariant.

Re-running the simulations with Monte Carlo analysis, using linear distribution, shows the effect of real world capacitative value variation.

Amplitude response variation across 60 units for bdr (**Fig. V**) shows no peak, nor any aberration above 0.1dB in the audio band.

But Cherry's scheme shows that the response and damping (*Q*) varies all over (so badly that the scale is halved to see just a bit of it) and the variation infects frequencies considerably above 20Hz.

In the worst-case true phase error at 20Hz, **Fig. VI**, bdr varies just 1.8° between +0.2 and +2°. Yet Cherry's scheme varies over 16° from at least +8° to –8°. Worse, the phase error varies by more than ±0.75° at 200Hz, a far more critical and phase-sensitive midrange frequency.

Looking again at the square wave response, even with only 20 Monte Carlo runs, **Fig. VII**, bdr shows only mild changes while Cherry already varies wildly. In fact Cherry's response – completely different from the slight tilt intended – makes it most dubious where anything but individually-selected oven-mounted electrolytics, measured and calibrated monthly, are available.

Finally, we should consider group delay. Plotted against logarithmic frequency, this displays frequency-dependent signal delay directly.

At first sight, delay varies almost linearly with frequency using all three schemes, **Fig. VIII**. However, both Cherry and the consumer method exhibit plots that are non-monotonic: try a ruler against them.

What matters most though, is the excess absolute delay. The consumer scheme is worst, with the largest delay (in only 30 random production units remember) being nearly 400μs. With Cherry, the worst delay at 80Hz is below a quarter of this, 70μs. Again, bdr is best, with barely 10μs. For an 80Hz partial to be lagging 70 or 300μs behind the mid-range may not sound much, and even those with critical ears will not easily hear this difference. But, clearly, few audio designers have ever thought through the entire-path ramifications. ■

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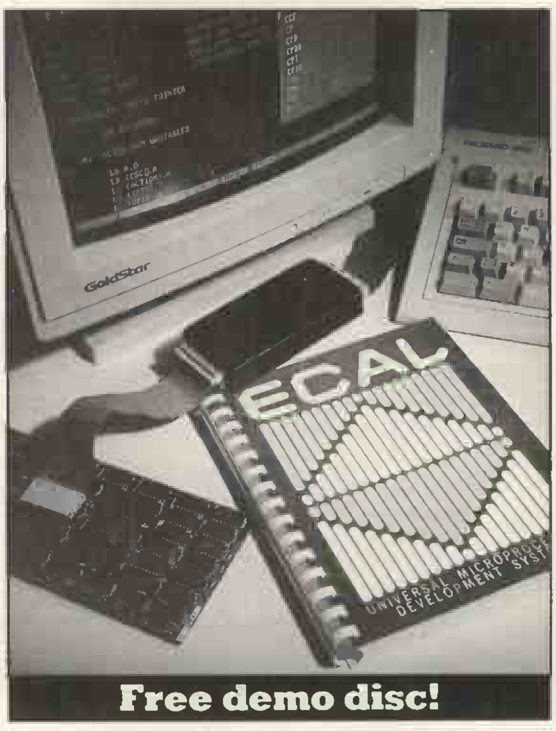

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Migrating to C++

Object-oriented design has been heralded as offering radical benefits in the software development cycle. However, without adequate appreciation and management of the process, the gains expected may materialise, as Gerard Maloney explains.

In theory if not in practice, software development has traditionally been based on 'structured' design methods, which emphasise the procedures by which a solution is achieved. But the ever increasing size and complexity of software systems, not to mention the demands in areas such as graphical interfaces, cad/cam, artificial intelligence and distributed systems, has increasingly highlighted the inadequacies of this approach. As a result, alternative design methods are coming increasingly to the fore.

Of these alternative methods the 'object oriented' approach is the one currently gaining ground across a wide diversity of applications. Here, we will outline the underlying philosophy of object-oriented programming, looking in particular at what has become the dominant programming language for implementing such designs – C++.

Fig. 1. In the traditional structured design cycle, progress is linear.

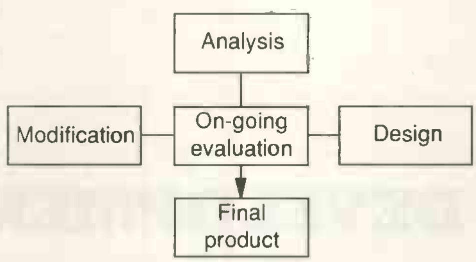

Fig. 2. Object oriented design cycle involves an iterative approach throughout the design cycle.

Programming with objects in mind

Object oriented design has as its basis a key shift in emphasis away from concentrating on how a task is achieved to identifying the key abstractions within an application. It also takes into account how these abstractions interact with one another.

From this basis it is hoped to model a more effective and intuitive solution to the task at hand. Coupled with this shift in emphasis is a movement away from the 'top-down' approach to the development cycle, to an approach whereby the development cycle is seen as an iterative process. Each phase in the cycle is reviewed, as the design evolves to fulfil its final requirement.

Figures 1 & 2 outline the change in emphasis. For a great number of engineers Fig. 2 only sets out precisely how they currently approach their development work. Within an organisation however, the change from a structured to an object oriented approach requires a review of the overall management of technical projects in order to implement the changeover effectively.

The use of object-oriented design has gathered apace over the past ten years, to the point where it now looks set to become the dominant design methodology within the software industry. This has no doubt been aided immeasurably by the emergence of C++ as a commercially available and mature language. Although not the 'purest' of object oriented languages, C++ has evolved to directly support the paradigm, while maintaining its roots in C.

Of itself, object oriented design is not a panacea for bad design. Likewise its adoption will not be effective unless project team structures and management practices change to enable its correct implementation.

The language requires a more fluid and evolutionary approach to design, and the extent to which its introduction benefits companies is largely dependent upon the recognition of this fact. Used correctly, object oriented techniques implemented in an appropriate language, will result in designs that map directly onto the applications domain, enabling increased software re-use, ease of maintenance and an evolutionary approach to future development.

Object oriented design – key concepts

To be effective any design methodology requires tools that support it directly. In this case these are the 'object oriented programming languages', a wide range of which are available. However, in order to be able to model and organise abstractions effectively, which concepts and mechanisms ought these languages support?

In his book 'Object Oriented Design with Applications', Grady Booch outlines the concepts which are fundamental to what he terms 'the object model'. These are direct support for abstraction, encapsulation, hierarchy and modularity. To these ought to be added support for parameterised types, which have the potential of adding significantly to software

Applications Domain:	Software Implementation:
Waveforms:	A range of waveform types.
Sine, Square, Triangle, Ramp	
Processes:	
Acquisition, Filtering, Output	Arrays, filter types, output drivers.

Fig. 3. Mapping abstractions. Object-oriented design allows 'types' to be created. These map directly into the application's. domain.

Gerard Moloney is MD of October Developments, 0181 968 3586.

re-use. Secondary properties which he outlines as desirable are strong 'typing', and support for concurrency and object persistence. A brief outline of each of these concepts is given below.

(i) Abstraction: in order to support abstraction a language must allow for the creation of user defined types which map directly onto concepts within the application domain. In a signal-processing application you might need to create waveform and filter types; in a graphics library, matrix and transformation types. **Figure 3** illustrates the concept.

(ii) Encapsulation: any abstraction can be said to have two major attributes: its structure and its behaviour. Within software this translates to a representation and an associated set of functions (procedures/methods). Generally, the functionality is of interest; the representation/implementation should not be accessible except through a strictly defined set of functions implementing the interface to the user.

In effect the representation should be 'encapsulated'. **Figure 4** illustrates how encapsulation might be achieved for a type representing a sinewave.

(iii) Hierarchy: within object oriented software, creating hierarchies of user types is of prime importance. The base of the hierarchy provides generalisation with further specialisation provided by the lower layers. Support for hierarchical types allows for designs that are highly intuitive and efficient, and provides a basis for further evolution. **Figure 5** is an example of a partial hierarchy for geometric transformations.

(iv) Modularity: any complex system needs to be modular. Within object-oriented systems, modularity exists to keep related abstractions together.

Modularity exists at a number of levels; libraries provide re-usable collections of domain specific abstractions, source files provide modularity at the application level while encapsulation provides modularity at the abstraction level.

(v) Parameterised types: often, structures and functions are required that can be used across a range of types. As an example, consider matrices. The structure of a matrix and its operations have a generality across a range of algebraic structures. The ability to capture this type of generality is a powerful aid to extended re-use.

(vi) Typing: static type checking can ensure errors are caught at compile time, and it can introduce a strong discipline into programming. Not all object oriented languages support static typing, but in most instances the benefits far outweigh the perceived loss in flexibility.

(vii) Concurrency and persistence: support for concurrent processes is not inherent within object oriented languages. However a process itself can be viewed as an abstraction and therefore concurrency can be implemented. Likewise the need for objects which exist over extensive periods of time – as in database and distributed systems – can easily be supported at the abstraction level.

Having outlined these concepts I will now look specifically at language support for these within C++.

Objects and C++

C++ was developed as a general purpose programming language which would directly support object-oriented programming in an efficient and straightforward manner. By guaranteeing that C++ would maintain C's inherent low-level strength and by maintaining a high level of compatibility with C, C++ has been in a unique position as developers looked to adopt object oriented methods.

In his work 'The Design and Evolution of C++', Bjarne Stroustrup says that in his view, C had successfully addressed the 'computational' aspects of a language. In developing C++, one criteria was to maintain this, while dealing effectively with the 'organisational' aspects.

A further criteria was to remove the necessity for the unsafe practices used widely in C, such as casts and the proliferation of pre-processor directives and global data.

Object oriented development support

Within C++, there are various structures, included to aid object-oriented development.

(i) Classes: Within C++, a 'class' is the fundamental mechanism by which user defined types are implemented and they receive almost identical support within the language as the built in types such as 'int', 'char' etc.

Classes not only represent the abstractions within the application, but within the class 'encapsulation' is enforced. A class defines a scope, and is the fundamental organisational component in C++. Below is a simple sinewave class showing the separation of the representation from the interface to it.

```
class sinewave{
   //the representation
   float frequency;
   float amplitude;
public:
   //the interface to the representation.
   sinewave(float x,float y){frequency=x;amplitude=y;}
   ~sinewave();
   //other appropriate functionality.
};
```

C++ allows for different levels of access to be defined and very efficient and intuitive interfaces can be built, given features which allow for in-line code and the defining of operators on a class specific basis.

A user of a sinewave class requires only the interface to use the class, and application specific class libraries are the toolsets to be used by application developers.

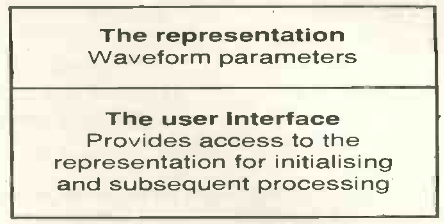

Fig. 4. Example of encapsulation. The representation and the interface parallel two major attributes of an abstraction – its structure and its behaviour.

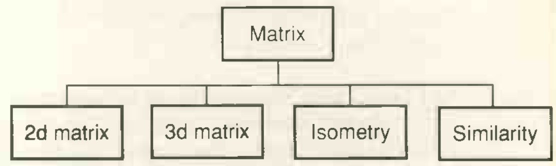

Fig. 5. A matrix hierarchy supporting geometric transformations. The root matrix provides generic behaviour while the derived classes provide for specific functionality.

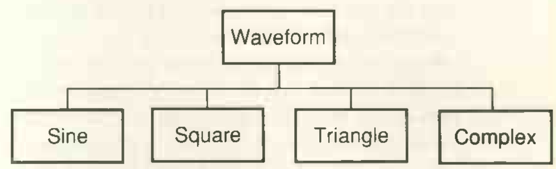

Fig. 6. Example of simple hierarchy structure for waveform generation.

(ii) Derived classes: Given an application, generally hierarchies of related types exist. Below is a hierarchy of waveform types, with the 'base' of the hierarchy being the 'waveform' class and the 'derived' classes being 'sine', 'square' etc, **Fig. 6**.

Hierarchies allow related types to share common functionality and to be viewed in many instances as objects of their common base class. Below the sinewave class has been derived from a waveform class allowing a large measure of its functionality to be expressed in terms of its base class.

```
class sinewave : public waveform{
//representation in base class.
//common to all wavetypes.
public:
sinewave(float x,float y):waveform(x,y,){
//only need sinewave specific functions.
//otherwise view as a generic waveform.
};
```

Whatever their type, waveforms share a great deal in common and are thus able to use a great deal of generic code. With an appropriate class library, C++ enables the following to be written:

```
complexwave1=sine1+square3+ramp5+sine7;
complexwave2=(mybandpass)(complexwave1);
```

Not only is this semantically clear but it is as

Requirements:	Solution:
general lists of employees, accounts, waveforms in a complex wave	a list type that can hold any type for which a list makes sense

Fig. 7. Parameterised types allow for the creation of generic classes and functions.

Fig. 8. Organisation using header files.

```
//App.cpp
#include "waveform.h"
//two header files for accessing
      waveform and processing stuff
#include "process.h"
//the application accesses required
functions via header files
sine sine1(1000,1.125);
```

efficient if not more so than code written in C.

Hierarchies, therefore have a crucial role to play in organisational terms and introduce a high degree of code re-use .

(iii) Templates: Whereas hierarchy supports re-use through derivation, templates support re-use through parameterised types. Thus you define a class or function to provide services across a range of types which may not necessarily be related to one another. **Figure 7** illustrates the general requirement and solution.

Initially, they arose from the requirement to provide a library of container classes which is a fundamental requirement within most development environments. Assume we need lists; but lists of what exactly? How is it possible to provide for the lists that may be needed in the future? Templates fulfil this requirement, below we look at the outline of a matrix template:

```
template <class T> class matrix{
   int col;
   int row;
public:
   matrix(int x,int y){col=x;row=y;}
   ~matrix();
   //other matrix stuff
};
```

A developer can now declare matrices of any type;

```
matrix <int> intmatrix(2,2);
matrix <complex> complexmatrice(5,3);
```

and given that those types are available matrix algebra can be applied to them. Likewise at a future date matrix algebra could be applied to as yet unspecified types.

Used together with derivation the potential for re-use and the impact on program organisation are enormous. Taking as a case in point, in our matrix example we can derive from matrix and apply templates to a specific type of matrix. I may perhaps wish to optimise for geometric transformations which are derived from a matrix and are able to take a variety of types as their parameters.

Together, classes, the related subjects of hierarchies, and templates, form the basis of support for object oriented techniques within C++. Also incorporated within the class concept are features to encourage semantically meaningful syntax, the efficient creation and deletion of objects and the minimisation of global data and pre-processor directives. In addition, there is the introduction of static typing, which is equally applicable to stand-alone functions. Static typing enforces compile-time checking of arguments, and can go a long way to eliminating run-time errors. It is to be recommended in almost all cases.

Finally, modularity is supported in C++ by the use of libraries and separate source and header files. Organisation is in terms of abstractions, related abstractions reside in the same files and are interfaced through their header files, **Fig. 8**.

Application specific libraries can then be generated from these files and made available for general use. With a good library of classes that map well onto the application's domain it should not generally be necessary to access the source code in order to use or add further speciality.

In summary

Without a doubt C++ is rapidly becoming the language of choice in many areas, and given its excellent support for object oriented programming coupled with its association with C it looks set to be a major development language in all spheres.

What is often overlooked, however, is that C++ also addresses those areas in which C is deficient. Features such as static typing, class specific dynamic memory allocation, static class members, exception handling are radical improvements when viewed from a software engineering perspective.

C++ also supports mixed-language development with a simple linkage model, allowing previous software investment to be fully used. Given these advantages there is a strong case both commercially and technically for companies to considering C++ seriously as the basis for their future software development.

However, while the benefits to be gained by adopting an object oriented approach to development – whether C++ based or otherwise – can be enormous; unfortunately without an adequate understanding of the issues involved, these benefits may not be achieved.

With no informed strategy for the adoption of C++, the net result within organisations will be disenchantment amongst development staff, and a discrediting of the whole process. Such a strategy should deal directly with the change in emphasis that the philosophy requires. It should set out a program in which object oriented design methods and programming are introduced over a period of time at both a project and individual level. Given such a strategy the resultant impact on design and implementation are indeed significant. ■

Further reading
Grady Booch, 'Object Oriented Design with Applications', Benjamin Cummings.
Bjarne Stroustrup, 'The Design and Evolution of C++', Addison Wesley.
The C++ Programming Language, Addison Wesley.

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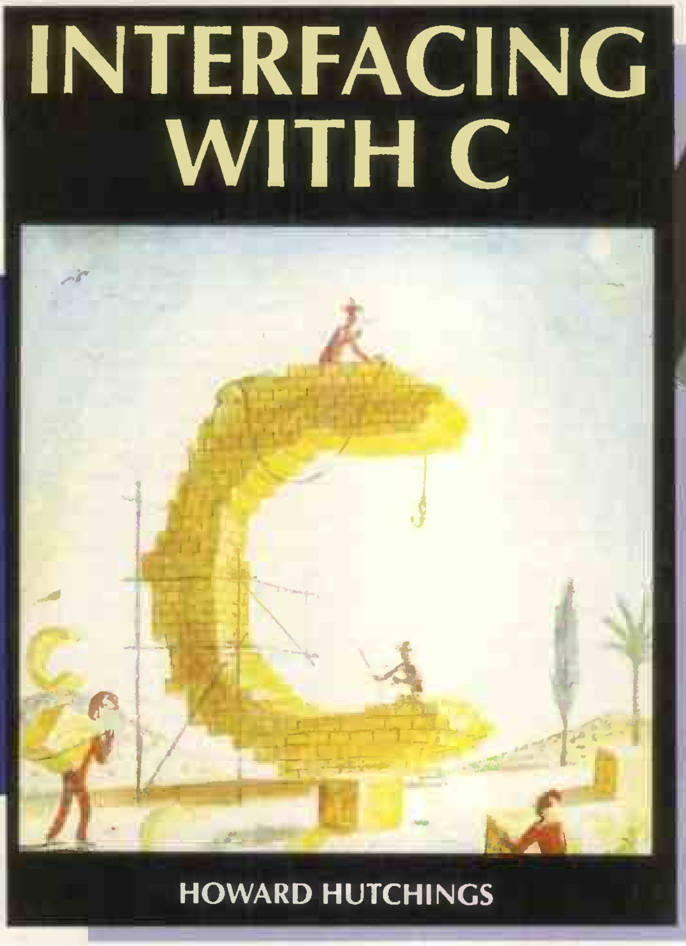

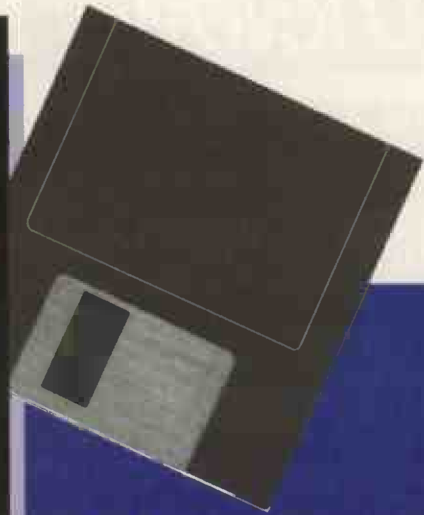

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Transient storage for ANALOGUE SCOPES

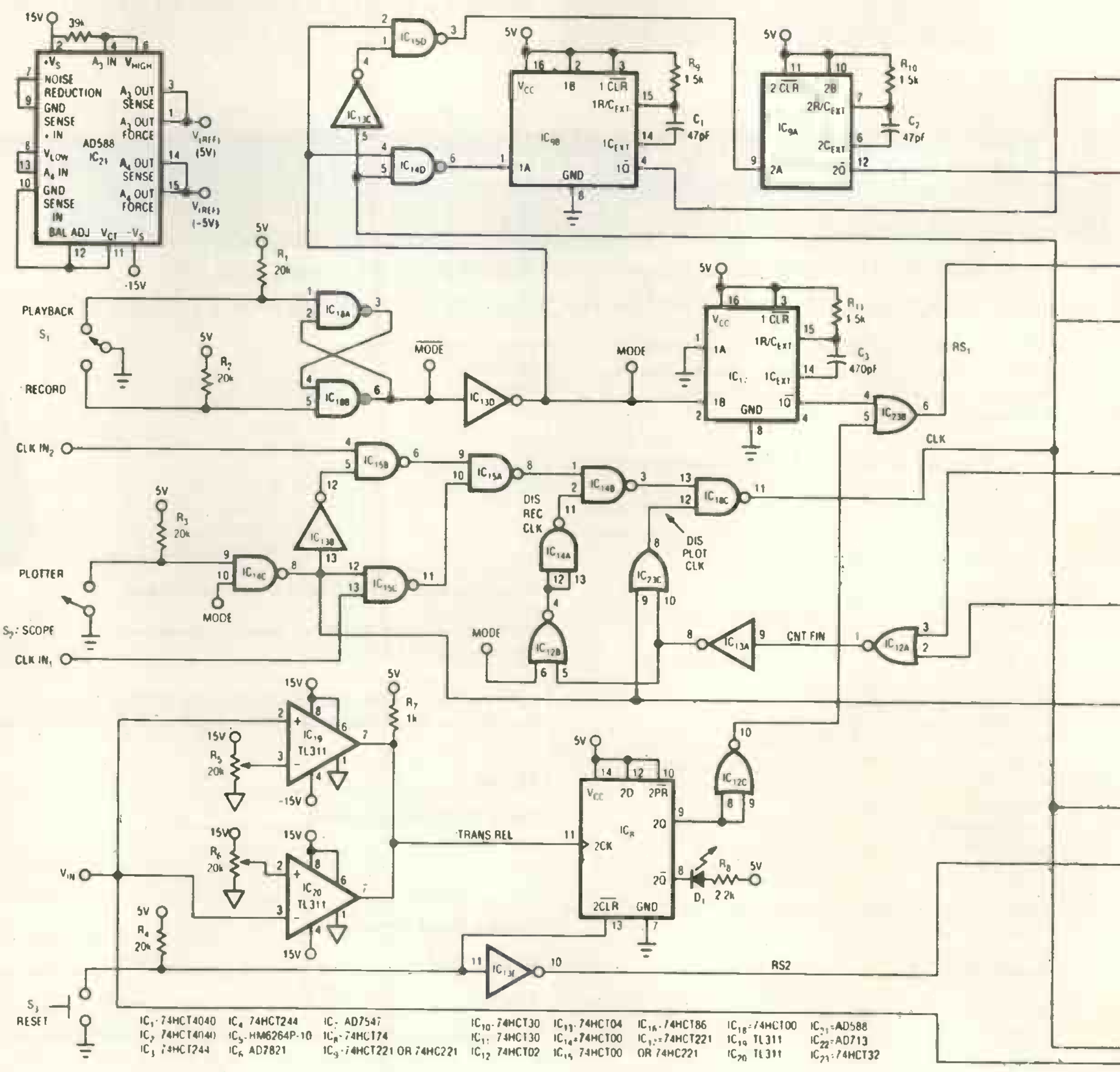
Rather than tie up an expensive dso looking for infrequent transients, Ken Deevy, Dan Sheehan and Mike Byrne show how to use a low-cost, dedicated transient recorder with an ordinary analogue oscilloscope or XY plotter.*

One of the difficulties in capturing single-shot events is the speed at which the transient recorder circuit responds once the input signal has crossed a predetermined trigger point. If the recorder circuit responds too slowly, it can miss fast transients altogether.

To capture fast events accurately, you need a high-speed a-to-d converter and a wide-bandwidth track/hold amplifier. For example, an eight-bit a-to-d converter having a 1µs conversion time can capture 1µs transients only when not preceded by a track/hold amplifier. With a 100kHz track/hold amplifier, the converter can recover 6µs-wide 5V transients.

To simplify fault detection or to take corrective measures, a transient recorder must be able to capture pre-transient information, which you can use to discover timing relationships between the transient and another waveform. Additionally, the recorder should be able to react to both positive and negative transients.

Another important criterion is cost. There is little point in replacing one expensive instrument with another. **Figure 1** shows that two counters, IC_1 and IC_2, determine where the circuit stores pre-transient and transient data, also clocking out data to the oscilloscope or X-Y plotter. You can use the



*Ken Deevy, Dan Sheehan and Mike Byrne are with Analog Devices Inc. This article first appeared in *EDN*.

fast clock input, CLK IN_1, for the clock source in record mode or when displaying stored data on an oscilloscope. A slower clock input, CLK IN_2, is for use when printing data on an X-Y plotter.

Switch S_1 selects the two basic modes: record and playback, IC_{18a} and IC_{18b} providing debouncing. With the MODE output of IC_{13d} low, one input of both IC_{15d} and IC_{14d} is low, so the clock inputs of IC_{9a} and IC_{9b} are disabled, ensuring that the 1Q\ and 2Q\ outputs of IC_{9a} and IC_{9b} are high. Besides disabling the chip-select inputs of the d-to-a converter, CSA\ and CSB\, the circuit disables the output enable signals of IC_3, IC_4 and IC_5, the *HM6264* memory chip, ensuring that the playback portion of the transient recorder is turned off.

Input CLK IN_1 serves as the clock source for the counters via IC_{18c}, IC_{14b}, IC_{15a} and IC_{15c}. While the MODE signal is low, CLK is the clock input for both counters and provides the RD\ (convert) signal for the *AD7821* a-to-d converter, IC_6. At the same time, IC_6's CS\ input is active, ensuring that the device is selected. After a reset from S_3 initialises the circuit, counter 2 begins counting. Monostable IC_{17} and IC_{23b} hold the reset (CLR) input of counter 1 high from power-up, keeping it in reset until the circuit detects a transient.

Connecting pin 7 of the *AD7821*, labelled Mode, to ground, sets the operating sequence in which, when the CLK signal toggles its RD\ input, the a-to-d converter executes continuous conversions of the input signal, V_{in}. (This Mode pin is in no way connected with the mode signal in the circuit diagram.) Counter 2 provides the memory addresses for the a-to-d conversion results. Data transfers from the digital outputs of IC_6 to IC_5 employ the INT\ output of IC_6 to drive the WE\ input of IC_5.

The circuit automatically loads the first conversion result after reset into location 0 of memory and the second into location 1. After transferring the result of the 4096th conversion to memory location 4095, the counter resets and stores the next conversion result in location 0. Memory always, therefore, contains the most recent 4096 samples of the input waveform.

Fast transients

Input signal V_{in} goes directly to two *TL311* comparators and the analogue input of the a-to-d converter. Comparator IC_{19} detects positive transients and IC_{20} negative ones, threshold levels being adjusted by R_5 and R_6. Wiring the outputs of the comparators together ensures that they produce a rising edge to the clock input of IC_8 when either a negative or a positive transient occurs.

Once the circuit detects a rising edge at pin 11 of IC_8, it illuminates a led, D_1. At the same time, it releases counter 1 from its reset condition by taking RS_1 low and both counters clock as a-to-d conversions continue, counter 2 counting up from the value it held before the transient was detected. Memory locations determined by the output of counter 2 store the transient data while overwriting the oldest 2048 samples of pre-transient data already stored in memory.

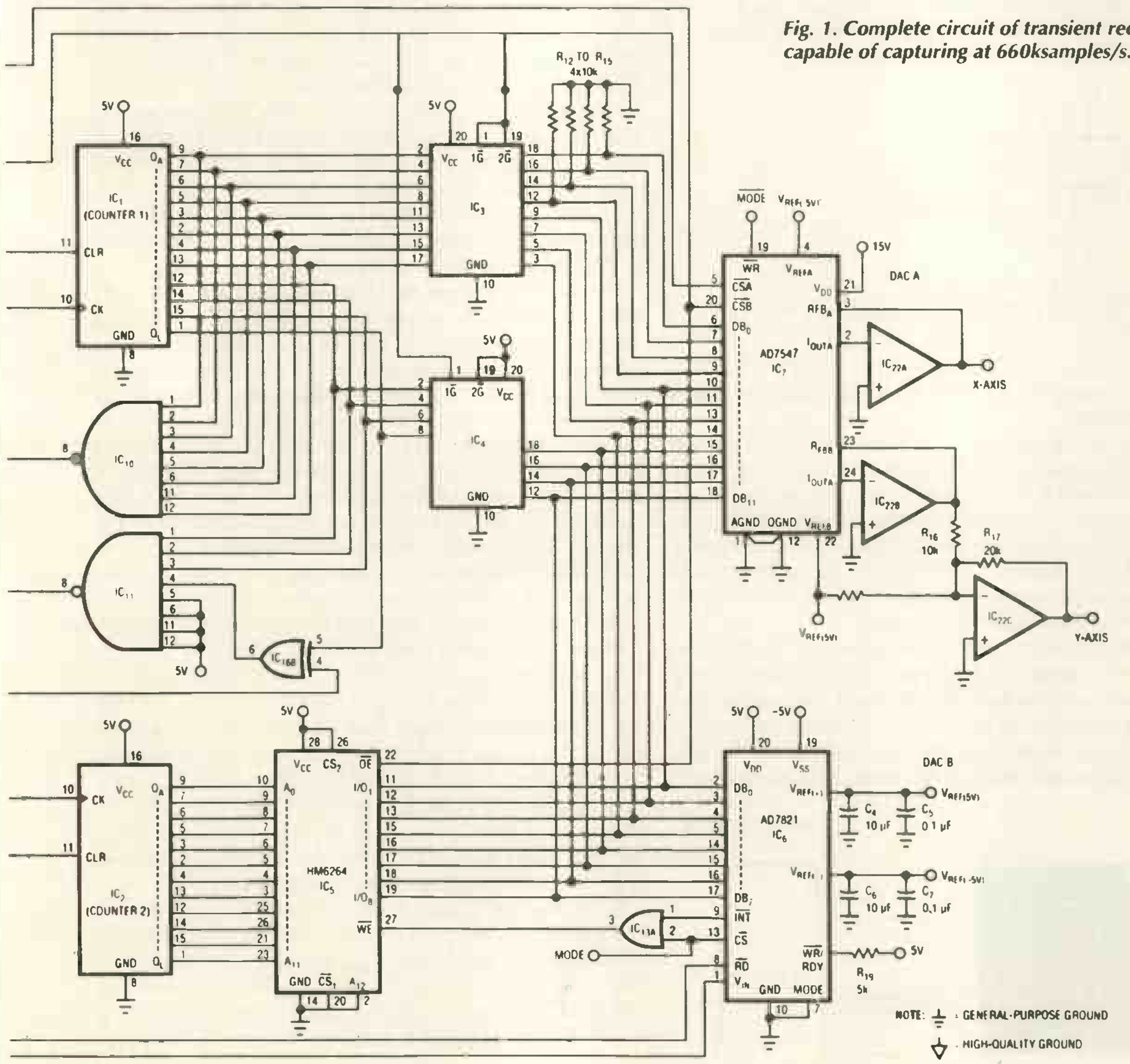


Fig. 1. Complete circuit of transient recorder capable of capturing at 660ksamples/s.

