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In next month's issue. Maxwell's waves. In 1865, James Clerk Maxwell came to the realisation that his now famous equations described a travelling wave. He hypothesised that a continuous interaction between magnetic and electric fields would result in an electro-magnetic wave travelling in free space. Martti Nissinen brings a new clarity to the understanding of electro-magnetic physics.

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The great purpose

This year sees the 80th anniversary of the *Marconigraph* of which *Electronics World + Wireless World* is the lineal descendant. We plan to mark the event by producing a joint pictorial history of electronics in conjunction with the Marconi Company.

Researching the combined archives in preparing this book provides a privileged, god-like perspective on the purpose of electronics, with every yellowing photograph holding secrets of both past and future. In evolutionary terms, they demonstrate but one direction.

But evolution has its blind alleys. The Hough transform describes an object's shape by returning the angles subtended by coordinate points making up its physical space. To the defence industry, it means fast pattern recognition regardless of object size or orientation with minimal computing power. The video arcade style of the Gulf war depended largely on Hough transform target acquisition delivered by an asic chip.

Surely surgical warfare cannot be the sole purpose of electronics?

Making hydroxyl ions ring like bells under the combined onslaught of pulsed microwave energy and an intense magnetic field looks more promising. The degree of hydroxyl resonance induced in human tissue indicates tissue density and hence the position of tumours. But the number of people who will need to call on computerised NMR tomography is thankfully small; there is no all-embracing purpose here.

Crystal diodes became valve diodes. Valve diodes became triodes. Triodes evolved into screened tetrodes, pentodes, klystrons and magnetrons. And crystal diodes, which until this time had defied evolutionary extinction somewhere down on the forest floor, waited their chance for development. They evolved through junction transistors, fets, bipolar ICs and mos chips ousting thermionic dinosaurs on the way.

Although impressive in evolutionary terms, component development has amounted to no more than enabling technology, an analogue to the climatic change which moulded life on Earth.

The purpose of electronics is located on a different path.

High power spark transmitters must have been an impressive sight and sound. Recent calculations suggest that transatlantic wireless telegraphy stations emitted upwards of 75kW RF peak power; the crackling spark gaps consuming kilowatts by the hundred.

No wonder engineers of the period worried that wireless communication adversely affected the world's weather. Substitute "greenhouse effect" for "wireless communication" in our early correspondence columns and the subject would not be out of place today.

Politicians had no such qualms. Six weeks to send a message from one end of the empire to the other before radio meant governments seized on wireless to exercise tighter control on the far-flung outposts, reacting instantly to local conditions. The political and commercial communication needs of the Empire thus became the imperative behind electronics development. It was so then and, in only slightly modified form, is still so today.

Electronics exists to allow centralised authorities and governments to communicate with the governed. DHSS computers keep track of, and communicate with, virtually every one of us. Politicians largely use electronics communication to reach the electorate. Business uses electronics communication to relieve us of our money through banking, advertising or whatever.

In short, electronics now provides society's neural pathways. Without the instant communication and control provided by technology, the human race could not walk its chosen evolutionary path.

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Ups or downs for anti-matter?

As we watched the hammer and feather fall to ground at the same rate in the "vacuum" of the moon, back in 1971, we were seeing on our television screens perhaps the first public proof of a concept formulated way back in the 17th century. But while any schoolchild now knows that the same force due to gravity acts on every normal object, physicists have not been entirely convinced that the same rules apply to anti-matter.

Anti-matter is a hypothetical material in which atoms comprise oppositely charged particles such as anti-protons and anti-electrons (positrons). While such material, if it exists, would be instantly annihilated on contact with ordinary matter, the various anti-particles can readily be created for a short time in big particle accelerators.

Experiments involving collisions between particles and anti-particles release a greater density of energy than existed in the first nanoseconds of the Big Bang birth of the Universe. They have also provided conclusive evidence for existence of the elusive Z-particle.

But to return to the properties of isolated anti-matter, two groups of physicists have independently reassessed the very limited experimental data on whether anti-particles in a gravitational field fall with the same acceleration as normal matter. According to Einstein's theory of General Relativity they should, but even on the moon you can not just open a box containing anti-particles to see what happens.

So the two teams, one from the University of Washington in Seattle and the other from the Los Alamos National Laboratory have looked instead at indirect evidence. The Seattle group argue (*Phys Rev Lett Vol* 66 no 7) that if matter and anti-matter react to gravity in different ways, that implies an additional sort of quantum force of the type implicated in the now generally discounted "fifth force" studies.

The Los Alamos team (also *Phys Rev Lett Vol* 66 no 7) have adopted a different approach and re-analysed experiments undertaken at Harvard University; these showed that protons and anti-protons have the same mass, at least to within 4 parts in 10^8. The Harvard team measured the way the different particles orbit around the lines of a magnetic field.

On the basis that gravity interacts with energy as well as mass, the Los Alamos researchers deduce that if there is any difference between the behaviour of free-falling protons and that of free-falling anti-protons, it must be very small indeed.

These conclusions are, of course, nicely in accordance with the theory set out by Einstein. But until the behaviour of antimatter under gravity can be observed directly, (as with the feather on the moon) there will inevitably remain some lingering doubts on what things would be like if we could ever catch a glimpse of a parallel, mirror-image Universe.

Ice or IC?

Diamonds could be much more than a girl's best friend, judging from research now going on in a number of laboratories around the world. Last year, *Science* (the journal of the American Association for the Advancement of Science) voted diamond its Molecule of the Year.

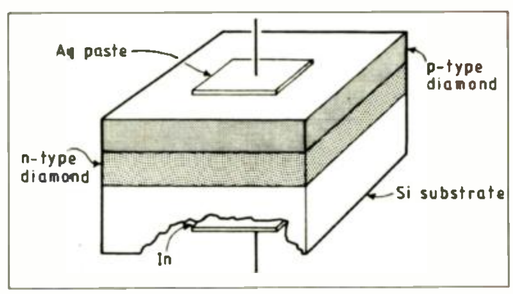
Reasons for all this excitement are at least threefold: diamond possesses unique physical properties due to its rigid cubic lattice; it can now be synthesised in forms purer than natural gemstones, and (being a Group IV element) diamond has the potential to form the basis of a whole new family of active electronic components.

The sparkling refractive index of diamond is well known; what is not so widely appreciated is that diamond is transparent to X-rays, UV rays and IR rays. It is also an excellent electrical insulator, a superb heat conductor and extremely resistant to heat, corrosion, physical abuse and nuclear radiation.

The only snag about this wonder material (at the moment) is its horrendous cost! But last year was marked by a series of technological breakthroughs in producing increasingly pure samples of synthetic diamond. For example, GE demonstrated an improved process for condensing tiny diamond crystals from methane gas and then creating larger stones by subjecting them to intense heat and pressure. Diamonds produced by this chemical vapour deposition (CVD) process proved to be better heat conductors and more resistant to damage from laser radiation than natural gemstones.

Research in this area has now leapt into top gear with the recent announcement of the creation of single crystal films of diamond at the University of North Carolina and Oak Ridge National Laboratory. In a recent paper (*Science* vol 252, 416) Jagdish Naayan *et al* reveal details of a new process that uses powerful bursts of laser emission to transform ordinary carbon into a flawless film of diamond.

The process starts with carbon atoms embedded in the top few atomic layers of a sheet of copper. For 45ns the temperature of the composite surface is raised to over 2000K, when the carbon layer is converted



Structure of the Tokai diamond diode.

to pure diamond. Because the laser pulse is so short there is no time for the diamond to revert back to ordinary carbon. While the resulting diamond is only a few atoms thick, it consists of a single crystal, potentially any size.

Although the films are currently too small to make into electronic devices, they offer great potential because the purity and crystal size are not constrained as they are with CVD techniques. But why bother to make active devices from diamond when the industry already has such a large array of group IV elements and III-V compounds? The answer lies in physical properties.

Diamond chips would be mechanically robust, capable of operating at 1000°C and also largely unaffected by nuclear radiation, X-rays or UV. They could operate in space or inside nuclear reactors, or many harsh environments that spell instant death to silicon or gallium technology.

In parallel with research into artificial diamond crystals, there is a great deal of work going into creation of practical semiconductor devices. Diamond doped with boron is relatively easy to make in the form of tiny crystals by CVD, and so far several metal-semiconductor devices based on this p-type compound have been created.

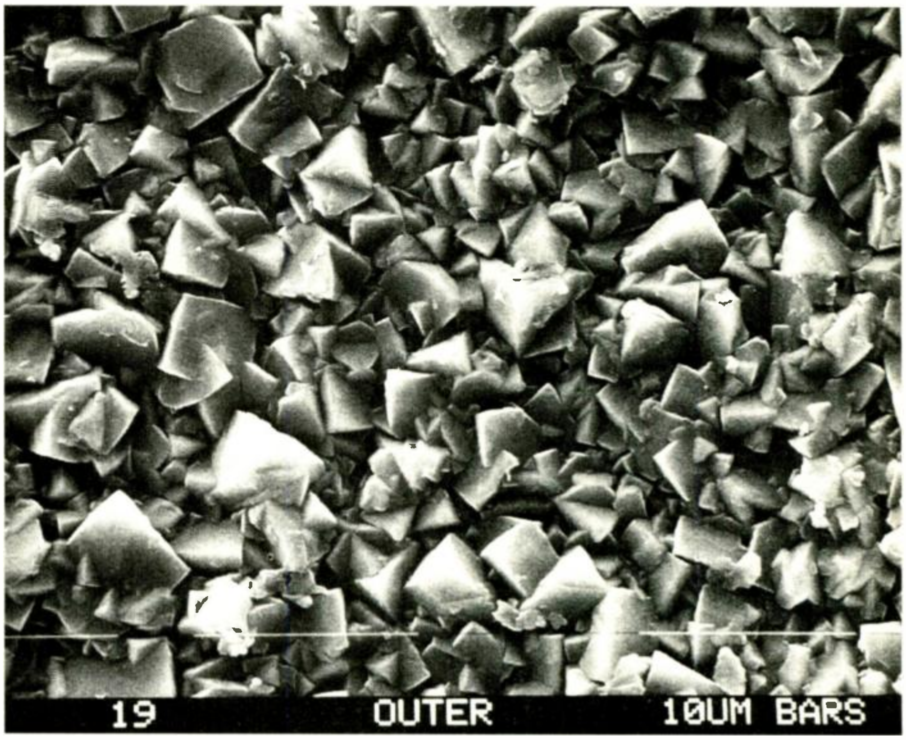
But junction devices, employing p-n junctions have proved difficult, because n-type diamond is hard to make. Using group V atoms to dope pure diamond either does not succeed at all, or results in destruction of the diamond lattice.

That problem has recently been overcome by work at Tokai University in Japan in which n-type diamond was created in a CVD process with diphosphorus pentoxide incorporated into the methane/hydrogen mixture from which the diamond crystals were condensed.

The Tokai group have now taken a significant step forward (*App Phys Lett* 58, 840) in which they describe their first diamond p-n diode. Construction is as shown in the diagram, while performance seems better than expected.

Obviously there is still a lot of work to be done before we have a diamond transistor, let alone a diamond IC — nor for most purposes will they be necessary.

But in environments that are harsh and where long-term reliability is vital, diamond electronics looks like playing a big part.



A number of groups have created synthetic diamond using CVD processes This picture shows pure polycrystalline diamond produced by a British group working for Pilkington Electro-optics, deposited by high energy methane plasma. Hydrogen, introduced into the vapour phase effectively mops up the graphite which tends to be formed along with the diamond.

Molecular footballs roll towards organic IC goal

Ball-shaped buckyballs — or buckminsterfullerenes to give them their more formal title — are poised to play a major role in organic semiconductors and perhaps in novel classes of superconductors. That at least is the implication of two important papers by researchers at AT&T Bell Laboratories in Murray Hill, NJ.

Buckminsterfullerenes, named after the inventor of the geodesic dome, first came to light about six years ago when scientists found tentative evidence that carbon atoms could link together in even-numbered clusters of between 30 and 100. Though this phenomenon was only observed in high temperature vapours, it led to speculation that an entirely new allotrope of solid carbon might exist, wholly different to diamond, graphite or black carbon.

Sure enough physicists in Germany and the US last year, managed to synthesise molecules consisting of 60 or 70 carbon atoms arranged on a lattice rather like a geodesic dome or a football. They also found tentative evidence that large quantities of such molecules exist in space.

Since then, several research groups, most notably AT&T Bell, have been examining the properties of the new materials, keeping

Changing fashions in liquid crystals

Anyone who believes that liquid crystals are limited to LCD displays and thermochromic heat sensitive paints should have gone along to the recent fashion show organised to mark the 150th anniversary of the Royal Society of Chemistry. There they would certainly have had their eyes opened (wide).

Almost two decades after the pioneering work on liquid crystals, Merck Industrial Chemicals has succeeded in incorporating them in microcapsules 10-15μm in diameter. As a natural extension of this development they went on to mix the microcapsules into screen-printing ink to make high fashion garments that change colour — chameleon-like — with the temperature of the wearer (or their surroundings).

Mark Aartson of Merck explains how an apparently black dress suddenly acquires a red colour when first put on. As it warms up, it can go through a complete spectrum (that is if the wearer ever reaches 45° C). Hot spots on the body become immediately apparent, as do parts that have been touched. Aartson speculates that in future, nightwear might be a rather interesting development...

a careful eye on commercial applications. Now they have set the molecular football rolling in a big way by publishing a report (*Nature* Vol 350 No 6316) on C_{60} and C_{70}-based molecular semiconductors, unique in at least one respect in that they hold the potential for isotropic conduction.

What the team did was to synthesise films of C_{60} and C_{70} in a vacuum and then carefully add impurities of potassium and caesium. Doping gave the normally non-conducting fullerenes an electrical conductivity comparable with best existing non-metallic conductors. Only snag in practical terms is that the resulting materials are chemically unstable and break down, either over time or on contact with air.

Research is continuing using smaller dopant atoms — presumably lithium and sodium — in the hope that these might be stable and easily incorporated into gaps in the molecular lattice. AT&T is confident that eventually it will achieve stability and a material that conducts well in all directions. In the last respect, fullerene-based materials are all but unique in a field where most organic conductors are markedly anisotropic.

Not content with one breakthrough in the physics of exotic carbon molecules, AT&T has just published another paper (*Nature* Vol 350 no 6319), this time on molecular footballs and their superconducting properties. The same team have found that doped fullerene molecules become superconducting at a temperature of 18K, the highest transition temperature yet recorded for an organic material.This finding, regarded as remarkable and unanticipated, is seen as a key to forging links between organic and inorganic superconductor theory. It will be particularly interesting for example to see if the fullerenes prove to be isotropic superconductors, differing from the two-dimensional characteristics of the better known cuprate superconductors.

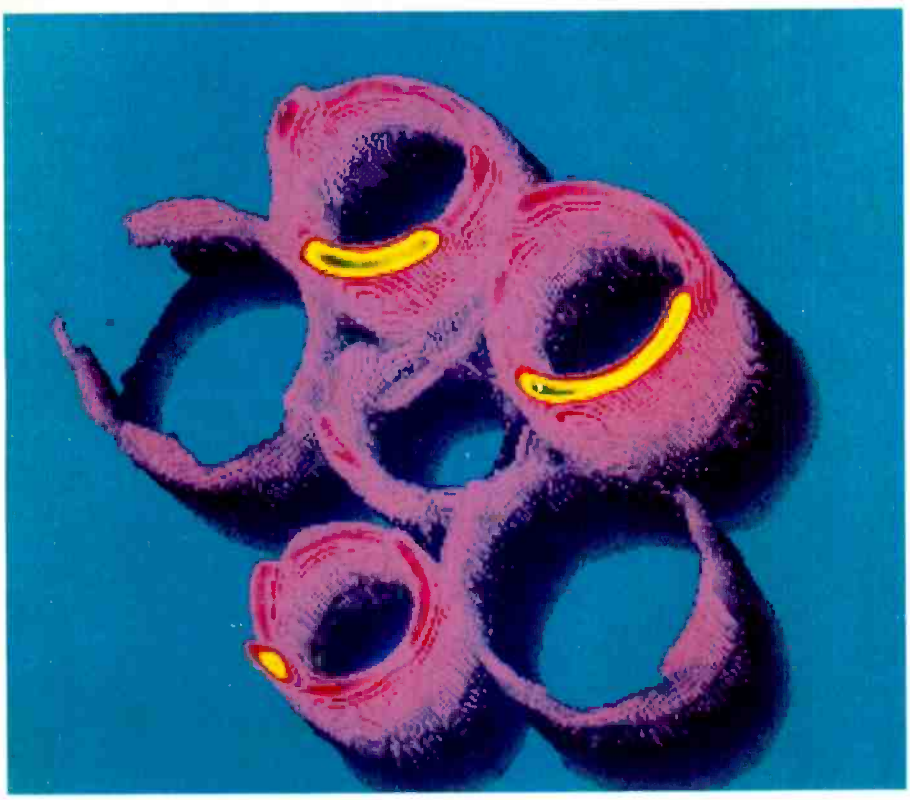
Excitement is clearly running high at AT&T. In a telephone comment, Dr Art Hebard, one of the authors, envisages applications ranging from optics through dielectrics to signal processing. When it comes to considering new ways of doping the molecular footballs, Hebard adds optimistically that: "We look at the periodic table and there's a whole lot of opportunity there." A view with which no-one could disagree.

Proton probing reveals microelectronic detail

A powerful new tool for studying the shape and density of materials may hold promise for use in a variety of industrial and medical areas, including the study of cancer and microelectronics.

Called ion microtomography (IMT), the emerging technology produces detailed images of slices of objects much like the more familiar medical X-ray cat (computer-aided tomography) scan. But IMT images are approximately 1000 times more detailed. High resolution allows it to "see" constituent parts as small as one micron — diameter of a human hair is about 100µm. Images can be computer manipulated to produce different perspectives and cross-sectional views.

Ion microtomography can be used to produce a 3-D rendition of tomographic slices.



Researchers at Sandia National Laboratories at Livermore California are leading the development of IMT in collaboration with Lawrence Livermore National Laboratory. They are also working with scientists at the University of Melbourne, Australia.

IMT is particularly useful for samples with low total density or where small density variations make X-ray analysis difficult. For example, it has been used to produce three-dimensional images of small junctions between two glasses with different densities.

For biomedical specimens, IMT has the added advantage of causing significantly less tissue damage than other imaging techniques. Unlike X-ray cat scans, IMT uses concentrated proton beams with energies in the mega-electron volts (MeV) range. The positively charged particles pass completely through the sample to a silicon surface barrier detector while transferring only a portion of their energy to the specimen. X-rays are absorbed and release much of their energy within the specimen, causing cell damage.

The technique, which was developed from defence work, could also have important industrial applications for materials used in microelectronics, non-destructive testing, fission and fusion research. For example, IMT could be used to examine small structures or to inspect extremely thin coatings for uniformity on silicon chips.

It also has potential for inspecting extremely small manufactured parts for flaws and weaknesses without the need for sectioning.

Research Notes is written by John Wilson of the BBC World Service

DTI on the track of low power radio

The DTI has set up an industry group to tackle the problem of "pollution" of the airwaves from low power equipment. The move has been made in response to growth in use of low power radio equipment such as anti-theft devices and radio microphones.

Such devices operate at up to 10mW VHF or 500mW UHF. A licence is not needed for their use but they still need Type Approval to DTI standards. But if they operate outside these conditions there is a danger of interference to other radio users.

To make sure standards are adhered to, the DTI has set up an industry group comprising more than 40 manufacturers and users. The Low Power Radio Association aims to improve communications between those who set the standards, those who make the equipment, and end users.

The other problem is that individual countries in Europe operate on different regulations and use different parts of the spectrum. ETSI, the European standards-making body, plans to standardise these regulations and the LPRA is represented on this body.

The LPRA also aims to be a source of information for people having problems using or wishing to buy equipment.

Science is for boys says schoolchildren

Sexual stereotyping already exists in children as young as five years old, according to a survey by the Engineering Council and NASUWT (the National Association of Schoolmasters and Union of Women Teachers).

The survey interviewed more than 500 five-year olds split almost equally between boys and girls. It revealed that tasks such as car repairs and woodwork are seen by nearly all as jobs for men only and mending and washing clothes for women only.

Both the boys and the girls gave similar answers. For example, 95.8% of the boys and 88.7% of the girls saw car repairs as a men only job.

The best score for activities appropriate for both sexes was wearing trousers (48.3% boys and 52.2% girls).

Rather worrying were the figures for the scientist — 72.6% of boys and 65.6% of girls saw it as a male only job. Only one in five saw it as a job for both sexes.

The report comments that the children are "to a large extent reflecting back what they have picked up from their parents and other influences... From birth onwards children are exposed to a powerful representation of separate expectations for men and women, which may become emotionally deep seated."

The report recommends that teachers should be made aware of the extent and pervasiveness of sexual stereotyping among young children and that girls should be helped and encouraged to involve themselves fully in the science and technology curricula.

£5m boost for PCB work: Irlandus Circuits from Craigavon in Ireland has been given a £5million cash injection by the Northern Ireland Industrial Development Board. The money will improve production techniques for printed circuit boards (see picture) and is expected to provide 75 new jobs. Work will start immediately on a Class 10,000 clean room that will house inner and outer layer photographic processing. The firm also plans to install a new aqueous strip/etchline and horizontal electroless line as well as upgrading its cam system.