Transient recording

A transient recorder or burst-mode event sampler consists of a high-speed a-to-d converter, a wide-band track/hold amplifier, and an antialiasing filter. The a-to-d converter needs a sampling rate of at least twice the bandwidth to satisfy the Nyquist criterion, although at this rate the filter needs an infinite roll-off rate to avoid aliasing effects. With three times oversampling, the roll-off requirement drops to 50dB/octave in an eight-bit system and oversampling at a ratio of 10:1 requires a filter roll-off of only about 16dB/octave.

High-speed, sampling a-to-d converter chips often include track/hold amplifiers on the same chip; the *AD7821* is an example of this trend, combining a 100kHz track/hold amplifier with a 1Msample/s, eight-bit a-to-d converter. Because the a-to-d conversion rate is ten times the input bandwidth, there is no need for a complex antialiasing filter; indeed, if the input signal exhibits only a low-power spectral content at and above 500kHz, no filter is needed at all.

The *AD7821* uses a half-flash conversion technique to perform an eight-bit conversion in 660ns which, with the requirement of a 350ns signal-acquisition period between conversions, results in a maximum acquisition rate of 1Msamples/s. It accepts either single or dual supplies for unipolar or bipolar inputs.

Figure A1 is a block diagram of a transient recorder, showing the minimum hardware needed to build a high-speed transient recorder with playback. For simplicity, the design uses a clock with an even mark/space ratio, which limits the acquisition rate to 660ksamples/s rather than the a-to-d converter's 1Msample/s maximum rate, the oversampling ratio now being 6.6:1. A memory chip stores the digitised data for later playback on an X-Y plotter or oscilloscope, via a dual, 12-bit d-to-a converter and a quad op-amp. Half the samples are pre-transient information and the other half transient data.

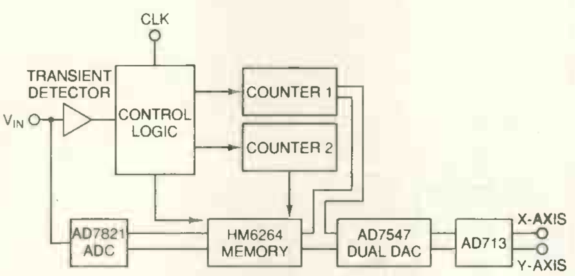


Fig. A1. Block diagram of the transient recorder – mainly digital, but with data converters at each end.

Counter 1 counts off the 2048 clock states that correspond with the samples.

Because the output of IC_{16b} is always high in the record mode, when counter 1 reaches 2047, all inputs to IC_{10} and IC_{11} are high and the outputs of both ics go low. As a result, the output of IC_{12a} goes high, causing the output of IC_{14a} to go low via IC_{13a} and IC_{12b}, this DIS REC CLK signal gating off CLK IN_1 from the rest of the circuit in IC_{14b}. The output of IC_{18c} ensures that the CLK signal is held low, stopping both counters and the a-to-d converter.

At the end of the transient-record cycle, the memory will contain 4096 samples of the input waveform. Half of these samples are transient data, the other half representing pre-transient information. Whatever value is in counter 2 will be the last memory location for the transient data and the next memory location will hold the first of the 2048 words of pre-transient data; when playback mode starts, the first output from the counter will correspond to the memory location of the first pre-transient sample. To alter the ratio of transient to pre-transient samples, simply alter the connections from counter 1 to IC_{10} and IC_{11}.

To convert the input waveform to stored data accurately, you must pay close attention to the circuit. Use a precision reference, IC_{21}, to generate 5V and –5V references for the V_{ref}+ and V_{ref}– inputs of the a-to-d converter. Make sure that these reference voltages are properly decoupled, along with the V_{DD} and V_{SS} lines of the a-to-d converter. Connect the GND pin of IC_6 to the star ground of the system, ie the point in the circuit at which you connect the analogue and digital grounds. Make sure that the conductor between the a-to-d converter and the star ground is as wide as circuit board layout constraints allow. Further, ensure that the WR\/RDY line is pulled high via R_{19} to avoid noise pickup on this pin.

Playing back captured signals

Information is retained as long the power remains on or until you depress the reset button. Select play-back mode with S_1. This takes the MODE\ signal low, activates the WR\ input to IC_7, and deselects IC_6 by taking its CS\ high. Display the transient on either an analogue oscilloscope or an X-Y plotter, depending on the position of S_2. Make sure to select the oscilloscope or the plotter before starting playback.

For the oscilloscope display, the clock source for the circuit is the same as in the record mode. If you use a plotter for playback, the clock frequency is much lower and is applied via the CLK IN_2 input. CLK, from either CLK IN_1 or CLK IN_2, passes through gates IC_{15d} and IC_{14d} because the MODE signal is high. IC_{9a} and IC_{9b} generate the CSA\ and CSB\ pulses for IC_7 from this CLK signal.

Monostable IC_{9a} drives the CSA\ input of IC_7 as well as providing the enable signals for IC_3 and IC_4. In playback mode, counter 1 resets and starts counting from 0 to 4095, its output being the digital input code to DAC A of IC_7, which drives the X axis of either the oscilloscope or the plotter. d-to-a converter A produces a unipolar output range from 0 to 5 V, with a resolution of 4096 steps.

Output of IC_{9b} drives the CSB\ input of IC_7 and also sets the logic level on the output-enable line of IC_5, OE, to latch the data from memory into DAC B, which drives the Y axis of the oscilloscope or plotter. Use of dual supplies allows DAC B to be set for a bipolar output range to reconstruct both positive and negative transients.

Counter 2 starts its count from the point at which it stopped at the end of the record mode; the first memory output word to IC_7 is the oldest sample in memory. Scanning then proceeds through the 2048 samples of pre-transient information and the 2048 samples of transient information. Output of each sample from memory to the Y axis, via DAC B, corresponds to the output of a count value from counter 1 to the X axis via DAC A. In this way, the circuit reconstructs the pre-transient and transient waveforms.

For oscilloscope display of waveforms, place S_2 in the 'oscilloscope' position. Doing so locks out CLK IN_2 from the rest of the circuit but allows CLK IN_1 to operate as clock signal for the circuit. Unlike the operation of plotter display, where counter 1 runs through once and then stops, CLK runs continuously. CNT FIN does go high when counter 1 reaches a count of 4095 but, because the output of IC_{14c} is high, the DIS PLOT CLK signal does not go low. **Figure** 2(a) shows a typical oscilloscope waveform display.

Switching S_2 to 'plotter' locks out the CLK IN_1 input from the rest of the circuit and permits CLK IN_2 to generate the clock signal for the circuit. IC_{16b}, IC_{10}, IC_{11} and IC_{12a} generate a high CNT FIN signal function, as in record mode, but this time IC_{10} and IC_{11} go low when counter 1 reaches a count of 4095. IC_{13a} goes low and, because the output of

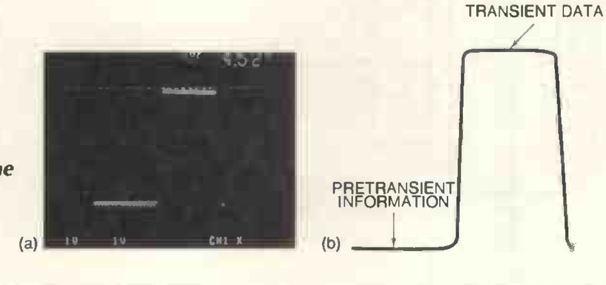


Fig. 2. Recorder presents results on either an analogue oscilloscope (a) or on a plotter, as at (b). Pre-transient information occupies the first half of the trace, the second half being the data after the trigger.

IC_{14c} is already low, the DIS PLOT CLK signal goes low, turning off CLK IN_2 at IC_{18c} and holding the CLK signal high. Figure 2(b) shows a captured transient displayed using a plotter as the display method.

Record-mode timing and clock waveforms

Figure 3 shows the logic relationships for the record mode, when MODE (not shown) is low and the DIS REC CLK signal is high. Signal RS_2 goes high when the recorder receives a reset command via S_3, resetting counter 2. The next falling edge of the CLK signal clocks out an address for IC_5 from counter 2 and initiates a conversion. Within 700ns, the INT\ signal of IC_6 goes low, activating the WE\ input of IC_5. The rising edge of CLK resets the INT\ line 50ns later.

When the circuit detects a transient, TRANS REC goes high, causing the RS_1 line to go low and releasing counter 1 from its reset state, the next falling edge of CLK clocking out the contents of counter 1. When the output from counter I reaches 2047, CNT FIN goes high and causes the DIS REC CLK signal to go low, shutting off the CLK signal.

Since, in record mode, the a-to-d converter needs a CLK-low time of 750ns to convert and latch the data into IC_5, the 50:50 mark/space ratio of the clock signal limits clock frequency to 660kHz. However, the CLK-high time can be as short as 350ns, the time required between conversions by the *AD7821*. Therefore, if the input to CLK IN_1 has a low time of 750ns and a high time of 350ns, the circuit can make one conversion every 1100ns – equivalent to approximately 900ksample/s.

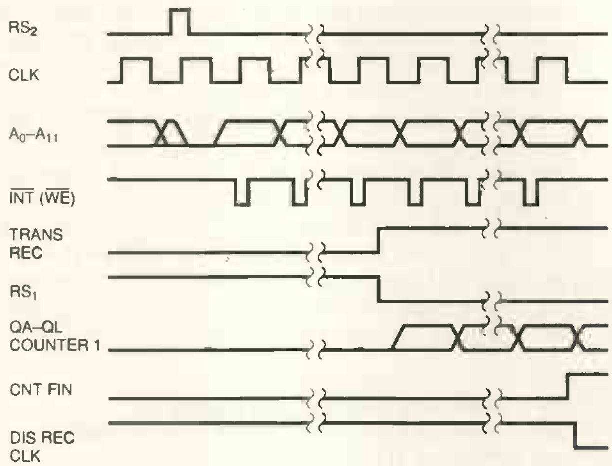


Fig. 3. Record-mode timing waveforms, the process beginning at the first falling edge after RS_2 goes high.

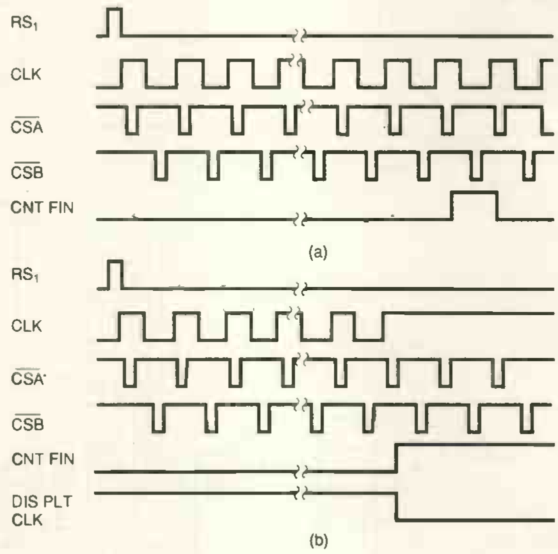


Fig. 4. Waveforms in play-back configuration, which runs once in plotter mode (b) and continuously for oscilloscope play-back (a).

Record-mode timings

Figure 4 shows waveform timing during playback to an oscilloscope. MODE, the WE\ input of IC_5, and the DIS REC CLK signal are high and, with S_1 in the playback mode, RS_1 goes high, resetting counter 1. CLK generates a CSA\ signal for IC_7 on its rising edge and a CSB\ signal on its falling edge. Data from counter 1 is clocked out on the falling edge of the CLK signal and the rising edge of CSA\ updates the X axis; the falling edge of OE\ outputs stored data from memory and the rising edge of CSB\ updates the Y axis. CLK runs continuously when the circuit is in oscilloscope play-back mode.

Figure 4(b) shows circuit operation for play-back on a plotter. Once again, MODE, the WE\ input of IC_5, and the DIS REC CLK signals are high. The circuit generates CSA\ and CSB\ to update the X and Y axes. Compared with oscilloscope play-back, the difference in the circuit's operation is that when the output count from counter 1 reaches 4095 and the CNT FIN signal goes high, the DIS PLOT CLK signal goes low, forcing the CLK signal into a high state.

Sampling in burst-mode

Burst-mode event sampling places requirements on an a-to-d converter similar to those for transient recording. In burst-mode sampling, the recorder looks at the input waveform infrequently, but when it does, it must acquire a large number of samples in a short time. With slower microprocessors or microcontrollers, timing constraints impose a much lower throughput than the a-to-d converter can deliver.

Timing limitations in a burst-mode sampler are reduced by using a direct-memory-access, dma, controller to initiate a-to-d conversions and transfer conversion data to memory, allowing the a-to-d converter to run at or near its maximum sample rate and permitting high oversampling ratios and the acquisition of short transients.

Building a burst-mode sampler is relatively easy with the popular *8052* microcontroller, shown in the circuit diagram of **Fig. 5**. Although the *8052* does not support hardware dma, it does support what is termed 'fake dma'. However, the response time to dma requests is much slower than is possible with microcontrollers that support genuine dma.

Memory chip IC_3, an *HM6264P*, stores the control program for IC_1, of which the first part is the initialisation routine. This routine, **Listing 1**, sets up the sense of the DACKO line of the *8237* dma controller, IC_2, to be active high and loads the starting data address into it for the first conversion results. Microcontroller IC_1 initialises the counting register to control the number of conversions before IC_2 returns control to IC_1. The program must also set up IC_1 for 'fake dma'.

After running the initialisation program, IC_2 is ready to take control when requested to do so. Although IC_2 has four

Listing 1. Initialisation routine for the burst-mode sampler.

```
10   XBY(8008R) = 80H        :SETS DACK SENSE ACTIVE HIGH
20   XBY(800FH) = 0EH        :CLEARS DREQ0 MASK REGISTER
30   XBY(800BH) = 94H        :SETS MODE REGISTER
40   XBY(800CH) = 00H        :CLEARS FIRST/LAST FLIP-FLOP
                             :(ONLY NEEDED IF 8237 IS
                             :NOT RESET BETWEEN DMA REQUESTS)
50   XBY(8000H) = 00H        :LOADS LOWER BYTE OF STARTING DATA
                             :ADDRESS TO BASE AND CURRENT ADDRESS
60   XBY(8000H) = 08H        :LOADS HIGHER BYTE OF STARTING DATA
                             :ADDRESS TO BASE AND CURENT ADDRESS
70   X8Y(8001H) = 00H        :LOADS LOWER BYTE OF COUNTING NUMBER
                             :TO COUNT REGISTER
80   XBY(8001H) = 02H        :LOADS HIGHER BYTE OF COUNTING NUMBER
                             :TO COUNT REGISTER
90   DBY(38) = DBY(38).OR.02H
100  IE = IE.OR.81H
110  GOTO 10
```

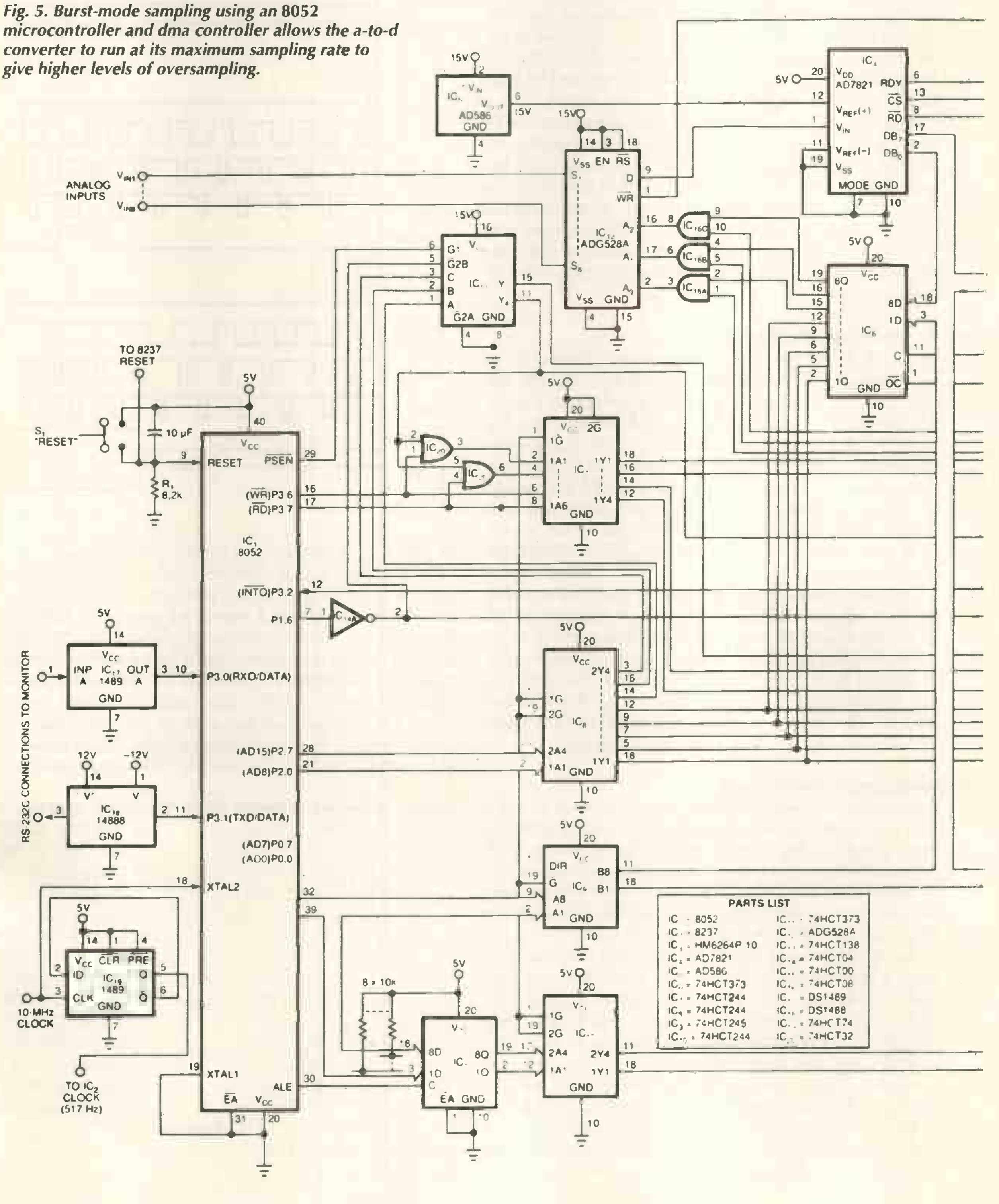
interrupt-request lines, this circuit uses only one, DREQ0. An external command signal drives this interrupt line high, telling IC_2 to take control of the circuit and start the a-to-d converter sampling the input waveform.

When IC_2 receives the DREQ0 request, its HRQ line goes high and IC_{14c} output, which drives the INT0\ line of IC_1 low, which takes the INT0\ line of IC_1 low, its P1.6 line low and the output of IC_{14a} high, selecting inputs of IC_7, IC_8, IC_9 and IC_{10}. When the output of IC_{14a} goes high, it shuts off IC_1's address and data lines from the rest of the circuit and deselects the output's address decoder, IC_{13}. The inverted P1.6 line also feeds the HLDA input of IC_2, acknowledging IC_2's request for control, IC_2 then taking control of the address and data bus and sampling of the input waveform.

To reduce pin count, IC_2 multiplexes the eight higher-order address bits on the data lines, an external device being needed to latch these address bits. Address strobe signal, ADSTB, takes AEN high to switch the OC\ line of IC_6 low; ADSTB drives the C input of IC_6 to latch the higher address lines to the outputs of IC_6. The inverted AEN line also drives one input of IC_{16d}, the other input of this gate being fed by the decoded output of IC_{13}, Y0. Therefore, because both IC_2 and IC_1 must be able to access IC_3, either a high on AEN or a low on the decoder output selects it.

Acknowledge line DACK0 goes high at about the same time that ADSTB latches the address and drives one input of

Fig. 5. Burst-mode sampling using an 8052 microcontroller and dma controller allows the a-to-d converter to run at its maximum sampling rate to give higher levels of oversampling.



IC_{15a}, this and IC_{15b} ensuring that the CS\ line of IC_4 goes low only when an input/output read operation of IC_2 occurs. IC_{15c} provides the correct polarity for the RD\ input and equalises the delay paths for the CS\ and RD\ lines, ensuring that the circuit obeys the CS\-to-RD\ setup time.

Once IC_4 receives a CS\ signal, it acknowledges receipt of the signal by bringing its RDY line low, placing the controller, IC_2, into a wait state for as long as its RDY input is low. When the device completes a conversion, the RDY line goes high, releasing IC_2 from its wait state; pull-up resistor R_2 takes account of IC_4's open-drain RDY output.

When the circuit releases IC_2 from its wait state, data from IC_4 is valid and the address lines of IC_2 determine where data

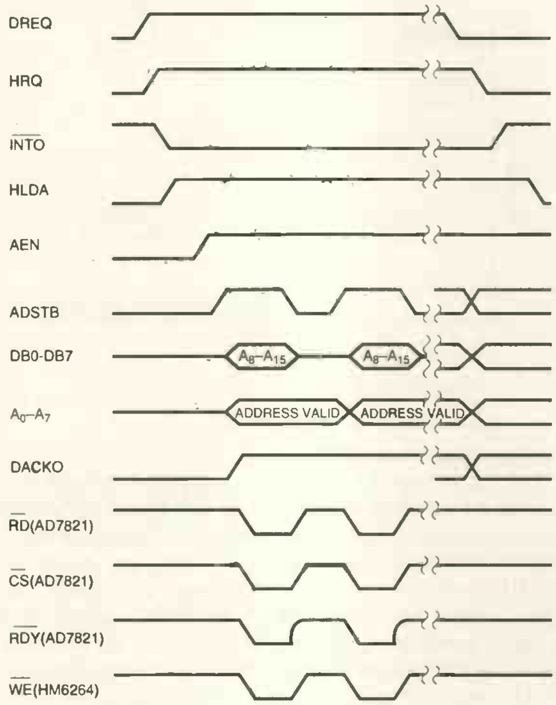
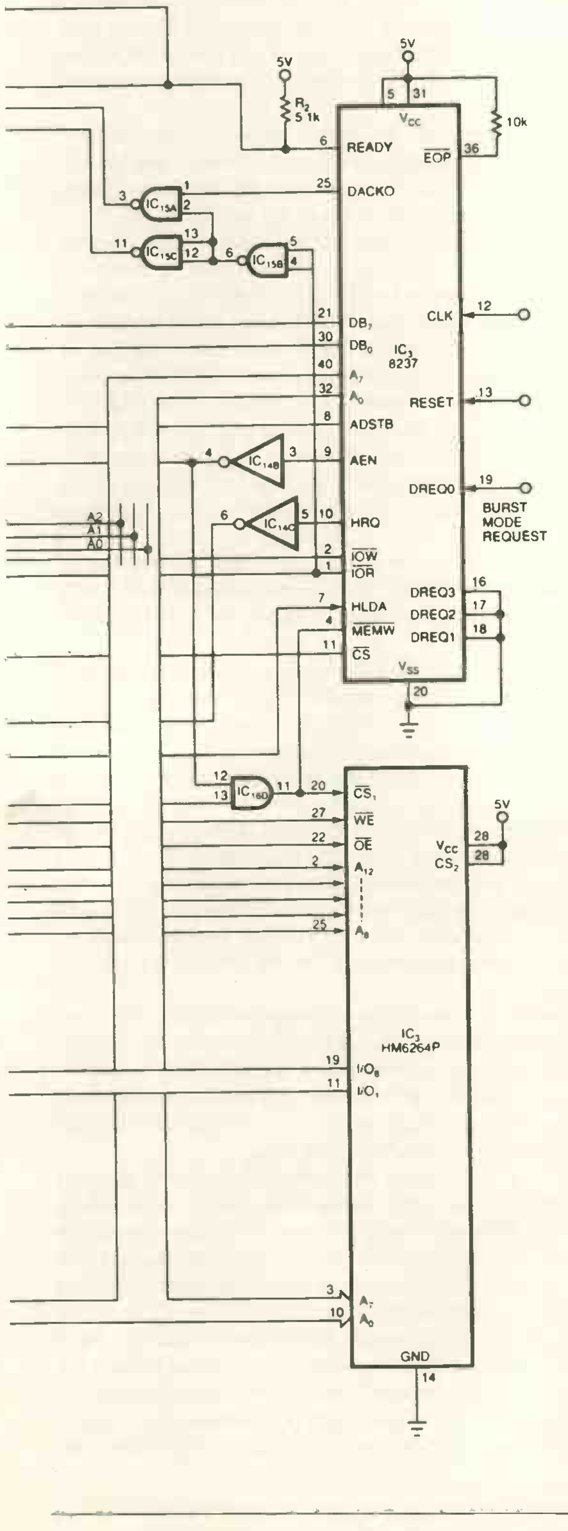


Fig. 6. 'Fake dma', used because the 8052 does not support true dma, allows rapid data transfer to memory.



loads into memory. Controller IC_2 performs all of these operations automatically because a memory write accompanies each input/output read. Depending on the value loaded into the counting register, IC_2 will continue to issue read commands to IC_4 until the circuit completes the required number of conversions, automatically incrementing the memory address after every write operation.

Multiplexer IC_{12} accommodates eight input channels, selected by the three highest and three lowest address lines of IC_2, gated through IC_{16a}, IC_{16b} and IC_{16c}. If the three upper lines are all at 1, IC_4 will convert each channel in sequence and the conversion results will be stored in consecutive memory locations. For example, if the first conversion takes place on the channel 1 input voltage, V_{in1} and the result is stored in location M of IC_3, the next conversion will take place on V_{in2} and the result will be stored in location M+1. If the three uppermost address bits are set to 011_{16}, the circuit will sequence through channels 1 to 4 only.

Ready or not

The RDY line of IC_4 drives the WR\ input of IC_{12}, loading the address for the next channel to be converted into the multiplexer. If there is only one input channel to convert, remove IC_{16a}, IC_{16b} and IC_{16c} and drive the A_{0-2} inputs of IC_{12} directly from the three uppermost address lines. With this arrangement, the program chooses the input channel.

Microcontroller IC_1 selects the device it talks to using a 1-of-8 address decoder, IC_{13}, the outputs of which provide signals for IC_{12}'s write line and chip-select inputs of IC_3 and IC_2. One of the outputs also gates read line P3.7 and the P3.6 outputs from the controller to drive the IOW\ and IOR\ inputs of IC_2.

Three upper address lines of IC_1 select the required device, the lower address lines being multiplexed with the data lines in a similar manner to those of IC_2. Decoder IC_{10} demultiplexes the lower eight address lines, the microcontroller's ALE signal latching them in IC_{11}; tri-state buffers, IC_2, IC_8 and IC_{10} isolate the microcontroller outputs from the address bus when IC_2 takes control, since it cannot place its address and data buses into a high-impedance state when IC_2 takes control of the circuit. IC_9 also acts as a buffer, but is bidirectional because the microcontroller must read data from

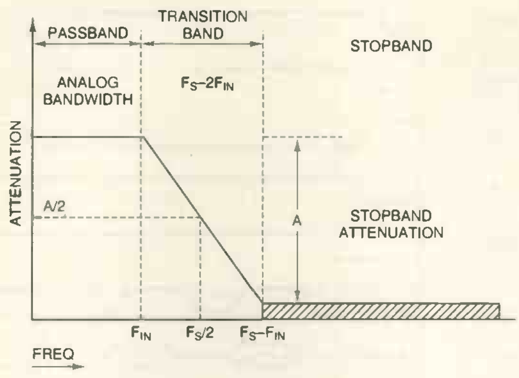


Fig. 7. Requirements of an antialiasing filter depend on the degree of oversampling. Since 10 times oversampling allows three octaves for roll-off, and since an 8-bit a-to-d converter needs 48dB of attenuation, a three-pole filter giving 18dB/octave will suffice.

and write data to memory.