Hackers face stricter controls

A new way is to be sought to beat computer hackers because detecting and prosecuting offenders is proving such a serious problem for business, commerce and the police.

The study, for the DTI, is being carried out by management consultant Coopers & Lybrand Deloitte. It will look at what expertise is available and will find out whether new sources of advice may be needed. It is nearly a year since the Computer Misuse Act came into force making hacking a criminal offence. The fear is that without such advice the police may be unwilling to bring prosecutions under the Act or, if they do, cases may be mishandled.

Results of the study will be presented at a special conference planned for the autumn.There are three offences that can be committed under the Act: basic hacking where the offender browses through other computers with no malicious intent; using information gained from hacking for fraud or blackmail; and altering the contents of a computer.

GaAs process opens up optoelectronics

Optical and electronic circuits can be combined on the same chip using standard semiconductor fabrication processes, claim researchers at Georgia Tech in the USA.

Such circuits will be needed for the next generation of consumer electronics such as videophones, fibre optic data links and imaging systems like high definition television.

The chips are a mixture of silicon and gallium arsenide. Silicon is still the best choice for integrated circuits, but it cannot be used to make devices that emit light from electrical stimulation alone. Here GaAs comes into its own, but it cannot be grown directly onto the silicon.

Timothy Drabik, Georgia Tech's assistant professor of electrical engineering, explains that: "Lack of a good technology for putting light modulators or light generators on silicon hinders progress in computing devices that use electrical inputs and outputs with optical inputs and outputs. Growing films on relatively large silicon wafers involves considerably more expense than growing them on GaAs wafers."

What the Georgia Tech team has done is grow GaAs devices on a GaAs substrate.

The devices are then peeled off using a modified version of a process developed at the US electronics company Bellcore. The modifications look at device alignment and selective placement on the host substrate.

The process involves placing the devices on a transparent polyimide sheet that is used to align each device or an entire array of devices on the silicon host wafer. They are then transferred from the polyimide to the host substrate.

GaAs devices can be made in sizes from 2µm up to 1cm on a side and as thin as 1 to 2µm. They can be deposited onto nearly any smooth host substrate including silicon, glass and lithium niobate.

Mark Allen, a member of the research team, says: "The GaAs chiplets are so thin that the flatness of the host silicon wafer is not substantially affected by their presence. This permits use of standard semiconductor fabrication processes which may help lower the cost of manufacturing optoelectronic circuits from GaAs on silicon."

Similar work is also going on at Texas Instruments and the firm claims to have developed a working chip that combines silicon logic circuitry with an array of GaAs components. Texas calls its device an OEIC or optoelectronic integrated circuit.

We must address the packaging and assembly issues required to put this technology to use."

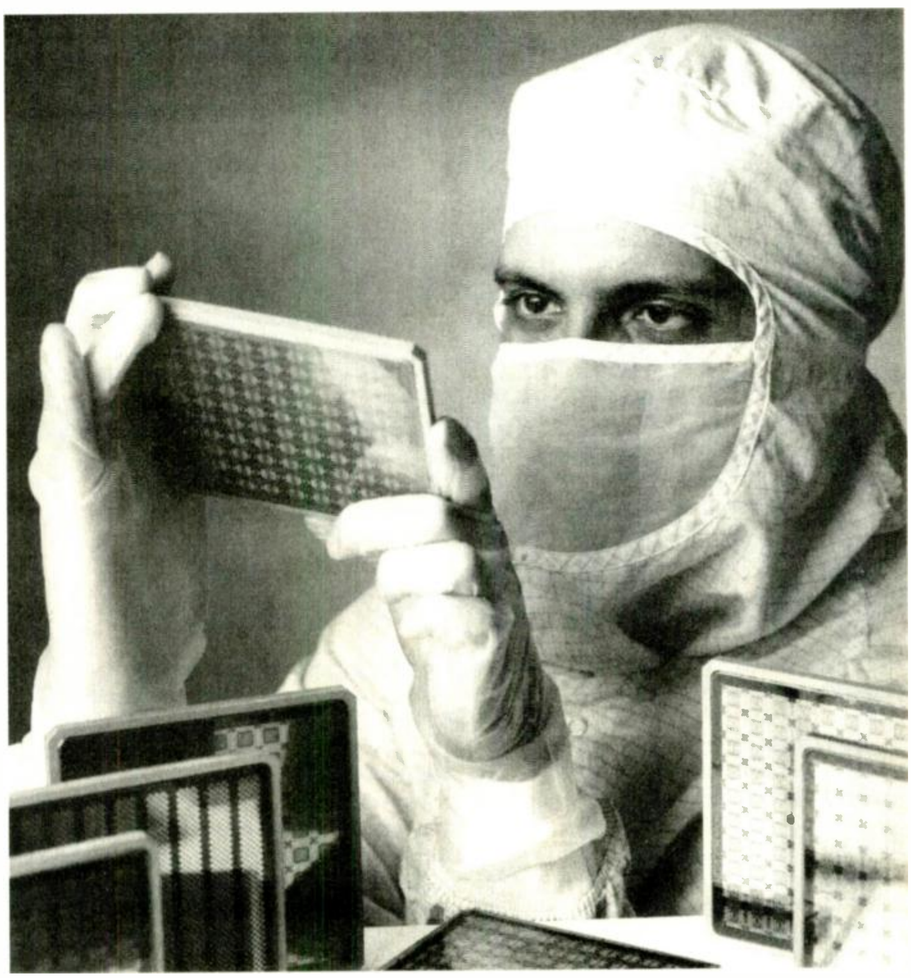
He estimates that the OEICs will be used in electronic systems in the next five to ten years.

Ultra-stable quartz

Researchers at STC Components reckon they have cracked the ageing problem experienced with ovened oscillators. In traditional oscillators the crystal is a piece of quartz with an electrode, all in a metal or glass package. The ageing problem is caused by movement, with time, of the crystal and electrode with the packaging.

But STC has built prototype oscillators using packages made out of the same type of quartz as the crystal. This means that the package and crystal react similarly to temperature changes, reducing movement between the two. The firm claims that tests on the prototype show a dramatic improvement in stability and repeatability of the crystal.

A range of quartz-in-quartz ovened oscillators is expected to be introduced later this year.



Glass ceramic for new computers: IBM has updated its thermal conduction module invented in 1980. The old alumina-ceramic base has been replaced with 63 layers of glass ceramic and the molybdenum wiring has been replaced with thin copper wiring. The result is 121 chips crammed into a 12.7cm square package. The chips are less than 1cm apart and mounted directly onto the ceramic. The package will form part of the System 390 series of computers.

Funding shadow falls over light computer

Within two years a group of British scientists at Heriot Watt University could surprise the world and build a computer capable of processing data literally at the speed of light. But the long timescale before any practical product becomes available means that a row is building up between academics over whether the project should continue to be funded at all. The Scottish team has spent the last three years creating the optical equivalent of a logic gate, the basic building block of any computer. Now they are building an all optical computer with the potential to make today's microchip powered computers as obsolete as yesterday's valve driven adding machines.

But does this fall into the category of "blue-sky" research which UK research budgets can no longer support, or a basic enabling technology for the next century which British industry cannot afford to miss out on? On this question British academics have started to doubt the logic of supporting the all optical computer project which will not produce a commercial product for many years.

"Very few people today seriously believe that optics will replace electronics," comments John Midwinter, Professor of optoelectronics at University College, London.

It is argued that the limited funds available in the UK for basic research should be targeted at programmes that provide a more direct benefit for industrial research.

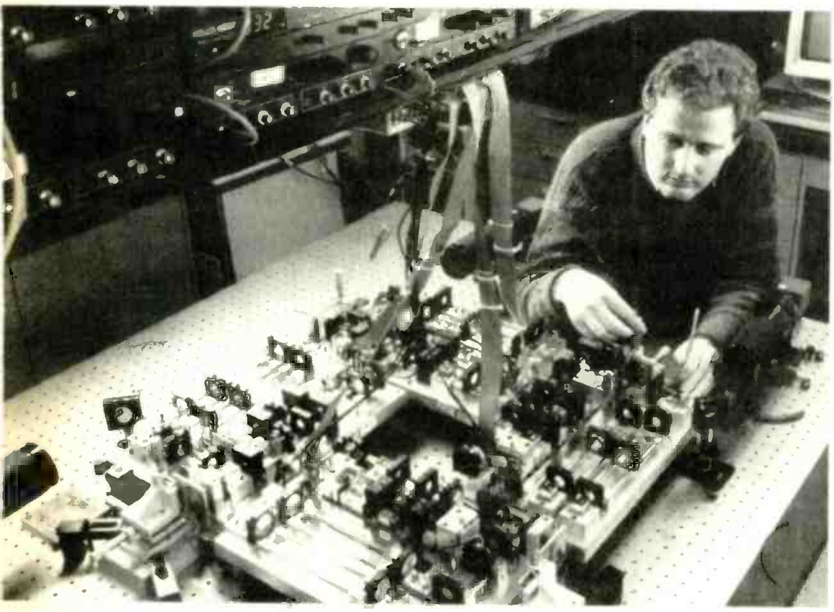
Professor Alec Gambling of Southampton University, who is also chairman of the Science and Engineering Research Council's optoelectronics committee, says "In my view UK industry is fairly desperate right now and we need to give it all the support we can by directing research into ideas which have a shorter than five year timescale."

The Heriot Watt work is unlikely to lead to commercial machines before the end of the century. But Des Smith, professor of physics at Heriot Watt, believes this is British short-termism which misses the point of optical data processing.

"The direction work may go in is long term, but it offers a revolutionary change to the way we process information," he explains, "It may take a high risk route, but that is what universities should be doing, in my view."

Professor Smith believes optical data processing is the most obvious means of retrieving data from mass storage optical disks. Using existing electro-mechanical techniques it takes two hours to read the five billion digital data bits that can be held on a compact disk.

Optical processing, says Professor Smith, can improve on this data read rate by as much as a factor of 10,000. This is because a large number of basic optical logic functions can be carried out in parallel by making use of the information carrying capacity of optical signals.



Michael Prise at AT&T Bell Laboratories adjusts a component in the world's first digital optical processor. The question now being asked is should research funds be committed to such long term projects in the UK?

Such a machine could have the processing power to match the image recognition capability of the human brain.

The brain receives an enormous amount of information — 7^{10} bits of information each second — and yet it has a relatively slow signal processing rate. Despite this the brain's power of recognition is fast because it compares image information with that already held in memory, using massive parallelism like Heriot-Watt's optical processor.

"What is missing is British or European interest in the overall concept of the optical computer," comments Professor Smith.

Contradicting conventional wisdom

One problem is that Professor Smith's work challenges the conventional wisdom that accepts superiority of electronic data processing. Companies are already heavily committed to improving the speed performance of semiconductor technologies such as silicon and gallium arsenide.

Scientists at AT&T's Bell Research Laboratories have led the world in optical data processing research over the last ten years, but even they are reviewing its practical value.

The first Bell Labs optical gates needed an optical bench one metre across with lenses for the free-space optics. As well its bulk, switching speed was only 1MHz, or over 1000 times slower than the fastest transistor.

Dr Mike Prise of Bell Labs says the devices have the potential to work at 30GHz switching speeds, but admits "We regard the optical logic gate as the future, now we realise that optical interconnection is more important as electronics becomes faster."

Higher electronic data processing speeds and the use of parallel techniques are showing up the limitations of electronics as a high speed interconnection medium. Optical transmission techniques originally used in telephone networks are now migrating into computer system designs.

Current research at Bell Labs and IBM is integrating optical transmitters and receivers into electronic chip design which will make chip-to-chip optical interconnection a reality within five years.

Professor Midwinter believes the UK has the necessary background in basic optoelectronic materials research.

The issue is this: will the Scottish optical computer work make the most efficient use of it?

Rob Causey

Why low brain power is computer goal

Neural networks will replace digital chips in computer systems over the next twenty years, according to Dr Carver Mead, professor of computer technology at the California Institute of Technology. One of the main attractions is that they will consume less electrical power to do the same job.

Dr Mead made his comments during the Instat semiconductor forum held in Phoenix, Arizona. His prediction was based on the fact that in the long term the system cost will become directly proportional to the amount of power it consumes.

Today's microprocessors perform about 10 million operations/s and consume about 1W, or use about 10^{-7}J/operation. Dr Mead compared this to the human brain, which also consumes about a watt, but performs 10^{16} operations/s, 10^{-16}J/operation.

"To charge a capacitor's gate takes 10^{-13}J today and will take 10^{-15}J in 10 years. So the individual device is not the problem. Where did all that extra energy go? That's about a factor of a million we've lost somewhere," according to Mead.

Mead himself has developed a chip which takes two audio inputs and performs a real time convolution in silicon, attempting to mimic the operation of the cochlea, which would probably consist of 10,000 transistors.

It would dissipate 10μW to perform the same task as a microprocessor running at 10mops, corresponding to using energy at 10^{-13}J/operation.

Mead's device takes up 30,000 transistors, dissipating 10mW to mimic one billion microprocessor operations/s, or about 10^{-11} J/operation. "It's not as good as 10^{-13}, but it's much better than DSPs. This makes a model of using silicon in a way that's different from what we do now."

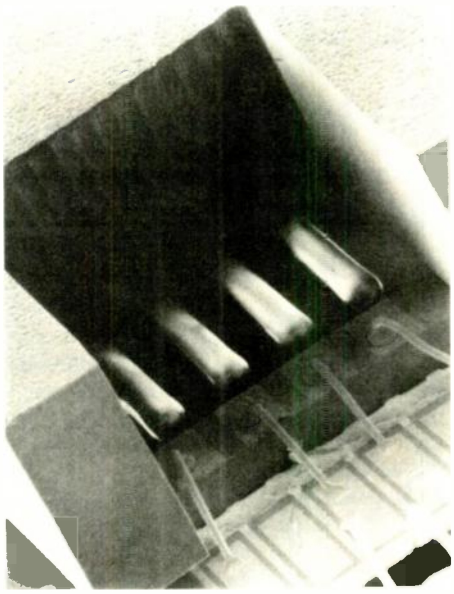
To perform the whole function of the ear would take a whole wafer worth of silicon, according to Mead.

But this presents a power problem.

"It takes a lot more power to do it digitally than with analogue circuits. We use digital processing because it's there and because we know how to write programs for it," he points out.

More systems are now using digital processing to solve adaptive control problems. "Given that we're going to adaptive anyway, wouldn't we be better using an adaptive approach from the beginning? Adaptive devices could be taught not only to change with the environment they are controlling but with defects in their system," according to Mead.

"We need to cover a wafer with adaptive analogue devices. If there's a problem, it can be learned around. It'll do about 100 billion operations/s just using the stuff I'm doing today and the whole wafer will take about a watt. If we edge mount it we can let the normal air flow cool it."



Four optical fibres are fed by microscopic lasers in IBM's experimental optoelectronic chip set. Such an arrangement could be the shape of tomorrow's optical computers.

Mead says this kind of system will only be built in about twenty years time. A real computer will consist of a mixture of this kind of processor and the successors of today's digital technology.

"It's modelled after the way mathematicians prove theorems. It's the cognitive model. You wouldn't want a human being without a cognitive facility."

386 development leaves Intel behind

A single-chip PC will go on sale in the next two months built around a 386-based microprocessor — the second 386 developed without Intel's blessing . The device has been developed by Chips & Technologies and will appear a year before Intel's own one chip computer.

Industry sources expect the device to be built around an SX version of the 386 running at 15MHz. It will be a bi-cmos costing about $50 and will have output circuitry which can drive up to 25mA, enough to supply a small LCD.

Gordon Campbell, president of Chips & Technologies, speaking at a US semiconductor conference, said "I will make a prediction that this year we will definitely see the first single chip PC architecture and that it will be close to the $5/mip mark."

Analysts believe this year will probably see the second and third such devices as well, but not from Intel. Another company working on a chip is S3, founded in 1989 by former Chips & Technologies staff.

A third group, called Integrated Information Technology, is working on a risc-based microprocessor core which will be able to emulate other micros and will include VGA drivers on-chip. All these devices are designed for use in palmtop and laptop computers.

Apple Computers is also hoping to build a laptop computer next year using a specially developed version of Motorola's 68040. The chip will operate at voltage levels of 3.3V except the I/O circuitry which will use 5V levels. Power consumption of the device should be cut by about 40% and it will run at 25MHz, processing around 20mips.

In the autumn of next year, Motorola will start selling a fully-static version of the 68040 core with the Mac's peripheral circuits integrated onto the die.

Cutting the noise

Quantisation noise from digital musical instruments annoys recording engineers. Richard Brice outlines an electronic noise gate design which puts the dynamic range back into the recording process.

Using modern digital audio recording equipment with a dynamic range of more than 90dB, the noise sources up-stream of the recorder become a source of worry and annoyance. It becomes a constant fight to reduce noise from interference, air-borne and structure-borne noise picked up in the microphone channels and electrical noise in the analogue mixing and processing electronics.

A further source of noise in the modern audio studio is the digital synthesisers. Some of this is due to Johnson and 1/F noise in the analogue output stages of this equipment, the rest derives from quantisation noise on the audio samples.

Digital mixing processes also add their own noise. This builds up in the mixing and processing stages of these systems, the residue of truncated digital multiplications and additions.

The audible character of digital noise is coarse and unpleasant. Having chased noise contributions from microphone pre-amps and the desk electronics, it is very galling to have to put up with noise on a high level signal which enters the mixer at mix-bus voltage levels[1].

A noise gate tackles this problem. The single ended noise reduction system outlined here provides a beneficial level of noise reduction without introducing the "breathing" or "pumping" effects that so often plague noise reduction.

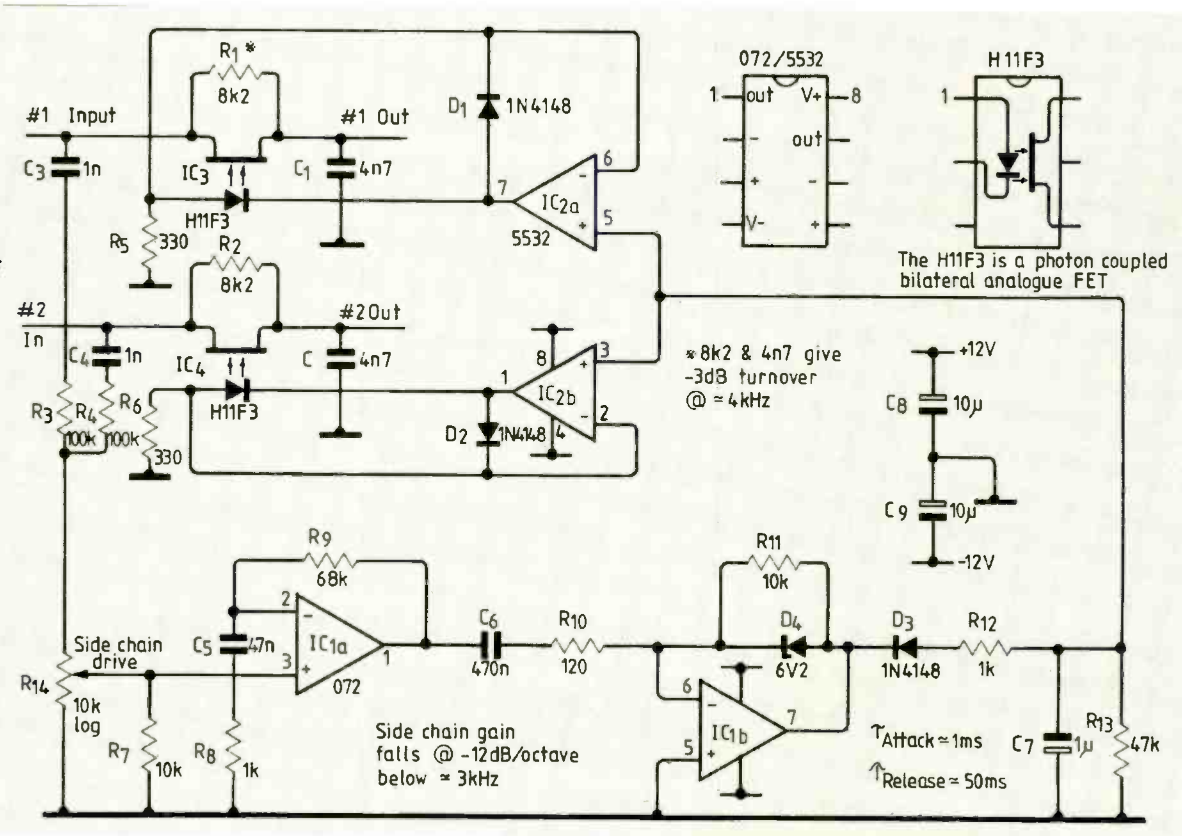
The design employs an unusual semiconductor device, the photon controlled bilateral analogue fet. The part combines the advantages of the photoresistor and optoisolator with the speed of a fet.

But it doesn't suffer from non-linearity of these other devices nor the complexity of circuits employing a "Blackmer" voltage controlled amplifier[2].

Theory of Operation

The noise reducer uses an expansion technique where low level audio signals are amplified less than high level signals. A threshold is set so that the residual system noise has insufficient energy to cause the variable gain amplifier to change to its higher gain regime. The design must ensure that the presence of useful audio signal raises the gain of the amplifier sufficiently quickly without destroying the transient start of the signal. The period of time the amplifier remains in the high gain regime once a high level signal has ceased must be carefully controlled. Too long and the amplifier will

Fig. 1. Stereo noise gate circuit, working as if the treble control of a pre-amp were quickly varied. The effect is of a single ended noise reduction system which cuts the treble response during quiet passages.



be unable to return to the low gain state in the gaps between wanted signal. Too short and the expander will mutilate the reverberant part of the audio signal.

Expander systems produce a characteristic noise signature. This comes from envelope modulation of constant input noise behind the wanted signal. When this is amplified by the changing gain of the expander, the noise takes on a varying quality which has been described as sounding like breathing or swishing. All forms of noise reduction using signal dependent amplification suffer to a greater or lesser extent from the phenomenon and it places an upper limit on the maximum expansion ratio employed before noise modulation becomes noticeable.

The noise-reducer also takes advantage of two psychoacoustic phenomena; masking and the non-linear frequency response of the ear. As a result of nature's signal processing, the presence a single pure tone at 60dB above the threshold of perception will cause the desensitisation of the ear by as much as 20dB in the octave and a fifth above the original tone. The threshold shift may be as much as 40dB near the tone frequency. Music has very many pure-tones simultaneously present but, for the majority of the time, its masking effect only operates at low to middle frequencies. This is because system noise, whether generated by thermal agitation or from quantisation errors, has a very flat energy versus frequency characteristic.

It sounds hissy to the human ear because the frequency response which, at low levels at least, is about 28dB more sensitive at 3.5kHz than at 100Hz and then falls away slowly to around -10dB at 10kHz reference 3.5kHz. Music, in order not to sound shrill and thin to our non-linear ears, must complement the ear's rising frequency response and has an average energy versus frequency characteristic which falls with frequency.

A signal which has an uneven energy versus frequency characteristic like music will sometimes fail to mask one which has: noise. This is especially significant since the music signal fails to mask the noise in the high frequency portion of the audible range where our ears are most sensitive to detecting the noise part of the signal.

The circuit shown in **Fig. 1** operates by automatically controlling the frequency response of the forward signal path of the noise reducer using controlling information derived from the high frequency content of the programme. The principle, which is used in some commercial noise reduction systems[3] works rather as if the treble control of a pre-amp is constantly and quickly varied. Thus in the absence of a music signal, the control attenuates the system noise in the HF part of the audio spectrum where it is most subjectively annoying. The control is only turned up when the wanted signal, containing high frequencies, occurs.

The circuit has this effect. If a bass guitar is the only instrument playing, the high frequency gain is not raised since a bass instrument does not require a wide frequency response for faithful reproduction, and has insufficient upper partials to mask the system noise. The subjective effect is to lose the hiss. If, on the other hand, the signal is a snare drum hit in a reverberant acoustic, control must operate very quickly to allow the high frequencies of the snare drum to pass through the system. Gradual reduction must follow... not so slow that the noise resurfaces after the masking effect of the signal has ceased yet not so fast that the reverberant tail of the signal is destroyed.

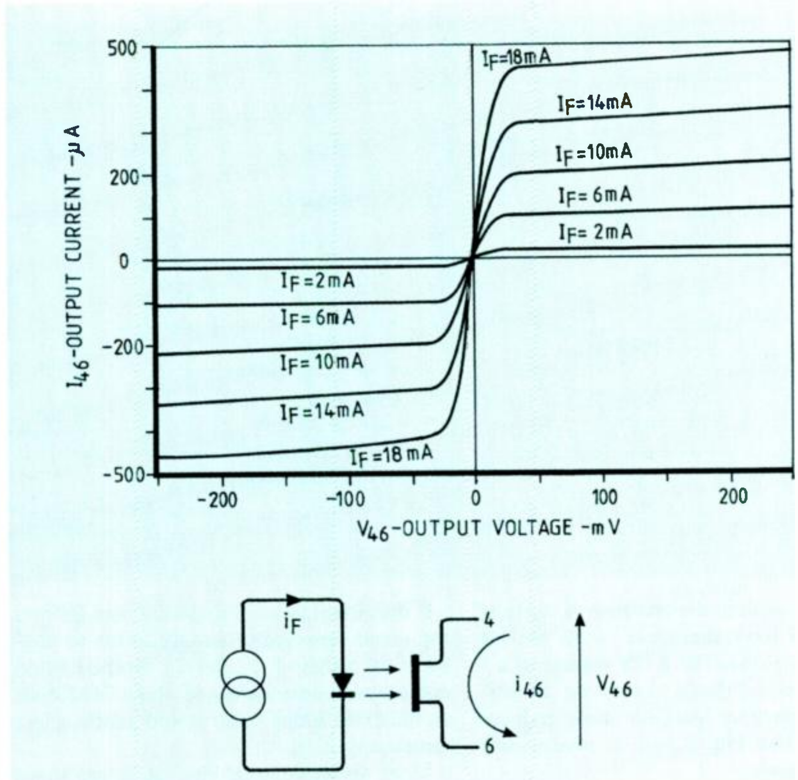


Fig. 2. Output characteristics of the H11F3 — photon coupled analogue bilateral fet.

The active device

The gain controlling element in the noise-reducer is the H11F3 made by Harris Semiconductor. The part rejoices in the description photon coupled bilateral analogue fet. It integrates a gallium arsenide led with a symmetrical bilateral silicon photodetector. The detector is electrically isolated from the control input and performs like an ideal isolated fet. The part is designed for control of low-level AC and DC analogue signals. It responds in less than 15μs.

Figure 2, device output characteristics, demonstrates that it looks like a fet operated below pinch-off and controlled, not by a gate potential, but by the current through the led. Because the element is not a triode, and controlling circuit need not share a terminal with controlled circuit, the fet may be used bi-directionally, with current flowing from source to drain or from drain to source. Practically, within certain operating limits, one may think of the device as a variable resistance element. The huge advantage that these parts have over normal fets is that control can be effected by a completely isolated circuit. It is also much simpler than the traditional variable transconductance multiplier arrangement.

Low-Pass Circuit

The device resistance is controlled by the current flowing through the integral diode. The turnover frequency, in the absence of signal, is defined by R_l and C_l since, when no current flows in the led, the fet has a very high resistance indeed. In this design, the turnover frequency is set on the high side: about 4kHz.

There is a complex compromise to be made between signal level handling capacity, the effectiveness of the noise reduction and the minimising of modulation noise.

The prototype unit was designed to operate directly at a line level of 0VU = -10dB(V). I settled on the 4kHz turnover empirically.

Refinements

Operation of the fet directly at -10dB(V) line level is a little optimistic. The device is specified in terms of the maximum allowable RMS signal current and maximum allowable RMS signal voltage it can handle linearly at specified resistances. Consider two cases: 1) a single tone input 1kHz at -10dB(V) and 2) a single tone input 4kHz at -10dB(V).

Case 1: I have assumed that the side-chain sensitivity has been set so as to start widen-

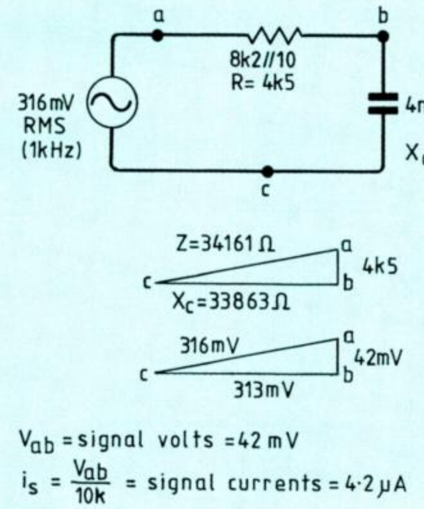


Fig. 3. Noise reducer stage — assuming an infinite non-capacitive load — and its phasor diagram associated with the conditions of Case 1.

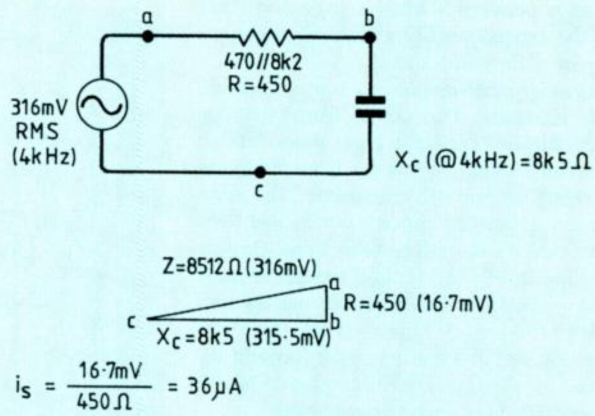


Fig. 4. Noise reducer stage and phasor diagram for Case 2. -10dB(V) tone input of 4kHz is assumed to open the bandwidth. Fet resistance will fall to an assumed 470Ω.

ing the bandwidth in the presence of 1kHz at -10dB(V). I have therefore taken the fet resistance as 10kΩ. The RMS voltage of a -10db(V) tone is 316mV. Assuming an infinite, non-capacitive load, the noise reducer stage looks like **Fig. 3** and its phasor diagram is as shown.

The maximum signal levels are therefore, 4.2μA and 42mV. The specification of the device states the maximum allowable RMS current and voltage in the linear region as 6μA and 50mV respectively.

Case 2: the -10dB(V) tone input of 4kHz is assumed to open the bandwidth right up and for that the fet resistance will fall to an assumed 470Ω. The diagrams now look like **Fig. 4**.

The maximum signal levels in case 2) are therefore 36μA and 17mV. The maximum permissable figures are 35μA and 15mV — right on the specification limit of the device and, since one must assume peak signal some 10dB higher than the steady state 0VU signal, some distortion from the circuit seems inevitable. In fact measurements failed to confirm such pessimism, with distortion being less that 0.1% in the high or low gain regime at levels of -10dB(V) at all audible frequencies. The onset of waveform distortion of several percent happened abruptly at about twice the limits suggested in the data sheet. When they appear, the distortion artifacts are predominantly 3rd harmonic.

I have been unable to detect any audible distortion from the prototype unit at all when used in the studio. I suspect this is principally due to the phenomenon noted earlier that music does not have much high-frequency energy and that such distortion as there may be is of a fairly innocuous kind. When the fet moves beyond its linear region (see Fig. 2), the element operates like a constant current source with an essentially capacitive load. The unit will slew-rate limit rather than amplitude limit and slew-rate limiting is a far less audible form of distortion than clipping.

If the circuit is left unbuffered, any following cable capacitance simply forms to augment the value of C_1 and C_2. Normal audio cable has a capacitance of about 30pF/foot so the extra 300pF or so would hardly affect circuit operation.

More serious is that the following input resistance must be high, at least 47kΩ, otherwise overall operation will be adversely affected. A buffer based on an AC coupled NE5532 makes connection far more flexible and, if the following op-amp stage is arranged to give some gain, the signal may be attenuated before entering the noise-reduction stage to improve headroom.

Side chain

Only one side chain is necessary for a stereo noise reducer. In fact, unless the control is common to both channels, the stereo image can appear to wander. The side chain comprises the mixing resistors R_3 and R_4 which take an equal proportion of the left and right signals to the sensitivity control. R_7 pads VR_1's control law to be more manageable. IC_{1A} is straight-forward HF gain stage. IC_{1B} gives a very large gain until the output swings minus 6.2V when the Z_1 goes into zener conduction and the gain reduces very quickly. The output can only swing positive by about 0.6V when the zener diode goes into forward conduction. C_6 and R_{10} roll-off the voltage gain below 2.8kHz. The IC_{1B} stage virtually provides the rectification necessary to derive a control signal. D_3 ensures no positive signals are applied to the control-voltage storing C_7. The two time constants formed by R_{12} and R_{13} with C_7 determine the attack and release times of the noise reducer.

Strictly speaking, the side-chain should full-wave rectify the audio signal since the magnitude of negative and positive peak signals can differ by up to 8dB. A purist might install another dual op-amp, the first part acting as an inverter and the second part as an identical twin to the IC_{1B} stage in Fig.1. This stage could feed R_{12} via another diode so that the most negative signal always predominated.

The control voltage stored on C_7 drives the dual op-amp IC_2. The infrared emitting diodes are connected within the feedback loop of the op-amps; the diode current is controlled linearly by the voltage on the non-inverting inputs of IC_2 and the value of R_5 and R_6. I found that no adjustment of R_5 and R_6 was necessary to achieve channel matching, so well matched were the H11F3's devices.

D_1 and D_2 are included so that IC_{2A} and IC_{2B} do not saturate in the unlikely event of their receiving a positive voltage input.

The design of the side chain ensures that nothing bottoms — good audio design requires as little spikey current about the place as possible. The led offset voltage is continually compensated for by the action of the feedback loop of IC_{2A} and IC_{2B}. This guarantees the dynamic response of the circuit is dominated by the time constants formed by R_{12}, R_{13} and C_7. Part of R_{13} could be replaced with a potentiometer so allowing control of decay action; the best value for this is not always the same for different types of music.

The circuit requires no setting up and it is very easy to operate: One simply, gently increases the sensitivity of the side chain, using VR_1, until all the high frequencies in the untreated signal seem present in the noise reduced signal. While setting the side-chain drive, I use the bypass route to compare the untreated and treated sound and to check the noise reduction operation. ■

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College may win race to digital amp

Andy Gothard listens in to latest developments at a King's College in hot pursuit of the true digital amplifier .

Driving a load directly with a digital signal, removing the problems specific to analogue components in the audio chain, is an attractive possibility. But at King's College, London, recent design work has meant that that possibility could soon be a reality.

Funded by the Science and Education Research Council (SERC), and more recently the British Technology Group (BTG), the work initiated by King's Dr Mark Sandler has already produced a novel method of D-to-A conversion where output is digital, but looks analogue to an analogue load.

From there, researchers believe it is a small step to realise a digitally amplified version able to drive higher power loads — achieving the goal of digital amplification.

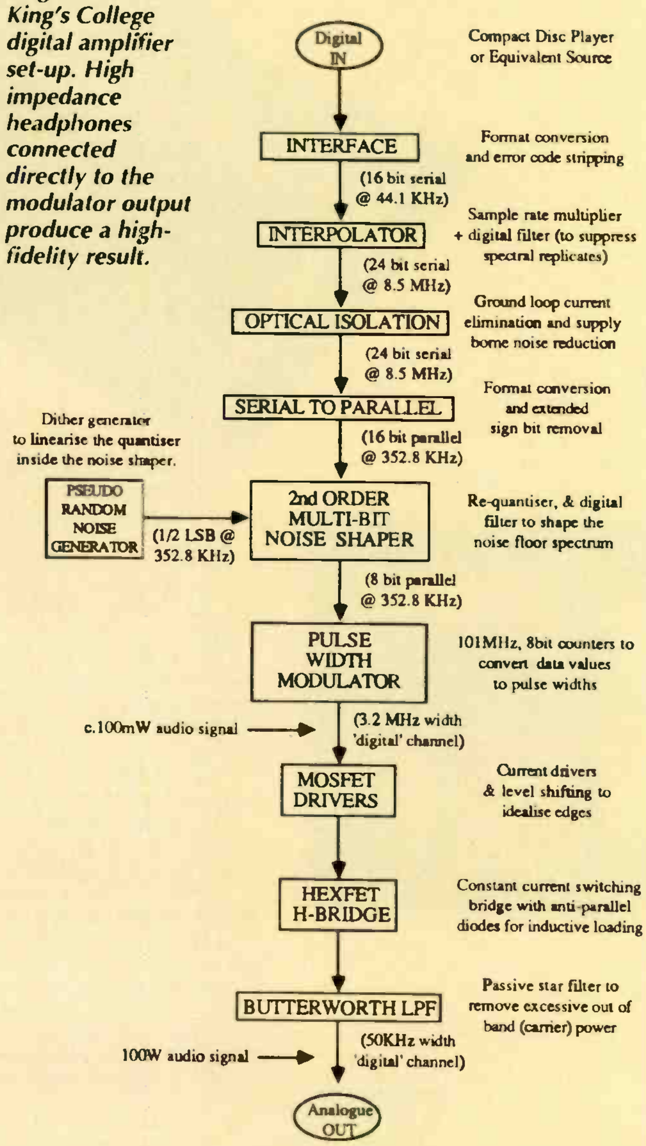
Sandler says the King's technique will outperform current audio D-to-A convertors: "What it means is that, with very little extra hardware, you can drive a load. The total harmonic distortion is -115dB, and that's confined to a single harmonic."

Pre-production prototypes

Sandler's initial theory — pursued by Rod Hiorns, Jason Goldberg, Rob Bowman, and Allan Paul at King's — has now reached patent application stage, and pre-production prototypes are ready for silicon implementation.

The fairly familiar technique of pulse width modulation (PWM)

Fig.1. Block diagram of the King's College digital amplifier set-up. High impedance headphones connected directly to the modulator output produce a high-fidelity result.



PROGRESS TO DIGITAL AUDIO

Digital audio, in professional use for about 15 years, reached the home less than 10 years ago. The initial claims of "perfect sound" were soon dropped when manufacturers of CD players worked out how to better their original efforts.

Since then acronyms and jargon have proliferated, and manufacturers have played a numbers game of increased digital resolution.

Oversampling, a technique allowing playback equipment to interpolate between samples coming from the digital source, increasing the effective sampling rate, has become the rule, rather than the exception. At the same time, intense effort has gone into developing new digital to analogue conversion techniques, producing commercial results such as bit-stream and mash.

Not all of these are "hype" and the more recent equipment represents a great improvement over early systems.

Rapid progress has also driven designers of amplifiers and loudspeakers toward critical analysis (both objective and subjective) of their systems.

These parts of the audio chain are essentially analogue, and so present their own particular problems outside the digital numbers game.

This in turn makes the idea of driving a load directly with a digital signal very attractive and focuses attention on work such as that taking place at King's College, London.

underlies the system (**Fig 1.**), where digital signals are represented in terms of time duration of a regularly recurring pulse.

Choosing to work with this kind of data might seem at best unwise, and at worst downright foolish — 16-bit digital audio data represents sounds as any one of 65536 discrete levels, with samples arriving at a rate of 44.1kHz. Two adjacent levels in a basic PWM scheme would produce pulses whose widths would differ by just 346ps. Working to this kind of resolution involves resolving frequencies in the GHz range.

The real key to making the technique viable is an approach called oversampled noise shaping, requantising the input signal to a smaller number of bits before the PWM stage, without sacrificing signal to noise ratio performance.

The D-to-A converter part of the system, according to Sandler, requires little more development. It is the digital signal processing needed to make the system viable that is the clever stuff.

In theory Sandler says 24-bit conversion is possible, dependent on availability of the latest generation DSP chips; the research group intends to use Motorola's 96002 chip for the DSP functions.

Sandler says he expects the chip, which was launched last year, to be available at rather less than the original $750 sample price. It will handle the interpolation, digital filtering, and pre-compensation DSP functions, at the high speeds required.

The advantage of PWM signals is that they can be used to drive a load — be it loudspeaker or a motor — directly, or can be converted to higher level signals (ie amplified) with a simple switching circuit. "We can produce a 100W audio signal using a basic Hexfet H-bridge," says Hiorns. "It doesn't require a heat sink, and so is very compact."

System design

The development system uses a standard Sony compact disc player as its digital source, providing 16-bit samples at the usual CD rate of 44.1kHz, as a serial data stream.

After conversion from the CD's PCM format, a process which also strips out the signal's error coding portions, a Sony CXD2550D interpolator chip is used to step the effective sample rate up to 352.8MHz. The interpolator produces a 24-bit serial data stream, and, in frequency terms, shifts unwanted alias frequencies (spectral replicates) up the spectrum where they are suppressed by digital filtering.

The signal is then optically coupled to the succeeding stages, to reduce power supply noise and eliminate ground loop currents.

What follows is a serial to parallel convertor, which produces a 16-bit output at a sample rate of 352.8kHz, eight times the original CD sample rate. This effectively produces extra bandwidth.

At the next stage the noise shaper converts the 16-bit signal to 8-bits. Sacrificing resolution in this fashion produces so-called requantisation noise. But the noise shaper contains a high pass filter, so that overall effect of this noise is smaller at low frequencies than high frequencies. Because of the extra bandwidth provided by oversampling, filter characteristic can be arranged to dump all of the requantisation noise on a part of the spectrum outside the audio bandwidth.

Pulse arrangements

The cmos technology pulse width modulator itself follows, driven from a low phase noise 101MHz crystal oscillator. This clock signal is also divided down and used to drive the other system components, including the CD player.

Eight-bit data is taken by the modulator which uses fast asynchronous counters to produce pulses with a width proportional to the data sample. The fastest signals are routed using microwave stripline, although Hiorns says that the high-frequency nature of the device produces less problems than expected.

Pulses themselves can be arranged to appear at the same time as the signal's timing marker, or to be centred around it.The two techniques lead to different spectral performances, one of the group's avenues of exploration.