The microcontroller uses a 10MHz input-clock frequency, a *74HCT74* counter (IC_{19}) dividing this frequency to form the clock input to IC_2. As the standard *8237* operates from a 3MHz maximum clock frequency, you can divide the 10MHz clock by four to give an acquisition rate of 608ksample/s. A faster version of the *8237*, the *8237-5*, operates from a 5MHz input clock, allowing you to divide the clock frequency by two and enabling the circuit to take 812ksample/s. If IC_1 were used on its own to control the sampling of the input waveform, the best acquisition rate would be approximately 100ksample/s.

The entire circuit operates from 15V and 5V supplies. If there is no 5V supply in your system, add a regulator to generate 5V. In addition, use a precision 5V reference (IC_5) for the a-to-d converter, allowing an input range of 0-5V. To obtain accurate conversion results, obey the usual guide lines regarding decoupling and grounding in both the circuits described.

Slow and medium speed microprocessors that support direct memory access requests can be used in this circuit to provide a much faster dma response than that of the *8052*'s 'fake dma'. Because microprocessors that support genuine dma will tri-state their address and data lines during a dma transfer, you can eliminate the tri-state driver chips.

Oversampling and antialiasing

In the spectrum of a periodically sampled waveform, the spectrum of the (unsampled) input signal repeats around harmonics of the sampling frequency. Any frequency contained in the input signal is repeated above and below each harmonic of the sampling frequency. Therefore, in the spectrum of the sampled signal, the band between 0 and f_{in} (the input spectrum) appears, among other places, between f_s–f_{in} and f_s, where f_s is the sampling frequency.

Although you may be under the impression that the input-signal bandwidth is 100kHz, if the sampling frequency is 1Msample/s, a signal at 991kHz in the input spectrum would appear as a 9kHz alias component in the spectrum of the sampled signal.

An antialiasing filter removes or at least attenuates any noise or spurious signals that could be aliased back into the bandwidth of interest. **Figure 7** shows the frequency response of such a filter for a generalised a-to-d converter. Determine the filter roll-off by drawing a straight line between the highest signal frequency of interest, f_{in}, and the stop-band attenuation frequency, f_s–f_{in}. As the ratio of f_s to f_{in} increases (that is, as the oversampling ratio increases) the slope of the line decreases.

In an eight-bit system. an ideal a-to-d converter's signal-to-noise ratio (s:n) is slightly greater than 256:1 or 48dB. To prevent noise limiting the system performance, the ratio of the input signal-to-noise ratio should exceed the approximate 48dB limit imposed by the converter. Here, the signal is the peak-to-peak value of the signal within the band of interest, and the noise is the square root of the sum of the squares of the amplitudes of all the frequency components outside that band.

Attenuation required for signals outside the band of interest depends on the application and the expected magnitude of the out-of-band signals. In most cases, the magnitude of these signals is much lower than that of the desired signal.

Usually, eight-bit systems require 50dB of attenuation for signals that can be aliased into the band of interest. Even if 50dB is not the desired number, the following calculations show the kind of reduction in antialiasing filter requirements brought about by oversampling. With 2× oversampling, i.e. with f=2f_{in}, f_s and f_{in} are at the same point and the filter has to have infinite roll-off to attenuate signals at f_s–f_{in}. With f_s=3f_{in}, (3× oversampling), the filter's attenuation must drop from 0dB at f_{in} to 50dB at 2f_{in}. In other words, the slope of the attenuation *vs* frequency curve must be 50dB/octave; the filter (if it has a Butterworth characteristic) must have more than eight poles.

With 10× oversampling, there are three octaves for the attenuation to drop from 0 to 50dB; the required slope is a little more than 16dB/octave and a three-pole Butterworth filter will do the job.

This analysis of the antialiasing filter holds true regardless of the type of a-to-d converter that follows the filter. No matter what the conversion technique, oversampling reduces the antialiasing filter requirements. Oversampling also reduces the converter noise within the signal bandwidth because it spreads the quantisation noise over a wider bandwidth. Oversampling has recently gained considerable popularity in connection with sigma-delta a-to-d converters. In the case of these converters, the advantages of oversampling are much greater than with successive-approximation or flash converters because noise shaping produces dramatic improvements in noise performance as the oversampling ratio increases.

However, the relationship between antialiasing-filter performance and oversampling is exactly the same for an oversampled sigma-delta modulator as for half-flash or successive-approximation alternatives; sigma-delta and half-flash a-to-d converters with the same oversampling ratio place the same demands on the antialiasing filter.

Pipelining or averaging inherent in sigma-delta converters is a disadvantage of the sigma-delta process for transient recording. Because of the pipelining, a step change requires a significant time (the settling time of the converter's digital filter) to ripple through to the output. Therefore, there is a delay before a sigma-delta converter produces an output that represents an input change. Between the time the input changes and the sigma-delta converter's output reflects the change, the a-to-d converter's output does not accurately represent the converter's input. Such performance is not appropriate for transient recorders of the type discussed here. ■

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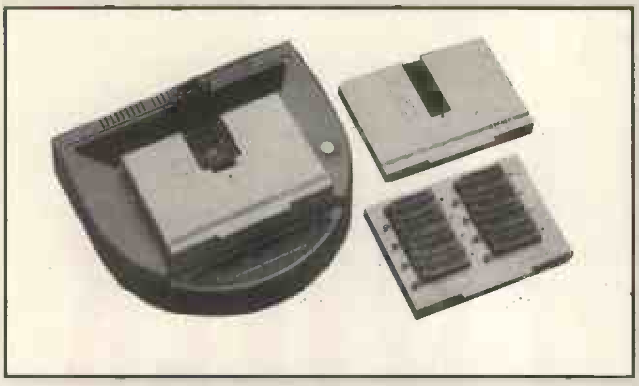

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ECC82	3.00	GZ32 Mull	8.50	UF89	4.00	6CL6	3.75	12E1	15.00
ECC83	3.50	GZ33	6.00	UL41	12.00	6CG7	7.50	12HG7/12GN7	6.50
ECC85	3.50	GZ34 GE	7.50	UL84	3.50	6CH6	8.00	30FL1/2	1.50
ECC88 Mull	6.00	GZ37	6.00	UY41	4.00	6CW4	8.00	30P19	2.50
ECC91	2.00	KT61	10.00	UY85	2.25	6D6	5.00	300B(PR)	110.00
ECF80	1.50	KT66	10.00	VR105/30	2.50	6DQ5 GE	17.50	572B	70.00
ECH35	3.50	KT88	15.00	VR150/30	2.50	6DQ6B	12.50	805	50.00
ECH42	3.50	N78	9.00	Z759	25.00	6EA8	3.50	807	5.75
ECH81	3.00	OA2	2.70	Z803U	25.00	6EH5	1.85	811A	18.50
ECL80	1.50	OB2	2.70	2D21	3.50	6F6	3.50	812A	65.00
ECL82	3.00	CC3	2.50	3B28	15.00	6FQ7	£7.50	813	27.50
ECL83	3.00	OD3	2.50	4CX250B STC	55.00	6GK6	4.00	833A	85.00
ECL86 Mull	3.50	PCF80	2.00	5R4GY	6.00	6H6	3.00	866A	25.00
ECLL800	25.00	PCF82	1.50	5U4G	5.25	6HS6	4.95	872A	20.00
EF37A	3.50	PCF86	2.50	5V4G	4.00	6J5	3.00	931A	25.00
EF39	2.75	PCF801	2.50	5Y3GT	2.50	6J6	3.00	2050A GE	10.00
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EL32	2.50	PL82	1.50	6AS6	3.50	6L6GC GE	12.50	7199	10.00
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CIRCLE NO. 129 ON REPLY CARD

LOW POWER single-chip fm receiver

With fm receivers designed for battery-powered equipment, disconnecting the audio amplifier from the supply when it is not in use saves power and eliminates unnecessary audio hiss. Ed Baker describes an fm receiver ic designed to disconnect its own audio power stage.

This article describes how to apply the *ULN3883A*, a low-power, narrowband fm receiver ic providing the second converter, second IF demodulator and audio amplifier circuitry for communications and scanning receivers.

The device offers a number of advantages over other types of narrowband frequency-modulated receiver circuits, particularly for cordless telephones and other battery-operated receivers. Most such units operate in a mode in which the receiver is muted by removal of the audio input to the amplifier driving the loudspeaker, while still leaving this amplifier drawing a considerable current. This current can often be many times greater than that drawn by the rest of the receiver.

A more sensible way to mute the receiver is to disconnect the audio amplifier from its power supply so that it draws little or no current. This not only improves battery life (or intervals between charging), but also removes what can be a very annoying hiss from the loudspeaker.

This is exactly what is achieved in the *ULN3883A*. During normal operation, with no input present, the ic draws up to 15mA. Once the mute is operated, this drops to typically 3mA, drawn by the rest of the circuit: i.e. the mixer, IF amplifier, detector and filter amplifier. This current reduction extends battery life considerably, depending on the operate-standby ratio of the equipment. In an extreme case, where a receiver spends 95% of its life in standby mode, battery life would be increased by a factor of ten.

Functional description

The device, which contains a number of distinct on-chip functions, **Fig. 1**, was originally designed for use as the second IF stage of a dual-conversion superheterodyne receiver with a first IF of 10.7MHz and a second IF of 455kHz. The high performance of the input circuitry, which exceeded its designer's expectations, also allows it to be used as a single conversion receiver for frequencies up to the low end of the vhf band. A typical application of the device in this role is the cordless telephone receiver shown in **Fig. 2.** Functions included in the *ULN3883A* are as follows:

Double balanced mixer. The active mixer, because of its nature, has an extremely high rejection of both input and oscillator frequency feedthrough, as well as reduced local-oscillator re-radiation. The circuit also exhibits a very wide dynamic range; in excess of 80dB.

Since the input circuitry is internally biased,

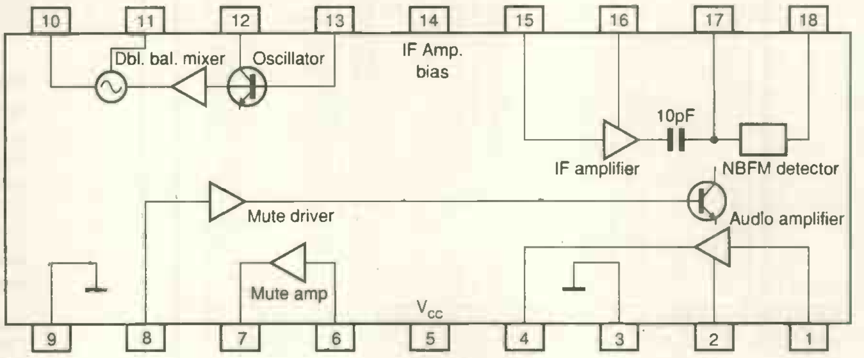


Fig. 1. Schematic of the ULN3883A fm receiver ic shows the three subsections – converter, If demodulator and audio amplifier.

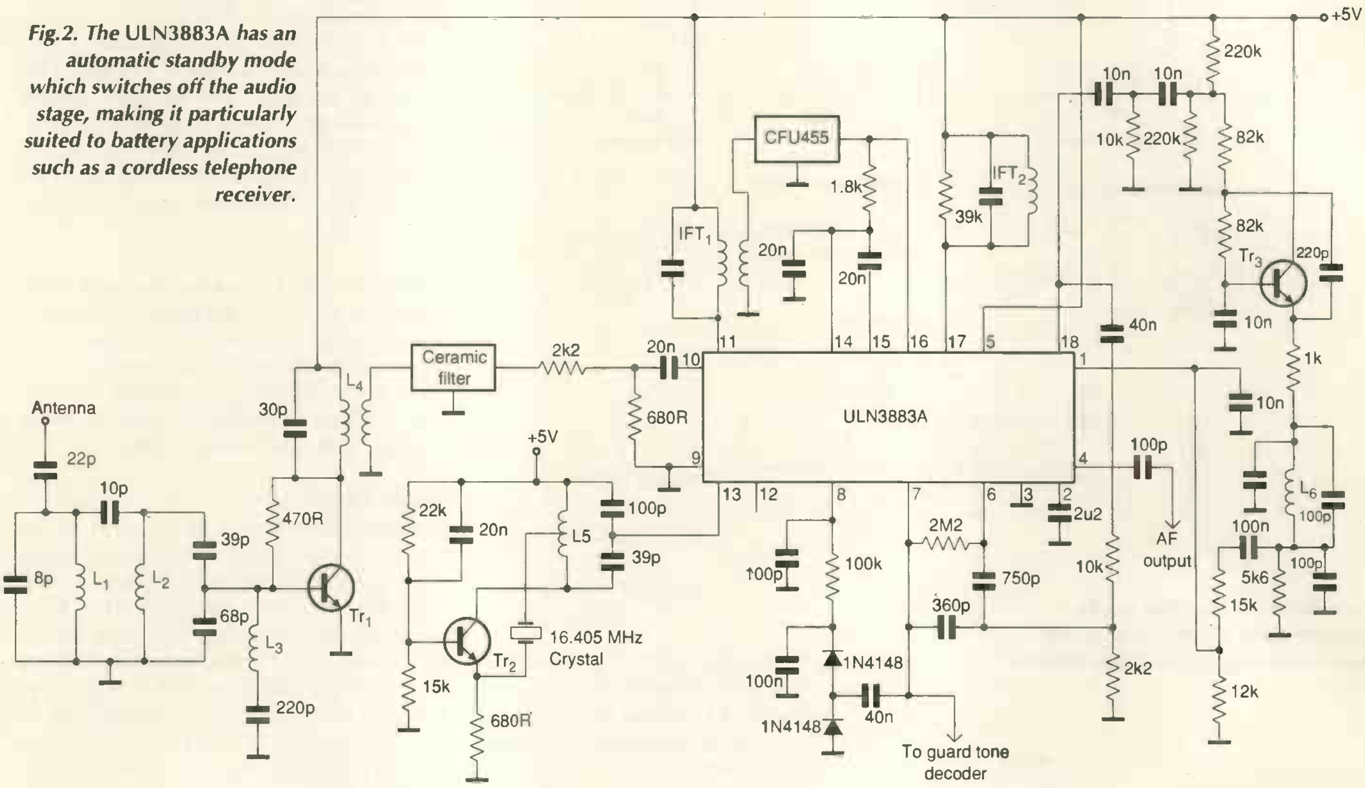


Fig.2. The ULN3883A has an automatic standby mode which switches off the audio stage, making it particularly suited to battery applications such as a cordless telephone receiver.

an input coupling capacitor is required for the purposes of dc blocking. However, its small-signal impedance equates to a 3kΩ resistor in parallel with a 20pF capacitor. The input ground is separate from the rest of the ic circuitry, and is connected to pin 9. It should be connected via the shortest possible path to the input-circuit grounding.The small-signal output impedance is approximated by a 100kΩ resistor in parallel with a 3pF capacitor, and it has an output drive capability of about 400μA. For correct operation, a dc path to the positive supply rail is required. Converse transconductance is typically 600μmho; however, if required, the mixer can be disabled and used as an amplifier by connecting pins 12 and 13 together. Under these circumstances, the transconductance is typically 1.4mmho.

Oscillator. This circuit is configured as a standard Clapp oscillator, and the base pin 13 and emitter, pin 12, are brought out of the ic for connection to the external circuitry. This can be either a crystal, shown in **Fig. 3a** or an *LC* circuit for instances where a tuneable circuit is required (Fig. **3b**).

Since the transistor is a pnp type, the bottom end of the coil must go to the positive rail, unless a capacitor is connected between pin 13 and the tuned circuit. If required, the oscillator can be disabled by leaving pin 12 open circuit and injecting an external oscillator signal into pin 13.

In the circuit shown in Fig. 2, a crystal oscillator operating in a third-overtone mode is used. The base input circuitry exhibits a stray capacitance of about 7pF, and has to be taken into account when designing the external oscillator circuitry.

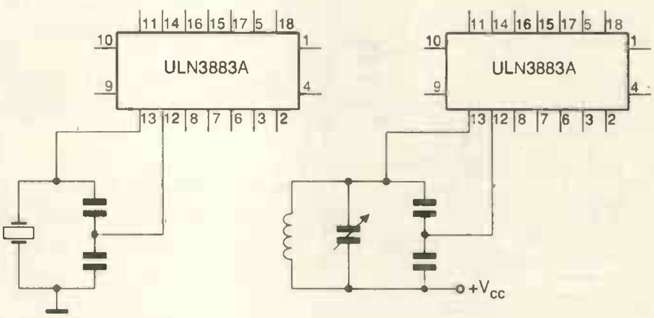


Fig.3. Two possible oscillator configurations: (a) crystal for fixed frequency operation; (b) tuneable LC circuit. An external oscillator can also be used, see text.

IF amplifier. Pin 15, which is the input stage, is internally biased by a 2kΩ resistor connected to pin 14. However, an external resistor is normally used to give good impedance matching with the rest of the circuitry. In the example shown in Fig. 2, a 1.8kΩ resistor is used to accommodate the *CFU455* filter requirements. Although there is internal biasing, an external resistor of between 0 and 10kΩ has to be used for correct balance of the IF amplifier.

The amplifier has a response of –3dB at about 1.5MHz, and rolls off at 6dB per octave above this. The 3dB limiting sensitivity is 13μV at 455kHz.

Noise-blanking fm detector The square-wave output of 570mV from the IF amplifier

Table 1. Performance of receiver Fig. 2.

maximum sensitivity	1μV for a signal to noise ratio of 12-20dB
quieting sensitivity	3.6μV at 3dB
limiting sensitivity	<1μV
apparent peak separation at 1mV input	12kHz
overload capacity	3000mV
am rejection (m=30%)	
at 100μV input	41dB
at 1mV input	38dB
distortion at 2.5kHz deviation	4%
adjacent channel rejection at ±30kHz	76dB

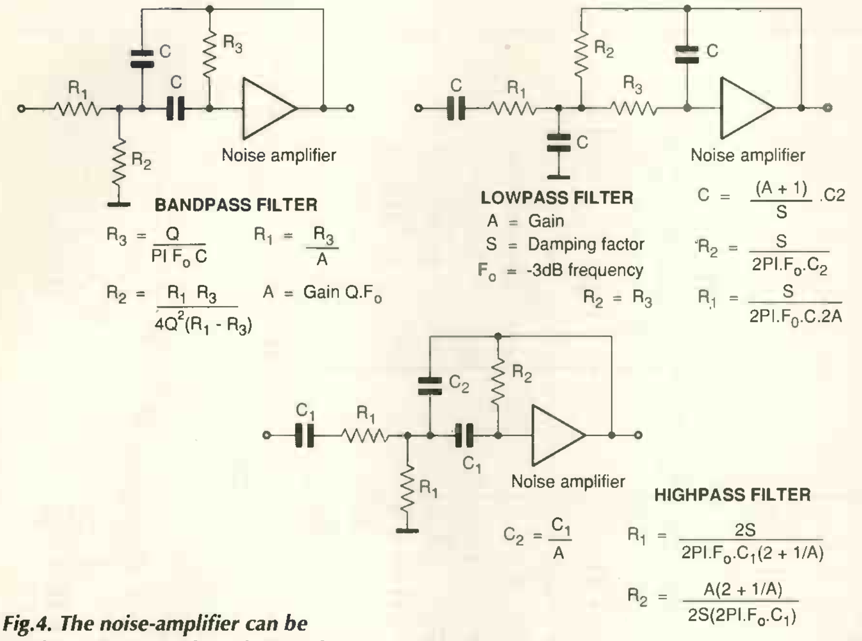
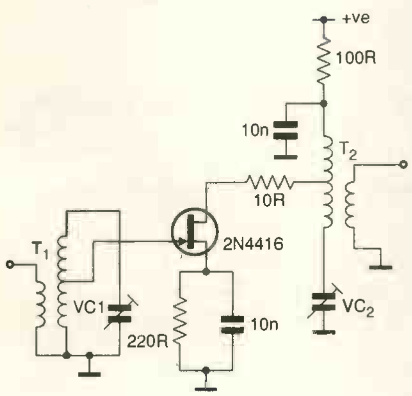


Fig.4. The noise-amplifier can be configured in a number of ways, the most common being the highpass filter.



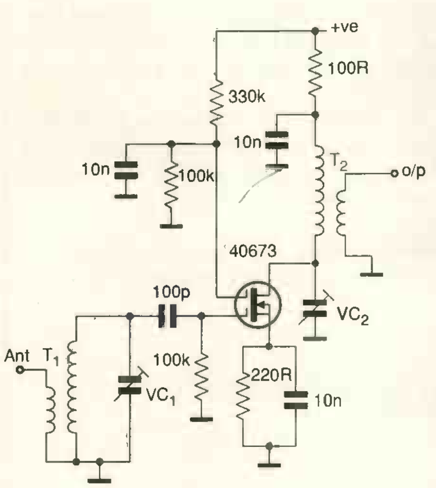


Fig.5,6. Improvements on noise factor and sensitivity of the receiver can be achieved using a jfet or a double gated mosfet in the rf input stage.

is fed into the detector output via an on-chip 10pF capacitor. This is brought out to pin 17, and connected to an external tuned circuit which is tuned to the IF frequency. The signal level on this pin should have a minimum level of 100mV rms for correct detector operation. The component connected to this pin is determined as follows:

$$V_{17} = V_1 Q_1[10\text{pF}/(10\text{pF}+C)]$$
$$R_1 = Q_0 C[Q_1/9Q_0 - Q_1)]$$

where
V_1=140mV rms
C=detector tuning capacitance
Q_1=loaded Q of detector coil
Q_0=unloaded Q of detector coil
R_1=damping resistor across tuned circuit.

The output circuit of the detector is an emitter of 400Ω output impedance. Since some of the IF signal is still present, care needs to be taken with the circuit layout so that the circuitry connected to pin 18 does not associate with the components connected to pin 16.

Audio amplifier. The stage gain of the power amplifier is typically 35dB, and is designed to drive either a 4Ω or an 8Ω loudspeaker. With a supply voltage of 5V, it is capable of an output of 260mW at a third-harmonic distortion of 10%.

The output-circuit coupling capacitor should be selected to give the desired IF response and to reduce power consumption caused by unwanted IF drive to the loudspeaker. To ensure optimum stability, the ground side of the speaker return should be connected as close as possible to pin 3: the amplifier (and main) ground connection.

Noise amplifier. This is an inverting amplifier with an open-loop gain of 53dB at 4kHz, and requires a feedback resistor between the input and output (pins 6 and 7) to reduce the gain to a more practical level.

The amplifier can be configured as a lowpass filter, a bandpass filter or a highpass filter, the last being the most commonly used in applications of this type (**Fig. 4**). All capacitors used should be of a high-Q variety such as polystyrene or polycarbonate; if ceramics are used, the filter will not perform to the required specifications.

Muting switch. The input circuit is a 22kΩ resistor in series with the base of a transistor whose emitter is connected to ground. As expected, the threshold is the same as the forward bias point of a transistor (around 600mV). Since all muting functions are on the chip, this stage has no output pin.

Applications

The application shown in Fig. 2 is by no means definitive. Improvements in this design can be made by changing the rf input stage to a jfet (**Fig. 5**), a dual-gate mosfet (**Fig. 6**) or even a gaAsfet. Since receiver sensitivity is determined by the selection of this stage, a device must be chosen to give a noise factor and gain which presents sufficient input to give full limiting (8μV) and enough sensitivity for a reasonable signal to noise ratio with the signal being received. The market abounds with suitable alternatives to those given (e.g. *U310, BF800, BF981, 3SK51, 3N200, 3N140* etc.). Depending on which is chosen, the component values will have to be modified to suit the transistor selected.

The ceramic filter connected to L_4 determines the degree of rejection of image signals and so should have a good out-of-band rejection characteristic, while the filter connected to IFT_1 determines the overall receiver bandwidth and adjacent channel rejection. The first filter could be replaced by a saw filter, and the second by a crystal filter, if improved performance is required.

The circuit shown in Fig. 2 has an audio filter which tailors the audio for speech reception in series with the af amplifier. If this is not required for reasons of cost or fidelity, it can be omitted, and a simpler circuit using a 50kΩ volume control can be used.

As shown in Fig. 2, the *ULN3883A* is used with (a) a crystal oscillator using the onboard circuitry; (b) a tuned *LC* oscillator, again using the onboard circuitry; or (c) either of the above using an external oscillator or a synthesiser. If option (c) is required, a signal with an amplitude of 500mV is required at pin 13 of the *ULN3883A*.

The device is, of course, not limited to acting as a single superheterodyne receiver. As indicated, it can also act as the second mixer/oscillator and IF amplifier in either a fixed capacity or as a tuneable If with a broadband front-end circuit. This practice is very common in vhf and uhf receivers where it is difficult and expensive to manufacture stable oscillators or synthesisers. ■

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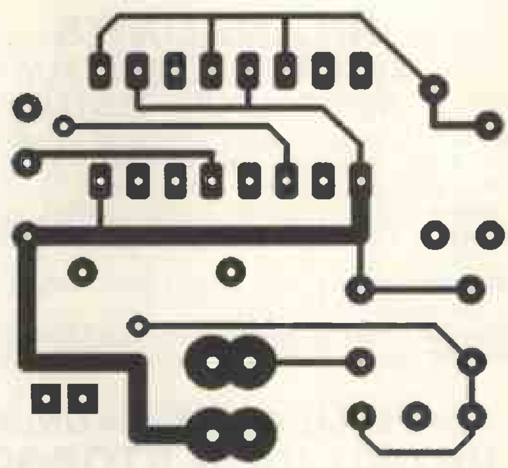

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Smash – simulation via Windows

***Smash* – the subject of this month's free disk offer – is a multi-level, mixed-mode simulator running under Windows and featuring true behavioural modelling.**

The simple example, starting on the right, demonstrates the possible analyses in *Smash*. As it may be the first example you will try, it is kept simple, being purely analogue and using only primitives. However, it demonstrates features like parameter sweeping and Monte Carlo analysis. It is a simple *RC* network, the demonstration files for which are on the evaluation disk. The disk is a fully-working version of *Smash*, limited only to 25 analogue and 50 digital nodes.

Notes on behavioural modelling

Behavioural modelling is a term you have probably heard a number of times. The fact is that most often, people talk about behavioural modelling as soon as the model is not a low-level primitive – a transistor or gate.

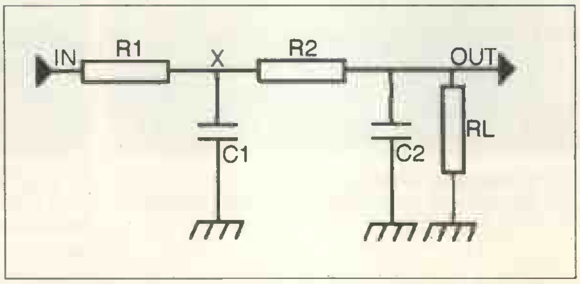
This is particularly true where analogue simulation is concerned. Some people even consider, or want you to believe, that a G device (i.e. Spice-device) is a behavioural model. But genuine behavioural modelling goes far beyond this.

The designation behavioural has long been reserved for a design method that describes parts of your systemvia a high-level programming language. Behavioural means that you describe the way a component works, without presuming the way it is actually implemented. The purpose of the method can be to make an architectural study of a system at early stages of the design, before implementation has been fully decided. Or you can use it simply to increase the speed of a simulation – a few lines of code can easily replace thousands of transistors or gates.

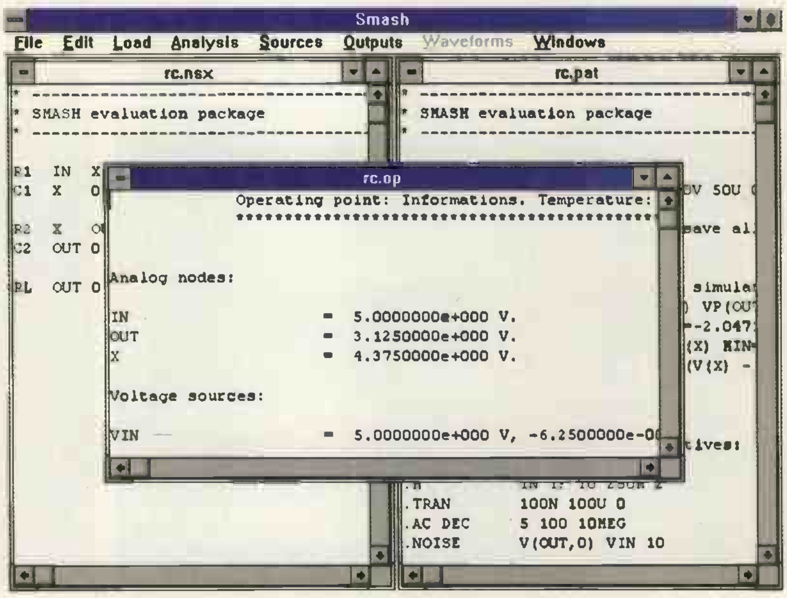
There is nothing wrong with using a different term (behavioural) for differentiating things which do not readily map to anything physical, like a G-device, a Laplace-defined block, or a non-linear equation. But you should be aware that behavioural modelling may have more than one meaning.