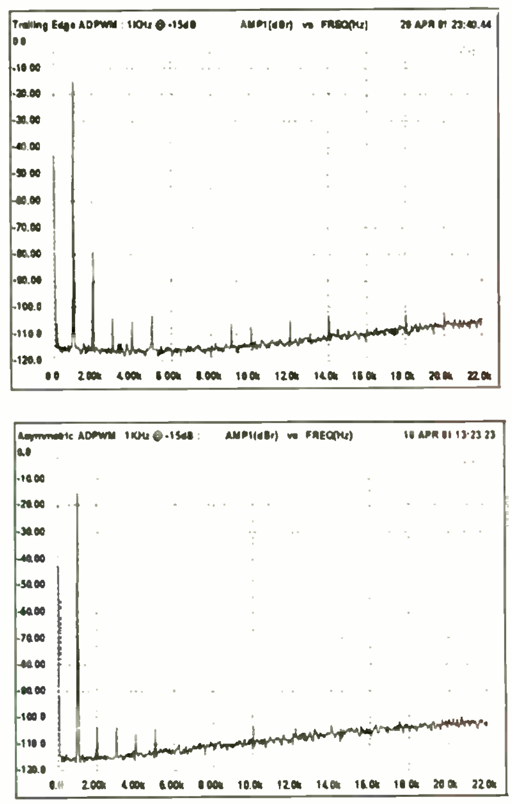
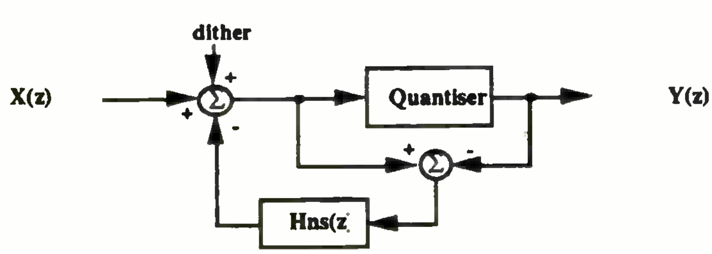


Fig. 3. Output spectrum of the D-to-A converter using trailing edge (top) and two-sided (bottom) modulation. In the trailing edge case, the second harmonic is at -79dB. The 3rd harmonic should not be visible (its calculated value, -123dB, is below the noise floor). Higher harmonics, at first thought to be due to the inability of the D-to-A's power supply to keep a constant voltage at high speed, are actually due to electrical characteristics of the measuring equipment used. Two-sided performance is rather better, the expectation being that all harmonics will be below the noise floor. In fact, the PWM distortion is swamped by the measuring problem.

Fig. 2. Basic structure of the noise shaper circuit, showing the feedback path and the general filter transfer function



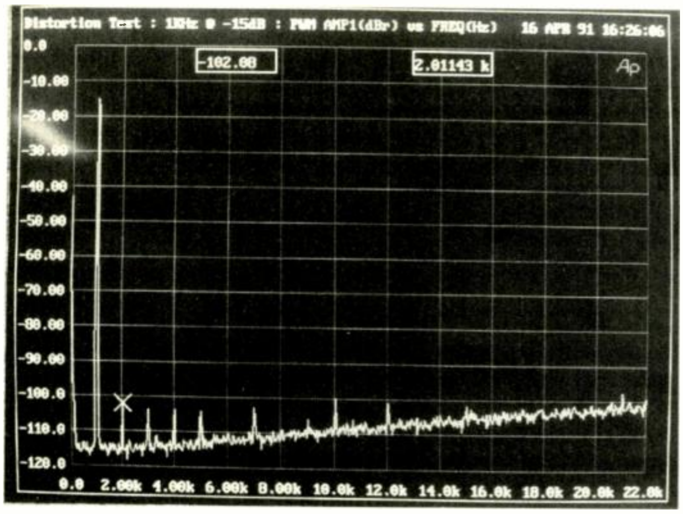


Fig. 4. Screen shot of two-sided measurement shown in Fig .3.

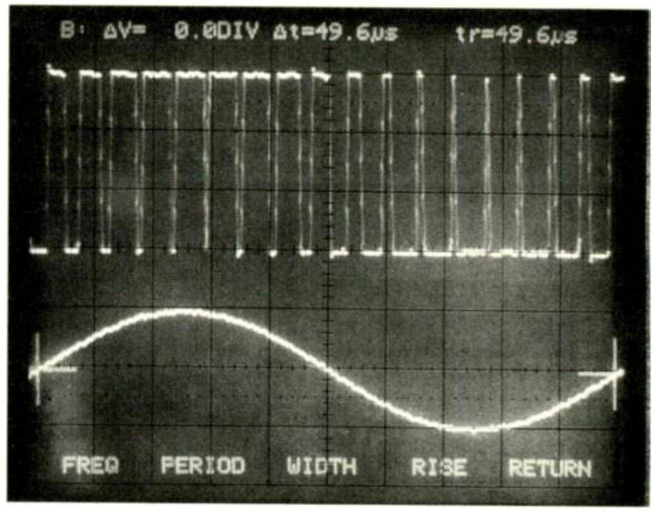


Fig. 5. The pulse width modulated signal produces wide pulses at high amplitudes, and narrow ones near zero.

The harmonic distortion of the "two-sided" implementation (**Fig. 3.** bottom) is considerably better than the trailing edge equivalent (Fig. 3. top). Input tone is 1kHz at -15dB relative to full scale.

The resulting signal can be listened to on headphones, because the high frequency components of the pulses are well beyond the audio range. Power is around 100mW, sufficient to drive a variety of loads, not just audio equipment.

After passing through mosfet current drivers which perform some level shifting and improve the edge performance, the signal can be applied to a constant current H-bridge, designed using standard hexfets, producing a high-efficiency amplifier. Hiorns says that 480W is attainable, because the hexfets will cope with operation at 100V/4A.

Configuration considerations

King's configuration does have a drawback: under certain conditions, all of the hexfet switches close, and "shoot-through" results, with the power supply effectively connected direct to ground. Design includes filter protection to eliminate this possibility.

Another feature of the output stage which might at first seem like a drawback is the fact that the bridge produces a symmetrical "see-saw" effect. As one output node of the bridge rises in potential, the other falls by an equal amount, so that both speaker cables are "live". The advantage is that electromagnetic interference is eliminated.

Using a bridge circuit also means the amplifier power supply specifications can be relaxed. The amplifier draws a constant current, as long as the input pulse amplitude is consistent, so there is no problem with sudden demands on the current supply. A passive Butterworth low-pass filter is used to remove the high frequency carrier power, producing a 50kHz channel.

The next version of the amplifier, using the 96k, should provide even better quantitative performance.

Listening tests seem to suggest "tight" bass sounds, with an overall impression of cleanness, and no noticeable growth in distortion with increasing frequency.

NOISE SHAPER

The noise shaper at King's is implemented as an asic, using 2 micron process technology, and has about 6800 transistors. The filter itself is a second order sinusoidal type (although the asic can be reconfigured to provide first order filtering), with a transfer function of the form:

$$Hns(z)=1-(1-z^{-1})^N$$

where N is an integer, in this case 2 (**Fig. 2**). The noise shaper can perform a selectable level of requantisation, producing output word-lengths of between 1 and 16-bits. In the current implementation, this figure is set to 8.

Theory says that a noise shaper with this type of transfer function can reduce the word-length by N+1/2 bits for every doubling of sample rate after the first doubling (provided by the earlier oversampling). But increasing the filter order to three can produce overflow problems at the noise shaper's input, increasing the sample rate by more than the eight times used at King's requires more complex designs to avoid confusing the later modulation stages — hence the figures chosen. Hiorns says that it is possible to design a third order filter and greater than eight-times oversampling, and that this is on the agenda as future development of the system.The putative 96k implementation will use floating point arithmetic to produce higher order filters, and use 16-times oversampling.

This should produce signal to noise ratios of the order of 150dB.

A pseudo-random dither signal is added to the data samples at the noise shaper stage, to prevent distortion at low levels arising from the "step-like" nature of the quantisation process.

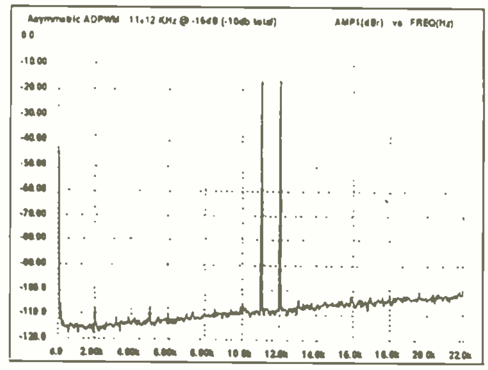


Fig. 6. Twin tone test using 11 and 12kHz tones, both at -16dB relative to full scale. Intermodulation products are just visible, at levels of -105dB, and frequencies 1kHz away from the fundamentals.

Sandler says that the patenting process, which is being handled by BTG, should be completed by the end of the year. ■

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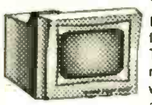

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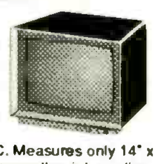

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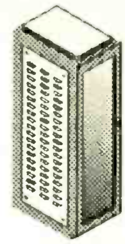

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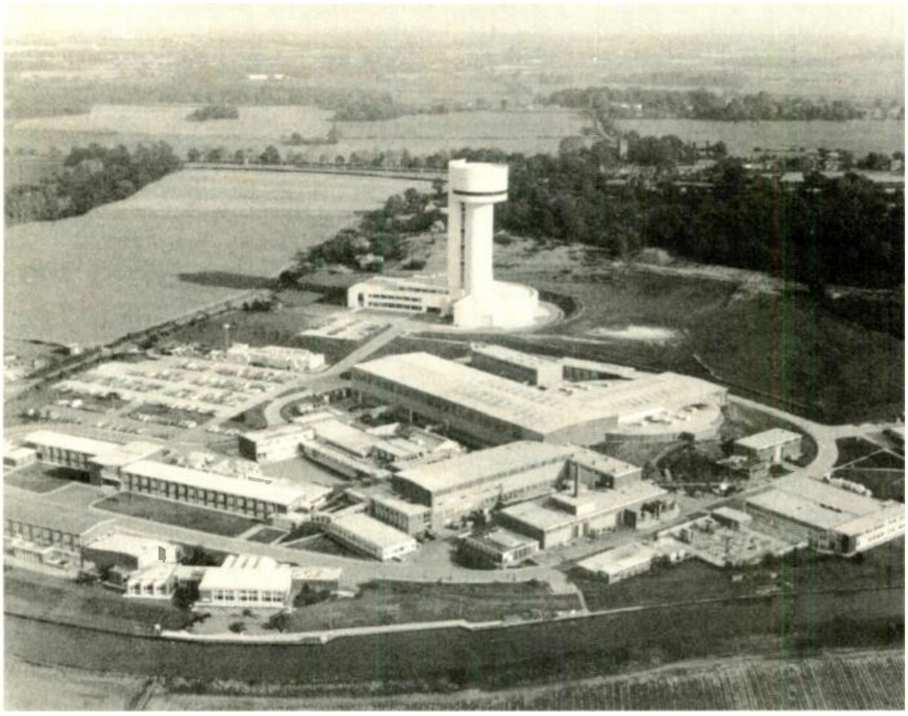
CIRCLE NO. 125 ON REPLY CARD

Despite some benefits from Alvey, notably a closer rapport between industry and higher education, it is criticised for bad management and poor planning within the project, technical problems and, crucially, the lack of skilled users capable of adopting the advanced technologies produced.

Some academics contacted by Electronics World believe the UK is toppling on the edge of a decline which will leave the country with a Third World technological status.

SERC allocation goes into electronics-related research, including materials and physics. As the biggest council, SERC has also felt the full effect of the funding squeeze.

According to the Lords Select Committee report, SERC's £12.7m increase for 1991-92 was a paltry 2.9 per cent rise over the previous year - and well short of the £40m SERC estimated it would need to run the '91-92 programme. In consequence the council has imposed a 50 per cent cut in funds for new



Closed - the nuclear structures facility at Daresbury laboratory is a victim of SERC underfunding, criticised by the Lords Select Committee on science and technology.

While many people around the globe still admire UK electronics research expertise, the scientific community warns that overseas companies may themselves end up benefiting from whatever UK work survives the funding crisis. The same academics report that UK industry support for fundamental research has dwindled, painting a disturbing picture of imminent decline in the science base and missed opportunities for industry.

Research teams in the UK are still right up with the world leaders in certain fields, notably advanced materials, computer software and military technology . The top echelons of UK high-tech companies are competitive on the international stage, at least in niche markets, through the results of long-term commitment to R&D. Yet these successes only serve to magnify the widespread failure to exploit electronics and computing innovations.

Five research councils sit at the heart of the UK national R&D structure. The Science and Engineering Council (SERC) is by far the largest and oversees almost all the work done in electronics. SERC received £451.3m, almost half of the overall science budget of £920.8m. Around a quarter of the

research grants and studentships and a sharp cutback in areas such as IT, advanced manufacturing engineering and engineering design. Support for SERC's supercomputing facility at the Appleton Rutherford laboratory has also been cut back, along with reduced support for central computing facilities in Swindon. These last two measures will hamper those researchers who need to use advanced computers unavailable in their institutions.

Beyond the electronics field, SERC has been compelled to close the nuclear structures facility in the Daresbury laboratory and may withdraw funding for two neutron facilities central to collaborative European projects in basic science.

SERC does not escape criticism from the Lords committee. The council overextended itself in commitments for this year, expecting that future grant pledges would be covered by a substantially increased cash allocation. This accounts largely for the £40m shortfall between SERC's spending plans and its budgeted funds.

The Lords concluded that an extra £12m should be immediately given to the research councils, mostly to SERC. "It is incomprehensible to us that a whole area of United Kingdom science should have been precipitately abandoned as part of a series of crisis measures and we roundly condemn the practices and policies which have put so much at risk whatever the excuse," they declared.

Criticism of the UK government in the Lords report focused on the quality of the advice it acts on regarding science and technology, apart from the more obvious funding issue. The process of working out the science budget allocations occurs through talks between the Department of Education and Science (DES), the Advisory Board for the Research Councils (ABRC) and other government departments. Many witnesses invited to speak before the Lords committee believe that - contrary to present practice - the ABRC's recommendations should be published. Ministers claim that confidential advice from the ABRC is more valuable than published results, but this has heightened suspicion in the research community over perceived sharp practice by the DES. And the Lords noted press reports in February which showed the ABRC had warned the sums mooted by the DES were not sufficient. The Lords disagreed with the DES claim that maintaining confidentiality on such advice is conducive to good government.

Since the R&D advice taken within government circles remains confidential, the Lords could not pinpoint the source of "....this politically untenable settlement." It is impossible to assess dealings between the Treasury, the DES and the Cabinet committee on science and technology over the research budget and its non-financial implications.

Other aspects of government policy over R&D worried the Lords, in particular the planned, though now postponed, dismantling of what is called the dual support system. This would involve shifting the funds allocation of the Universities Funding Council (UFC) for research into the remit of councils like the SERC, where previously each party balanced the other in the dual system. It would take any control of funding away from higher education. The DES claims the changes will have a neutral effect on the universities, while they in turn predict research in education will lose out without any guar-

"The main difficulty experienced in the academic-only programme was the shortage of funding," Dr Mark Wilkins, director of IT at SERC, writing in the JFIT annual report.

SERC WORK

Despite the stringent cuts in grants it has been forced to bring in, the Science and Engineering Research Council (SERC) remains responsible for the health of the UK science base. It has developed a programme which aims to balance demands from developers with available resources.

Electronics work sponsored by SERC now falls into four main categories: devices; systems engineering; systems architecture, and control and instrumentation. SERC's IT directorate oversees this programme under a strategic umbrella, called the Joint Framework for IT, with the DTI. The SERC agenda for IT is veering more towards advanced computing and away from devices. Yet devices will still claim about 35 per cent of SERC's total spend on electronics, down from around 56 per cent in 1989-90.

The components of SERC's IT directorate divisions are as follows:

Devices. Includes semiconductor technology, compound semiconductors, microelectronics design and opto-electronics. There are close links with the Advanced Materials directorate to develop compound devices using materials such as gallium arsenide mixed with metals such as aluminium and indium. Work is progressing on Gunn diodes, quantum well lasers and light, radiation hardened devices to be used in space, along with other applications.

Systems engineering. Covers artificial intelligence, knowledge based systems, software engineering and object-oriented software techniques. Two key areas of work are an inter-research council project on cognitive science regarding the human computer interface and a distributed processing programme which SERC will launch next year with the DTI.

Systems architecture. This division has projects on parallel architectures, neural networks, communications and computer recognition of speech and vision.

Control and instrumentation. SERC's goal here is to integrate different technologies. The division works with many small companies which have an idea for an application and need to find academic partners to supply fundamental research.

antees over how SERC spends the former direct university funds.

Governmental responses to the crisis, identified by scientists and endorsed by the recent reports, are simply to state that it does not exist. The Secretary of State at the DES told the Lords Select Committee that enough real-term cash had been provided in the budget to support the science base, ignoring claims that research has to carry a higher premium than other economic elements. "The pot is empty," said a DES spokesman in response to the Lords' call for the extra £12m.

The Department of Trade and Industry (DTI) is not directly responsible for the research done in higher education, but has a key role in promoting R&D in industry. Yet cabinet office statistics show that the DTI's spending on R&D has steadily declined. In 1987-88 the DTI spent £324.4m on R&D, boosted to £417.7 with a technology transfer grant. By 1989-90 the comparable estimate figures had fallen to £304.8m for R&D and £401.3m for the total.

Under DTI provision plans, its base line R&D spending will have dipped to £213.7m in 1992-93, despite an upturn this year to £334.5m. There is no breakdown available to show how much of this is spent on electronics technology.

Officials at the DTI project the department's role as encouraging "appropriate high-technology options" and may even back low technology in some cases. An example of this would be a company turning to product redesign, instead of using robots, when faced with manufacturing problems. The DTI does not want to direct the development of advanced electronics and IT, believing that industry itself should decide what will be important in the future.

UK high-tech companies have failed in general to use the fruits of fundamental research, according to the DTI. It acknowledges that the top firms have a good record in exploiting university and polytechnic-based R&D, while comparing the overall investment by the electronics sector unfavourably with industries such as chemicals and pharmaceuticals.Although the chemicals and drug suppliers spent less on R&D in total, their investment has risen steadily and proved more effective. Companies such as ICI, Glaxo and Beechams among others, are dominant in the international market. The same cannot be said of UK electronics.

To boost the industrial take-up of raw research, the DTI has launched a number of schemes aimed at putting companies in touch with SERC and its university clients. These activities are handled under the Joint Framework for Information Technology (JFIT) in the high-tech field. Three years old this autumn, JFIT is a natural successor to Alvey as the umbrella to manage pre-competitive research. Run between SERC and the DTI, the framework's goal is to "improve the utility and usability of IT for users of all kinds," according to Nigel Horne, chairman of the Information Technology Advisory Board (ITAB) in the foreword of the second JFIT annual report published in October 1990.

Schemes such as LINK and the Information Engineering Advanced Technology Programme (IEATP) come under the aegis of JFIT. LINK is intended to bring industry and academia together in strategic collaboration, with government fronting up to 50 per cent of the costs. DTI sources claim LINK is going well and 27 projects were listed in last year's JFIT report.

The IEATP started life in 1988 with funds of £65m and is set to finish next year. Three major areas are covered: silicon microelectronics, systems architecture and systems engineering.

While the DTI has tried to move closer to SERC and UK-based research support, it is also keen to stress that firms requiring advanced technology should also look abroad for off-the-shelf research. DTI officials say the UK accounts for only five per cent of the global R&D spend and it is vital for companies to check out the other 95 per cent. The DTI channels over a fifth of its total R&D spending overseas.

Labour has developed an election manifesto for R&D which proposes radical changes in government responsibility in the area. In contrast to the non-interventionist role assumed by the Tories, Labour would create a Ministry of Science and Technology separate from the DTI. According to Dr Jeremy Bray, the party's science and technology spokesman, "Research will remain in the separate ministries, but there are many issues where the departments share common ground. The minister for science and technology would be responsible for SERC and its budget."

Labour reckons it can boost the UK's total R&D spending from 1.8 per cent of the gross national product to 2.5 per cent, over a period of time. Most would be in industrial research, but some basic research would be included.

The first Labour priority is maintaining a good science base, Bray explained, and this would take several forms - including the public perception of technology. "The public as a whole needs to understand science better and how it affects their daily lives. We will restore science as a core subject in schools to produce people who are better educated and qualified in science subjects," Bray said.

Labour would probably raise the research councils' budget, but Bray observed that throwing money at the problem has to be coupled with some tough choices about what research to support. "We have laid plans in

"I am very worried about endangered university research, the situation seems to be getting serious," Brian Oakley, director of Logica Cambridge and former head of the Alvey project.

CONTINUED ON PAGE 566

INNOVATION UNDER THREAT

The cash crisis in science research could leave Britain an also-ran in the race to new technology. Dom Pancucci reports.