In *Smash*, you can use Laplace-defined blocks and non-linear conditional equations. But the true power of the software comes from its capacity to mix genuine behavioural models – both analogue and digital – with primitives. As the *Smash* HDL is based on the popular C language, you can use variables, complex control structures – loops, etc – and all the features available in a high-level programming language.

Since these models are compiled, not interpreted, they are highly efficient and you can simulate complete systems, ics and/or pcbs, that you would not be able to simulate with any other tool.



A: This is a simple RC circuit used to demonstrate some of Smash's features.



B: These three windows are the netlist, pattern and operating point files for the simple RC circuit. These files are contained on the evaluation disk in the 'eval' folder (example continued over)...

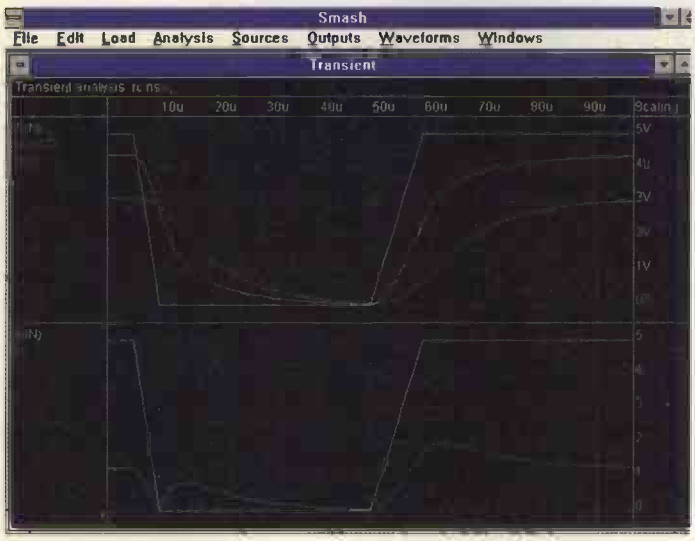
Free CAD software offer

The full version of the Smash multi-level, mixed-mode simulator costs £1500. The first 1000 EW+WW readers sending in the coupon opposite this page can obtain a size-limited but otherwise fully functional evaluation version of Smash free of charge.

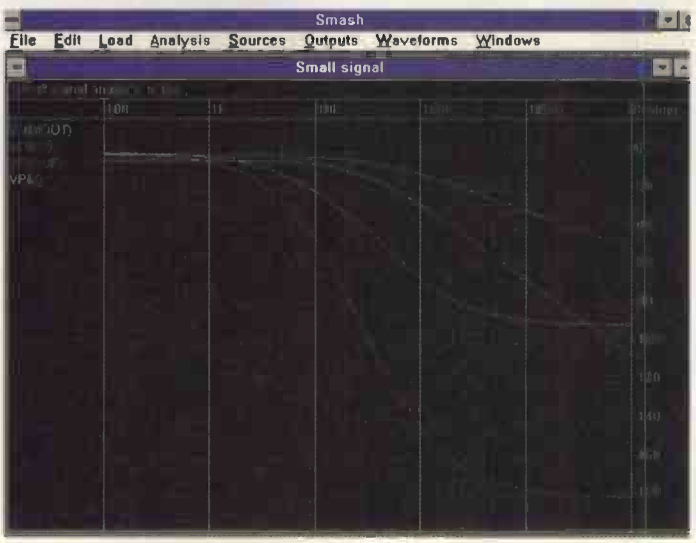
Smash and schematic entry

There is no proprietary schematic entry in *Smash*. Instead it interfaces at the netlist level with commercial schematic entry packages. Basically any schematic entry program with a Spice netlist output can be used with *Smash*.

Some packages are tightly integrated with *Smash*, with libraries available etc. Among these are *DesignWorks* from Capilano Computing, *ECS/Synario* from Data I/0, and *Opus 4.2.2* from Cadence. The *DesignWorks* and *ECS/Synario* libraries for *Smash* are contained on the evaluation floppy. ■

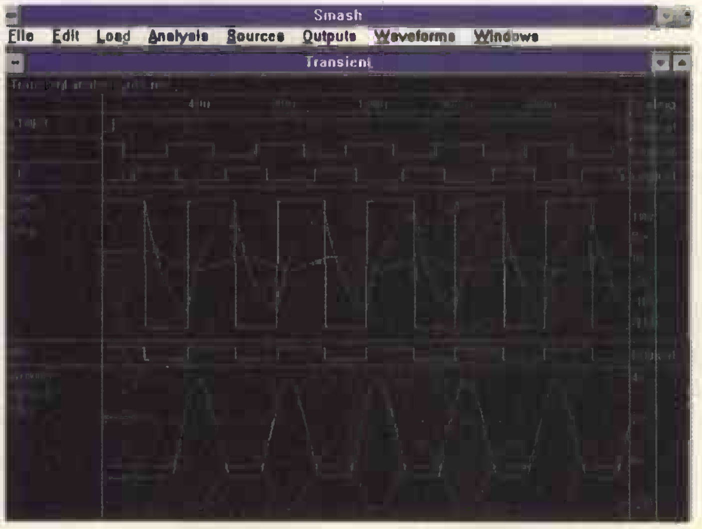


C: Analysing the circuit for transients is simply a matter of selecting the transient parameters under the Analysis menu and running the routine.



D: Small-signal analysis is equally simple. Note that running this analysis does not result in the previous transient analysis window being lost. Waveform processing – zooming, measuring etc – is available, even when a simulation is running, through the commands under the Waveforms menu. You may add new signals in the window with the Add analogue signals item. A dialog box displays a list of available signals. Simply double-click the name of the signals you want to view.

E: In Monte Carlo analyses component values are varied at random, according to specified statistical distributions and tolerances. Also, the analyses are re-run a number of times. In this way, you can simulate how off-the-shelf component tolerances affect the circuit's response.



F: An example of running the transient analysis routine for a mixed analogue and digital circuit. In this case, Smash has to deal with both analogue voltages and logic levels. Whenever a node connects to both analogue and digital components, it becomes an interface node.

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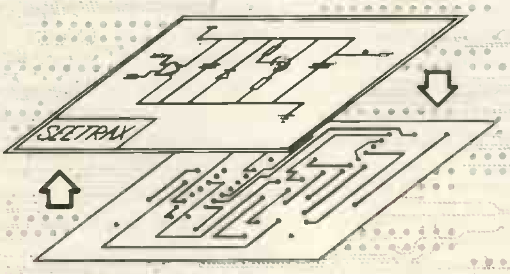

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Oscillating AT uhf

Two basic circuit configurations are responsible for most oscillator designs working at frequencies up to the uhf range. Ian Hickman describes the often conflicting requirements of uhf oscillators – including a disadvantage of the emitter-follower now put to good use.

Oscillators for frequencies to uhf and beyond have been built using all sorts of active devices, from valves onwards. Most of them use three terminal active devices, often connected to a simple tuned circuit in one of two basic ways, which were enumerated for my benefit as a student by an older colleague of many years experience with the aid of a sketch which I call *O'Connor's Universal Oscillator Circuit*, **Fig. 1**. It is drawn in an unconventional way to emphasise the following points.

For the circuit to function as an oscillator, Z_2 and Z_3 must be reactances of the same sign – both inductances or both capacitances – while Z_1 must be of the opposite sign. With this proviso, the diagram shows that, relative to the cathode (emitter, source), the voltages at the other two electrodes are in antiphase.

No earth connection is shown, since in principle the circuit could be provided with the necessary power supplies via ideal rf chokes of infinite reactance at the operating frequency, and *a, g* or *k* earthed as convenient, or the whole circuit left floating.

If Z_1 is an inductor with capacitors at Z_2, Z_3, the circuit is a Colpitts oscillator, whilst if a tapped inductor forms Z_2 and Z_3 with Z_1 being a capacitor then the circuit is a Hartley oscillator. One way or another, all three electrodes of the active device must be connected to the tuned circuit.

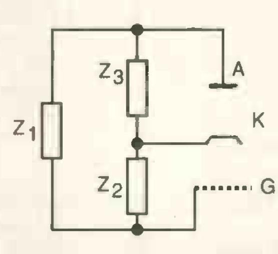


Fig. 1. O'Connor's universal oscillator circuit. Z_1 is a reactance of one sign while Z_2 and Z_3 are both of the other. For 'valve' read n-p-n bipolar, n-channel fet, hemt etc, as appropriate.

Many other circuit arrangements are possible, some using more than one active device, a variety being shown in **Fig. 2**. However, at uhf a circuit using a single device, connected as in Fig. 1, often proves best because additional phase shifts associated with a second active device or parasitics associated with coupled windings introduce additional complexities into the design process, effects that would be smaller or negligible at vhf or hf.

Colpitts oscillator

As a basis of a signal generator, an oscillator with a wide tuning range is required. While at one time this would have been tuned by a precision mechanical variable capacitor, in a more modern application varactor tuning will usually be employed, permitting accurate frequency control by means of a phase-lock loop. With a possible application in view, I experimented with what might be regarded as a Colpitts oscillator, if you draw in the transistor's internal base/emitter capacitance to go with the 3.3pF external collector/emitter capacitance as Z_2 and Z_3, **Fig. 3(a)**.

In a wide-range oscillator, one needs to be able to vary its frequency over a wide range at will, but then instantly have its frequency as stable as a rock once one has set it to a particular desired frequency. To start with, it pays at the outset to design the oscillator circuit to have very stable dc conditions, ensured in Fig. 3(a) by the supply regulator, and by the base bias chain with its low source resistance at dc, which is moreover well decoupled at rf. As first constructed, the oscillator covered from under 400MHz to over 600MHz, but was modified as shown for the intended purpose to cover well over 200MHz centred on 400MHz.

This is shown in Fig. **3(b)**. The oscillator was tuned back and forth across its range during the six-second exposure required by the home-made oscilloscope camera, which does duty also for my spectrum analyser. There is a general slope in level of several decibels across the tuning range. But the superimposed ripples are due to the connection to the spectrum analyser. This effect was demonstrated by doubling the length of coaxial cable used for the connection, which gave twice as many ripples. Clearly, the analyser's input impedance isn't exactly 50Ω on the most sensitive range used; switching in 10dB at the input attenuator largely removed the ripples.

Base-current phase shift

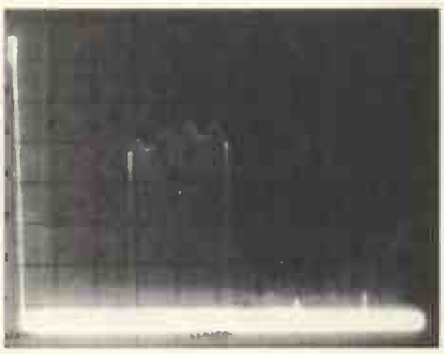
It is a convenient fiction that, in common-cathode, emitter or source mode, an active device is an inverting amplifier, i.e. that the voltages at the other two electrodes are in antiphase. This is true in the case of valves up to fairly high frequencies, since the velocity of electrons *in vacuo* is a good deal faster than minority carriers in silicon. But in a transistor, phase shifts start to show up even in high-frequency devices at a much lower frequency, as is illustrated in **Fig. 4**.

Figure **4(a)** shows the relation between the currents in the three electrodes of a transistor at dc, and recaps on the relation between the current gains α and ß. The latter is often also called α′ or h_{FE}. Figure **4(b)** shows how even a small phase shift in the collector current can result in a phase shift in the base current which is much larger, and moreover in the opposite direction.

In the simplified treatment given here, any phase shifts suffered by the base or collector currents after they part company, due to 'transmission line delay' in different regions of the bulk of the semiconductor, are assumed to be negligible.

The higher the dc value of ß, i.e. the more nearly the magnitude of the collector current equals that of the emitter, the smaller the phase shift in the collector current needed to give a 45° advance to the base current. For an audio-frequency transistor such as the *BC109* with its typical ß of 300 and f_T of 300MHz, this occurs at around 1MHz. At higher frequencies, the base current can lead the emitter current by not far off 90°.

An emitter follower is an extremely useful and widely used circuit, acting as a buffer and permitting a high-impedance source to drive a lower-impedance load. But the circuit has an unfortunate tendency to oscillate, particularly if the load is a bit capacitive. The phase advance suffered by the base current is the culprit.



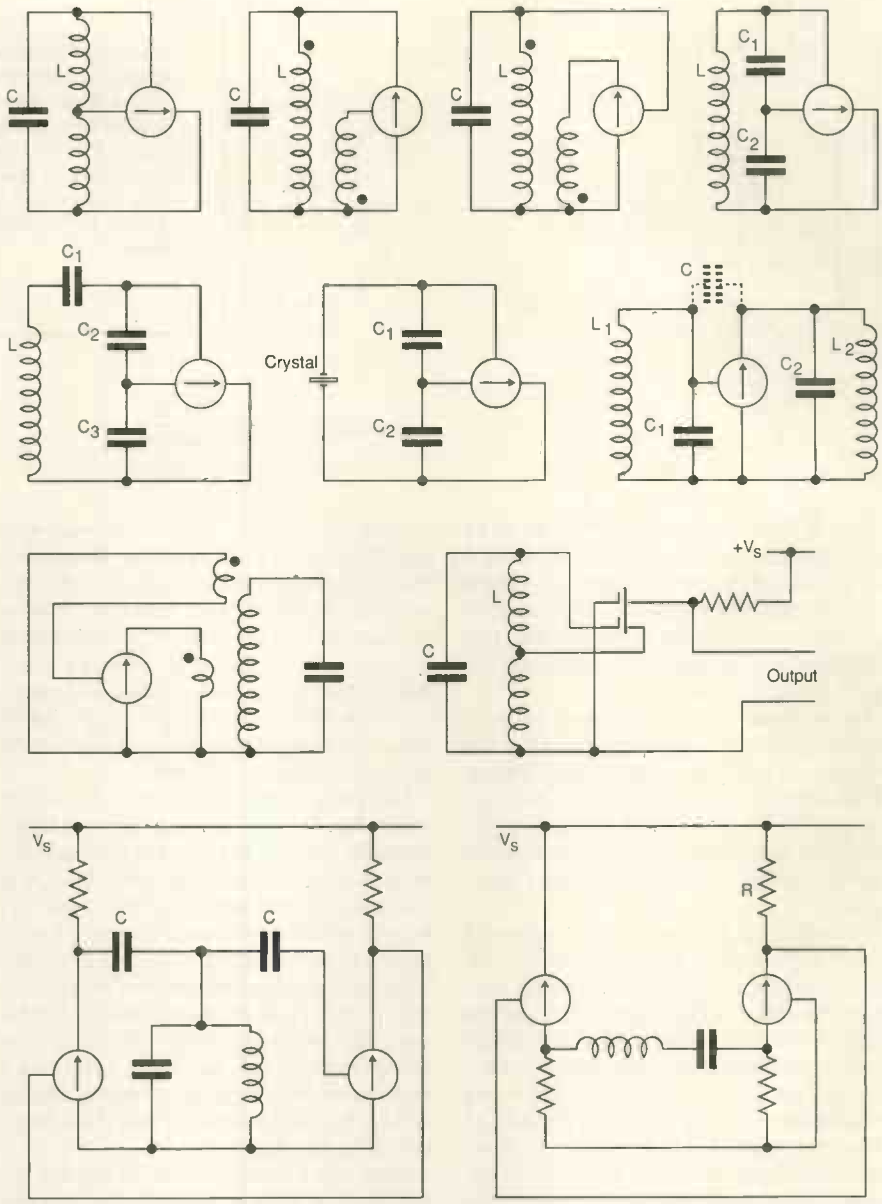
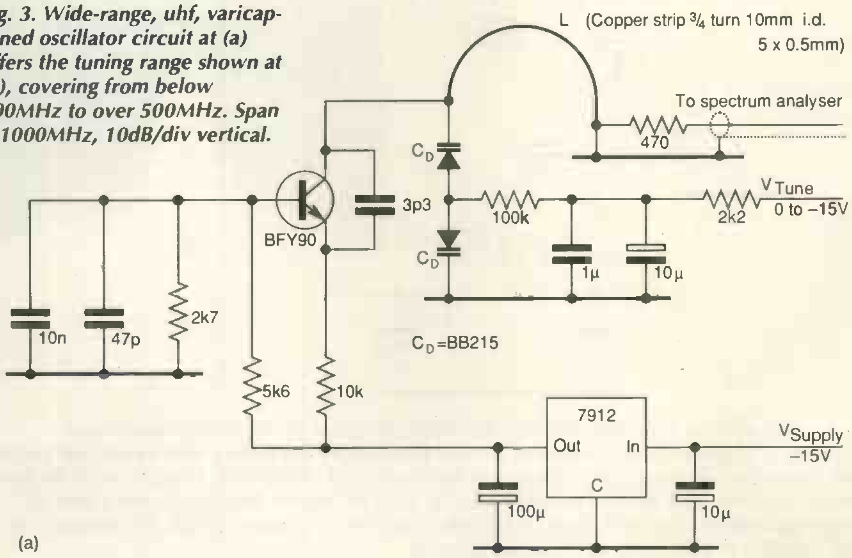
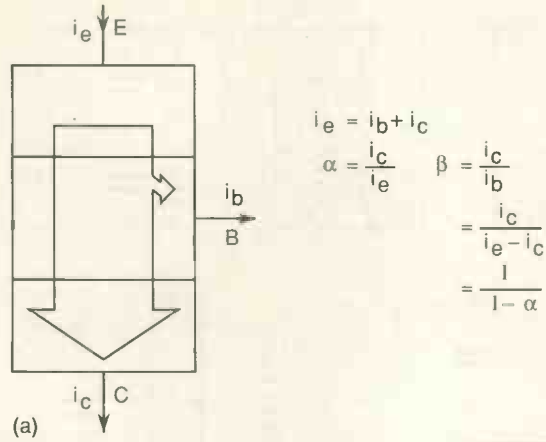


Fig. 2. A variety of oscillator circuits, some more suited to lower frequencies, reproduced from Newnes Practical RF Handbook *published by Butterworth Heinemann.*

Fig. 3. Wide-range, uhf, varicap-tuned oscillator circuit at (a) offers the tuning range shown at (b), covering from below 300MHz to over 500MHz. Span 0-1000MHz, 10dB/div vertical.





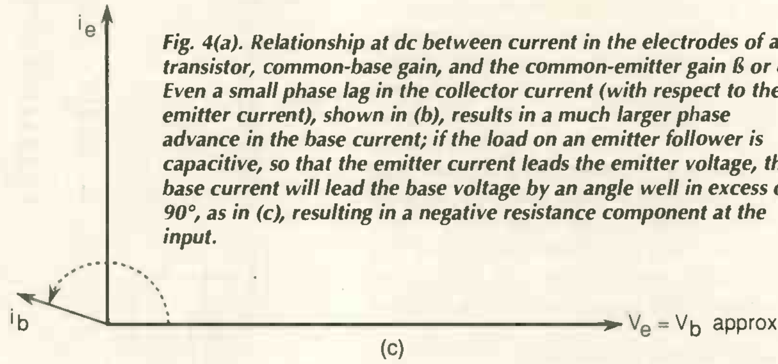


Fig. 4(a). Relationship at dc between current in the electrodes of a transistor, common-base gain, and the common-emitter gain ß or α. Even a small phase lag in the collector current (with respect to the emitter current), shown in (b), results in a much larger phase advance in the base current; if the load on an emitter follower is capacitive, so that the emitter current leads the emitter voltage, the base current will lead the base voltage by an angle well in excess of 90°, as in (c), resulting in a negative resistance component at the input.

This is illustrated in Fig. **4(c)**. Here an important assumption is made: the mutual conductance of the device is high (its output impedance low compared to the impedance of the load connected to the emitter) so that, to a first approximation, the voltage at the emitter equals that at the base.

As the emitter current is leading the base voltage by up to 90°, with a purely capacitive load, and the base current substantially leading the emitter current, it follows that the base current leads the base voltage by well over 90°. The input impedance consists of a negative resistive component in parallel with a capacitance.

This effect has been used as the basis of a microwave oscillator design producing over 100mW output at 2GHz[1]. It can equally well be used at uhf, and **Fig. 5** shows just such an application. The reactance of 18pF at 345MHz is 25Ω, doubtless effectively reduced somewhat by the inductance of the leads even though these were kept as short as possible, so the emitter circuit load is almost purely capacitive. The capacitance tuning the inductor consisted only of the capacitive component of device input impedance, and device and circuit strays.

If the circuit of Fig. **5(a)** is compared with that of Fig. 3, it will be seen to be almost identical. In both cases, the collector is connected to the opposite end of the tuned circuit from the base, while a capacitor is connected from the emitter to the collector end of the tuned circuit. Thus in fact most oscillators operating at vhf or above and using a single active device are likely to be found on analysis to be negative resistance oscillators.

Depending on the *Q* of the tuned circuit (and that in Fig. 5(a) was certainly not very high), the noise performance or short term stability of such an oscillator can be good, though of course the medium and long term stability will be poor unless the oscillator is used as a voltage-controlled oscillator in a phase-lock loop.

Figure **5(b)** shows the output of the Fig. 5(a) circuit, the centre frequency being 345MHz and the horizontal scale 5kHz/division. Analyser bandwidth was set to 1kHz and a great many sweeps occurred during the six second exposure needed to record the background and graticule.

Some noise modulation is evident but the overall shape is not so very different from that of the analyser's 1kHz filter. However, towards the end of the exposure the oscillator took it into its head to start wandering up in frequency; a stability of 1kHz in an open-loop uhf oscillator could be achieved, but only with a more sophisticated circuit, using a high-*Q* cavity resonator for example.

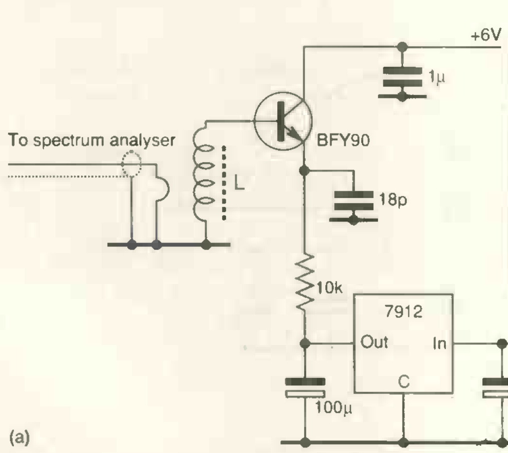
Line stabilisation

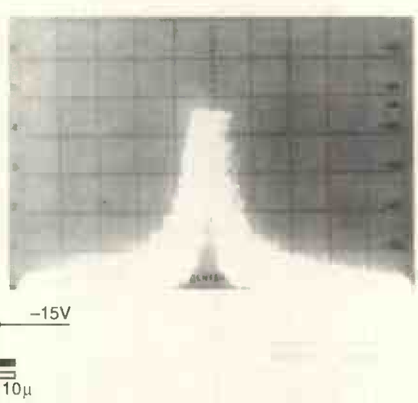
Another arrangement providing improved frequency stability without resorting to a phase-locked loop is the line-stabilised oscillator. Using a line consisting of 150cm of 50Ω miniature coaxial cable, believed to have a velocity ratio of around 0.66, with its far end shorted, the Fig. 5(a) was modified to work in this mode. A tuning capacitor was added to enable the tank circuit to be tuned to a frequency at which the emitter load looked capacitive. It oscillated at 235MHz, at which frequency the length of the line would be just over one and three quarter wavelengths, i.e. capacitive.

Clearly there are other frequencies, both higher and lower, at which the line looked capacitive, for example where the line length is 5/4λ, 9/4λ, 11/4λ etc, and the tuned circuit is used to pick out one of these as the operating frequency. If the tank circuit *Q* is high and the regeneration only just sufficient to ensure oscillation, then only one of these modes can be sustained. If the tank *Q* is lower and the negative resistance much lower than necessary to sustain oscillation, the circuit can oscillate in several modes at once.

This was the case when the collector supply was the same as in Fig. 5(a). Reducing collector voltage until it equalled the base voltage, as shown in **Fig. 6(a)**, prevented oscillation in several modes simultaneously. With a constant tail current generator or rf choke/resistor combination in place of the 10kΩ resistor to −12V, the oscillator circuit would work happily on a supply of a volt or two.

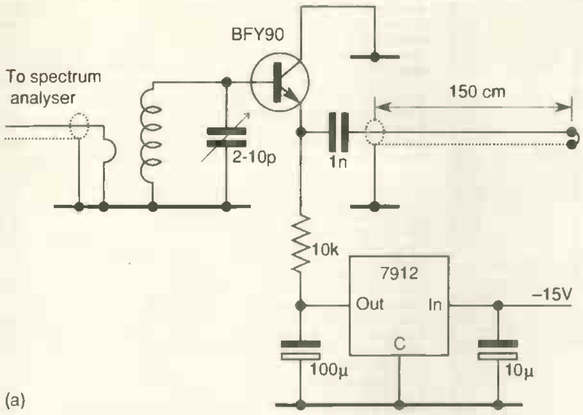
Output from the loosely coupled winding was as in Fig. **6(b)**, where the span is 0-1000MHz and the fundamental at **235MHz** is visible, together with the second, third and fourth harmonics. Figure **6(c)** zooms in on the fundamental, at 5kHz per division horizontal. At the selected video filter bandwidth, a single sweep took six seconds and at 60dB down, the



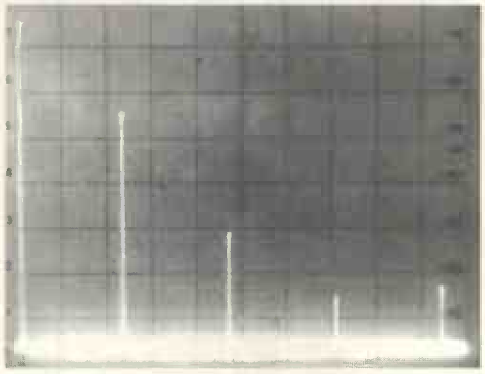


(b)

Fig. 5. Uhf oscillator at (a) uses the negative input resistance effect, tuning capacitance consisting of the capacitive component of base circuit input impedance plus device and circuit strays. Inductor L is three turns (spaced one wire width) of 16swg tinned-copper wire, on 5mm internal diameter with a 3.75mm ferrite slug. At (b) is the output from the loosely coupled, single-turn winding, centre frequency 345MHz, 5kHz/div. horizontal, 10dB/div. vertical, ref. level −10dBm, IF bandwidth 1kHz, video filter off.



(a)



(b)

Fig. 6. Simple and fairly crude line-stabilised oscillator (a) gives output at (b); span 0-1000MHz, 10dB/div vertical, ref. level (top of screen) –10dBm. Fundamental component of (b) shown in (c), with centre frequency 235MHz and horizontal scale 5kHz/div, IF bandwidth 1kHz, video filter at max. (giving a post-detector bandwidth of 1.5Hz), 10dB/div. vertical, ref. level –30dBm.

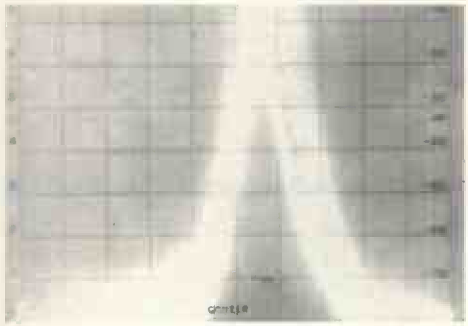
response is 15kHz wide, which is more or less identical to the analyser's 1kHz filter specification.

Of course, a length of coaxial cable does not make for a very convenient line stabilised oscillator. Even if semi-rigid, solid-outer coaxial were used, the stability of the oscillator with temperature would not be wonderful. But line stabilisaton is now very attractive and competitive, in the form of surface acoustic wave resonators.

Owing to the extremely slow propagation speed of acoustic waves in lithium niobate – slow at least compared with the speed of light – a compact package can contain a line length of many wavelengths. Such devices are used at uhf in lieu of crystals, where tight frequency control is required. An example is the range of 418MHz telemetry modules featured in Ref. 2.

Connecting a negative resistance across a tuned circuit results in an oscillator, and the negative resistance need not imply a three terminal device. Many years ago a two terminal device – the tunnel diode – was a popular means of making uhf oscillators. This was at a time when transistors with adequate performance were not available, or at best very expensive.

Now that transistors with more than adequate performance are common and cheap, the tunnel diode uhf oscillator has taken a back seat. But negative resistance two terminal oscillator circuits are still used at microwave frequencies, in the form of the Gunn diode oscillator. ■



(c)

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2. Hickman I. Low power radio links, *EW+WW*, February 1993, pp. 140-144.

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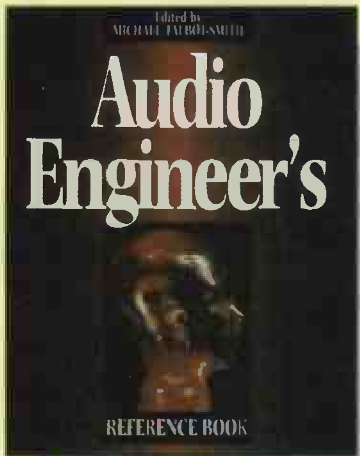
For Audio Engineers



Subjects include

- Recording, microphones and loudspeakers
- Digital audio techniques
- Basic audio principles
- Acoustics and psychoacoustics
- Audio and television studios and their facilities
- Radio and telephony

- Comprehensive – over 600 pages
- Written by leading authorities from the audio world
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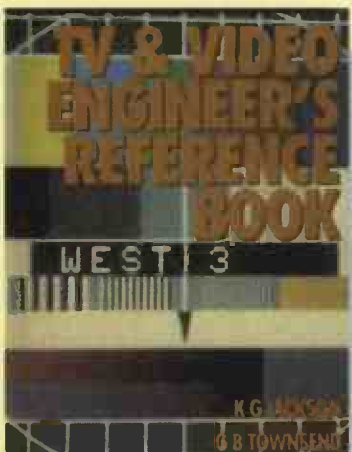
- Concise and authoritative
- Covers topics from noise measurement to studio installation

Invaluable reference work for anyone involved with audio – from broadcast consultant to serious enthusiast. *Audio Engineer's Reference Book* is written by an international team of experts and edited by Michael Talbot-Smith – previously a trainer of audio engineers at BBC Wood Norton and now a freelance audio consultant and technical writer.

For TV & Video Engineers



Subjects include

- Fundamentals of colour TV
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All-in-one mains monitor

£100 WINNER

All the components of this monitor will work separately or form a complete indicator of the health of a mains supply, showing the presence of spikes, over/under voltage or voltage fluctuations and containing a mains noise filter.

Filter. Removes the 50Hz waveform to reveal the presence of noise and harmonics, heard on a speaker, and spikes indicated by a bicolour led, which shows by its predominant colur whether the spikes are positive or negative. Adjust the 22kΩ pot. in the filter for least light from the led.

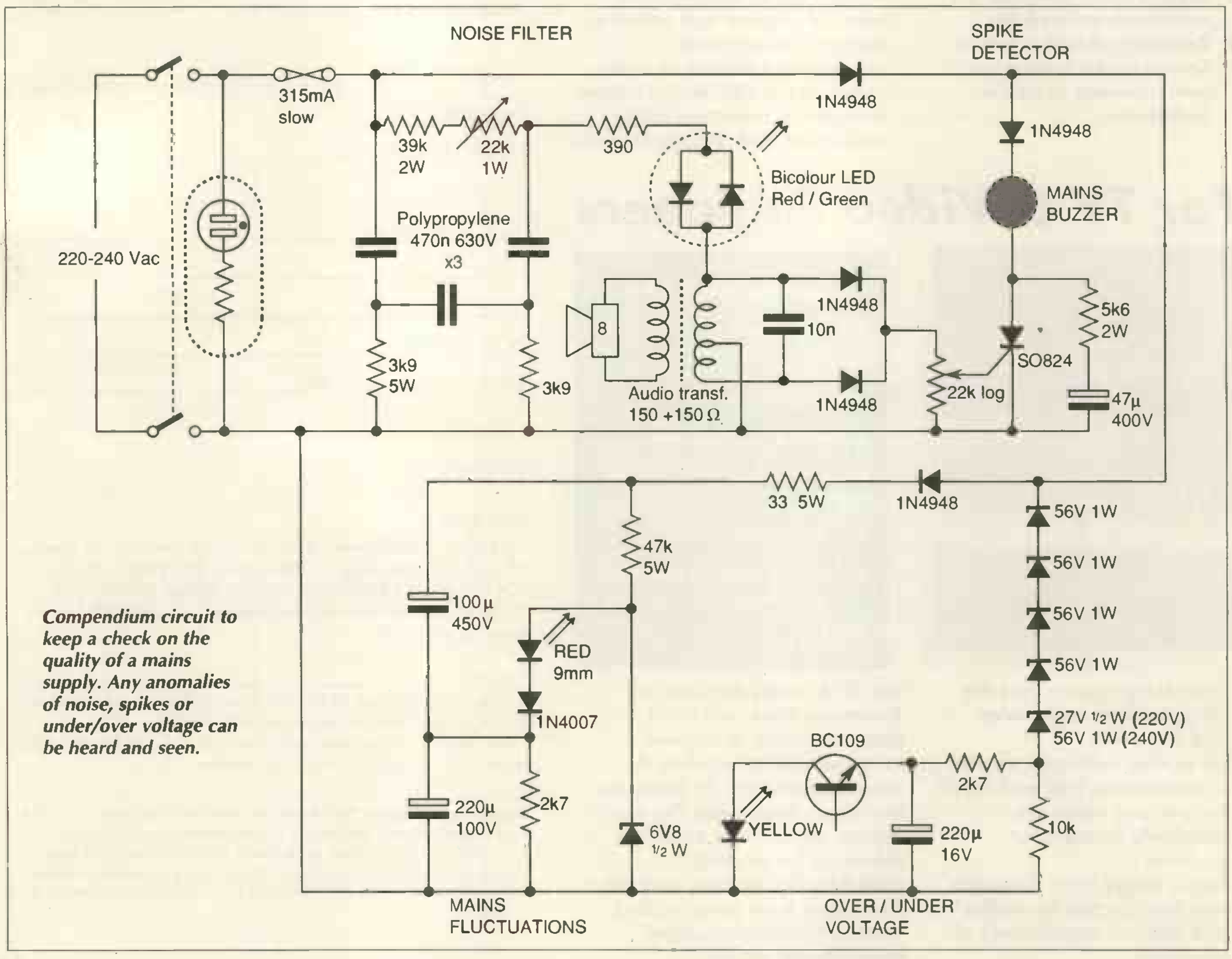
Spike detector. Spikes on the rectified filter output trigger the SCR and sound the buzzer for just under 1s, until current is established through the SCR. Triggering occurs when household appliances switch on and off and the 2.2kΩ pot. should be adjusted so that the circuit does not trigger when the monitor is switched on. Do not use a sensitive SCR.

Over/under voltage. Normally, the led flashes at around 6Hz, this frequency doubling for a +10% mains voltage change and stopping for a –10% variation. Choose the correct zener for the relevant mains voltage.

Mains fluctuations. Significant variations in mains voltage modulate the red led heavily, from full on to off, independently of average mains voltage.

Bear in mind that the circuit is connected to the mains and that the large capacitors will probably stay charged for some time.

D Di Mario
Milan
Italy



Compendium circuit to keep a check on the quality of a mains supply. Any anomalies of noise, spikes or under/over voltage can be heard and seen.

YOU COULD BE USING A 1GHz SPECTRUM ANALYSER ADAPTOR!

Got a good idea? Then this Thurlby-Thandar Instruments TSA1000 spectrum analyser adaptor could be yours.

Covering the frequency range 400kHz to over 1GHz with a logarithmic display range of 70dB ±1.5dB, it turns a basic oscilloscope into a precision spectrum analyser with digital readout calibration.

Recognising the importance of good design, **TTI will be giving away one of these excellent instruments every six months** to the best circuit idea published in the preceding period until further notice. **This incentive will be in addition to our £100 monthly star author's fee, together with £25 for all other ideas published.**

Our judging criteria are ingenuity and originality in the use of modern components – with simplicity particularly valued.

Thermally stable current source

This thermally stable current source features very high dynamic impedance, high output voltage swing and wide bandwidth.

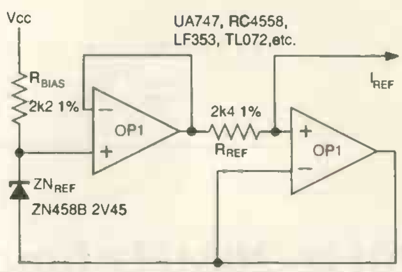
In the connection shown, the op-amps maintain the same voltage drop across R_{ref} as across the reference diode, so that the output curent is precisely determined. Op-amp OP_2 sinks bias current, which has therefore almost no effect on I_{ref}.

Highest instantaneous output voltage is given by the highest value of Rbias consistent with there being enough bias current to operate the diode, while the lowest R_{bias} value is determined by the maximum power from OP_2. Output current and reference voltage determine the value of R_{ref}.

With values given, a 24V supply and 1mA output, a 2.2kΩ R_{bias} gives 50mW of power in OP_2; R_{ref} gives the 1mA output when used with a Plessey *ZN458B* reference diode and the minimum diode current gives a 17V output swing.

Since both op-amps act as buffers, it is unnecessary to use high-performance types, although improvements would be seen. As it is, the circuit works well over the audio range with any op-amp and diode.

Andrea Scozzari
Livorno
Italy



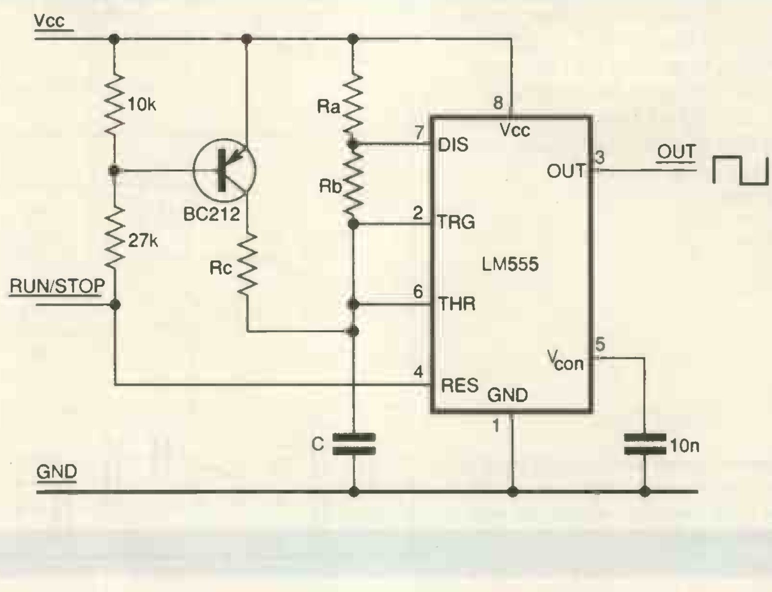
Current source provides very high thermal stability. Output current is determined by value of R_{ref} and diode voltage.

Positive start for 555 oscillator

Using a 555 as an astable oscillator in a digital delay circuit entails holding the reset pin low until the oscillator is required to start. Normally, this causes the timing capacitor to discharge completely via the timing resistor, so that the first charge is longer than succeeding ones at $1.1(R_a+R_b)C$ instead of $0.69(R_a+R_b)C$.

To avoid the effect, the capacitor must be held at $V_{cc}/3$ when the oscillator is stopped, by means of the p-n-p transistor controlled by the run/stop signal, R_c being $2R_b$.

Mike Aldington
Gillingham
Kent



Circuit prevents total discharge of timing capacitor in 555 astable oscillator when oscillator stops, ensuring time of first mark period same as subsequent cycles.

Prescaler functions to 1.3GHz

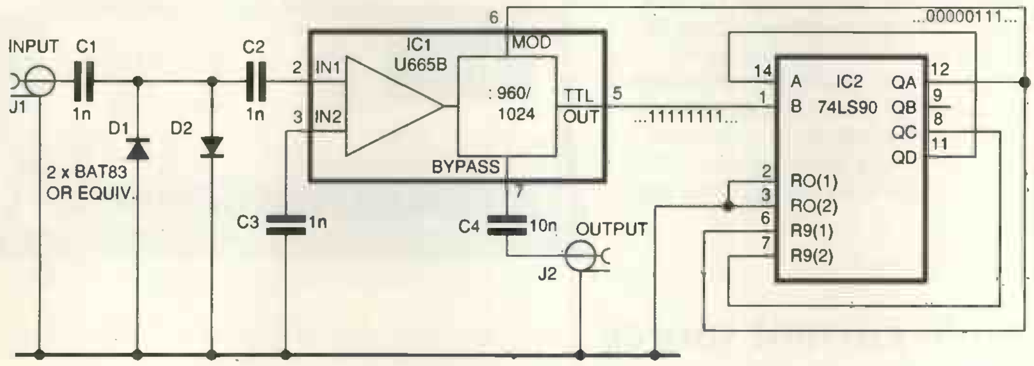
Using two ICs, a *74LS90* and a *TFK U665B* two-modulus (960/1024) divider, the circuit divides frequencies up to 1.3GHz by 1000.

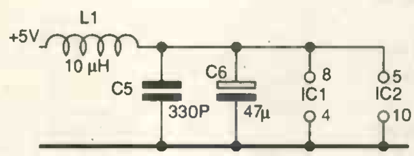
A logic level on the *665B*'s mod input, pin 6, determines which modulus is used – logic zero gives 1024 and one, 960. Pulses from the QA output of the *74LS90* decade divider form the sequence 00000111 to give 5 at 1024 and 3 at 960 (5×1024+3×960=8000 input pulses for eight output pulses, or 8000/8=1000).

Biquinary connection of the *74LS90* allows forced resetting to 9, when its natural output is 7, by the connection of its reset-9 inputs to QA and QB. One's first thought, that a shift register might perform the function, is not valid, since glitches and noise have a tendency to cause errors.

For connection to a long output lead, use the prescaled output on pin 7.

Stefano Pigozzo
Belluno
Italy





Two ICs, one of them a two-modulus type, divide 1.3GHz by 1000.

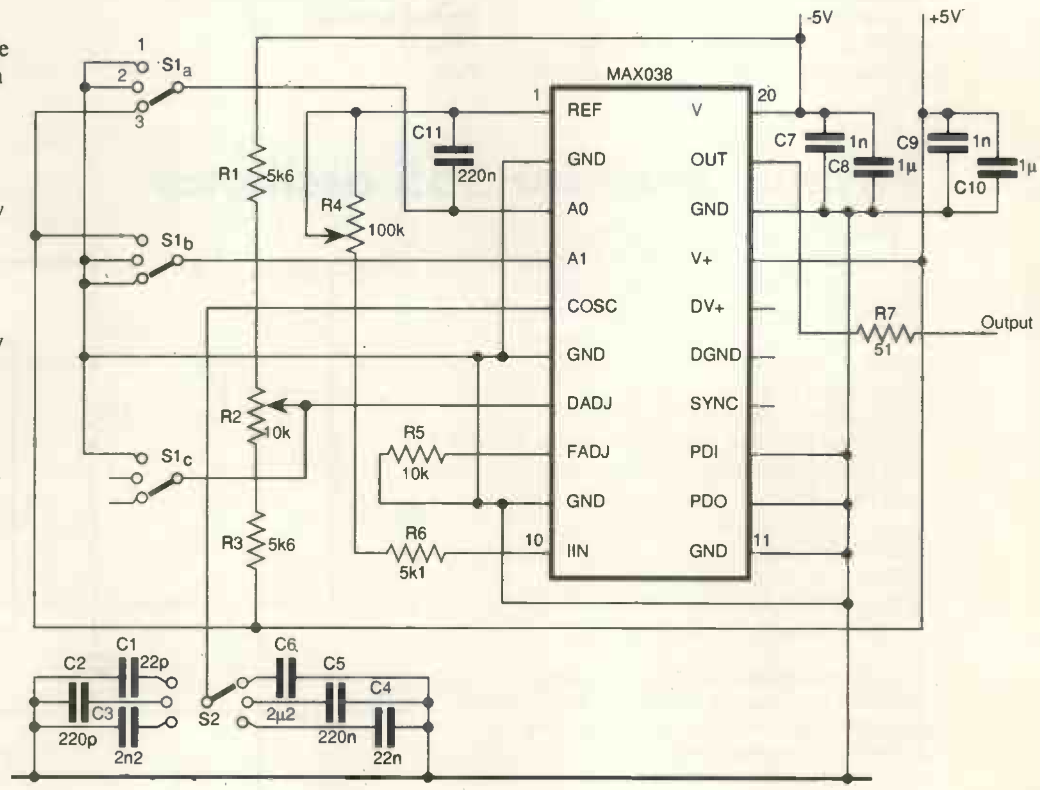
20Hz-20MHz function generator with duty-cycle adjust

Giving a 2V pk-pk output, the Maxim *MAX038* is a 20Hz-20MHz function generator providing sine, square and triangle waveforms with an adjustable duty cycle on squares and triangles of 15%-85%.

Logic levels on A_0 and A_1 pins select the output waveform; position 1 of *Sw*1 gives sine, 2 square and 3 triangle. Output frequency depends on current into I_{in}, set by $R_{4,6}$ and the 2.5V reference voltage output, and the values of $C_{1\text{-}6}$ on the C_{osc} pin, selected by Sw_2 to give six 10:1 ranges.

Varying the voltage on the DADJ pin between –2.3V and +2.3V by R_2 varies duty cycle from 15% to 85% when square and triangle waves are in operation.

Yongping Xia
Torrance
California
USA



Flexible function generator uses MAX038 to provide sine, square or triangle waveforms over a very wide frequency range and with adjustable duty cycle.

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On board ISO 7816 Card Reader Socket (Videocrypt etc). Software runs on IBM/PC enabling the user to read & write to card. Board also contains a PIC16C84 programmer. Ideal smart card development tool — £59.95
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Tiny 72mm x 42mm PCB contains socketed 44 pin CPU, turned pin rom socket, 12 MHz xtal and ports 1, 3 output on IDC connector. Ideal for stand alone projects or development work. Supplied with CIRCUIT & MCS8051/52 development software — £49.95

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Replaces all 18 or 28 pin PICs. All ports Bi-directional, OSC2 output, RTCC input. On board A/D converter for PIC167C1. Supplied with **PICDEV54** and **PICDEV71** software, manual, connecting leads & headers, ASM examples, and hardware circuit projects. — £159.95

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- Includes 2 software packages, the first is a TSR which runs under DOS, the second runs as a minimised window in Microsoft Windows

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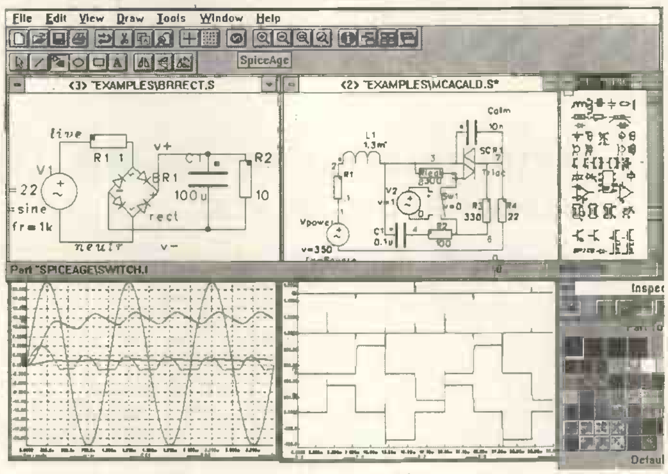
Tel: 01179 699352 Fax: 01179 872228

CIRCLE NO. 140 ON REPLY CARD

The new schematic capture program *Geswin* (*GESECA* for Windows™) adds more than a pretty face to *SpiceAge*. **Upgrade for £100+VAT***



- *Geswin* DDE links with *SpiceAge* to provide instant circuit editing. Because this link enables *SpiceAge* to retain all its simulation settings, the schematic (produced by *Geswin*) is uncluttered so that you can create clean drawings that may be clipboarded into your other Windows applications.
- You can clipboard sections of your netlist from *SpiceAge* back into *Geswin*'s attribute Inspector if you wish to use patches of existing circuits.
- *Geswin* has inherited *GESECA*'s speed and ease of use. You will find it's best-loved *"bucket of bits"* components' store waiting for your instant use from a special self-replenishing window.
- The *SpiceAge* component library has been expanded and re-drawn into "stubbies". The new symbols allow more components to fit within a given screen area without compromising clarity.
- Multiple windows allow you to scratch pad your designs (simulating as you work) and clipboard them into a fair copy window.
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Those Engineers Ltd

CIRCLE NO. 141 ON REPLY CARD

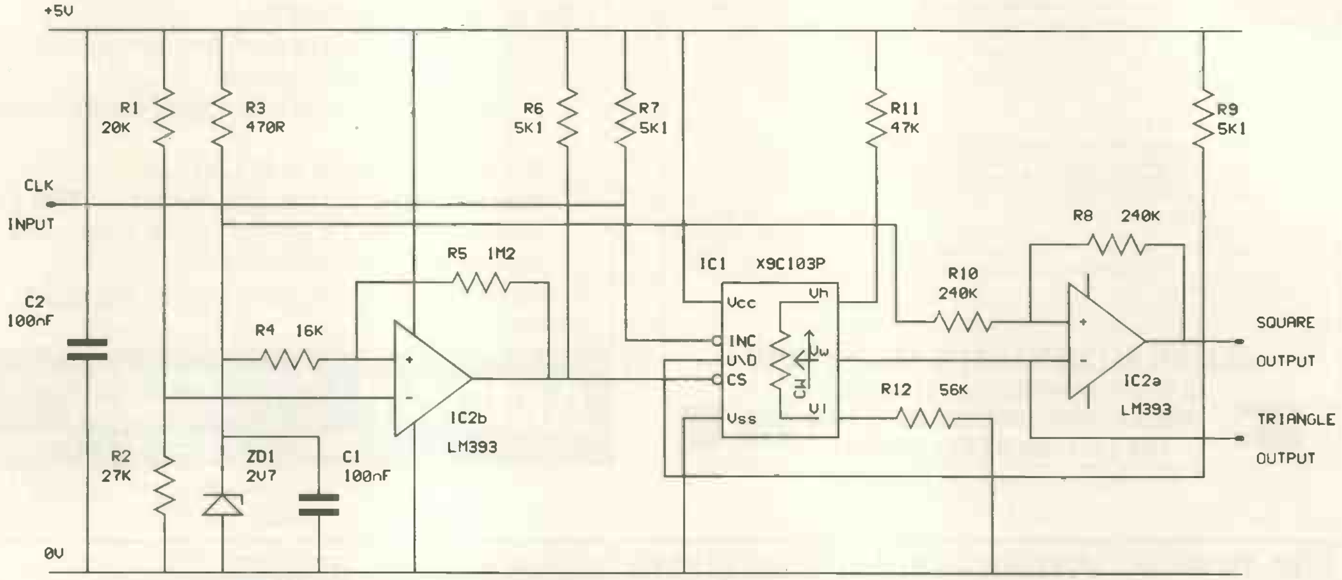
Bistable switch

Providing a bistable output that reverses after a set time in each state, this switch continues in the same state after a loss of power.

Digitally controlled potentiometer IC_1 – a *Xicor X9C103P*, for example – and comparator IC_{2a} are the basic elements, IC_1 wiper moving its complete travel when 100 pulses are applied; the values of the potentiometer and $R_{11,12}$ determine the full-scale output voltage. As the hunredth pulse arrives, the potentiometer output voltage to the comparator exceeds the reference voltage from the zener, the output changes state and the potentiometer changes the direction of travel.

To ensure that the chip-select line of the potentiometer is low after the power supply has settled and high before it falls below the 4.5V lowest working voltage of IC_1, IC_{2b} controls this input to the potentiometer.

A J Stephenson
Seaford
East Sussex



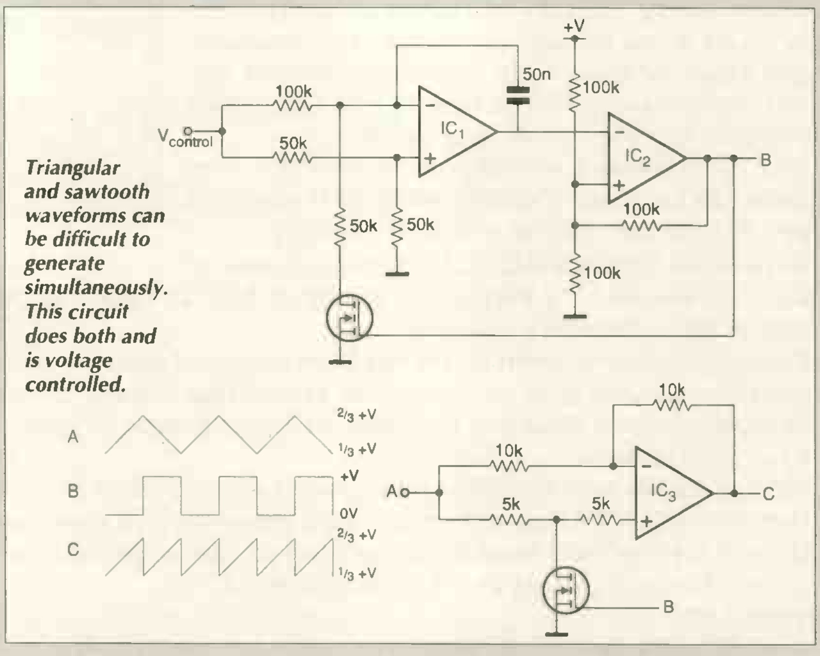
Bistable circuit changes output state after a given number of pulses are applied to the input, retaining its setting after power is removed.

Simultaneous sawtooth, square and triangle waves from a vco

A voltage-controlled oscillator producing square and triangular waves was described by Horowitz and Hill in *The Art of Electronics*, published by Cambridge University Press. *CA3160E* op-amps $IC_{1,2}$ form the oscillator, supplied from a 5-12V rail and generating triangular and square waves at A and B respectively.

A third *CA1360E* operates as either a follower or as an inverter, depending on whether the mosfet conducts or is cut off. If the input to IC_3 is taken from the triangle wave and the mosfet drive comes from the square wave output, output C is a replica of the rising ramp of the sawtooth, followed by an inverted version of the falling ramp, the result being a sawtooth. Input voltage $V_{control}$ should conform to $0 \le V_{control} \le 2(V^+ - 1.5V)$, so that $f = 150 V_{control}/V^+$.

L Szymanski
Stamford
Lincolnshire



Triangular and sawtooth waveforms can be difficult to generate simultaneously. This circuit does both and is voltage controlled.

MONO VGA MONITORS
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RGB/CGA/EGA/TTL COLOUR MONITORS 12" in good condition. Back anodised metal case. £79 each REF JUN79

ANSWER PHONES Returns with 2 faults, we give you the bits for 1 fault, you have to find the other yourself. BT Response 200's £18 ea REF MAG18P1. PSU £5 ref MAG5P12.

SWITCHED MODE PSU ex equip, 60w +5v @5A, -5v@.5A, +12v@2A,-12v@.5A 120/220v cased 245x88x55mm IEC input socket £6.99 REF MAG7P1

PLUG IN PSU 9V 200mA DC £2.99 each REF MAG3P9

PLUG IN ACORN PSU 19v AC 14w , £2.99 REF MAG3P10

POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

ACORN ARCHIMEDES PSU +5v @ 4.4A. on/off sw uncased, selectable mains input, 145x100x45mm £7 REF MAG7P2

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13.8V 1.9A psu cased with leads. Just £9.99 REF MAG10P3

PPC MODEM CARDS. These are high spec plug in cards made for the Amstrad laptop computers. 2400 baud dial up unit complete with leads. Clearance price is £5 REF: MAG5P1

INFRA RED REMOTE CONTROLLERS Originally made for hi spec satellite equipment but perfect for all sorts of remote control projects. Our clearance price is just £2 REF: MAG2

200 WATT INVERTER Converts 10-15v DC into either 110v or 240v AC. Fully cased 115x36x156mm, complete with heavy duty power lead, cigar plug, AC outlet socket Auto overload shutdown, auto short circuit shut down, auto input over voltage shutdown, auto input under voltage shut down (with audible alarm), auto temp control, unit shuts down if overheated and sounds audible alarm. Fused reversed polarity protected. output frequency within 2%, voltage within 10%. A extremely well built unit at an excellent price. Just £64.99 ref AUG65.

UNIVERSAL SPEED CONTROLLER KIT Designed by us for the C5 motor but ok for any 12v motor up to 30A Complete with PCB etc. A heat sink may be required. £17.00 REF: MAG17

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VIDEO SENDER UNIT. Transmits both audio and video signals from either a video camera, video recorder, TV or Computer etc to any standard TV set in a 100' range! (tune TV to a spare channel) 12v DC op. Price is £15 REF: MAG15 12v psu is £5 extra REF: MAG5P2

***FM CORDLESS MICROPHONE** Small hand held unit with a 500' range! 2 transmit power levels. Reqs PP3 9v battery. Tuneable to any FM receiver. Price is £15 REF: MAG15P1

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UNIVERSAL PC POWER SUPPLY complete with flyleads, switch, fan etc. Two types available 150w at £15 REF:MAG15P2 (23x23x23mm) and 200w at £20 REF: MAG20P3 (23x23x23mm)

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FUTURE PC POWER SUPPLIES These are 295x135x60mm, 4 drive connectors 1 mother board connector. 150watt, 12v fan, iec inlet and on/off switch. £12 Ref EF6.

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PC POWER SUPPLIES (returns) These are 140x150x90mm. o/ps are +12,-12,+5 and -5v. Built in 12v fan. These are returns so they may well need repairing! £3.50 each ref EF42.

***FM TRANSMITTER KIT** housed in a standard working 13A adapter!! the bug runs directly off the mains so lasts forever! why pay £700? or price is £15 REF: EF62 Transmits to any FM radio. (this is in kit form with full instructions.)

***FM BUG KIT** New design with PCB embedded coil for extra stability. Works to any FM radio. 9v battery req'd. £5 REF: MAG5P5

***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

TALKING COINBOX STRIPPER originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? Price is just £3 REF: MAG3P1

TOP QUALITY SPEAKERS Made for HI FI televisions these are 10 watt 4R Jap made 4" round with large shielded magnets. Good quality. £2 each REF: MAG2P4 or 4 for £6 **REF: MAG6P2**

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DOS PACK Microsoft version 5 Original software but no manuals hence only £5.99. 3.5" only.