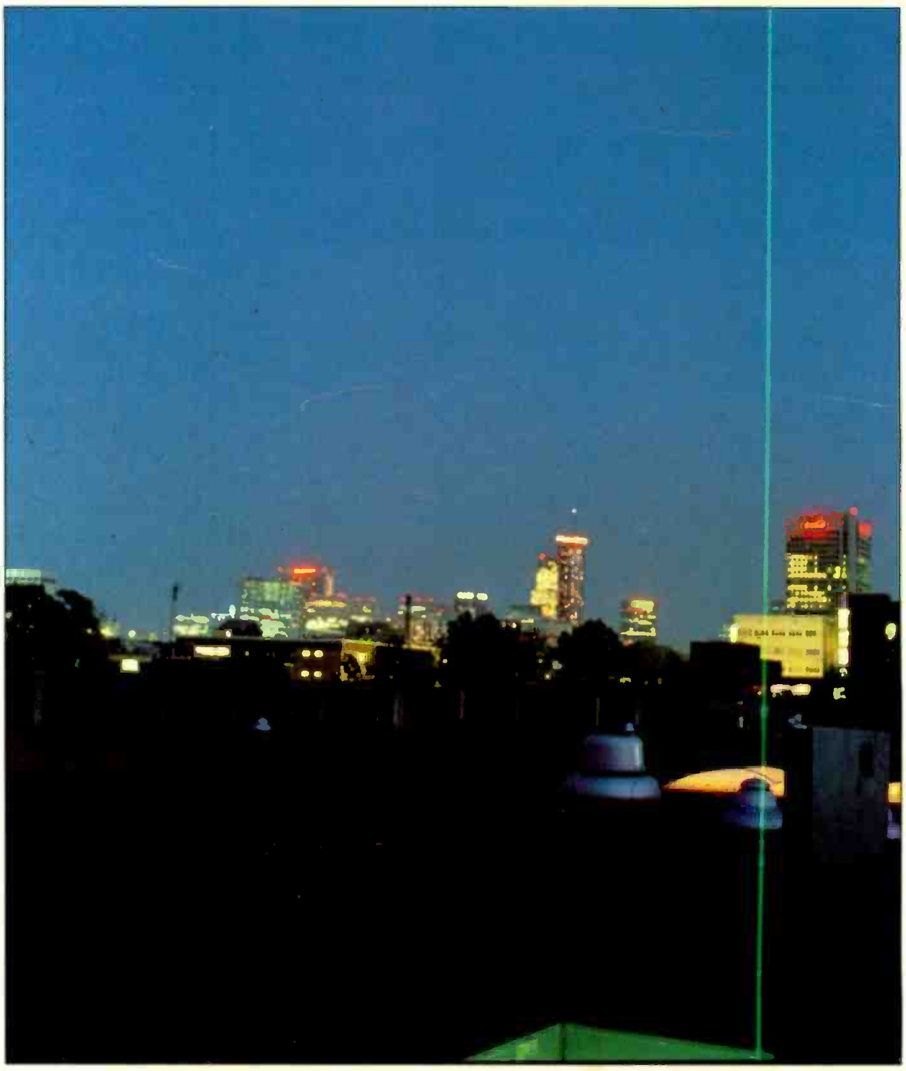
Britain faces a crisis over high technology research and development which could soon lose the country its international renown for excellence in this field. A government squeeze on cash for research councils threatens the health of the science base, while the longterm failure of industry to exploit academic innovations is compounded by cutbacks in R&D spending.

When the Secretary of State for Education and Science doled out the 1991-92 budget for research councils in late January, the reaction from scientists was so extreme that the Lords Select Committee on science and technology set up an urgent inquiry. Claims by academics that important work would be abandoned, or not started, without an instant injection of new money, were supported by the Select Committee, which published its findings in March. It slammed the research budget as inadequate.

The six per cent inflation model used by the government to work out the research budget was, the committee found, one point lower than the underlying figure in the economy as a whole and three per cent under January's retail price index. Since R&D often costs as much as two per cent above prevailing inflation levels, this leaves a serious shortfall.

This grim news from the Lords Select Committee was followed by a report in May detailing how the Alvey project, the most ambitious UK collaborative high-tech research programme of the 1980s, had failed to stimulate the UK information technology sector to perform competitively.

Undertaken by the Science Policy Research Unit (SPRU) at Sussex University and Manchester University, the survey into Alvey's progress revealed that indifference and a lack of funding by companies were partly to blame for Alvey's failure. The government also failed, according to the SPRU/Manchester report, to invest in an infrastructure developed enough to give a project like Alvey an industrial competitive edge.



Research at Georgia Tech into light-based radar which can measure ozone depletion in the atmosphere. In 1988, the US spent 2.9% of its gross domestic product on R&D. Japan spent 2.7%, Germany 2.8% - and Britain 2.3%. Academics warn that if we don't do better, we could become a third-world country as far as technology is concerned.

High quality punch for radiocomms

Every communications engineer knows that conventional speech processors improve intelligibility at the expense of sound quality. While such a compromise may be acceptable for HF telephone links, digital information carried over speech links can be rendered indecipherable by the action of clippers and filters. BTG sponsored Louis Thomas proposes a better system.

A new loudness control technique is claimed to punch up the average loudness of communications signals by up to 20dB without exceeding the peak modulation level of the system with which it is used. Furthermore, unlike conventional speech processors, it preserves the naturalness of the signal.

Called Simitar (for SIMultaneous Near-Instantaneous and Time Average Response), it operates by combining the functions of a mean loudness controller and a waveshape compressor. These are two similar processes which differ mainly in the rate at which gain changes are applied to the input signal to control its amplitude.

Waveshape compression can increase the loudness of an audio signal without increasing its overall amplitude. It does this by reducing the crest factor, that is the peak-to-RMS voltage ratio. This makes it particularly suitable for speech which has a low average power level compared with its peak power. Improvements in intelligibility are achieved by raising the level of the intelligence carrying and quieter sounds like the consonants. The system block diagram is shown in **Fig. 1**.

Dr Thomas comments: "Historically this was done by clipping methods but they distort the waveform so the waveshape compressor was designed to replace these systems."

Clipping methods have proved useful on long range radio systems, but the change in speech naturalness and the increase in background noise has prevented its use on higher fidelity systems.

The waveshape compressor was first designed at Swansea University as far back as 1977 and Thomas said that "it replaced the sideband clipping methods very well".

The measured quantity in the waveform is the peak amplitude of each individual half cycle between the points where it crosses the zero axis. Only the magnitude is used and not the sign. In other words it does not matter whether the waveform is falling from plus to minus or rising from minus to plus when it crosses the axis.

The changes in gain are applied at the points where it crosses the axis. The effect of this is that each half cycle has virtually the same shape before and after the gain is applied. The only difference is in the peak amplitudes. This effect can be seen in **Fig. 2** with typical gain changes shown in **Fig. 3**.

To work out the peak magnitude of a half cycle and put in the gain changes where it crosses the zero axis before the half cycle starts, a feed forward system configuration is needed with a delay in the signal path.

While this works well on its own, Thomas realised that it could work better and has spent the last six years in further development by adding the mean loudness controller. This can be thought of as a fast acting volume controller. There are obviously other ways of doing this, usually analogue, but these have the disadvantage of also increasing background acoustic noise. Thomas's digital circuit isn't so affected because the amplitude transfer characteristic provides low gain at low levels.

Another advantage is that it does not create distortion through overmodulation — it controls the waveform at all times. This is done by using an 8ms signal delay to the main signal path so the peak of the waveform can be measured before the signal comes out of the delay line.

The controller smooths the peaks with a digital filter characterised by a first order low pass filter with unequal rise and fall times. The filter is updated when the waveform crosses the zero axis and its output remains constant at all other times. In this way the controller responds in a given number of half cycles of the input waveform and thus its performance is synchronised with the characteristics of the input waveform.

The gain inserted by the controller is determined by the output of the digital filter and a gain function defining the required amplitude transfer function. This is different to the waveshape compressor in that there is no digital filter and the gain is determined only by the gain function and the peak value of the input voltage.

Because these two processes are similar, the tandem connection can be implemented by superimposing the two processes as

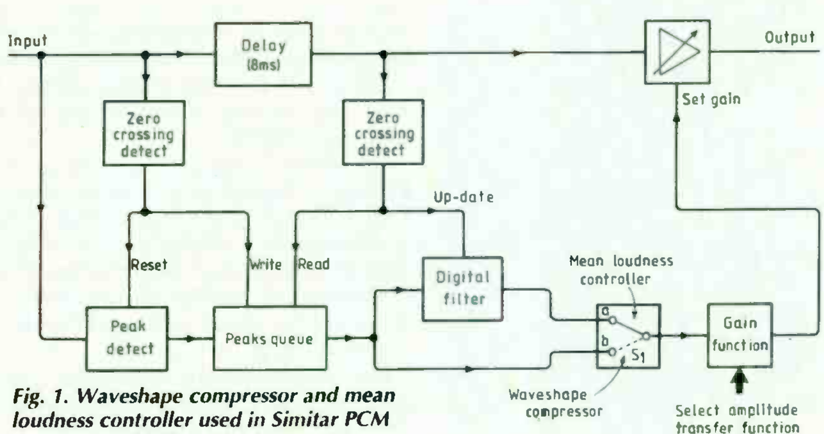


Fig. 1. Waveshape compressor and mean loudness controller used in Simitar PCM loudness controller.

shown in **Fig. 4**. A range of amplitude transfer functions can be provided by the mean loudness controller.

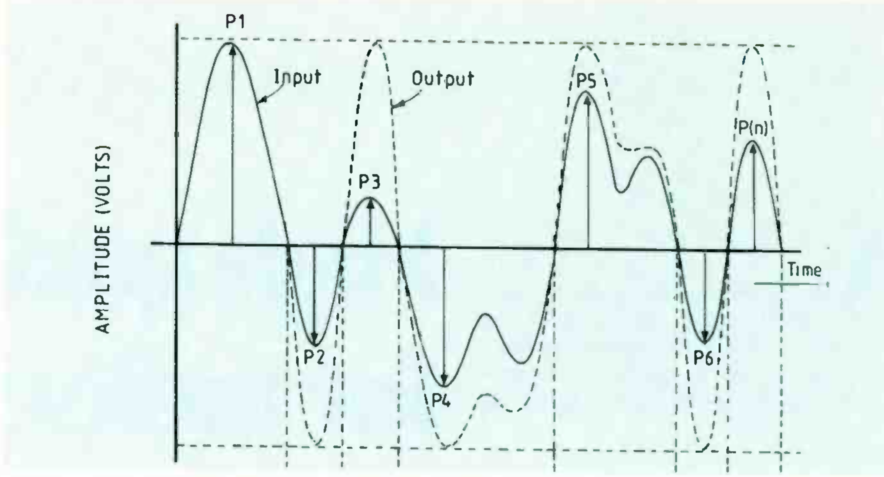
The amplitude transfer function for the waveshape compressor determines the level of waveshape compression. The shape of the characteristic reduces background noise and for normal operating conditions gives an improvement in the signal to background noise ratio of the input signal.

This compression gives a mean loudness increase of up to 9dB and an increase in loudness of the quieter speech sounds, the consonants, of up to 20dB. Compression levels are user-programmable from 0 to 24dB in 3dB steps. Loudness limiters for either normally limiting or non-limiting operation can have thresholds at -9, -15, -21 and -27dB relative to the maximum input. Noise gate characteristics for background noise or soft-squelch operation can have thresholds at -30, -40 and -50dB relative to the maximum input.

The combination of the waveshape compressor and mean loudness controller in a single digital process lets programmable levels of loudness enhancement be applied to any mean loudness control characteristic. Conventional compression or expansion transfer characteristics can be selected as alternatives to the loudness control characteristic. Precision amplitude control to within ±1dB for speech and ±0.15dB for tones allows maximum modulation of a transmission system to be maintained.

Either audio-to-audio or audio-to-digital operation is possible. In the audio-to-audio mode the compressor can go in any convenient position in the audio path. In audio-to-digital mode it may form an integral part of an existing vocoder, encryption or digital transmission system.

Simitar compression, when applied to the speech, compensates for high peak-to-mean power ratio and the variation in loudness between talkers. The requirement for this compensation exists independently of the type of system over which the speech is transmitted. But the benefits are greatest for systems with noise or loss degradations.



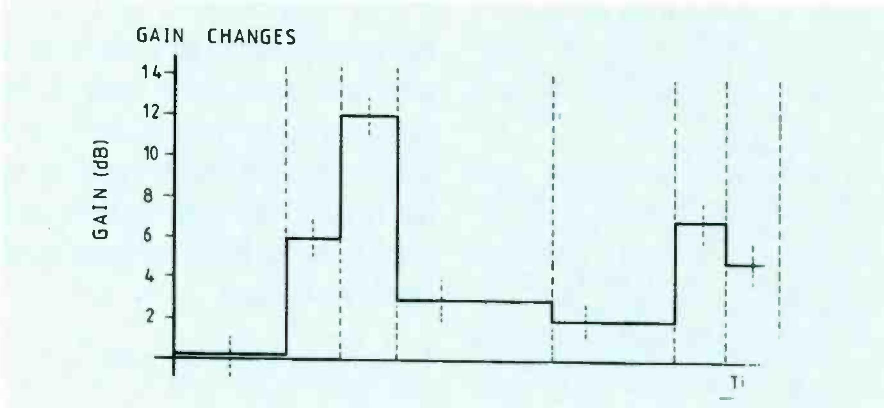


Fig. 2 (top) ***Input and output waveforms of Simitar PCM audio loudness controller. A feed-forward signal delay allows anticipation of waveform peaks.***
*Fig. 3. (lower)****Typical system gain changes involved in fig. 2.***

One way process

Simitar needs only a single device, normally at the transmitter, without further processing at the receiver. For this reason it is not system specific. The devices can also be used in pairs with complementary (companding) or non-complementary characteristics.

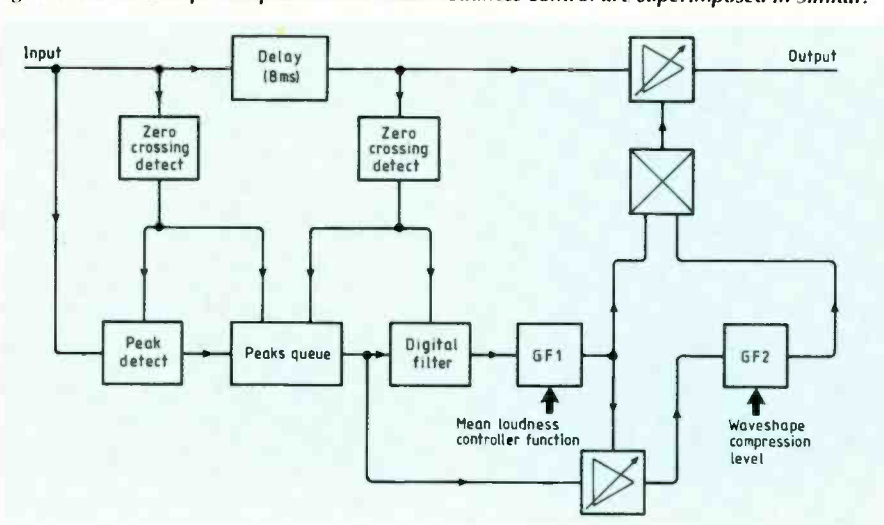
Thomas envisages many uses for his invention: professional comms equipment such as radio transmitters and receivers; industrial public address and intercom systems: speech processing systems including digitisers, vocoders, recognition, detectors, echo suppressors, and frequency translators; line communications systems for data systems, such as modems, and line termination units; recording and data logging systems and hearing aids.

Basically these are all high performance systems that could justify the extra cost of the system. Thomas said that the components will cost about £12 compared with only £5 or £6 for the systems used in cellular telephones. When Simitar is mounted on a board with the required packaging and mark ups, Thomas believes it will sell for about £35 to OEMs.

The British Technology Group is currently looking for somebody to develop a product. Even if the BTG find a licensee to make it, it is unlikely that it will be used for consumer electronics in the short term even though the technology is applicable to this area. Basically the added cost would limit the market too much.

But anywhere there is an audio signal, there is usually a need to control its loudness there is a a potential application for a compressor claims Thomas. ■

Fig. 4. How waveshape compression and mean loudness control are superimposed in Simitar.



the light of the current bad background in R&D, but won't change things for the sake of change. Rather we will seek to build on the present structure," he added.

Spending on R&D by industry will be boosted by planned tax incentives. If elected, the party will promote technology conversion from military to civil applications as a part of its global environmental plans and is proposing a Defence Diversification Agency. This agency will work closely with the newly-formed Defence Research Agency to shift military innovations into wider industry.

"We need to stimulate effective research and exploit the results quickly. Without an up-to-date administration you end up in the Soviet situation where no-one quite knows who is doing what and where. You have to balance your approach," Bray said.

The academics: *anger, alarm and unfunded alphas*

To say that academics working in UK electronics research are unhappy at present would be an understatement. Stuck at the sharp end of the funding crisis, the professors and their departments do not have the resources to develop coordinated programmes. They see themselves falling behind the international competition, while many of their highly-rated proposals fail to get funding and industry remains sluggish about adopting their discoveries.

Selectivity has become the name of the game for high-tech research in universities and colleges. Unless a professor is part of a big department, there is only a slim chance that he or she will get funding for a project, academics are claiming. With a 50 per cent cut in funds for new grants announced this year by the Science and Engineering Research Council (SERC), the situation can only worsen.

Given the high level of interest in UK academic R&D by industrial rivals such as Japan, many scientists in higher education are looking abroad to find outlets for their work. And with the grants available for overseas students coming to study in the UK, universities report the quota of visitors on advanced courses is rising, to the detriment of homegrown talent. Fewer British students are taking up science studies and those who excel are often advised to seek prestigious research placements in other countries.

"We cannot plan long-term, there is not enough cash to retain continuity and consistency and therefore the infrastructure has become weakened," said Professor Dave Armour, chair of Salford university's electrical and electronic engineering department. "There are some good people in SERC holding it all together, but the dual funding system [between SERC and the Universities Funding Council] fell apart years ago. We are appalled at the situation." Armour's group is working on ion implantation techniques for low-dimensional structures with Warwick university and he reckons it takes around £2m to get such an advanced materials project off the ground. Only 10 per cent of the funds Armour would like to see pumped into the project have been supplied and his group has to make do with scrabbling money from other sources and exchanging "help in kind".

SERC rates research proposals into alpha and beta categories for priority when it comes to the queue for funding. Grant statistics published by SERC last year for the 1989-90 session, show that 718 applications were received by its IT directorate for academic only research with 351 alpha-rated projects valued at £34m. But only 183 projects finally got funding, costing around £17m. Subjects covered can be banded into devices, systems architectures and systems engineering. These activities are bundled together under the Joint Framework for Information Technology (JFIT) set up by SERC and the Department of Trade and Industry.

The funding crisis at SERC is beyond the council's control, a point which was discreetly made in last year's JFIT annual report. Mark Wilkins, SERC's director of IT, contributed the chapter on academic programmes.

"The main difficulty experienced in the academic-only programme was the shortage of funding," Wilkins wrote. "Financial commitments were much the same as last year, but demand remains high and success rates low.....at current levels of funding, a structured approach to (their) academic programmes is not feasible and that resources must simply be allocated to the very best proposals." And this comment predates the funding announcement for research councils for 1991-92, where SERC got an insignificant 2.9 per cent rise in government cash.

Salford is one university suffering in the cash-starved research community. Being smaller than many other institutions,it has to fight hard to get the awards. Armour said that Salford has three alpha projects going through the system now, two of which were held up for a long time.

"Our number of unfunded alphas is far too high, but this is common across the board. What's needed is a change of policy to put the science infrastructure right, but there is no sign of this," Armour said. He added that it is hard to get small and medium-sized firms interested in collaboration.

Dr Keith Bateson is director of the Industrial Electronics Group at Surrey University. He pinpoints the higher UK interest rates in recent years, compared to countries like Japan and Germany, and short-termism during the Thatcher years as the main reasons why the research scene is so imperilled.

"Competitor nations with lower interest rates can allow investors to take a lower return over a longer period," Bateson said. "The key thing people here don't realise, is that if a developer cannot prove a net profit within two years the money will not appear. High-tech research takes a lot longer than that. In Japan and Germany researchers typically get five years."

The Conservative government has survived on the back of North Sea oil, according to Bateson, and because the science base has become so denuded the UK could become a Third World state. "Cutting back research is a culpable approach, especially when it is only 10 per cent of getting a product to market," he said.

Extra risk capital should be raised for research and venture capital companies persuaded that technology will not lose money if invested over a longer time frame, Bateson added.

Professor Alan Sangster works in the electronics department of Heriot-Watt university near Edinburgh. He has an alpha project currently on hold, his area being microwave radar antennae and electron beam tubes. Heriot-Watt is heavily involved in optical computers and gets a lot of funds from the US.

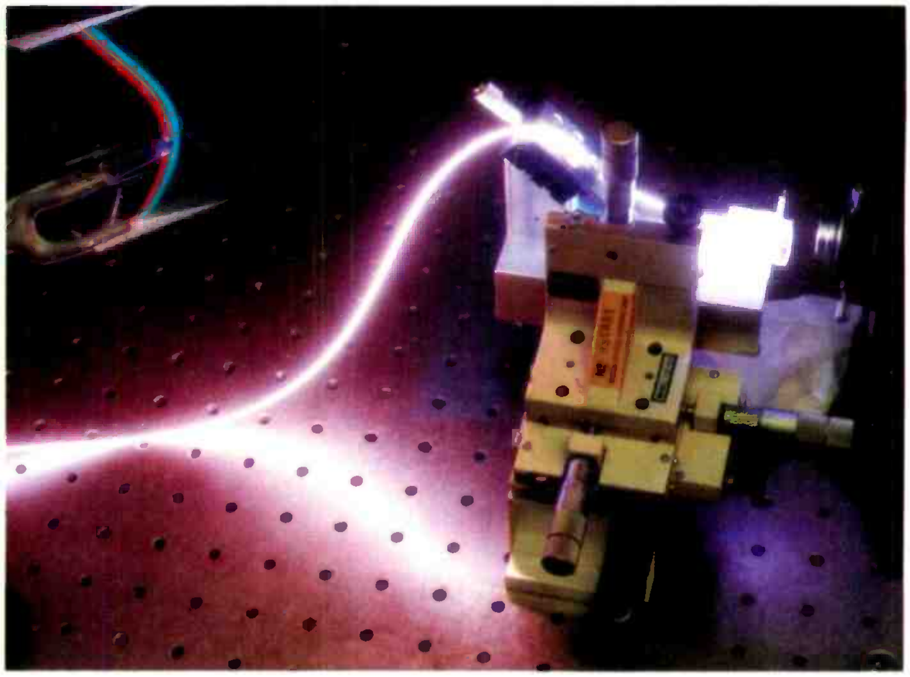
If that work becomes commercial, Sangster warns, the UK will lose out. This is a worrying development corroborated by other academics.