PIR DETECTOR Made by famous UK alarm manufacturer these are hi spec, long range internal units. 12v operation. Slight marks on case and unboxed (although brand new) £8 **REF: MAG8P5**

MOBILE CARPHONE £5.99 Well almost! complete in car phone excluding the box of electronics normally hidden under seat. Can be made to illuminate with 12v also has built in light sensor so display only illuminates when dark. Totally convincing! REF: MAG6P6

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CIRCLE NO. 142 ON REPLY CARD

Circuit round-up

Contributed by designer John Burnill, this collection of circuit ideas covers a variety of applications.

Meter response equaliser

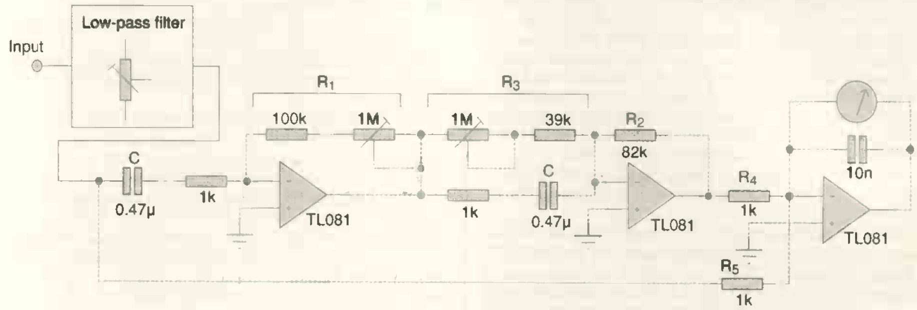
Pointer movement of dc milliammeters exhibits a second order response to changing current. This can be equalised by the circuit shown, speeding up the response typically by a factor of ten. Response time is limited by the low-pass filter on the input, which is there to prevent the subsequent circuitry clipping on full scale steps in amplitude.

Values shown are for a typical 200μA/1kΩ 'VU' meter. Resistor R_3 adjusts the Q. This is independent of R_1 which adjusts the corner frequency.

These equations give the corner frequency and the Q. Resistor R_4 is assumed equal to R_5.

$$f = \frac{1}{2\pi C\sqrt{R_1 R_2}}$$

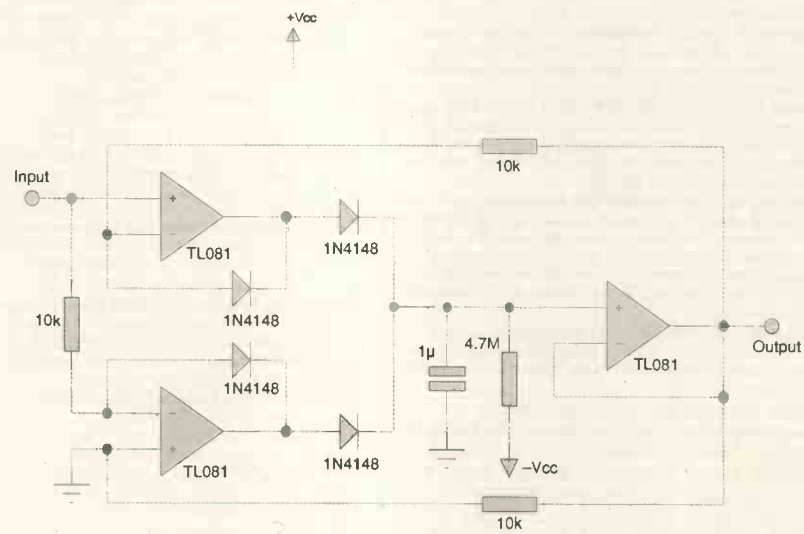
$$Q = \frac{R_3}{2\pi f R_1 R_2}$$



Meter Response Equalizer

Fast full-wave peak rectifier

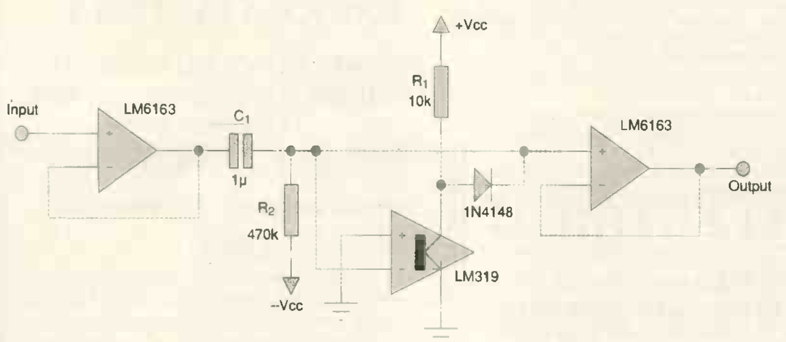
This full wave peak rectifier is fast due to the fact that none of the op-amps saturate. The circuit is accurate to 1dB to 300kHz using *TL081*s. Attack time is limited by the limited output current of the op-amps. Decay time is set by the 4.7MΩ resistor. Taking this resistor to the negative supply rail gives approximately linear decay against time.



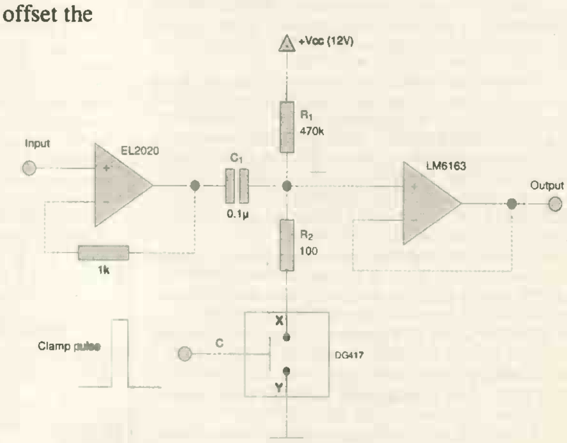
Video-signal processing

Two ideas related to each other in that they concern the processing of video signals. First is a precision dc restorer. Basic circuits using a diode can mangle the sync enough to cause loss of frame sync on some receivers. The circuit shown here solves the problem. Resistor R_1 controls the 'attack' time and R_2 the tilt.

The second circuit is a very simple clamp with more than adequate performance. Clamping time is determined by the time constant R_2/C_1. Resistor R_1 is to offset the input current of the output op-amp to minimise drift on the clamped wave form. The input amplifier is a *EL2020* because when the clamp is switched on it must drive a 100Ω load.



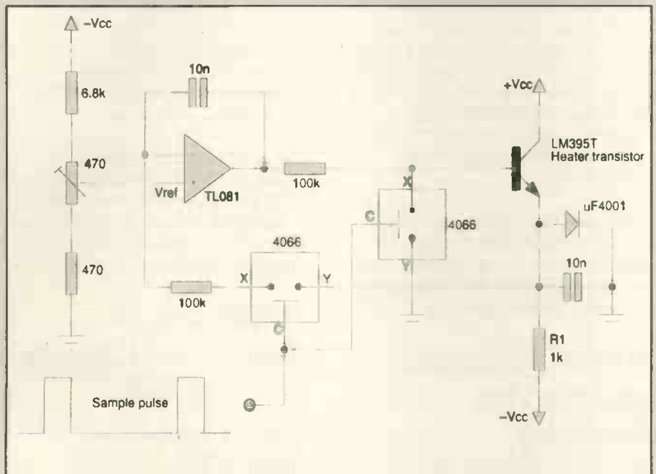
Precision Video DC Restorer



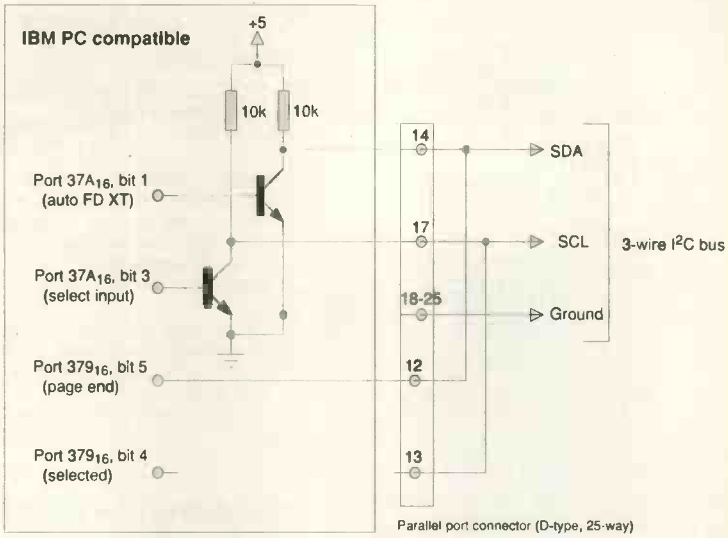
Oven for crystal stabilisation

A circuit to use as a heater for temperature stabilisation of a crystal. Base emitter junction voltage of the heater transistor is sampled as a measure of device temperature while collector current is held constant. Resistor R_1 provides reference current. The op-amp is the sample-and-hold and loop error amplifier. A reference voltage is applied to the non-inverting input to set the temperature.

The heater transistor used is a *LM395*. This device is overload and overtemperature protected, making temperature adjustment idiot proof. For best performance the crystal to transistor thermal resistance should be minimised and the thermal resistances from the two to ambient maximised. Power supplies are ±8V. Sample timing is not critical. A 1ms period and 0.2ms sample width are fine.



Temperature Stabiliser



Simple I²C interface for pcs

This is a way of interfacing an IBM pc compatible to the I²C bus. The software is too lengthy to be given here. Port 379_{16} is used to read data in. The relevant output must be off (port $37A_{16}$ set low). Port $37A_{16}$ is for outputting data. Note there is polarity inversion.

Both SDA and SCL lines need 1kΩ pull up resistors at the receive end if the bus is to be used at full speed over reasonable length connections.

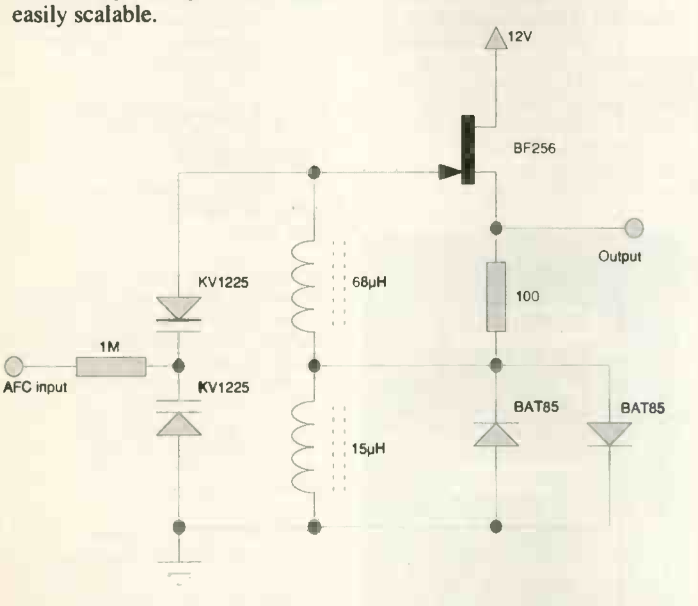
Narrow and wide-range voltage-controlled oscillators

Two more related ideas. A voltage controlled crystal oscillator designed to maximise the pulling range of a parallel crystal. The two diodes decrease the rf voltage across the varicap.

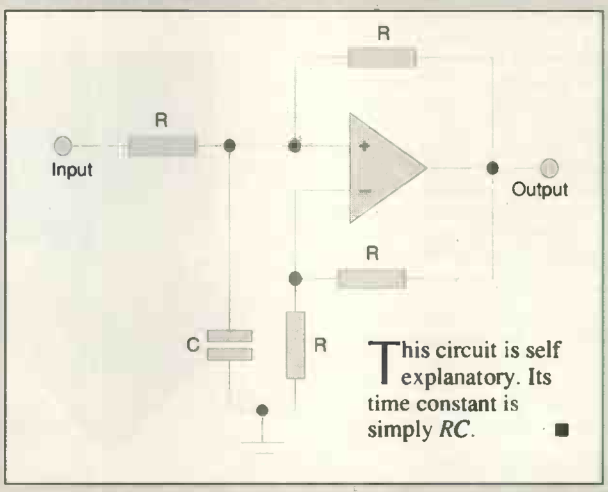
Capacitor C_1 sets the centre frequency. This is done using the final layout to compensate for circuit strays. There is no need for a trimmer if all the crystals are cut to the same load capacitance. Pulling range is about ±50Hz for a typical 2MHz crystal.

A simple wide-range vco is shown in the second diagram. The diodes decrease the rf voltage across the varicap and have the added benefit of making the output waveform symmetrical.

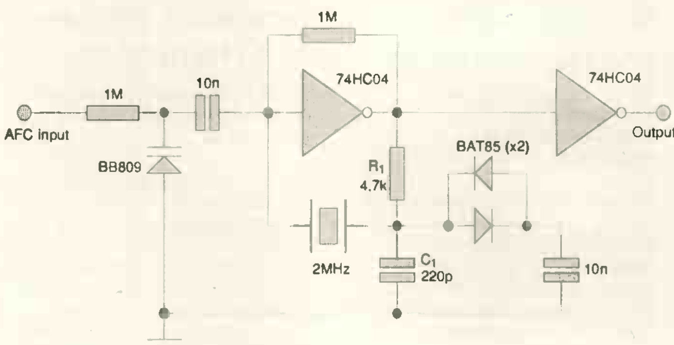
Output is low impedance. Range for this circuit is 1MHz-3.5MHz for a voltage swing of 1-29V on the varicap. The arrangement is easily scalable.

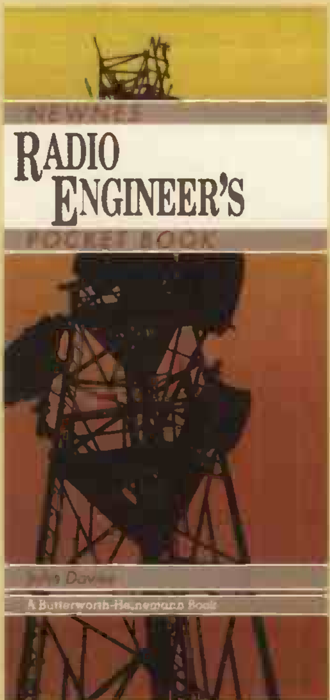


Integrator with no signal inversion



This circuit is self explanatory. Its time constant is simply *RC*. ■





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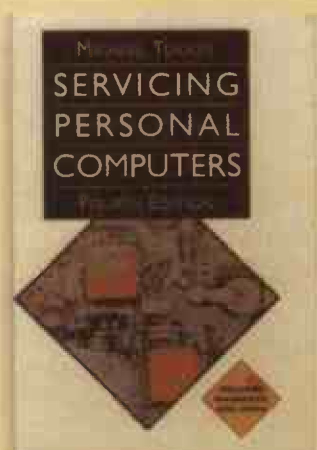

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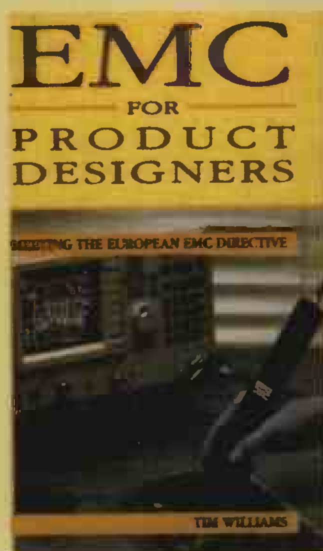

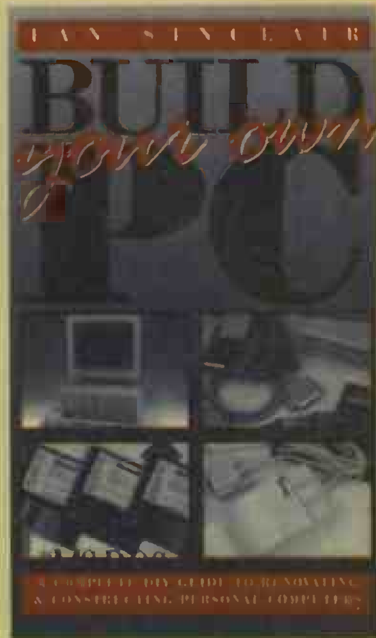

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LETTERS

Letters to *"Electronics World + Wireless World"* Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

UK mains change – any effects?

Kettles, toasters, electric ovens and any piece of domestic electrical equipment with an ac motor – even if it has a power stabiliser for its dc electronics – all have reduced power following the normalisation of Britain with the European Union's electrical standards body Cenelec, based in Brussels.

Electricity boards can take advantage of the new rules to supply more consumers from a single generator. This, rather than any change in hardware, reduces average supply from 240V to 230V.

The 8.2 per cent associated average decrease in power was too subtle to be obvious to everyone, but hundreds of complaints have been reported.

On the individual scale, last minute rushers have found themselves missing buses and trains in the morning after a slightly delayed breakfast.

These complaints may soon be forgotten as people adjust to get up a few minutes earlier, but the attempted cover-up was quite a remarkable piece of work. A Sunday tabloid editor was successfully fobbed off by an electricity board public relations spokesperson.

Only when a sackful of irate letters arrived at the tabloid's London office after the paper's editor wrote about his search for 'loose wires' or 'crumbs' in his kettle and toaster, were experts consulted as the media began to wonder whether January's regulations change could really be to blame.

Confusion has arisen over the difference in the changes in volts and power. Power is simply volts squared and divided by resistance. The latter varies with temperature, but this is usually negligible over the 4.2 per cent reduction in volts. Thus, the mains electric power has been reduced by around 8 per cent.

Concerns over hospital life-support systems, word processors and computers, and video recorders slowing down are mainly unfounded. All use regulated dc power from an in-built mains ac converter.

Old fashioned electric clocks are of course unaffected, because the alternating frequency of the generators, still 50 hertz, keeps them on time. Mains electronic clocks using crystal oscillators again have a power regulator which compensates easily for the reduction.

We may also be able to turn the oven up easily, but we can hardly take some windings off the coils of our electric motors, or reduce the electrical resistance of our kettles.

So vacuuming, boiling for tea or coffee, toasting, and lawn mowing will just have to take longer. At least, until manufacturers reduce the resistance of their products by 8.2 per cent, so that they deliver the same average power and speed of work as their specifications state, and until consumers buy the new appliances.

Nigel Cook
Addlestone
Surrey

IEE 'nonsense'

Many people working in the field of bioelectromagnetics research have been shocked and angered at the review published last year by the UK Institution of Electrical Engineers. The organisation published a similar study in 1991, I believe, which no-one took very seriously.

The latest conclusions are that there are no effects, either hazardous or beneficial, from weak elf em fields. This is not only an absolute nonsense but contradicts many thousands of cellular live animals and epidemiological studies. In my view it is simply propogandist material masquerading as science.

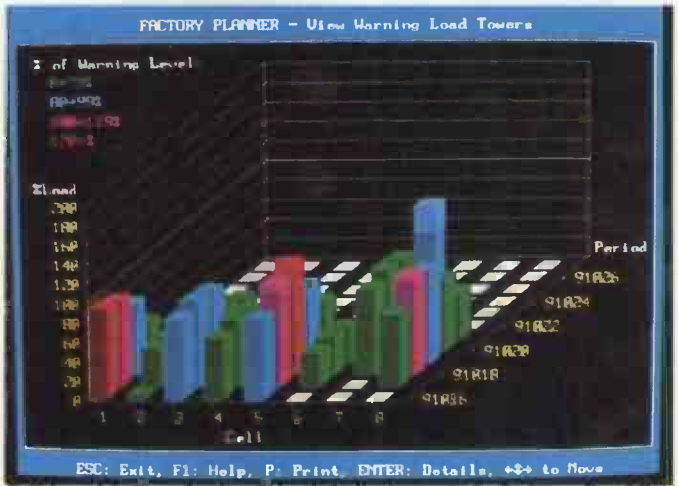
The IEE refuses to disclose the references on which it claims to rely. A look at the composition of its working committees shows that they are heavily weighted with power-utility-related personnel.

Roger Coghill
Gwent

Learning while earning

Andrew Ainger's leader 'Training Dinosaurs' in *EW+WW* March '95 expressed an interesting idea, but can he offer any clues as to how the idea of learning on the job might be work in practice?

H. Martinson
Newcastle



Cell-based factory: horizontal axis indicates manufacturing cells while the vertical axis gives overall load on the cells. 'Depth' axis is the time.

Andrew replies:

An example of human-centred technology – technology that enables staff to learn while they earn – is as follows.

Consider a very common industrial problem, that of planning what each machine has to do within a manufacturing organisation. For a manufacturer to remain competitive it has to remain profitable. To remain profitable the business has to maximise use of factory resources.

In the past this Manufacturing Resource Planning (MRP) was achieved by what has been termed MRPII computer systems. These systems attempted to plan out what each machine in the factory does, and when and how it does it. In theory, this approach works. In practice it may work well in companies where the products are relatively simple, but in the vast majority of cases, MRPII schedules are unrealistic, unreliable and – as many a manufacturing manager knows – often a work of fiction.

This is not really surprising as it only takes one small deviation from the plan to upset the rest of the downstream factory. It is rather like planning your car journey from Lands End to John O'Groats and telling your aunt, who lives in Birmingham, when she should put the kettle on for your cup of tea.

In modern manufacturing organisations there is now a move towards Cell-Based manufacture. This is rather like splitting the Lands End to John O'Groats journey into sections. In many ways this can be regarded as a way of remedying the planning problem via an organisational solution. There can be no doubt that cell-based manufacturing, with its added flexibility, has proved to be an extremely effective and profitable way of manufacturing products.

Traditional IT planning systems are trying to catch up and match this flexibility. However it is not only the IT systems that have to be flexible but also – and more importantly – the people.

For people to remain flexible they have to welcome change; in order to welcome change they have to gain new knowledge. Human Centred Systems appear to be the only solution to this problem.

Rather than presenting data to the manufacturing personnel, the human-centred way is to provide them with information.

The diagram depicts a cell-based factory: the horizontal axis indicates manufacturing cells while the vertical axis gives the overall load on the cells. The 'depth' axis gives the time, divided into periods, which may be shifts, days or weeks for example. Using this diagram and the information it embraces, three learning opportunities emerge:

- *First and most obviously, this view (map) of the factory enables the state of the factory to be judged at a glance, production hot spots* *identified and appropriate action initiated.*

● *Trends can be identified extremely quickly. For example, depending upon the work load and the factory's capacity, 'waves of colour' can be seen to ripple over the surface of the factory. These trends can alert the system operator to situations that have been hitherto undetected in traditional print-outs.*

● *Output of this particular planning system enables the 'sensitivity' of the factory to certain orders to be 'felt', just as the driver of a car can feel the difference when driving over different road surfaces. Over time the sensitivity to certain orders and the 'feel' of the factory can give advanced warning to the human-centred IT system operators when a particularly awkward product mix is being contemplated.*

This type of diagram adds credence to the saying that 'a picture is worth a thousand words'. It is these types of IT systems that enable users to assimilate and build knowledge while they work – a true learning earning environment. It is not easy to design IT systems that can be used in this human-centred way, but it is possible. The mindset of the design engineers concerned has to be woken up to this new design philosophy.

Bear in mind that although you cannot design human-centred technology you can design the opposite. Although the logic of this statement is initially surprising, it becomes quite straightforward when you consider that we cannot design a perfectly safe car but we can certainly design an unsafe one.

It is only by designing technology that can be used in a human-centred way – as will a true Human Centred System – that continued incremental learning can take place. By this I mean that the car may be designed with safety in mind, but it is the way it is driven that is most important.

The challenge is to design IT systems that can be used in a human-centred way, enabling people to learn while they earn. It is only through continued learning that organisations can continue to change, flex and survive. Engineers should take note. A new and powerful design philosophy has emerged, and if we fail to embrace it the 'future' may fail to embrace us.

Andrew Ainger
Human Centred Systems
Windsor

Beyond TV Sat 2

Reg Williamson's complaint (Letters, March '95) of arbitrary cessation of TV Sat and its 16-station service might cause a perceptive person to ask what are German listeners doing about it?

The answer must be that they, like me, are retuning to the lower powered Kopernicus transmission and receiving the same service – albeit with the odd flip if anything other than a very large dish is used. At my latitude, one metre is recommended, but an 80cm dish combined with an lnb made for the telecom band, is acceptable for my purpose, which is recording the audio on digital tape.

When the Kopernicus service ends, we will have to pay for digital audio satellite transmissions. But it will still be cheaper than buying cds, and preferable to Classic FM and its relentless commercials – not to mention Radio 3 fm, which varies from grand ole opry to children's hour, with cricket in the summer to induce total somnolence.

Hugh Haines
Sunderland

Roadside oxide

In a recent photovoltaics installation used for a display by the environmental group Common Ground, some components such as leds corroded and broke down after being exposed to the elements for a period of five weeks.

Can any of you say whether this is normal, or caused by adverse conditions such as acid rain? The installation was near a busy London road and quite a lot of rain fell during the five weeks.

Since we are planning a similar installation to coincide with the end of 1995, we would like to learn from this, especially if it involves a mistake on our part.

Nicolas Holliman
London

Cheap talk

I saw an article in Computing and Control Engineering Journal October 1994 about a development that could lead to entirely free electronic mail – once the equipment has been bought.

The problem with Internet is that it requires the use of the telephone system, which can never be free. However most broadcasting is free. Although some countries like the UK charge a licence fee, this is only to pay for the government station, in our case the BBC. The commercial channels are all free, as are foreign stations receivable here.

Although it sounds far-fetched, this freedom of broadcasting can be transferred to two way communication.

The secret is that every node is a transmitter and receiver of very low range, and the system relies on each node being able to send its message to the next node and so on. In addition, the message contains directional information, so nodes that are in the wrong direction can refuse it.

The system will not work in areas of low population density, but as humanity is fairly well concentrated in small areas of the planet most people should have access.

The article describes a wireless local area network. That is to say the network is limited to a particular business or other grouping of computers. However there is no reason why such networks shouldn't communicate with each other using a radio version of the Internet. The article also says that wireless lans would meet type approval so as to be licence free, as they are low power transmissions.

Initially the existing telephone-based Internet would be used to connect wireless lans that were out of range of each other, but as more and more are installed they would be able to communicate with each other directly and the use of the telephone Internet would fall.

John de Rivaz
Truro

Unknown rectifier materials

I know of no electrolytic rectifiers using the electrode combinations mentioned by 'unsigned' (*Letters*, February) being used as radio detectors. However, electrolytic rectifiers using similar electrodes were used with accumulator chargers and were described in 1920s radio books. So far, I have been unable to discover whether they evolved before or after Fessenden discovered the barretter, or the evolution of the crystal detector.

In 1935, when a schoolboy experimenter, I employed four electrolytic rectifiers in a bridge circuit to trickle charge 6V accumulators. Unfortunately I have long since lost my records but I seem to remember experimenting with aluminium/lead and aluminium/iron electrodes. Large jam jars served as cells and the electrolyte was ammonium phosphate.

'Unsigned' explains that with iron/zinc alloy electrodes, an insulating film develops on the alloy electrodes but this disappears when current flows from iron to alloy. Presumably the same applies to my electrolytic rectifiers.

On the other hand, rectification with the barretter seems to depend more on the movement of ions.

Nonetheless, I would like to experiment with the electrode combinations mentioned by 'Unsigned' and would be most grateful for any further information.

George Pickworth
Kettering

Hisses and glows from the past

George Pickworth's recent articles, *Detection before the diode*, and the unsigned letter from Middlesex in the February 1995 issue brought back memories of some seventy years ago.

In the very early days of domestic radio I had gradually acquired enough 12V lead-acid accumulator blocks to give me 120V ht. We lived out of town and I used to carry these on my bicycle to my grandmother's cellar where 220V dc was available.

Later on, electricity reached our house – ac of course – so I was able to recharge them at home when I'd made a rectifier. This was a chain of ten or twelve tiny sample jam jars with electrodes of aluminium strip and carbon rods from exhausted 4.5V batteries, in a solution of ammonium phosphate.

One could buy ammonium phosphate, sold as fertiliser, from the seed shop. These cells made a peculiar hissing noise and in the dark you could see a pulsating glow on the aluminium strips. I don't know what the reverse current was but it may have been good for the health of the battery. All this information must have come from *Wireless World* – happy days.

I was given a coherer some years ago and it still works. Put in series with a 1V cell and an AVO on the 3V range there was no visible deflection. Flicking 230V ac mains across a 4μF capacitor at a distance of 15cm gave an immediate deflection of several milliamps. A very light tap to the coherer and it immediately returned to its non-conducting state ready for the next burst of rf energy.

Ralph Wesr
Villereal, France

What conspiracy?

In a letter to *WW*, Nov. '81, JL Linsley Hood writes that "censorship has been effective throughout my own professional career...". He lists nine authors who could not have been published anywhere but in *Wireless World*.

As Pete Davis (*EW+WW Dec. '94*) asserts, there is usually no conspiracy to suppress heretical views. There is no need of one, except in some specific instances, because as Charles McCutcheon wrote in the *New Scientist* (itself a notorious suppressor, but not as bad as *Nature*) on 29 April 1976, p225, "An evolved conspiracy" suffices. For example, I ran into a discussion in the interval at the Royal Institution seminar to celebrate the centenary of the Michaelson-Morley experiment. An American who was setting up an international conference on relativity discussed with one of the lecturers whether ether buffs should be suppressed at that conference. He also asked the lecturer how Harold Aspden should be dealt with. They concluded that if Ether believers kept to Establishment mathematics, they should be allowed to put their case.

The American told me he regarded heresy in science much as he regarded heresy in religion. More generally, suppression in science results from fear that a new idea will disrupt the normal, calm progression of academic career progress and research funding.

Suppression is the norm rather than the exception. Even Maddox, editor of *Nature*, now says he is worried[1]. With his track record, that is mind-blowing. Scientists have successfully resorted to false authorship and false addresses to get into *Nature*.

The most interesting and most destructive aspect is the pandemic suppression of advances relating to the AIDS epidemic. Other experts, whose names I can supply, specialise in the allied subject of fraud in science. Stewart and Feder lead this field.

My first publication on suppression in science was 'The Rise and Fall of Bodies of Knowledge', published in *The Information Scientist* No 12 (4) Dec. 1978, pp. 137-144, where I discuss some of the cases of suppression which litter science. My article was re-published in my book 'Electromagnetic Theory vol 1', 1979, p. 117. All of the content of that book is suppressed, including the point that I raised at the Michaelson-Morley centenary seminar, asking about the apparent paradox in their experiment that although Michaelson-Morley pre-date wave/particle dualism, both wave and particle have to be assumed at different stages in the experiment to suppress anomalies.

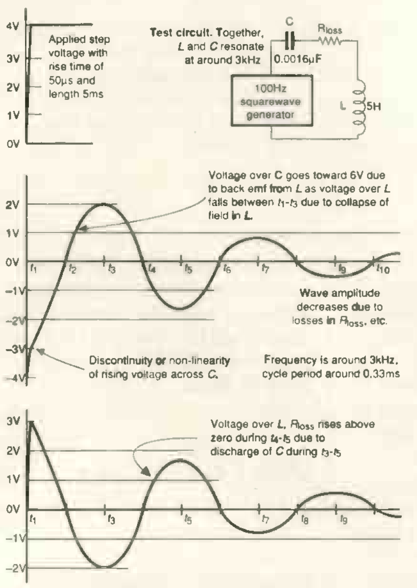
Sine waves – another turn

I see from the March issue of *EW+WW*, p. 215, that Ian Hickman has kindly accepted my challenge for an explanation of how sinewaves appear across an *LC* circuit from an applied step function of voltage.

In his case he prefers to use a very short and theoretically extremely high pulse of voltage from a generator with an extremely high internal resistance. He then proceeds with some high powered computer analysis and calculations which I do not understand at all. In fact, Ian admits that he may well be "simply solving the differential equations by stealth".

I agree, of course, that the terminal voltage across an inductor is proportional to the rate of change of magnetic flux linkage, and therefore current, within it. I also agree that the current through a capacitor is proportional to the rate of change of electric flux, ϕ_C, within it. This is in turn proportional to the rate of change of charge, q_C, across it. We may need to know, though, more about the Ether before we can fully explain these fluxes.

In the meantime however we can simply write the following equations. Voltage across inductor *L* is:



"Apart from the initiation waveform, which is non-linear and has a discontinuity, this waveform is explained by the mathematical analysis shown."

$$V_L = L\frac{d\phi_L}{dt} \equiv L\frac{di_L}{dt}$$

where ϕ_L is flux in the inductor, i_L is inductor current, d/d*t* is rate of change. Voltage across capacitor *C* is:

$$V_C = \frac{q_C}{C}$$

so,

$$\frac{dq_C}{dt} = C\frac{dV_C}{dt} + C\frac{d\phi_C}{dt} \equiv i_C$$

where ϕ_C is electric flux within the capacitor, and is proportional to the amount of charge, q_C, on it.

From these equations you can produce a second order differential equation whose solution is a sine function. I have discovered though that at the initiation of the oscillation, the rising voltage across the capacitance is non-linear since a small proportion of the initial voltage step appears across the capacitor before the sine oscillation gets underway. This seems to suggest that the capacitor also must contain some inductance which initiates the sine oscillation, then proceeding by the fall of voltage across the inductor which produces back emf to charge the capacitor.

Textbooks such as 'An Introduction to Electronics' by Dennis F Shaw, p 18, say though that initial voltage across the capacitor is zero, but I have found this not to be the case.

I conclude that simple mathematical analysis as outlined above gives the only explanation we can have at present for the waveforms produced. The exception is the initiation waveform across the capacitor, which is non-linear, containing a discontinuity.

Peter Dawe
Oxford

Ian replies:

On Mr Dawe's own analysis, there cannot be an instantaneous voltage step across an ideal capacitor, unless, that is, an infinite current flows – which was precisely the case with the delta function in Ref. 1. If Mr Dawe really seems to see an 'instantaneous' voltage step across the capacitor in his circuit, there is a limited number of possible explanations: i) the capacitor possesses significant series loss (possible, but unlikely, ii) The capacitor possesses significant inductance (as Mr Dawe himself suggests; was it a capacitor rated for pulse operation?), iii) The rise in voltage was not really instantaneous or, iv) There is a measurement error (it was not clear how Mr Dawe was measuring the voltage across the capacitor, which – from the diagrams – had neither end grounded.)

Analysis of the operation of his circuit is complicated by the fact that his 'step function' recurred, with alternating polarity, every 5ms; i.e. it was actually a 100Hz squarewave, while the resonant frequency of the tuned circuit to which it was applied was observed to be only some thirty times higher (approximately), with an unspecified Q. Furthermore, far from being instantaneous, the rise time of the 'step function' from zero to +4V was 50μs – around one sixth of the period of the tuned circuit's natural frequency.

A solution of the circuit's response to the given stimulation is straightforward, but could not be undertaken without exact values for the complex impedances of the components used. For example, the iron cored inductor doubtless had significant iron and copper loss in addition to its self capacitance. (The values of L and C – 0.0016μF and 5H – which Mr Dawe gives do not tally even approximately with his observed natural frequency of around 3kHz). The observed voltage step across the capacitor is probably due to the division of the applied step between the said 0.0016μF capacitor and the self capacitance of the inductor.

As the stimulus is a simple recurrent waveform, the circuit could be analysed in either the time or frequency domain though of course both analyses could give the same result. However, one important point is perhaps made clear more easily by consideration in the frequency domain. The squarewave drive signal will have significant harmonics up to the resonant frequency of the tuned circuit. If the tuned circuit has a high Q and resonates exactly at one of these harmonics, there will be no phase changes in the damped oscillatory response, only magnitude changes. However, slight mistuning either side of the harmonic can result in dramatic changes in the response, as was illustrated with actual measurements in Ref. 2. If, on the other hand, the circuit Q is so low that the response to one edge of the squarewave dies away completely before arrival of the next, then analysis of the effect of an isolated quasi-step function with a finite rise-time would give the complete solution. Either way, there is no need to invoke unknown effects of the Ether to explain the observed results.

1. Hickman, I, *Sinewaves step by step*, *EW+WW* March 1995, p. 215.
2. Hickman, I, Integrated creativity, *EW+WW* Jan. 1992, pp. 40-42.

It appears to me that for the experiment to have any value, the light must act as particles during its travel, because parallel waves would interfere with each other and ruin the experiment; but it has to act as waves on arrival in order to determine transit time difference by interference fringes. In the Michaelson-Morley centenary seminar, speaker Professor Kilminster said, "That has never been mentioned before". It has never been mentioned since – being suppressed for good reason.

To raise such questions, and there are many, is cheating, like making your pawn move as a combination of knight and bishop in a chess match. Science today is the manipulation of pre-agreed axioms and old knowledge; nothing more. Further, the request for more detailed statements of the axioms, as in my case with Michaelson-Morley, is resisted to the death. Today's science resembles the religious service, which should not be interrupted by the raising of theological questions.

My work on wafer-scale integration, described in *Wireless World* July 1981, was always rejected for publication by all learned journals, even though it attracted £16m of funding – including government funding – and became a widely praised product in the field. Of course, its suppression reduced the threat that it would upset the research funding being received in their universities by journal referees for their own approaches to WSI. In spite of my track record, my new WSI invention, *EW+WW* March 1989, for which I have worldwide patents, cannot be published in any learned journal.

In a letter in *Wireless World*, January 1983, I wrote that during 25 years of work, I have never succeeded in publishing any of my work on e-m theory in any British learned journal. This ban now extends to 35 years. However, Davis should particularly think about the refusal of the Establishment, when approached, to clarify the classical theory they are defending. Professor M Pepper FRS and his boss Professor A Howie FRS, head of Cavendish Laboratories, disagree with each other[2] as to where the negative charge comes from in the Catt Anomaly, *EW+WW* Sep '87. They refuse either to discuss it with us or with each other, or to say that the matter is of no importance.

Not only are new theories ignored and suppressed. We also find that the Establishment is nonchalant about its contradictory versions of old theory. See also the co existing, hopelessly contradictory, versions of a TEM wave pointed out in 'The Heaviside Theory', *WW* July '79, which has been totally ignored.

Ivor Catt
St Albans

1 Maddox says that suppression is increasing. "The epoch making paper by Francis Crick and James Watson outlining the structure of DNA, which appeared in *Nature* in 1953, would 'probably not be publishable today', Mr Maddox laments..." – *Daily Telegraph*, 1 May '89, p. 18.
2 Howie says it comes from the west. Pepper says that (since electrons would have to travel at the speed of light) it cannot come from the west, and must come from the south. Until this is resolved, we do not have a classical theory. Before it can exist, a theory has to be stated

Lend a golden ear

I followed Doug Self's series – and the debate that followed – with interest. As some of the statements expressed by readers that do not share Mr. Self's approach to amplifier design appeared to me at best biased, it is not surprising that Mr Self has lost his patience in the Feb. '95 letters column. True, the subjectivists' arguments have been around long enough, without much concrete progress, but could it be that engineers and the 'golden eared' are simply not speaking the same language?

To illustrate, one of my grammar school colleagues, who later became a professional musician, was able to detect signal level differences of a fraction of a decibel consistently, even if the changed level was presented to him after several minutes of silence. His ability was discovered accidentally. One of my stereo amplifiers had a 20.9kΩ resistor on one input and a 22.3kΩ on the other while the preamp output impedance was 1kΩ, and he noticed a difference in output levels between channels. No need to mention, he was able to detect absolute pitch, too.

Six years ago I owned an Alfa Romeo Sprint Veloce which developed a rattling sound in its engine. It turned out to be a loose screw on the air filter cover, but the mechanic noticed a hissing above 3000rev/min. Two days later I returned to him with a broken main bearing.

We are able to identify a familiar voice on the 'phone almost immediately, in spite of the badly distorted and band-limited signal, even if we have not heard the voice for many years.

Most of us will readily accept these impressive examples of performance of the ear-brain combination as a normal every-day experience. But when it comes to hi-fi equipment, our opinions change.

When discussing amplifier and speaker performance with musicians, I have often experienced that when I was talking of amplifier bandwidth, I had in mind the standard half-power definition, while they were referring to the frequency at which the phase is shifted by no more than a few degrees. When they were talking of clarity and presence, they were referring to being able to pin-point a sound source on the stereo image, while I was suspecting excessive 3 to 5kHz lift. When we were discussing transient performance, I was referring to the rise-time and overshoot of the response to a square-wave input, while they were referring to the attacking part of the complex waveform envelope which in most cases implied many waveform periods.

I'm certainly not advocating that audio engineers should rely on their ears only. But we should try to adopt the attribute of lawyers and doctors and listen carefully to what other people are saying before making a judgement. Indeed, we know the limitations of our instrumentation and we struggle hard to eliminate systematic errors when making sensitive measurements, so why not treat other people as sensitive instruments – albeit somewhat strange, sometimes unreliable ones?

Of course, the 'golden eared' must willingly accept being treated like instruments if they continue to seek credibility.

Erik Margan
Ljubljana
Slovenia

Supplies for audio power

I read with great interest the article 'Distortion off the rails' by D. Self in the March issue. While certainly not questioning Douglas' undoubted skills in audio amplifier design, may I draw attention to Douglas' statement, "I assume that any rail filtering arrangements will work with constant or increasing effectiveness as frequency increases; this is clearly true for resistor-capacitor filtering.

Taking as a base for availability the Farnell catalogue, data from Philips' 1994 Data Handbook, and assuming an axial capacitor of 100μF at 40V or more, as in Douglas' Figs 2&3, then the Philips 021 and 031 styles will have a self inductance of 40-50nH and an esr of some 0.55 to 1.2Ω at 10kHz, depending on exact choice. Also 47μF at 63V, depending on case size, can exhibit inductance up to 85nH.

Similar values of radial styles have less inductance, say 25nH. From Philips' data curves, these types have a self resonant frequency of around 20-50kHz. Above this they become totally inductive. Also at 100Hz, a typical esr of 1.25-2.5Ω must be expected.

As Douglas states, the amplifier internal loop gains will be reducing at frequencies when the capacitor starts to become inductive.

My two questions for Douglas are: what effect would a capacitor having 100μF, 50nH, 1Ω, as a series *LCR*, have on amplifier performance at 10kHz and above with regard to the simulation curves of Figs 2 & 3? Secondly, what effect would an esr of 2.5Ω, as a series *CR*, have on modelling or measurements at 100Hz?

Cyril Bateman
Acle
Norfolk

Douglas replies:
Mr Bateman is of course completely correct in pointing out that capacitors have parasitic inductance and esr, and that this is ignored in my article, which used only pure capacitance in the simulations However, a technical article is not a legal document; you cannot enumerate all the ifs and buts, and exceptions and caveats, without the prose becoming as uninformative as it would be unreadable. In this case, some of the concepts involved are not wholly straightforward (eg the change of reference in the voltage amplifier), and adding a further layer of complication simply to make the components more realistic would not have been a good idea.

The other point is that parasitic inductance, esr, etc, seem to make no difference in practice; ordinary electrolytics do the job very well. Ripple and signal voltages on the rails do not reach up into the rf regions, and even if they did, the series inductance of the supply conductors combined with the hf rail decoupling would reduce it. The only credible source of rf is commutation spikes in the bridge rectifier, and these need to be dealt with at source by the usual snubbing network.

Reflection on deflection

With reference to the piece 'Cathode-ray conundrum' in the April issue letters column, the proposition goes against provable laws of physics.
The effect described is of very small magnitude in relation to the others occurring at the same time – a potent source of error.
The flaw in Lerwill's proposition is that an electron beam which has been deflected off the precise axis of the acceleration system will have an effect in one or both of the orthogonal axes. There will be an electrostatic or electromagnetic interaction with the acceleration system, amounting exactly to the reaction which seems to have escaped – just too small to measure.

NPE Wheeler
Sutton,
Surrey■

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ACTIVE

Discrete active devices

Little mosfets. Meant for use on PCMCIA cards, Micrel's *MIC94030/1 TinyFETs* boast the lowest on resistance for their size, at 1Ω and 3.3V, and are contained in SOT-143 packages, being only a quarter of the size of current 8-pin SOIC mosfets. *MIC94030* is a basic 4-lead p-channel device, while the *MIC94031* has an internal gate pull-up resistor to turn the device off when driven by tri-state or open-drain logic. Solid State Supplies Ltd. Tel., 01892 836836; fax, 01892 837837.

Digital signal processors

NEC's *µPD7701X* family of general-purpose dsp chips has a new member with larger memory, the 3V *µPD77018*, which handles up to 250 million operations per second. Memory is 256 by 32 bit instruction ram and 24K by 32 bit rom, data memory consisting of two blocks of 3K by 16 bit ram and two blocks of 12K by 16 bit rom. The device has a 30ns instruction cycle time, a three-stage pipeline architecture and its instruction set enables eight operations to be performed in parallel. Development tools available operate through a workbench under Windows. NEC Electronics (UK) Ltd. Tel., 01908 691133; fax, 01908 670290.

Floating-point DSP. TI's latest digital processor, the *TMS320C32*, allows the use of floating-point techniques used for research and development in commercial products to eliminate the usual switch to fixed-point working for commercial use. It is available in 40MHz, 50MHz and 60MHz versions and uses new memory management and data packing features to allow the flexible use of 8-bit, 16-bit and 3-bit memory architecture. There is also a two-channel dma co-processor for data movement. SR Communications (Texas Instruments). Tel., 0181 692 7575; fax, 0181 692 8057.

Microprocessors and controllers

Miniature controller. Z World's newest C-programmable miniature controller is the *Little Genius*, with 26 i/o lines, intended for the OEM market for control and data acquisition use, although it also works as a core module interfacing with user-designed boards. Having 14 digital inputs and 12 digital outputs, seven of which handle high currents, and both RS232 and RS485, it is well suited to use in networked controllers. Features include an eeprom, battery-backed ram and real-time clock, programmable timers, a 9MHz processor clock, a watchdog timer and power-fail interrupt and an expansion port to the Z-World *PLCBus*, which allows the connection of a d-to-a converter or other boards such as the prototyping board on offer. If not in use for expansion, the bus will take eight more cmos inputs. The C development system for both dos and windows has many function libraries and program samples in source code. Greening Technology Ltd. Tel., 0116 2796500; fax, 0116 2796501.

Logic

3.3V logic devices. Quality Semiconductor announces seven 3.3V, 8bit logic elements, the *FCT3244* buffer/line driver, *FCT3245* transceiver, *FCT3373* buffered latch, *CT3240* inverting buffer, *FCT3540* flow-through inverting buffer, *FCT3541* flow-through buffer and *FCT3573* flow-through latch. They are all function and pin compatible with existing 5V devices and will accept 5V inputs while the outputs are at 3.3V. Speed is compatible with Bicmos and power consumption with cmos. Quality Semiconductor, Inc. Tel., 01420 563333; fax, 01420 561142

Memory chips

Low-voltage serial eeprom. New from Holtek of Taiwan, via Hero Electronics, is the *HT93LC46* 1Kbit serial eeprom, to which one can write to at 2.7V and read from at 2V. Operating current is 2mA and maximum standby 2µA. Data is retained for ten years. Hero Electronics Ltd. Tel., 01525 405015; fax, 01525 402383.

Mixed-signal ICs

Energy measurement. A range of five ICs from the South African firm of SAMES are for single and three phase ac power or energy measurement over a 60dB range, meeting the requirements of IEC 521/1036 for Class 1 ac watt-hour meters. They are protected against overvoltage and use shunt resistors or current transformers for current sensing, a voltage reference being built in. Output is either digital or analogue in form. Ginsbury (UK) Ltd. Tel., 01634 290903; fax, 01634 290904.

Optical devices

Laser measurement. Matsushita's *LM200* analogue laser is immune to surface irregularities and colour changes. This is because of its use of light feedback and triangulation range measurement to minimise analogue output error. An aspherical glass lens provides good linearity combined with low temperature drift. The measurement range is ±3mm or ±6mm while resolution is 1µm. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

Fibre pigtailed laser diodes. A series of diode laser assemblies designed to couple laser radiation into single and multi mode fibres is available from Melles Griot. Both visible and infrared diodes are used, the >700nm infra-red types being over 55% efficient and the <700nm visible diodes better than 30% efficient. Powers from 0.5mW to 30mW are offered. The housing is stainless steel and has a 1m length of fibre with a cleaved end, ST, FC and SC connectors being used. Melles Griot Ltd. Tel., 01223 420071; fax, 01223 425310.

Programmable logic arrays

Fast 128-cell device. AMD has brought out what it claims to be the fastest 128-macrocell complex programmable logic device, the *MACH231*. This is one of the new *Performance Plus* family of 7.5ns complex plds. The addition of power-down macrocells means that each macrocell can be configured into a low-power mode. Additionally, input/outputs and inputs have a latching facility to avoid the long pull-up times associated with resistors. Advanced Micro Devices (UK) Ltd. Tel., 01483 740440; fax, 01483 756196.

Oscillators

3.3V crystal oscillator. Q-Tech has a range of military-grade crystal clock oscillators, believed to be the first 3.3V types to operate over a –55°C to 125°C temperature range while preserving ±100ppm stability. Output is at logic level into 15pF with transient times of 3ns. Many package styles are available. Wavelength Electronics Ltd. Tel., 01843 602869; fax, 01843 862276.

PASSIVE

Passive components

Low-voltage tantalum. *Low-voltage Series* surface-mounted tantalum capacitors by AVX are rated at 2-10V and are meant for use in products needing 1.5-5V supplies. Packaging is of 1.2mm profile. AVX Ltd. Tel., 01252 770000; fax, 01252 770001.

Audio products

Audio codec. Crystal Semiconductor announces the *CS4225*, a multi-channel audio codec for automotive and surround-sound application, which replaces three stereo data

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converters, three volume-control ICs, an input multiplexer, a 12-bit a-to-d converter and numerous passive components, not to mention affording a reduction size over conventional equipment of around 90%. An on-board phase-locked loop generates clock pulses to reduce EMI. Crystal Semiconductor Corporation. Tel., (USA) 00 512 442 7555; fax, 00 512 445 7581.

Connectors and cabling

Board/board connector. Wieland pluggable board-to-board connector with 2-16 ways on a 5.08mm pitch is rated at 250V to VDE 0110 GR C and 10A. The female socket can be mounted vertically or at right angles to provide connection for daughter boards. Wieland Electric Ltd. Tel., 01483 31213; fax, 01483 505029.

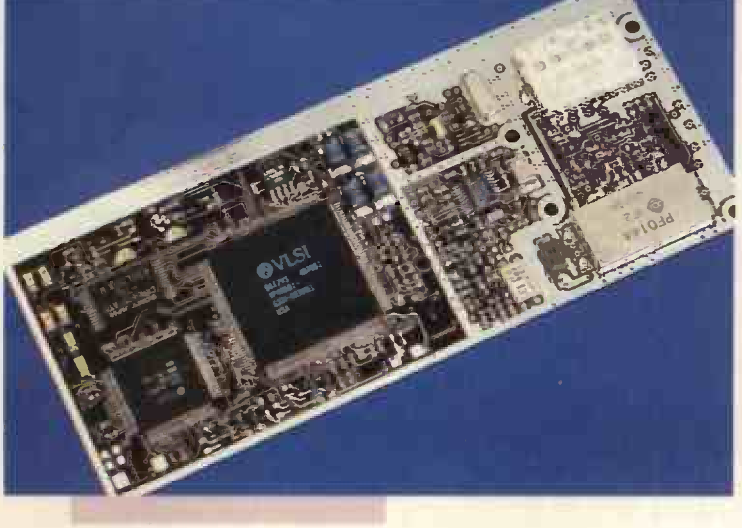
PCMCIA SM connectors. Methode *MCFK* Types I, II and III surface-mounting connector frame kits snap together without the assistance of glue or any other fixative. The connectors have stainless-steel covering, UL94V0 rating and electrical grounding via spring tabs. Surtech Interconnection Ltd. Tel., 01256 51221; fax, 01256 471180.

Bendy coax. From Belden comes *Conformable Coax*, an alternative to semi-rigid coaxial cable that can be hand manipulated into curves with radii down to 3.18mm, retaining its shape when formed. There are two types of microwave cable, *1671A* RG-405 type of 0.085in outside diameter and *1673A* (RG-402) of 0.138in od, both with 50Ω impedance. Type *1672A* is for video at 75Ω, having an od of 0.087in. Cables can be flexed many times without damage. Belden UK Ltd. Tel., 01483 726818; fax, 01483 771569.

IDC connector. Insulation-displacement connector blocks used by *Mod-Tap* in voice and data equipment are now available to network users. The blocks are designed for pcb mounting and can be used in wall sockets or patch panels. Termination tools are offered, but standard tools can be used. Blocks take two-pair and four-pair combinations and are in blue/orange, green/brown or in custom colour codes. MOD-TAP Ltd. Tel., 01703 701919; fax, 01703 704063.

Communications equipment

Two-chip GSM set. Two ICs from VLSI, the *VP22002* kernel processor and *VP22020* vocoder carry out all necessary baseband signal processing for a Global System for Mobile Communications (GSM) system, from speech vocoding to the radio system modular interface. The kernel processor contains the type-approved GSM blocks channel coder, equaliser, GSMK modulator and timing generator and VLSI's *Functional System Block* techniques including a 32-bit asynchronous response mode (ARM) microcontroller, operating at one instruction per clock cycle to give a processing power of 13Mips. Development tools are supplied. Operating at 13kbit/s, the vocoder provides fully asynchronous coding and decoding, having two asynchronous data ports and a host processor interface. The analogue front end has two low-noise input preamplifiers and a second microphone and speaker interface give hands-free operation. VLSI Technology Ltd. Tel., 01908 667595; fax, 01908 670027.



Displays

Tft colour lcds. Ginsbury's *GE10* and *GE14* 10in and 14in thin-film transistor colour lc displays are said to give a stable image with no flicker. They may be driven by a dedicated graphics card for best quality or by an internal analogue card to emulate crt monitors. As an option, a capacitive touch screen can be fitted, RS232 and Windows mouse emulation is standard. A robust polystyrene enclosure suits industrial use and can be fully IP65 sealed on request. Ginsbury (UK) Ltd. Tel., 01634 290903; fax, 01634 290904

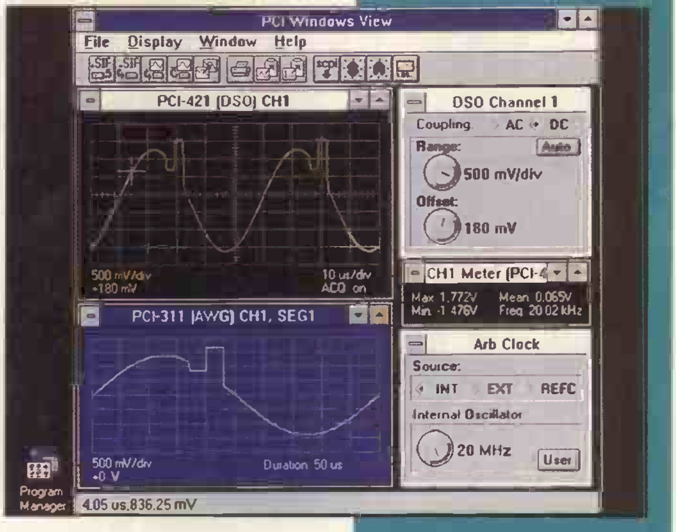
Filters

Programmable video filter. Raytheon's *RC6601* is an integrated continuous-time filter, fully programmable for video filtering, antialiasing, comms filtering and hdtv use. In addition, it costs about half as much as analogue filter alternatives. Cut-off frequency is voltage-variable in the 1 to 10MHz range and the device is phase-corrected to 0.2°; differential gain is 0.25%. It meets CCIR601 for NTSC and Pal signals, providing ±0.25dB pass-band ripple to 5.5MHz, with a –40dB pass-band starting at 8MHz. Ambar Components Ltd. Tel., 01844 261144; fax, 01844 261789.

Rf filters. Filters in the *BTF* range from BLP Components are for use in the protection of telephone networks, being flexible to accommodate future requirements, conforming to MIL-STD-220A and usable in all Tempest-rated networks as well as low-current control circuitry and audio lines. Configurations include two, four and ten line stand-alone forms and ten-line modules to fit 50, 100 and 200 line cabinets. They are in steel cases and are provided with idc connectors. BLP Components Ltd. Tel., 01638 665161; fax, 01638 660718.

Hardware

Control knobs. Attractive knobs in Sifam's *Trio* range are made using a technique whereby three shots of material are injected into the mould, providing a more versatile design and the opportunity for more detailed colour-coding. Material is nylon, with a matt body and contrasting gloss pointer. Two 11mm-diameter versions are made, with and without a nut cover, taking shafts up to 6mm diameter. The three-shot facility is also offered to customers needing custom-designed knobs, for which designs can be accepted in electronic form. Sifam Ltd. Tel., 01803 613822; fax, 01803 613926.



Waveform generator. Taking the form of a pc expansion board, the Scensys *PCI-311/2* occupy one slot and perform the functions of a stand-alone generator but rather more conveniently. Output from each channel is 12Vpk-pk into 50Ω from 12bit a-to-d converters with update rates to 50Msample/s to 0.01% frequency tolerance. A 99-segment waveform memory, each segment of which holding one waveform, allows the creation of irregular shapes such as video test patterns and encoded communications signals using *BenchTop* or *BenchCom* software, importing them from maths programs or from an oscilloscope card. Scensys Scientific & Engineering Systems Ltd. Tel., 01296 397676; fax, 01296 397878.

Instrumentation

Function generators. First members of Vann Draper's *H6000* series of function generators are the *H6000* and *H6001*, which produce sine, square, triangle, pulse and sawtooth outputs in the frequency ranges 0.1Hz-10MHz (*H6000*) and 0.2Hz-20MHz, prices being £149/199. Both allow external frequency control for modulation, sweep and pulse modulation. Outputs are ttl and 50Ω, with 600Ω as an option, controlled by switched attenuator and a continuous control. Thd is under 1% and triangular wave linearity better than 99%. Vann Draper Electronics Ltd. Tel., 0116 2813091; fax, 0116 2570893

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CPC – components. A new *circa* 1600-page catalogue from CPC – a company said to be UK's leading specialist spares distributor – is now available. Products carried include batteries, cables, capacitors, connectors, power supplies and semiconductors. This A4 publication also features industrial and office equipment, and, of course, a multitude of spares for consumer, office and industrial electronic equipment. CPC plc, Tel., 01772 654455, fax 01772 654466.