"Yes, there is a kind of brain drain going on. Academics are looking abroad, even to Japan, because things have dried up here. Expertise also goes abroad in the form of

> ***"Cutting back research is a culpable approach, especially when it is only 10 per cent of getting a product to market," Dr Keith Bateson, director of the Industrial Electronics group at Surrey University,***

> ***"We could become a Third World technological state," Dr Keith Bateson, director of the Industrial Electronics group at Surrey university.***

BT could gain a global lead in doping fibre optics to increase their capacity - here shown generating a number of colours, as seen in the prism, from a blue laser.



youngsters who would have stayed at home to do research," Sangster said.

An example of both overseas interest in UK research and the difference in timescales tolerated by other nations was provided by Neville Richardson at Liverpool university's software science Interdisciplinary Research Centre (IRC). There are several IRCs around the UK, intended as meeting points to draw together academic resources.

"The Japanese are coming to Liverpool because they are curious about what is going on. Many of them, Hitachi in particular, are looking at mid-21st century timescales," he said. And the differences in industrial attitudes between Japan and the UK spill over into cultural issues as well, according to Richardson.

"There is a high level of scientific literacy among the Japanese, where it is socially acceptable to be uninterested in science among the British. But if you go to dinner parties and don't know who won the Booker prize for literature, then people look down on you. This is a deep-seated UK problem in any high-tech area," Richardson said.

Research establishments set up by other countries are also more open to visiting scientists than their UK counterparts, Richardson added. Many sizeable British electronics companies have a paltry representation in this country's research effort, while sectors like chemicals put a lot of funds into higher education for research. On the subject of the IRCs, Richardson again sees a worthwhile idea running aground because of the dreaded short-term view. With nine IRCs now in existence, the government has stipulated that they must be getting at least equal external funding to the sums given in grants within 6-10 years. "At the same time these institutions are supposed to be for fundamental research, not applied. This is a difficult thing to expect and we are not reaching our target," he said.

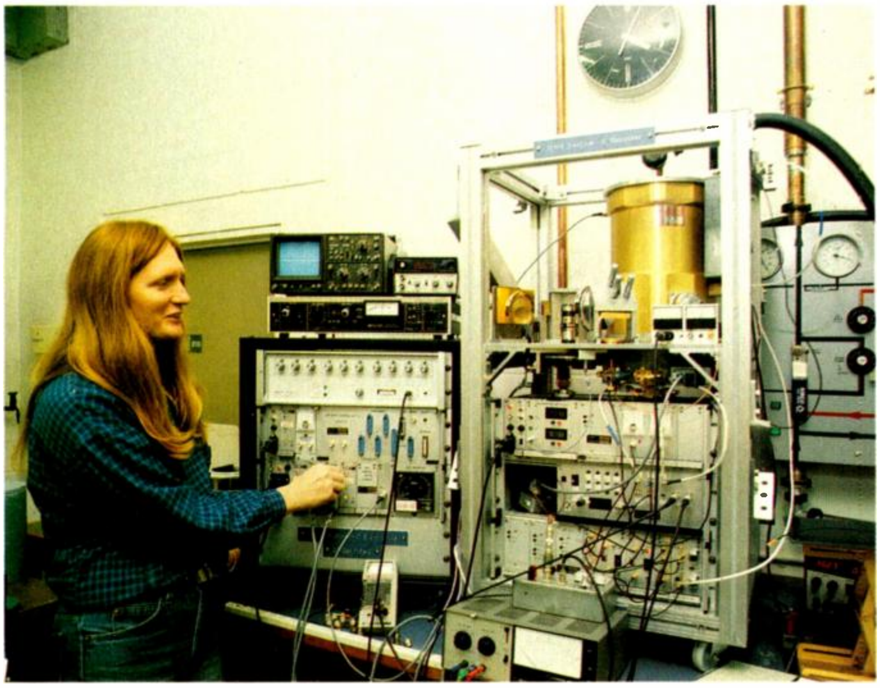
Industry: *some can hack it*

British high-tech industry has been criticised by politicians and academics for its reluctance to commit wholeheartedly to research work, but there are companies which can refute such accusations.

Some, such as the three companies profiled here have taken a longer-term attitude to research and used this as a platform for success when setting their business goals. The companies - BT, Smiths Industries and Logica - all enjoy good reputations in the R&D community.

BT spends £220m a year on research, according to Dr John Thompson, chief engineering adviser at the company's Martlesham laboratories near Ipswich. Although a substantial sum, this is still only 1.9 per cent of BT's turnover. The Martlesham labs have joined three LINK programmes, sponsored by the DTI and the Science and Engineering Research Council, in molecular computing, fast opticals and

Smiths Industries will be providing electronic load and fuel management systems for the Boeing 777, the most advanced civil aeroplane in the world, due in 1995. Unlike some British companies Smiths has maintained an R&D effort, as well as links with higher education.



British R&D, such as that carried out into "cold electronics" by Dr J F Gregg and her team at the Cavendish Laboratories, Cambridge, has an international reputation for excellence. But the health of UK science could be undermined if government cash continues to be denied.

> **"Clearly Britain is deciding not to do an awful lot of high-tech science," Professor John Sharpey-Schafer of Liverpool University physics department, in a letter to The Independent newspaper.**

personal mobile communications.

Two key research goals underpin the BT R&D effort. One is the provision of better existing services with lower costs. The other is to differentiate its future products in an increasingly competitive data transmission business, through using advanced software engineering.

In leaning towards software engineering, BT is embracing areas such as artificial intelligence, expert systems and voice recognition for controlling data networks. Object-oriented code is being devised for the System X digital exchanges,which will allow translation of incompatible software between different systems. Video will also be included, with mixed voice, image and data signals handled by a printed circuit board plugged into a personal computer. Using its integrated services digital network (ISDN) capability, BT will be able to offer the desktop user viewphone and other multimedia services using popular PC software such as Microsoft's Windows operating environment.

> **"There is a brain drain going on. Academics are looking abroad, even to Japan, because things have dried up here," Professor Alan Sangster, Heriot-Watt university.**

BT may also in time offer video with its mobile telephone products. Thompson believes the Japanese are within five years of squeezing voice and picture signals into a hand-held. Fibre optic research is more the concern of BT's suppliers nowadays, but the company has retained some involvement in this work. BT found that by taking the very pure glass fibres and doping them with materials such as erbium and praseodymium, the fibre acted like a laser. Used as amplifiers, such doped fibres significantly extend the power and capacity of networks.

In April Smiths Industries announced two major contracts to supply computerised electrical load and fuel management systems for the Boeing 777 passenger aircraft. When in service around 1995, the twin-engine jet will be the most advanced civil aeroplane in the skies. Smiths, which also has a strong presence in medical and general industrial markets, won this lucrative business through exploiting a decade of research shared with British Aerospace, according to John Hollington, technical director of the company's aerospace and defence group.

The electrical load management system (ELMS) devised by Smiths replaces the bulky wire bundles and control panels of the standard load management design, with compact digital electronics. Future Boeing 777 pilots will be able to get information from the whole system on their main displays. ELMS built-in testing and diagnostics have helped Smiths sell on the basis of low maintenance and downtime costs, as well as safety.

Smiths is also addressing future market trends in its R&D effort, including fibre optic data transmission, where the company is working with military and civilian standards bodies to develop the concept of fly-by-light, and display technology. The company has joined a LINK scheme on optical sensors, participated in the Alvey pre-competitive research programme and has kept good contacts with higher education over the years.

Logica is a systems house which has established itself in the only high-tech market in which the UK has remained competitive: software and systems integration. Brian Oakley is director of Logica Cambridge, the research arm of the company, and a former head of Alvey. He believes that the UK is in the vanguard of IT areas such as open systems and safety-critical software and hardware.

Research done at Logica has software engineering as its core effort. This splits into improving formal methods of computing and employing object-oriented code to reuse software.

Getting intelligent user interfaces to suit different needs is another focus. This includes advanced work on speech recognition - Logica has got computers to recognise whole sentences, instead of disjointed words. This work was done under the ESPRIT collaborative European research programme.

All three companies sampled here are looking to Europe to gain the most leverage from their research. The European Community's budget for the third Framework technology and science programme is heavily biased towards IT and telecommunications - both areas where UK industry can play an important part. This trend towards IT, in particular systems engineering and architecture, is mirrored by changes in the SERC portfolio of grants. As BT's Thompson put it: "What's needed is a focus to the infrastructure of basic R&D. Like BT, the country will have to focus its core business and make some painful decisions about where you can be successful. In research now you have to go European, if not global." ■

Coaxial-cable tester

Three leds indicate the condition of a coaxial cable: whether it is short-circuit, open-circuit or good. A constant-current ring-of-two circuit, zener diodes and a couple of flip-flops in a 7474 comprise the circuit.

The current source works as follows. Initially, current flows through the 680 resistor to Tr_1 base; as the supply voltage increases beyond $2V_{be}$, voltage across R_2 increases and supplies base current to Tr_2. With a further increase, Tr_2 conducts more heavily, diverting current from Tr_1 and keeping a constant current between A and B. In this application, the source supplies 5mA ($I_1 = V_{be}/R_2$ and $I_2 = (V_{R1}-2V_{be})/R_1$).

To test a cable, connect it by BNC connectors or other suitable types across X and Y and reset the flip-flops by the switch. If a good cable is under test, 5mA flows through the cable to the 3.3V zener D_5 which, being a lower-voltage type than D_1, prevents it from conducting. Since the Q\ flip-flop outputs are high when reset, Tr_4 is gated on and lights the green led D_8.

An open-circuit cable results in current being diverted through D_1 and Tr_3, setting flip-flop 1 and lighting the red led D_6. Short-circuit cables pull the preset input of flip-flop 2 to ground, setting it and lighting the amber led D_7.

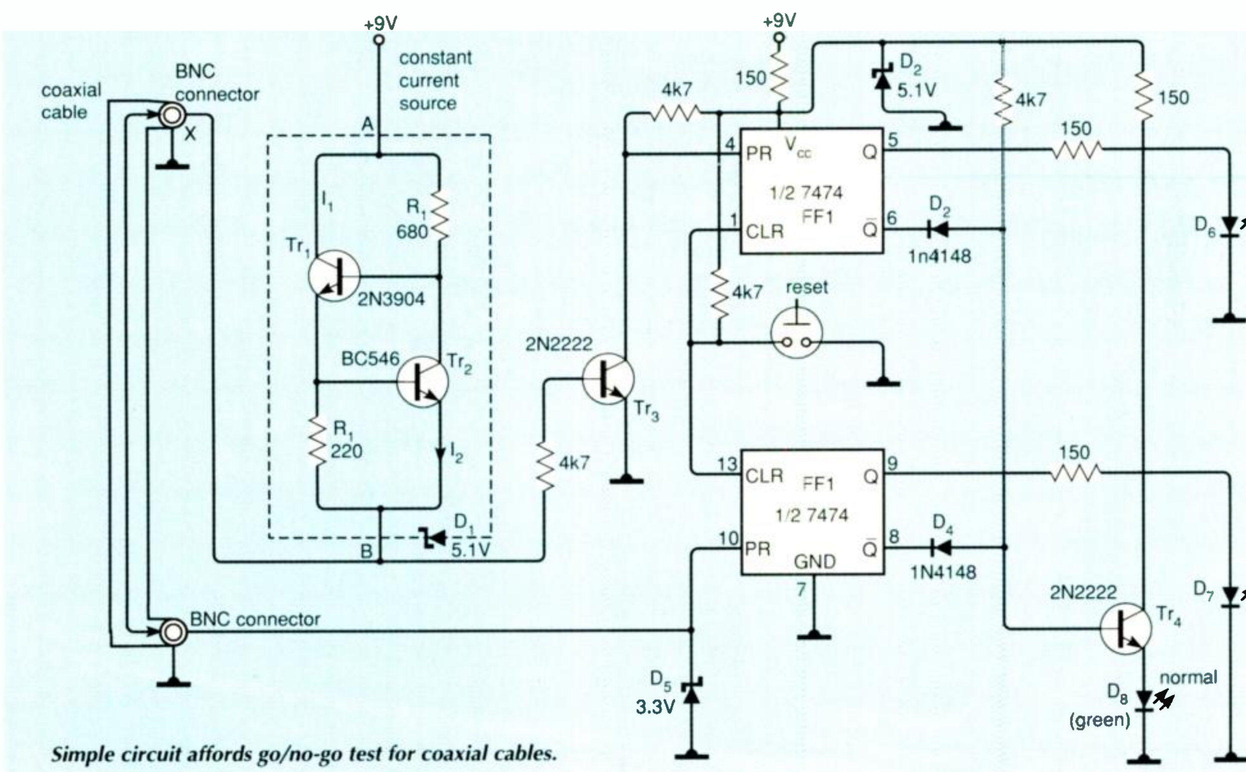
V Lakshminarayanan
Centre for Development of Telematics
Bangalore
India

Car intruder alarm

Three minutes after leaving the car, this alarm becomes effective and, on re-entering, provides about fifteen seconds grace in which to disable it before sounding for ten minutes.

Existing courtesy-light switches are used to activate the alarm. Each half of the dual D-type flip-flop is a monostable, regeneration being provided by C_6R_6, once the circuit has been triggered and as long as the voltage on the first flip-flop D input remains above the threshold: in the quiescent state, both clock and D input always return to a positive state. Applying a DISABLE signal forces both RESET and D inputs positive.

The components R_1, D_5, R_4 and C_1 determine the time delay before the alarm becomes effective after the car is vacated and R_2C_2 give the delay on re-entry and the doors closed, which is to say after the earth through the door switch and R_8D_3 has been



Simple circuit affords go/no-go test for coaxial cables.

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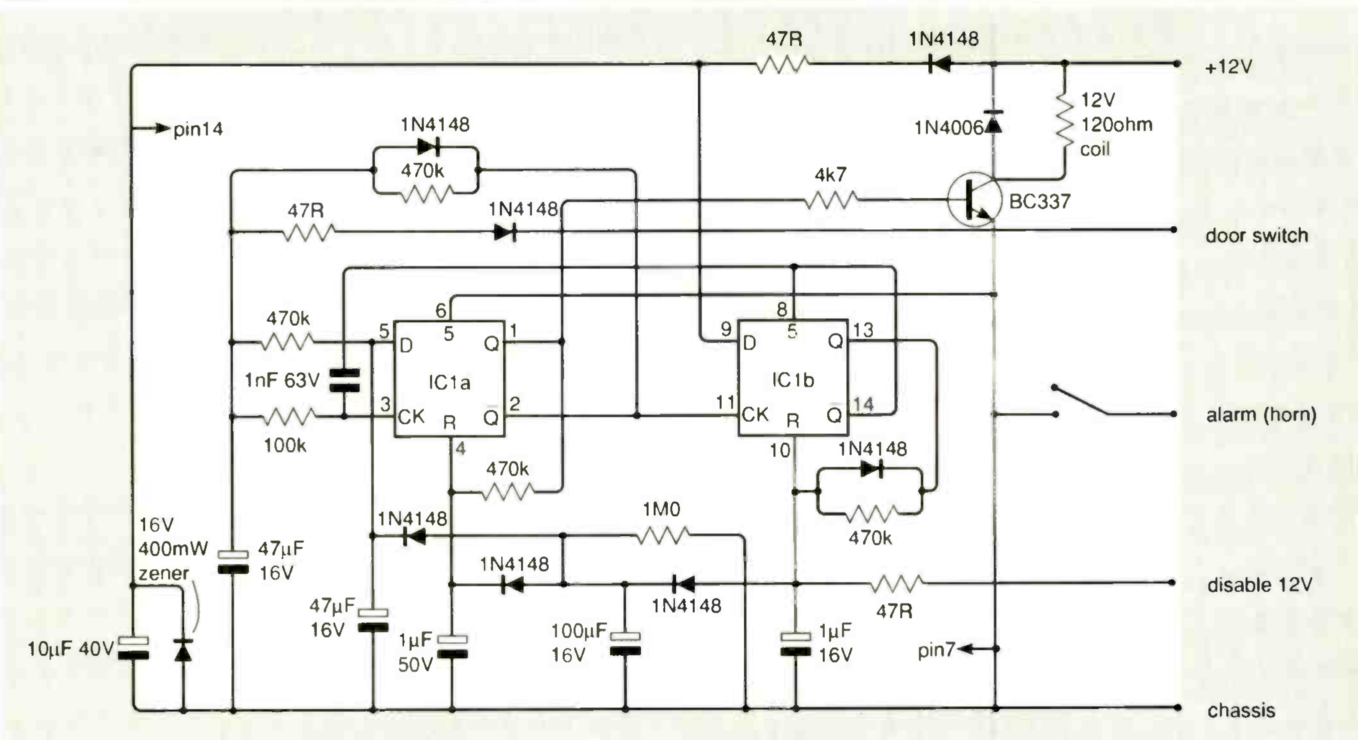


Car alarm sounds for 10 minutes, after giving 15 seconds grace to disable it

removed. Alarm duration is set by R_3C_3 and the duty cycle by R_4C_4 and R_5C_5.

Once the alarm is triggered, the door switches have no effect on the alarm, which resets itself 30 minutes after it has first sounded. The disabling supply can be taken to the auxiliary pole of the ignition switch or a separate hidden switch.

H Maidment
Wilton
Wiltshire

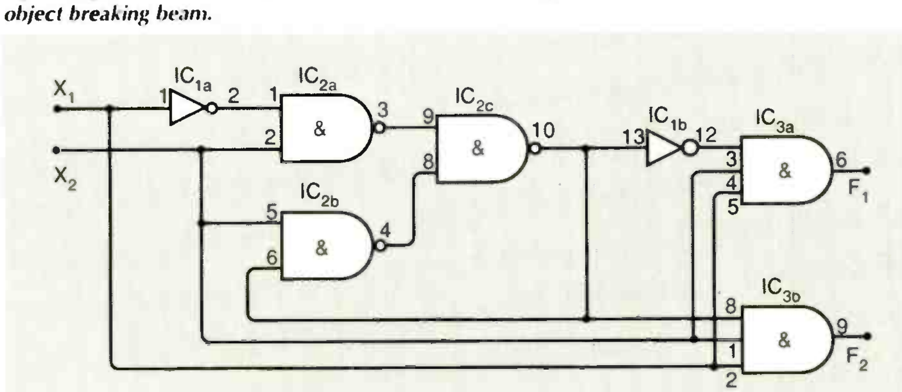
Motion-direction detector

Depending on which of the inputs x_1 or x_2 receives a logic 1 first, the outputs produce F_1F_2 = 10 or F_1F_2 = 01, thereby indicating the direction of motion of an object breaking an infrared beam. For the sequence of inputs x_1x_2 = 00-10-11-01-00, F_1 will be high and for the progression 00-01-11-10-00, F_1 is low.

Figure 2 shows the application, in which the two beams are used to indicate motion.

Continued on p572

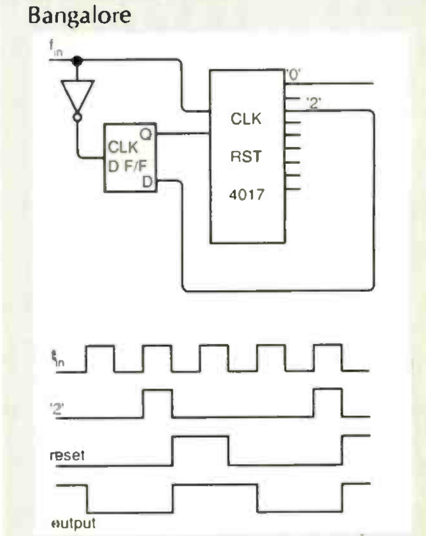
Fig. 1. Logic circuit of motion detector, where state of outputs indicates direction of motion of object breaking beam.



Simpler divide-by-three

Having noted with interest the divide-by-three circuits published in August 1990 and February 1991, I offer this circuit for its simplicity. It gives a further reduction in component count.

Philip Thomas
ISRO Satellite Centre
Bangalore



When F_1 is high, beam A has been obstructed first and the motion is therefore from left to right. Such an arrangement can be used where separate counts are needed of objects moving in opposite directions, the infrared beams being replaced by other types of sensor, if necessary.

M.Kumaran
University of Keele
Staffordshire

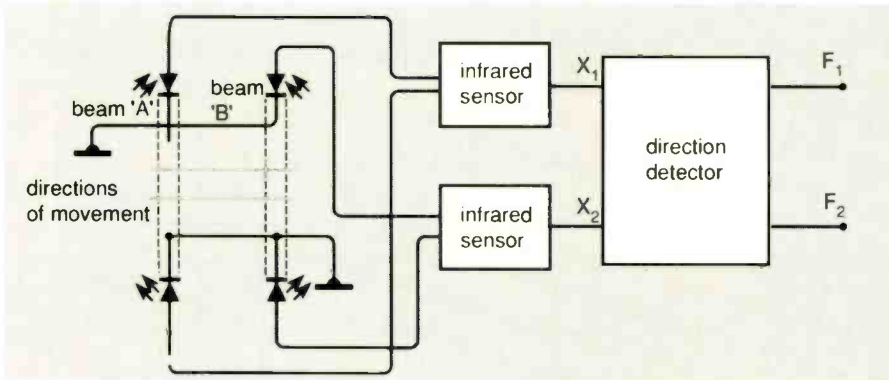


Fig. 2 shows application of detector. Beams may be replaced by switches.

High-voltage controller using OTAs

Needing only 100μA differential drive, the circuit shown provides an output voltage change of 100V in 1% increments.

Drive current is supplied by an operational transconductance amplifier IC_2 and power gain by three mosfets. Transistor Tr_1 is a source follower, its gate voltage being set by the voltage drop across about 1MΩ of current-sinking load, which is split between the two other mosfets to keep majority current power dissipation within limits. The combination forms a controllable power zener to set the load voltage across R_L. Transistor Tr_3's gate threshold voltage is above the minimum compliance level for the current mirror at IC_2 pin 12.

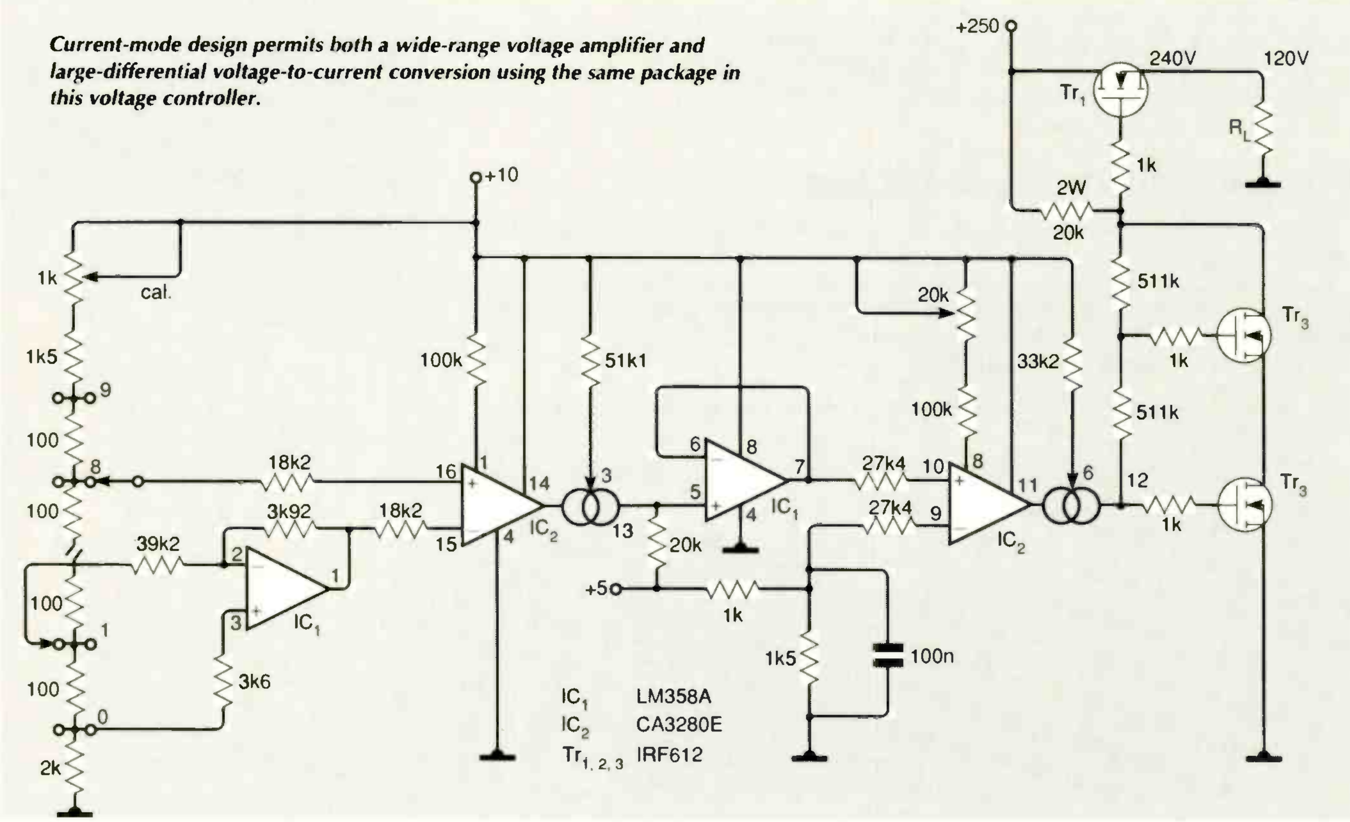
Bias voltages of +5V and +10V were needed for other sections of the system, so the input divider is calibrated by the variable resistor for nine 200mV steps across matched 100Ω resistors, contained in a thick-film package. Op-amp IC_1, with a gain of 0.1, accesses the same tapping points to produce two-decade resolution and good tracking at the OTA differential inputs.

This first OTA is a linear differential voltage amplifier which drives a 20kΩ load from +5V; linearising diode bias at pin 1 causes the 2V input to appear as a current to the load resistor. The resulting voltage drop, buffered by the second op-amp, becomes a +5V to +7V swing on a constant 3V, so that the second OTA receives a 2:1 voltage excursion at its inputs.

Diode bias at pin 1 allows proportional current sinking into pin 12 to determine the 2:1 output swing. The 20kΩ variable resistor adjusts range and magnitude.

John A Haase
Fort Collins
Colorado
USA

Current-mode design permits both a wide-range voltage amplifier and large-differential voltage-to-current conversion using the same package in this voltage controller.



FRESH IDEAS?

While we are not short of Circuit Ideas to publish, it would be agreeable to see some fresh input from the vast, untapped bank of talent that our thousands of readers represent. Please don't be reticent: we pay a moderate fee for all Ideas published. So send them to to Circuit Ideas, *EW + WW*, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. We will be happy to consider them.

4 X 4-bit parallel binary multiplier

Large computers and signal processors need to perform high-speed multiplication and do this by using arrays of gates, half and full adders. The arrangement shown is, so far as I am aware, new and is a four-bit parallel binary multiplier using a four-bit full adder, the 74283.

If two, four-bit binary numbers, A3-A0 and B3-B0, are to be multiplied, the partial products are:

W0 = A0B0; W1 = A1B0;
W2 = A2B0; W3 = A3B0
X0 = A0B1; X1 = A1B1;
X2 = A2B1; X3 = A3B1
Y0 = A0B2; Y1 = A1B2;
Y2 = A2B2; Y3 = A3B2
Z0 = A0B3; Z1 = A1B3;
Z2 = A2B3; Z3 = A3B3.

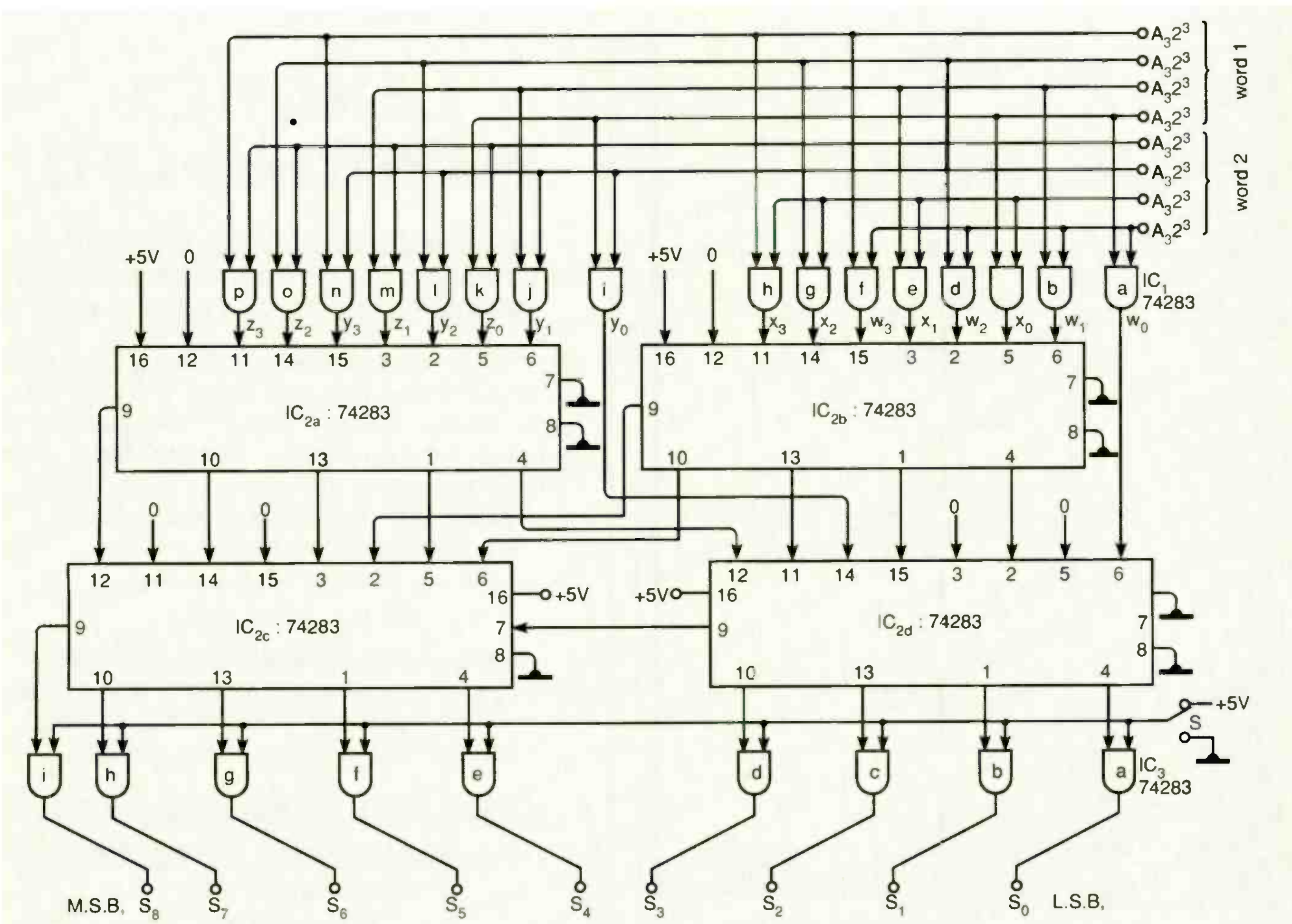
Add the partial products in W and X and those in Y and Z, then add these two partial sums to obtain the product; binary place values of the partial products must not be altered during the addition.

In the diagram, the array of And gates in IC1 provides partial products W.X.Y and Z. W + X and Y + Z being produced separately in the full adder IC2a,b. Full adders IC2c,d add these partial sums, the output of the second array of And gates in IC3 giving the final product of the two four-bit numbers.

This method is easily extendable to cope with eight-bit binary numbers.

PR Narayana Swamy
Kingswood
NSW
Australia

Correction
In I Hegglun's Circuit Idea "40W voltage doubler", which appeared in the May issue, the two electrolytic capacitors on the outputs of the op-amps were shown the wrong way round. We apologise for the error.



A 4 x 4 bit parallel binary multiplier

Cadstar 6.1: still setting standards?

Cadstar schematic capture and PCB layout packages are highly priced — but high performance too. Martin Cummings test drives release 6.1.

As soon as Cadstar arrives you get a measure of the competence of the package.

Documentation is extensive, the schematic capture and layout programmes each come with user manuals, reference manuals and tutorial books. A reminder strip is included to fit over the function keys and a laminated summary card both help to make life easy. Installation is straightforward though time consuming as compressed files have to be expanded during transfer to hard disk. But detailed instructions are provided and a menu prompts for relevant information, then the package gets on with the job. Simple graphics show what is happening.

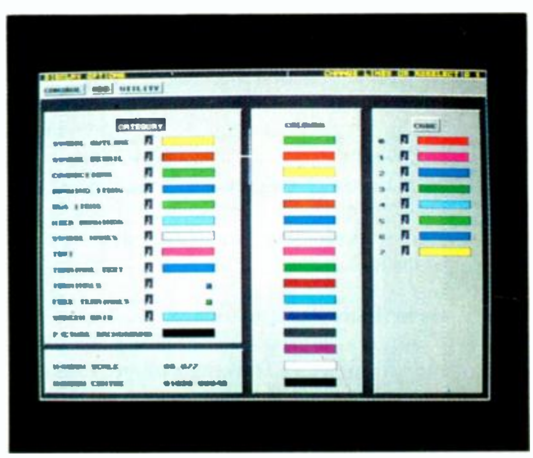
After such a long wait it is not surprising to learn that schematic capture and PCB layout take about 2.5Mbytes of disk space each. In larger organisations where several people have workstations, networking would centralise the libraries, saving some disk space and hopefully saving duplication of effort. Cadstar supports networking and a brief section in the manual explains how to organise shared files and outlines procedures to be adopted.

Schematic capture takes almost all available ram and will only just coexist with Dos version 4, so all but the most essential drivers must be removed from memory by reconfiguring AUTOEXEC and CONFIG files. This can be disruptive to an established system but is essential to get up and running. Running schematic capture on a 640kbyte machine would be a struggle, and a minimum of 2Mbytes is recommended to avoid limiting the size of circuits.

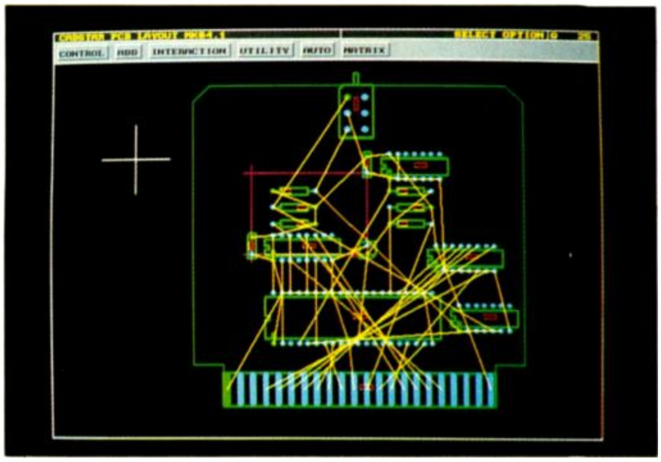
Exploring the screen

Cadstar will run on EGA, VGA or a selection of higher resolution graphics boards. Displays for schematic capture and PCB are almost identical. Three lines at the top of the screen are reserved to provide information with the remainder left uncluttered for drawing.

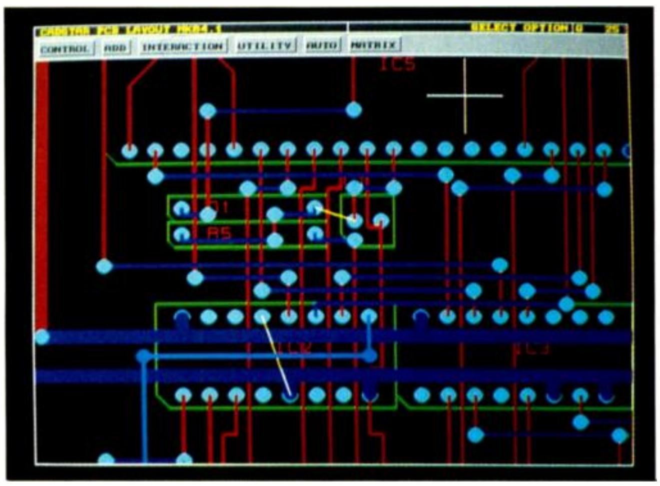
A line of commands along the top of the drawing give access to pull down menus, listing the commands on the screen only when necessary. Panning is by pressing a function key, prompting a screen redraw centralised about the current cursor position. The approach is unusual and effectively limits panning to half a screen at a time. But after a few goes it feels quite natural. Zooming in and out can again be achieved with a singe function key or by defining a window, so zoom factors are infinitely variable.



Symbols, connections, buses and text are treated as separate layers which can be turned on or off to unclutter the schematic. Screen colour for each entity can be selected. The menu for both features is mouse driven, informative and easy to use.



Airwires prior to routeing



Zooming in and out can again be achieved with a singe function key or by defining a window. Zoom factors are infinitely variable.

Mouse manipulation plays a leading role in selecting commands from the drop down menus. But each also has a three letter abbreviation which is often quicker to use for frequently employed commands.

When further information is required a dialogue box opens at the top of the drawing area with a prompt to type in file names, part names or similar.

Security dumps are automatically stored to disk during working so that in the event of a power failure or similar catastrophe, only a few minutes work are lost at the most.

Screen grids and working grids can be set to any reasonable resolution and turned on or off at will. Coordinates are continuously displayed in the top right hand corner and can be complemented by relative coordinates upon demand, though they tend to pop up of their own accord at appropriate moments.

Schematic capture

Cadstar's tutorial booklet is the equivalent of an intensive training course; detailed, well structured in its approach, anticipating common mistakes and giving reminders. The novice is led through the whole process, from placing the first symbol to a final schematic, exercising most of Cadstar's features along the way.

Pull out sheets show what worked examples should look like and example files on disk for each chapter allow the more experienced to jump in at any stage.

First step is to select components from the library and place them onto the schematic. At this stage they are symbols only and type of resistor or gate family, for example, need not be defined so that the drawing is not cluttered with values, identities or pin numbers. Parts can be selected from the library by typing in abbreviations such as NAND2 for a two input Nand gate or by browsing through the abbreviations under mouse control.

Name wildcards can be used to narrow down the selection by, for example, presenting only the various Nand gates available. As the schematic develops it is often quicker to add a symbol by clicking on one that already exists. Cadstar automatically creates a duplicate for placement.

Once the part to be added has been selected Cadstar temporarily shows it as an outline box with no internal detail. This can be a frustration — particularly if the symbol was rotated prior to placement — as it is easy to forget where the connecting points are. Often the part must be placed, causing the detail to appear, then clicked on again and moved to the exact position. Snapping onto grid positions can be enabled to help overcome this problem.

Connecting symbols is simply a matter of drawing lines with the mouse. Connections can be drawn at any angle, or limited to 90 or 45°, and are not allowed to start or end in mid air, only at legitimate terminals.

Cadstar has to be told where to put corners in the lines, and while a function key can be used to do this, the central button in a three button mouse makes life much easier. Drawing a bus is possible in a variety of widths, and as individual connections are made into the bus a 45° mitre is automatically inserted, of a size previously specified.

Turn layers on or off

Different entities on the schematic such as symbols, connections, buses and text are treated as separate layers. They can be turned on or off at will and can be useful to unclutter the schematic to study only those bits of interest. Screen colour for each entity can also be selected. The menu for both features is mouse driven, informative and easy to use, even in the middle of a design.

Adjusting parts positions is a simple matter. Connections follow the part, keeping to the specified angles as best they can. Full rubber banding is not employed but this has the advantage that very little tidying up is necessary after such a move.

Signals are automatically called "net1, net2, net3 ..." although this is not displayed. However the default name can be changed and signal names displayed if required. There is even the facility to place a bar over the name to indicate a negated signal. Allocating names to a sequence of similar signals, such as in a bus, is a pleasure because once the prefix is typed in, Cadstar increments the number as the signals are clicked down. More general text can be added — rotated if desired — and there is even the facility to edit the text font to create special characters.

Multi-sheet circuits

Circuit diagrams can span up to 50 sheets and as long as signals have appropriate names the connections will be maintained from sheet to sheet. Similarly, multi-level hierarchical diagrams can be created giving the designer a lot of scope to maximise design efficiency.

Once symbols have been connected, the next step is to allocate components. There are three separate library types. The parts library is the master and defines such things as component name, pin names, pin and gate

Continued over page

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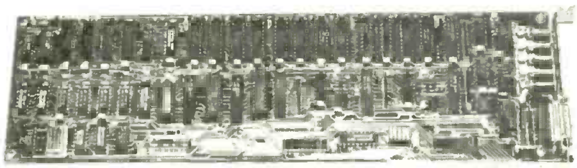

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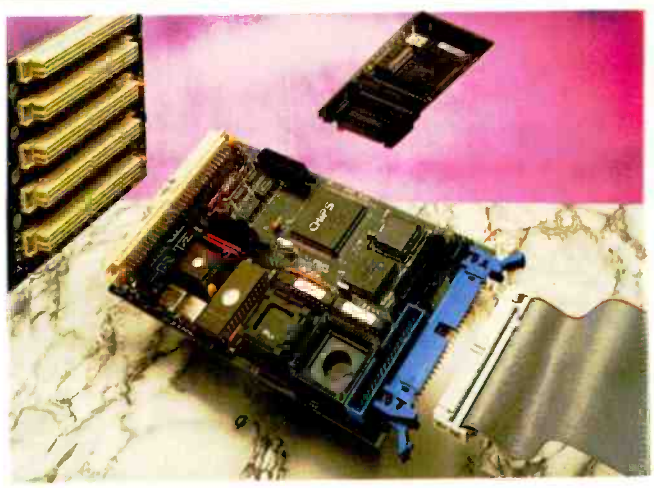

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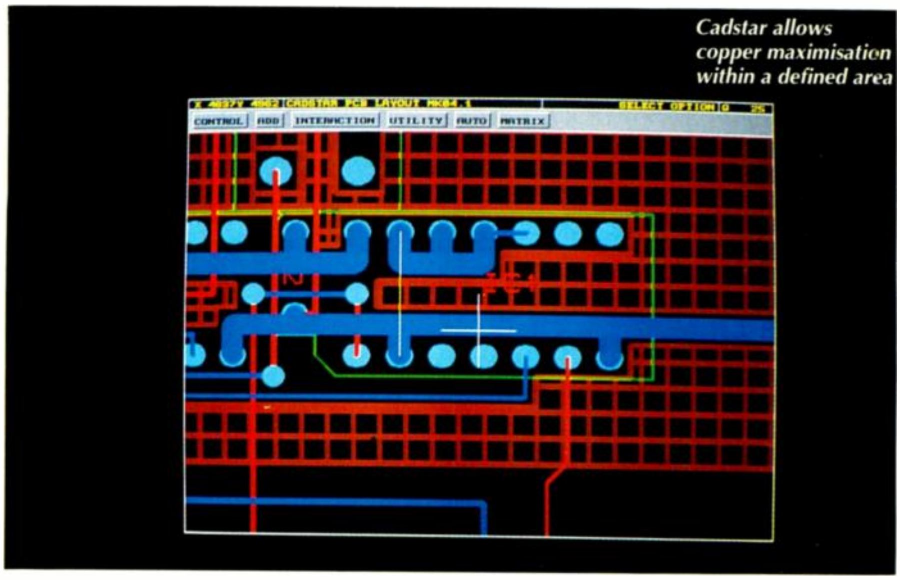


Cadstar allows copper maximisation within a defined area

swap data, and a reference to the symbol library and PCB library. The symbol and PCB libraries hold the shapes to be used on schematics and layouts. The approach is sensible, in that differing parts may use the same circuit symbol or PCB shape.