Digital video analyser. Rohde & Schwarz's *Video Component Analyser* is a video analyser and waveform monitor in one case, and said to be the first wholly digital instrument of its kind. Measurement of analogue television waveform monitors is combined with new functions to allow monitoring of digital encoding and signal transmission, detecting errors in transmission, showing bit errors and checking sync. frame. Features include the numeric dump function to allow video signals to be shown at bit level. Rohde & Schwarz UK Ltd. Tel., 01252 811377; fax, 01252 811447.

MIDI-Scope. Artistic Licence has the *MIDI-Scope*, a hand-held analyser for the Musical Instrument Digital Interface. When used as a receiver, the lcd screen shows data either in hex or as command icons, while received data can be stored for later analysis or re-transmission. The transmitter is used to regenerate received data or to transmit up to eight programmable messages. Other functions include cable testing, oscilloscope triggering and an RS485 output boost to drive long cables. Artistic Licence (UK) Ltd. Tel. and fax, 0181 863 4515.

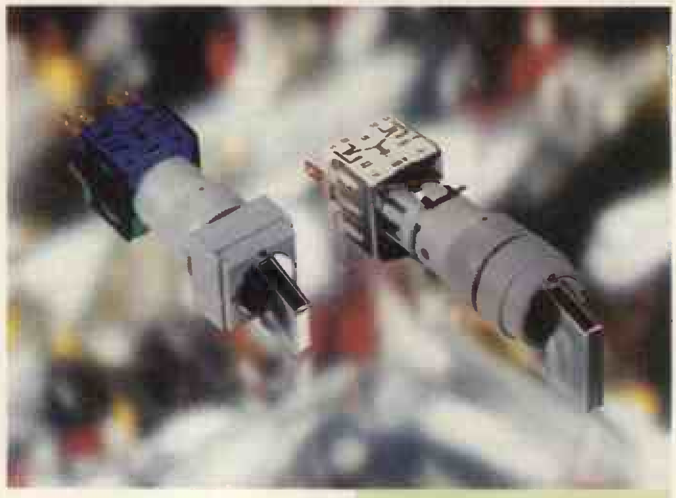
Cable simulator. Designed to simulate the effect of up to 500m of coaxial cable on serial digital signals, Faraday's *Cable Clone* is a hand-held unit, requiring no other equipment, that is simply connected in the cable. By means of eight switches, the effective cable length is increased in 5m steps until the signal deteriorates to an unacceptable point. The length of cable inserted indicates the margin. *Cable Clones* simulate amplitude and differential group delay of coax. with the SMPTE 267 360Mbit/s serial signal from 5MHz to 360MHz. Faraday Technology Ltd. Tel., 01782 661501; fax, 01782 630101.

Comms test set. H-P's *HP 8920B* communications test set has more than 22 functions to measure the performance of radio telephone equipment, including signal generator, modulation analyser, power meter, audio sources, digital oscilloscope, sinad meter, frequency meter and, as an option, a spectrum analyser with tracking generator. Measurement programmes are stored on a PCMCIA card. Hewlett-Packard Ltd. Tel., 01344 366666; fax, 01344 362269.

Nanovolt/micro-ohm meter. *HP 34420A* by Hewlett-Packard is a low-noise nanovolt-microhmmeter offering 7.5-digit resolution, 2ppm, 24-hour dc voltage accuracy and selectable filtering. There is a two-channel programmable scanner for ratio and difference measurement, and built-in conversion routines to display thermocouple, thermistor and rtd readings directly in degrees, resolved to 0.001°C. Features include scaling and statistics functions, 1024-reading memory, chart recorder analogue input, RS-232 and HP-IB interfaces and both SCPI and Keithley 181 programming languages. Hewlett-Packard Ltd. Tel., 01344 366666; fax, 01344 362269.

Direct recording oscilloscope. Gould's *DataSYS 765* dr oscilloscope has a 500Mbyte hard-disk drive and handles direct data recording to disk at up to 250Kbyte/s with no dead time. Recordings can also be made to paper or recalled from disk to paper. As a 150MHz digital storage oscilloscope, the instrument offers 100Msample/s single-shot acquisition on four channels. Although the *765* captures glitches down to 10ns, the storage provided allows recording for a period of 230 days, recordings being displayed as though on a paper roll, but with more control. Gould Instrument Systems Ltd. Tel., 0181 500 1000; fax, 0181 501 0116.

Conductive greases. Two types of grease from Planned Products of Santa Cruz not only lubricate and protect against moisture, but provide electrical and thermal conduction to drain away static and provide grounding and to dissipate heat. *Circuit Works Conductive Grease 7100* for low-to-medium loads and speeds is a silicone grease containing silver for greatest conductivity, giving a typical resistivity of <0.01Ωcm and high thermal conductivity. It is stable over the –57 to 252°C temperature range. Unworked and worked penetrations are 210 and 250, with steel-on-steel wear of 1.5mm. The *7200 Carbon Conductive Grease* has <30Ωcm resistivity, with penetrations of 335 and 338, wear measuring 2mm. Both types are chemically inert, thermally stable and non-flammable. Intertronics Ltd. Tel., 01865 842842; fax, 01865 842172.



Modular switches. Lever switches in the Swiss *SwissTac* range of modular types are now obtainable in the UK. Virtually all elements of the switches are interchangeable, contacts at the rear remaining in the same plane when switches are block mounted. Since contacts can be removed from the switch, it is possible to carry out the wiring as a separate process. Switches are available in five sizes from 18mm diameter to 24mm square, in grey or black, the actuators being black or chromed. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Literature

SM oscillators. Surface-mounted crystals and oscillators by *M-tron* are now obtainable in the UK and are described in a new 40-page catalogue containing details of, among many other devices, crystals for use in extreme environments and oscillators for use as clock generators and in military application. Semi-Dice (UK) Ltd. Tel., 01494 488353; fax, 01494 771396.

RS Components. In its new catalogue, RS Components introduces over 200 new potentiometers from makers including Bourns, Meggit Piher and Spectrol. From Bourns, a 6mm, 0.5W pot. for machine adjustment and with a multi-wire wiper; by Meggit Piher, a series of 10mm, 150mW and 12mm, 200mW units with plug-in spindles and top or side adjusted edge wheels as options; and 12mm cermet pots by Spectrol rated at 1W and offering ±100ppm/°C temperature coefficient. RS Components Ltd. Tel., 01536 201234; fax, 01536 405678.

Batteries. Batteries by Univercell are described in a new loose-leaf brochure. The company, formed by a group of managers from Ever Ready, manufactures layer cell zinc-carbon types, NiCd, special packs using various types of cell and memory-protection NiCd batteries. It also undertakes packaging to order. Univercell Battery Company Ltd. Tel., 01952 580505; fax, 01952 680075.

Loughborough Sound Images. In 132 pages, LSI provides details of a comprehensive range of digital signal-processing hardware and software support for VMEbus, PCbus and SBus, and a product guide to equipment for industrial image processing and video multimedia. Loughborough Sound Images Ltd. Tel., 01509 634300; fax, 01509 634333.

Blue Micro. Blue Micro is IBM's representative company, dealing only in IBM products. On offer is the company's 20-page publication giving brief details of, for example, the *Blue Lightning 486* 32-bit microprocessor, the *Power PC* 64-bit and 32-bit risc processors and the *403GA* 32-bit risc embedded controller. Also covered are peripheral chips and sets, MPEG-2 decoding, memory and PCMCIA products. Free from Blue Micro Electronics. Tel., 01604 603310; fax, 01604 603320.

Materials

Insulation for semiconductors. *Thermaflex* tube by Warth is in a flexible plastic material designed to fit round semiconductor packages to allow them to meet higher flash test requirements while retaining good thermal performance. A 0.5mm wall takes most standard packages and grips the device for assembly. Tubes come in two sizes: 25mm long by

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10mm wide for TO-220 packages and 30mm long by 13mm wide for TO-218/3P/247 and SOT-93. Catalogues and samples available. Warth International Ltd. Tel., 01342 315044; fax, 01342 312969.

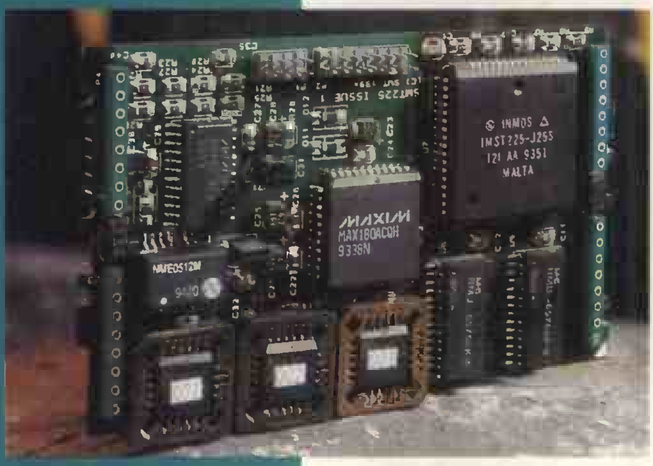
Power supplies

Power-factor correction. XP has provided power-factor correction on its *ZX series* 350/550W power supplies to meet the requirements of EN61000-3-2 and EN55022 without increasing unit size, so that they can replace uncorrected supplies with no mechanical redesign. The psus are universal-input types covering the 2V-60V range of outputs. XP plc. Tel., 01734 845515; fax, 01734 843423.

Radio communications products

Vhf transmitter/exciter. *SU 125* from Rohde and Schwarz is said to be the first true vhf transmitter/exciter, as opposed to those that are simply modulators, with driver stages and add-ons. This contains in one case the stereo coder, modulator, rf amplifier, deviation meter, transmitter control and monitor, the latter two facilities allowing the unit to be combined with any fm amplifier. The microprocessor would then monitor, protect and control the amplifiers and exciter. Inputs include af and auxiliaries such as RDS and interfaces for remote control. It is usable as a stand-alone 20W transmitter or can be used with an R&S 600W vhf amplifier. Rohde & Schwarz UK Ltd. Tel., 01252 811377; fax, 01252 811447.

Data converter interface. *SMT225* is a size 2 TRAM board (TRAnsputer Module in parallel processing systems) by Sundance that combines 12-bit d-to-a and a-to-d converters with a 25MHz transputer to provide a versatile interface for control. It is half the size of alternatives and about one-third the price. Sundance Multiprocessor Technology Ltd. Tel., 01494 431203; fax, 01494 726363.



Protection devices

3V transient protection. Protek's *SOT/SMDB* series of silicon avalanche transient voltage suppressors are expressly designed for 3V/3.3V use at up to 500W, protecting one or four unidirectional lines, being packaged in SOT-23 or SO-8 respectively. Theoretical response times are 8µs and 20µs. Hunter Electronic Components. Tel., 01628 75911; fax, 01628 75611.

Switches and relays

Power reed relays. *S series* vacuum reed relays made by Kilovac Corp. are high-voltage, high-power types for use at rf and with a mechanical life of 50 million operations. Voltage ratings are up to 10kV at 5A continuous, and the contacts switch 500W loads. Standard coils are 5V, 12V and 24V. LRE Relays + Electronics Ltd. Tel., 01962 734433; fax, 01962 734685.

Slow relay. With turn-on and turn-off times of 8.5ms and 4.1ms, Matsushita's *Soft-on/off PhotoMos* solid-state relay reduces the transients that occur when switching reactive or incandescent filament loads, thereby protecting itself and associated components; no other forms of transient protection are needed. Contacts handle 4A at 80V. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

Hf relays. *RK* and *RG* relays by Matsushita exhibit an insertion loss of 0.3dB at 900MHz and use only 200mW, or less when the optional latched type is driven by pulses. Contacts are single or double changeover and the footprint is 20.2mm by 11.2mm. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

Transducers and sensors

Low-pressure sensor. Higher sensitivity than is common, 100mV for 1lb/in^2 compared with around 50mV, is offered by IC Sensors' new board-mounted, temperature-compensated device in TO-8 or HIT packaging. Two ranges cover 0-0.03lb/in^2 and 0-1lb/in^2. Linearity (best fit straight line) is around 0.01% of span. Eurosensor. Tel., 0171 405 6060; fax, 0171 405 2040.

COMPUTER

Vision systems

PCI-bus image capture. Image Technologies has the *IC-PCI* high-speed board offering 'plug-and-play' facility for image acquisition on the PCIbus, direct-memory access being provided. Transfer rate is up to 80Mbyte/s directly to a PCI VGA card and acquisition rate to local memory up to 40Mbyte/s. DataCell. Tel., 01628 415415; fax, 01628 415400.

Computer board-level products

Single-board computer. Motorola's *68360* processor with on-board Ethernet and the *68060* make Syntel's *SYN-SBC5* single-board computer suited to both communications and control applications. It has a processing speed of 60Mips and possesses up to 32Mbyte of dram, 16Mbyte of flash eprom and 2Mbyte of sram. There is a PCMCIA interface, a SCSI interface and an on-board 32-bit graphics controller supporting lcds, electroluminescent and crt displays. Syntel Microsystems. Tel., 01484 535101/2/3; fax, 01484 519363.

PC instrument control. National Instruments offers the *PC/104-GPIB*, an IEEE488 interface board for embedded pcs with *PC/104* expansion. It is compatible with NI's *AT-GPIB/TNT* plug-in interface and uses the *HS488* mode for GPIB transfers to 1.6Mbyte/s, enabling an embedded pc with the *PC/104-GPIB* to control, monitor and communicate with GPIB-based instruments. National Instruments UK. Tel., 01635 523545; fax, 01635 523154.

Computer systems

Single-chip PC core logic. NEC and Future Technology Devices collaborated to produce the *FTD 82C4591*, a single-chip device containing the core logic of a *386/486* pc-compatible embedded control system with bus speeds to 66MHz. It has ISA and VL-bus interfaces with programmable speed and only needs standard buffers for the ISA address lines. The device connects directly to an sram-based, direct mapped, bank interleaved cache, supporting write-back and through modes. Sunrise Electronics Ltd. Tel., 01908 263999; fax, 01908 263003.

PC-AT-compatible board. Arcom has a new PC-compatible single-board computer, the *VSCIM486DX*, using the 100MHz 486DX4 processor. A full VMEbus interface is complemented by ports to the SCIM mezzanine local expansion bus, the *Signal Conditioning Scheme* (SCIM), STEbus and two memory expansion buses. It can be provided with 68Mbyte of dram, 256Kbyte of cache sram, 128Kbyte of battery-backed ram dual-ported to STEbus and an accelerated SVGA graphics controller with 1Mbyte of ram; the chip incorporates a 32-bit maths co-processor. Since the board runs dos and windows, software such as *LabView* is accessible. Arcom Control Systems Ltd. Tel., 01223 411200; fax, 01223 410457.

Industrial workstations. H-P's *HP9000* workstations are based on the company's *PA-RISC* processors running at up to 100MHz and supporting H-P's version of UNIX, HP-UX. Models *745i/50* and *745i/100* are the basic types with four EISA slots and 50MHz or 100MHz *PA-RISC* processors, while *747i/50* and *747i/100* have six VME slots and two EISA slots. XP plc. Tel., 01734 845515; fax, 01734 843423.

Data communications

Digital packet radio. *PackNet-2* by the Swedish company Radius is a vhf/uhf packet radio for remote control telemetry and data transfer, providing a link between the components of computer networks and control systems. Radio transceiver, microprocessor control and modem are combined in one box and a built-in repeater or external repeaters allow for extension of a network. *PackNet-2* offers both serial and parallel connection, a full RS-232-C interface being provided. Radius Telecommunications (UK) Ltd. Tel., 01256 469460; fax 01256 842362.

Multimedia

Installation diagnostics. Developed to assist those installing or upgrading pcs with multimedia hardware, Eurosoft's *CD-Check Diagnostic Disk* tests the installation and operation of cd drives, memory, sound cards and

Media accelerators. *BtV MediaStream* by Brooktree is first in a family of products combining hardware and software to allow a pc to take full advantage of the facilities offered by multimedia offerings. It is a three-chip set enabling dos games-compatible audio or digital sound, 1280 by 1024 graphics and 30frame/s, television-quality, full-motion video windows. BtV MediaStream is intended for use with add-on cards, 486 VL local-bus systems and the new PCI-based *Pentium* pcs, either on cards or on the motherboard. An important feature is the provision to output all-digital audio directly to consumer equipment with digital ports, such as DAT and cd players. The system produces high-quality graphics even when multiple windows run and good video lip-sync. at 30frame/s. It also supports standards such as the Microsoft MCI and DCI extensions under Windows and Microsoft's Plug-and-Play. Brooktree Ltd. Tel., 01252 811358; fax, 01252 811505

display, supplying a report on the results. It checks all system components to the Multimedia PC Council (MPC) standards. Eurosoft (UK) Ltd. Tel., 01202 297315; fax, 01202 558280.

Programming hardware

In-circuit programmer. In-circuit, board-level programming becomes necessary in military or other critical applications when ICs must be programmed after assembly, to ensure nothing happens to the data during soldering. Stag has produced the *ICP 9000* board-level programming system which reduces the need for extensive mechanical work in interfacing to the board and for complicated software where the board contains ICs other than eproms. With the *ICP 9000*, the only interface needed is a removable interface adaptor and the software can be written much more easily, by a technician, using a purpose-designed high-level language, so that boards not designed to accept ICP are able to benefit. A library of definition files further reduces the programming needed and facilitates the writing of programs for future requirements. The time taken for the process is said to be reduced from weeks to hours. Stag Programmers Ltd. Tel., 01707 332148; fax, 01707 371503.

Software

Interconnection analysis. *IPA 510 Interconnect Parameter Analyser* by Tektronix is an expansion of the earlier *IPA 310*. In essence, it models and verifies the interconnections of semiconductor devices on boards and even from the chip to the pins of packages. The system consists of a time-domain reflectometry oscilloscope and associated software. *IPA 510* will extract and verify Spice models, perform tdr and td transmission and execute network analysis, presenting true impedance diagrams of purely passive interconnections from zero to 12.5GHz and modelling energy through dissipation or coupling to effects on adjacent traces on the board. Interfaces for *Contec-Spice* and *P-Spice* are available and, since the system links measurement and Spice simulation, Spice models can be developed by extracting models from overlay of time-domain results. The oscilloscope used is an *11801B* and the software runs under Windows. Tektronix UK Ltd. Tel., 01628 486000; fax, 01628 474799.

Development tools. *TNT Embedded ToolSuite* by Phar Lap is a set of tools, running under dos or Windows, for the development of 32-bit embedded systems based on the Intel *386/486* family. It supports 32-bit C and C++ compilers from Borland, Microsoft and MetaWare. Facilities include the *TNT* embedded kernel, *Visual System Builder*, a 32-bit linker/locator, embedded cross-debugging, C and C++ run-time libraries and a floating-point emulation library. Phar Lap Software Inc. Tel., 00 617 876-2972; fax, 00 617 661 1510.

Ice debugger for Windows. Nohau has introduced a Windows-based in-circuit emulator debugger for the *8051* emulator. The debugger uses an unlimited number of windows instead of the common single one, displaying data in up to 12 different forms simultaneously. In this way, the user can view at the same time C source code, disassembled code, data, assembler with comments and more. The debugger comes either as a package with the emulator or as a software update for existing users. Nohau UK Ltd. Tel., 01962 733140; fax, 01962 735408.

Fm noise analysis. The fm noise simulation package by Phasor Design includes the facility to determine bit error rate in digital communications systems from carrier-to-noise ratio and the ssb phase noise of oscillators, fm deviation, emphasis and noise weighting being included. It carries out numerical integration in the frequency domain to obtain s:n ratio, numerical summation of the amplitude distribution giving error probability to one bit. The package runs on a pc with a gui, and data files of system characteristics such as phase noise and de-emphasis are included or can be written by the user. Phasor Design. Tel., 01858 432148; fax, 01858 432109.

Instrument-to-program translator. *SoftwareWedge* takes serial input data from measuring instruments fitted with RS-232, parses it and filters it to suit any application program running on a pc, as though the data were being typed in. In the other direction, keyboard and program instructions to the remote instruments are also translated into the correct form. Dos and Windows versions are available, the Windows version also supporting OS/2, NT and DDE. Kyle Data Service Ltd. Tel., 01292 311169; fax, 10292 318005.

Bare-board tester. *FIXpert* is a windows-based package to make drill patterns and test programs for the testing of unpopulated printed-circuit boards to design data. Since the 'known good board' approach is not used, the possibility of a fault being perpetuated is avoided. Drill files and their test programs are automatically produced and the whole process of creating the test routine from input to production of files and test program takes under an hour. Dense boards are 100% tested in two passes and double-sided boards are tested for side-to-side connectivity. Circuitest Ltd. Tel., 01903 218086; fax, 01903 218689. ■

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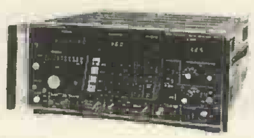

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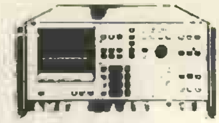

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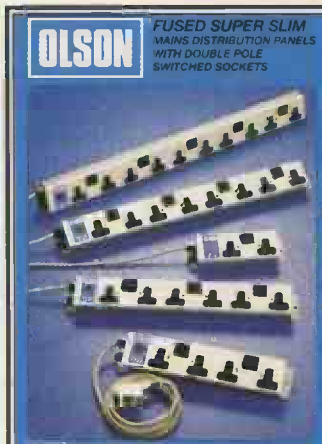

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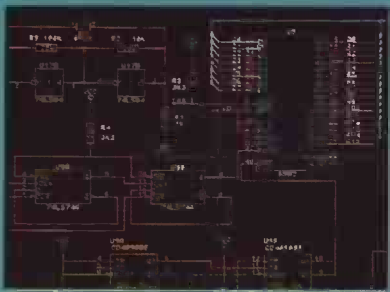
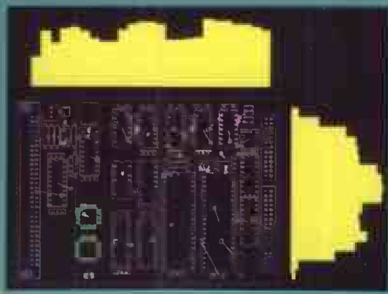
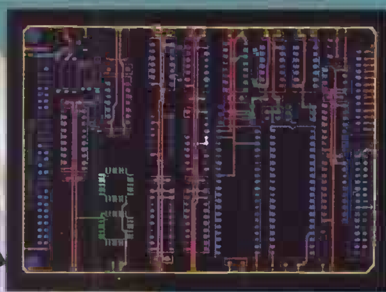


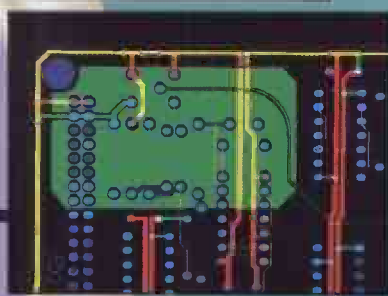
Your design ideas are quickly captured using the ULTIcap schematic design Tool. ULTIcap uses REAL-TIME checks to prevent logic errors. Schematic editing is painless; simply click your start and end points and ULTIcap automatically wires them for you. ULTIcap's auto snap to pin and auto junction features ensure your netlist is complete, thereby relieving you of tedious netlist checking.



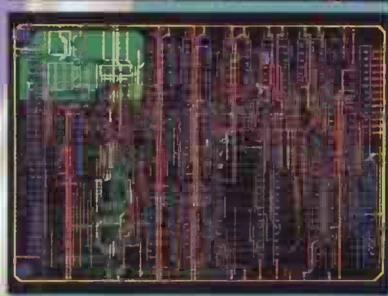
ULTIshell, the integrated user interface, makes sure all your design information is transferred correctly from ULTIcap to ULTIboard. Good manual placement tools are vital to the progress of your design, therefore ULTIboard gives you a powerful suite of REAL-TIME functions such as, FORCE VECTORS, RATS NEST RECONNECT and DENSITY HISTOGRAMS. Pin and gate swapping allows you to further optimise your layout



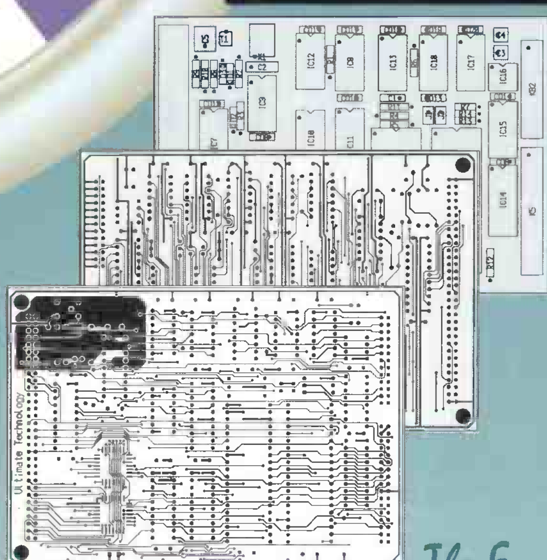
Now you can quickly route your critical tracks. ULTIboard's REAL-TIME DESIGN RULE CHECK will not allow you to make illegal connections or violate your design rules. ULTIboard's powerful TRACE SHOVE, and REROUTE-WHILE-MOVE algorithms guarantee that any manual track editing is flawless. Blind and buried vias and surface mount designs are fully supported.



If you need partial ground planes, then with the Dos extended board systems you can automatically create copper polygons simply by drawing the outline. The polygon is then filled with copper of the desired net, all correct pins are connected to the polygon with thermal relief connections and user defined gaps are respected around all other pads and tracks.



ULTIboard's autorouter allows you to control which parts of your board are autorouted, either selected nets, or a component, or a window of the board, or the whole board. ULTIboard's intelligent router uses copper sharing techniques to minimise route lengths. Automatic via minimisation reduces the number of vias to decrease production costs. The autorouter will handle up to 32 layers, as well as single sided routing.



ULTIboard's backannotation automatically updates your ULTIcap schematic with any pin and gate swaps or component renumbering. Finally, your design is post processed to generate pen / photo plots, dot matrix/laser or postscript prints and custom drill files.

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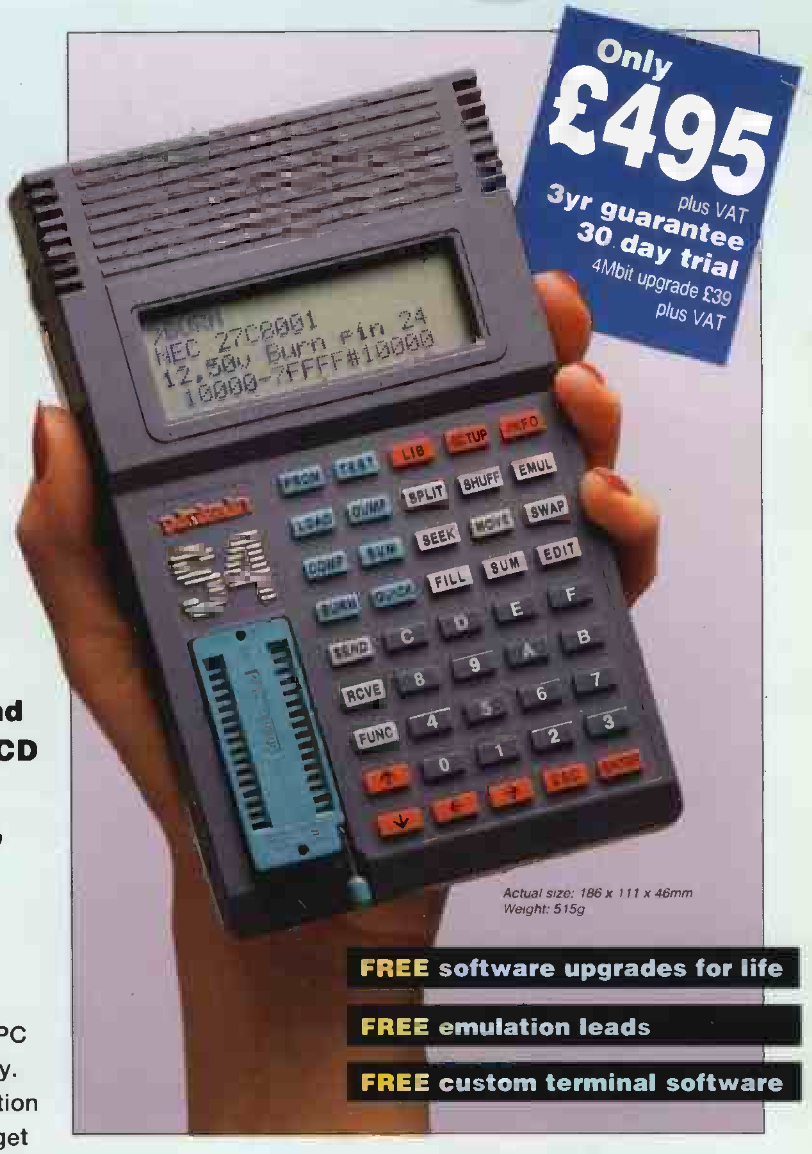

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