As expected from such a well bred system, component identities are automatically incremented within the relevant category as components are allocated to symbols, taking into account the number of gates/package.

Over 5000 parts are included in the library, covering several 74/54 series TTL families, cmos, some memory chips and a selection of discrete components. Despite the extensive library there is always the need to create components and the parts library is an ascii file which can be modified with any non-formatting text editor. Symbols and package shapes can be drawn with the mouse. Creating a curve or circle is a curious exercise involving drawing a line or rectangle then transforming or pulling this into a curve. With a little experimentation the technique can soon be mastered, but a flexible imagination is helpful. An up to date parts index can be created and printed out to be kept as a handy reference.

High quality hard copy

Cadstar expects schematic output to be to a plotter up to A0 size, or postscript laser printer, and is supplied with numerous plotter drivers. Check prints can be produced on a dot matrix printer, divided into sections. But it is a single-pass printout and though adequate for checking is not really presentable.

Ironically, cheaper schematic capture packages produce much better output on a dot matrix printer, but Cadstar is aimed at those who can afford plotters and laser printers.

Net lists and parts lists can be printed, and Cadstar will also print out a list of individual gates and an error report to show any unallocated symbols. The parts list includes a description field extracted from the parts library which could, for example, contain a company stock number.

There is no electrical rule checker to identify unconnected pins, outputs connected together or outputs connected to power supplies. But Cadstar is designed to be used with far more elaborate analogue and logic simulators such as Pspice and Cadat. It is even possible, from the menus, to run a PLD compiler and thermal analysis programme, if these options have been added to the software suite.

PCB layout

PCB layout screen is almost identical to schematic capture and commands follow the same pattern. Maximum board size is just over 32-in square with provision for 16 layers and another 16 layers for documentation only.

Smallest grid size is 0.001in, as is the thinnest track, so any limitations will be in manufacture rather than Cadstar.

Start point is usually files produced by the schematic capture programme which have to be read in.

PCB will accept files from one or two earlier Racal-Redac products and file format is documented in detail so it would be possible — but rash — to create the initial data on a text editor and use PCB as a stand alone. After reading in the data, all components gravitate to the bottom left of the screen and once the board outline has been drawn or loaded in, layout can begin.

Everything that can be automated has been, starting with automatic placement of components. The matrix needs only to be defined along with orientations allowed, then the programme will position any or all of the components. Usually the autoplacer needs to be run several times for different types of component. For example ICs would be placed first, then the matrix size reduced and resistors positioned to fill the gaps.

Most designers will start by hand-placing critical components then unleashing the autoplacer on the remainder. On completion a brief report explains what has been done, what is left and the total connection length on the board, the aim being to position items such that length is minimised. Autoplacement gives a professional looking result and saves a lot of laborious mouse work.

At this stage all connections are shown "as the crow flies" and when moving components around by hand, connections follow in real time.

Connections, and component detail, can be turned off to speed up movement around the screen, but in practice this is not necessary and is probably a legacy from the days of slower computers. Clicking on a tree brings up a brief report detailing where it starts and ends, whether it has been routed, how long it is and its proposed width.

As with schematic capture, screen colours are fully configurable and various entities can be turned off. During placement it can be particularly useful to turn off connections that jump from point to point at seemingly random angles.

With connections turned on, individual nets can be highlighted to check where they end up.

Several tools for optimisation

Connection length of trees can be minimised and an automatic gate and pin swap routine scans the layout for gate swaps within chips, gate swaps between chips and pin swaps on gates. The necessary swaps are made while a record is kept of any actions to bring the schematic back into line — so called "back annotation". The swap routine can often improve on itself given another one or two passes.

When the board becomes a jumble of components a useful utility allows renaming of all the components in a logical order, say from left to right or top to bottom.

Component group prefixes can be changed at this stage if required and naturally Cadstar keeps a cross reference to back-annotate, painlessly, the original schematic.

At this point it is easy to believe that creating layouts with tape at a light box was a technique from the stone age — and we have yet to examine the autorouter. Clearly layouts produced by Cadstar will not only be quicker and easier to design, but will perform better, electrically, as a result of computer optimisation.

Autorouter will route any two layers at a time, and has separate algorithms for power supplies, memory arrays or good old orthogonal routing.

Normal starting point is to take power and ground and specify such things as distance

SYSTEM REQUIREMENTS

- 80286 processor
- 640k ram — preferably 2Mbytes
- Dos version 3.0 or later
- hard disk
- EGA or VGA graphics
- mouse
- parallel port
- maths co-processor (PCB only)
- plotter or postscript printer

of the power bus from the chips and whether the bus runs along the chip axis or at right angles to it. Orthogonal routing can be biased towards one direction and is intelligent enough to finish off a route that has been started manually.

On completion a brief report tells what is left to route and provides statistics such as number of via holes, area per IC and density of components on the board. Like all reports this can be sent to the printer.

In general, the autorouter is extremely competent and flexible.

The grid used is selectable down to 0.01in so that respectable track densities can be achieved. Watching tracks being placed on the screen has a lot of novelty value. But the programme runs about 25% faster if not exhibiting itself and no doubt the novelty wears off quickly.

Speed can only be described as *phenomenal*. Cadstar makes use of the maths co-processor and will complete simple layouts in 10-15s. Many factors influence speed of operation but this is one of the fastest autorouters I have seen, and after all the data entry and manipulation that comes before, routeing time fades into insignificance.

There is yet more optimisation in the form of via hole minimisation. Fewer holes significantly reduce manufacturing costs and on a simple board it was both surprising and pleasing to find that Cadstar was able to reduce them by almost a half.

Virtually all features of modern boards can be implemented using Cadstar. Copper ground planes can be created, layers configured specially for power planes, tear-drop pad shapes and radiused corners used to improve manufacturing yield. Finally after this frenzy of design activity the completed layout can be subjected to a dimensional check programme.

Professional solution

Layout output can be to a Gerber photoplotter or postscript laser printer. An elaborate menu makes it is possible to specify layers to be plotted, orientation, whether to mirror the plot and a scale factor to produce, for example, 2:1 films. The drill drawing can be annotated with helpful text or a file created to programme an NC drill.

Checking on the plotter is possible, where pads are drawn unfilled and tracks drawn the width of the plotter pen. Usually designers will spend some time checking layouts at this stage.

But it has to be said that the programme installs such confidence in the user, both in operation and because of all the optimisation and checking performed along the way, that manual checking may be considered superfluous.

There is little to fault on both packages. They are professional, well rounded programmes that have stood the test of time but with features added along the way. Libraries supplied are generous, particularly strong on logic families, and the PCB library includes a fair spread of surface mount components as well as through hole devices.

Schematic capture can be bought alone, or with PCB layout in what is called Cadstar Full. The two together are also available as Cadstar Interactive, which is about half the price but lacks automatic features such as autoroute and autoplace that help distinguish it from many other offerings on the market.

It is almost impossible to find something that Cadstar cannot do. The autorouter is particularly impressive and must be ranked amongst the best available on a PC workstation. Documentation presents the product from every angle including reference sections, library listings and cross references and the tutorial booklets help to reduce the inevitable learning time.

Cadstar cannot be considered as budget cad software but where performance, flexibility and features are the prime issue it will fulfil and probably surpass expectations. ■

SUPPLIER

Racal markets a whole suite of computer aided engineering programmes under the name Cadstar all of which have a long and respectable pedigree. Release 6.1 is available from:
Racal-Redac Limited, Newtown, Tewkesbury, Gloucestershire GL20 8HE.
Tel: 0604 294161
Cadstar Schematic £495
Cadstar Full £4850
Cadstar Interactive £2450

Notebook control of data acquisition

Labtech's Notebook offers powerful control of data acquisition and analysis. But does the packaging match the product? Allen Brown reports.

LabTech Notebook is a powerful software package for control of expansion cards collecting data from a variety of sources — such as thermocouples, strain gauges and transducers — and providing channelled analogue and digital data output.

Extensive facilities allow the user to build up a control system from a large variety of predefined, interlinked block units and these can be integrated to form an open or closed loop real-time operational system.

But installation can be messy. Notebook needs three terminate and stay resident (TSRs) to reside in the 640kbyte user memory, and this can be a real drawback when other programs needing maximum memory have to be run.

As a result CONFIG.SYS and AUTOEXEC.BAT files have to be continually changed to remove the TSRs, one of which is a display driver selected by the user, and is quite unnecessary when the installed graphics card type can be auto-sensed.

When the package is eventually up and running (*I had to make several attempts to get going - see box - because the package would not recognise the supplied dongle and even a replacement did not alleviate the problem*), the display greeting the user appears to be quite thin: a single command line at the top of the screen.

Each option in the command line leads to more options, no sign of the customary drop down menus and menu overlays, and the user interface looks rather old fashioned. Iconview graphics user interface (GUI), one of the upgrade options, appears to been tacked on the end of Notebook to dispel this impression.

Command Options

First option in the command line, SETUP, gives rise to a sub-command line which includes CHANNELS and it is this option that begins to reveal some of the strengths of Notebook.

Setup for data acquisition (**Fig. 1**) contains a detailed list of options allowing the user to exercise considerable control, with relative ease, over the nature of data acquisition. Some entries in the list have several options and an option menu can be evoked.

Number of active channels can also be controlled from this list, each one individually tailored to user requirements.

DISPLAY allows users to choose how acquired data is displayed, and TRACES enables the showing of up to five input channels on the screen in a graphical format. Scaling and channel allocation on each display window can be adjusted.

ADJUST permits positioning and sizing of

Current Value: Analog Input

NORMAL DATA ACQUISITION/CONTROL SETUP

Number of Channels	1
Current Channel	1
Channel Type	[Analog Input]
Channel Name	
Channel Units	Volts
Interface Device	[0: DEMO
Interface Pt/Channel No [0..15]	0
Input Range	[±10V]
Scale Factor	1.000
Offset Constant	0.000
Buffer Size	500
Number of Iterations	1
Number of Stages [1..4]	1
Sampling Rate, Hz	10.000
Stage Duration, sec [0.0..1.0E+08]	29.500
Start/Stop Method	[Immed]
Trigger Channel	1
Trigger Pattern to AND [0..255]	0
Trigger Pattern to XOR [0..255]	0

Analog Input
Analog Output
Digital Input
Digital Output
Thermocouple
Strain
Time
RS-232
Calculated
RTD
Resistance
Counter
Frequency
Pulse Output
Replay
GPIB Input
GPIB Output
Thermistor

↓ MORE ↓

Fig. 1. Menu for selecting options for data acqoisition.

CIRCLE NO. 113 ON REPLY CARD

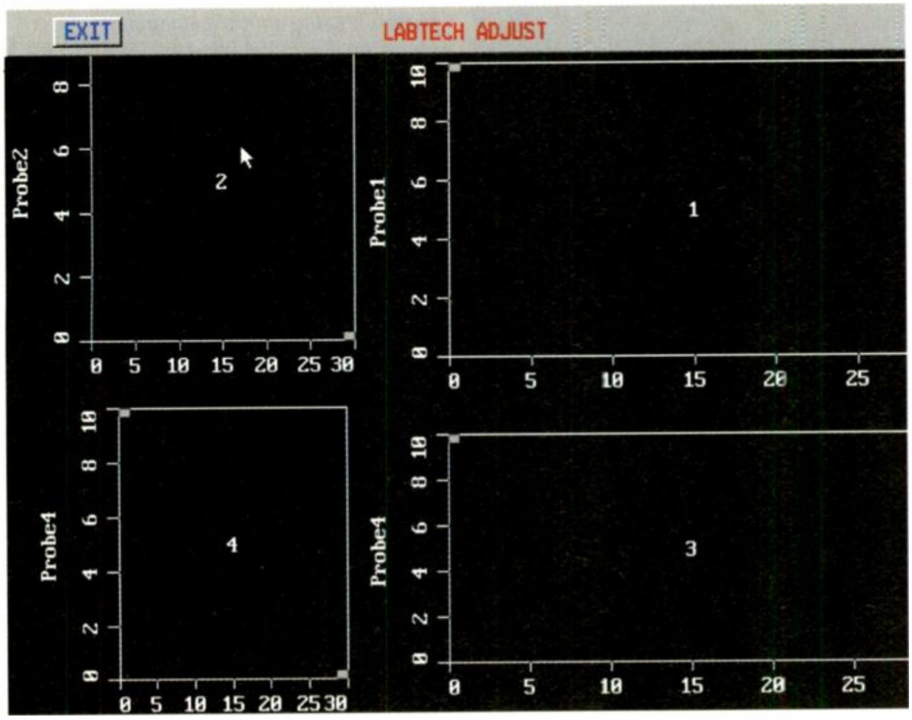


Fig. 2. Defining the graphical display windows

windows for the data display. But contrary to information given in the user's manual, at first I was unable to use this option since it failed to work with a Mouse Systems mouse. Only after replacing with a Microsoft mouse could I progress (**Fig. 2.**).

An attractive feature of the SETUP command line is VERIFY which perform a check to ensure that the chosen configurations from the channel listing are compatible. VERIFY can also produce a detailed list of the system set-up and the settings of each channel.

ANALYSE leads to another sub-command line which includes the ability to evoke either the Lotus 1-2-3 or Lotus Symphony curve-fit routine or a FFT.

Curve-fitting is very good and the menu offers several options for controlling the tolerance of the fit. The ANALYSE list also contains the obligatory FFT option which is a standard feature of software packages of this type. A tutorial exercise devoted to using Notebook with Lotus 1-2-3 is helpful for anyone with a Lotus product.

High scoring acquisition

Data acquisition via an analogue input expansion card is one of the main requirements of this type of software, and here Notebook scores very highly. Attractive features allow processing of signals from a variety of sensors and give the normal control over sample rate, batch sample periods, magnitude, offset, scale factor and triggering levels.

Special provisions are made for taking measurements from temperature sensor devices and for thermocouples Notebook samples the cold junction and performs polynomial linearisation on the input voltage to provide corrected temperature readings. A choice of device types is given in the thermocouple menu. When using platinum resistance thermometers (RTDs), a linearisation table gives the corrected temperature.

DONGLE DISAPPOINTMENT

Where input signals are derived from strain gauges, Notebook offers easy conditioning of the signal by allowing the user to enter various strain parameters such as gauge resistance, gauge factor and gain resolution. Output measurements are given in corrected absolute terms.

Measurements on the input signals can also be performed, providing resistance, frequency, period and event counter.

One further enhancement is CALCULATION mode which allows input data to be processed by an extensive array of mathematical operations. These also include an impressive selection of statistical operations such as moving average and moving deviations, and logical operations can be performed on digital input data for control conditioning. For non-linear sensors, an automatic polynomial curve fit can be applied to the input signals where the coefficients are stored in a disc file.

The opportunity to perform digital filtering on the input data is especially useful for closed loop control applications where component transfer functions can be realised. But it will only work efficiently if a cache memory in the PC is available to retain coefficients and previous sample values for fast processing. As all the functions in Notebook are implemented as numbered block units, coupled together in the desired manner, selective turning off of a range of block units is possible. If necessary this can be used as a panic switch to turn off all the component blocks in the setup.

RS-232 enthusiasts will find that Notebook provides features for controlling data flow from devices via the RS-232 ports. Personally I question the value of this since perfectly adequate facilities exist on the PC's expansion bus for data acquisition purposes.

Process control strength

Notebook's ability to implement process control operations is one of its most appealing features and there are three sectors of operation: data acquisition, data processing and channelled data output.

Control over operation of the input and output channels is exercised from the CHANNEL option in the command line.

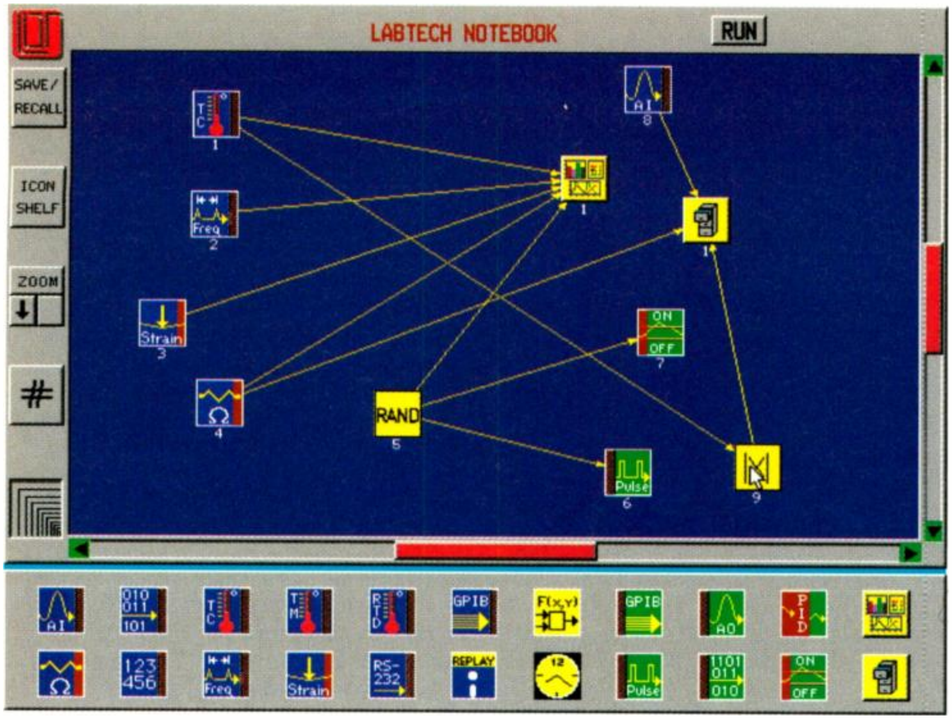


Fig. 3. Iconview: potentially impressive GUI option

Open or closed loop operation is possible. In open loop mode channelled data output is taken from a disc file and fed to a D-to-A converter on an expansion board for an analogue output, or directly to a digital I/O board for switching actuators or as a pulse bit stream. Selection is through the CHANNEL option in the appropriate command line.

Output channels can be monitored with the TRACE option which is certainly very helpful during the design stage of a control system.

Disc files can be created externally (using a spread sheet) or using the WAVEFORM option from the CHANNEL listing.

Many waveforms can be generated by this method, with control over their characteristics (frequency, sample rate, amplitude etc).

Data sample rates and throughput are largely dependent on the PC used to run Notebook. There is no mention of DMA in the manual — a standard feature on many data acquisition expansion cards.

But once a control system has been constructed it will run satisfactorily in a background mode provided the CPU is not heavily loaded.

For closed loop, real-time operations the user can evoke the well-known PID (proportional integral derivative) algorithm, and appropriate adjustments for loop gain, reset and rate are made in the CHANNEL listing. However the description given in the user manual of how to use this facility is somewhat brief.

One feature I would have expected in a package of this type is a routine for implementing process control through multivariable state space models. After all the architecture of 386 and 486 based PCs certainly allows low frequency, multivariable closed loop real-time systems to be realised.

Graphical interface option

ICONview option — an icon front end user interface — at first appears quite impressive. But you must have a Microsoft mouse. No other mouse will do and the interface will not operate without one.

Stripping out my Mouse Systems driver and replacing it with a Microsoft driver and mouse I was eventually able to get back to business. But Microsoft is not yet the industry standard and provision ought to be made for other mouse manufacturers.

ICONview is a good attempt by LabTech to brighten up the front end display of Notebook without having to redesign the whole package (**Fig. 3.**) Bottom section of the display shows the input, output channels and function blocks (the icon tray) and using the interface the true block unit design can be fully appreciated.

Blocks are mouse selected from the icon tray and dragged into the central working area or drawing board. Interconnections between the icons are drawn by using the appropriate mouse button. By clicking the other button the CHANNEL menu list appears (Fig.1) allowing it to be configured to the user's requirements. When a block is no longer required it is dragged over to the cute on the left hand side where it disappears.

ICONview is certainly an attractive feature of Notebook. A separate manual allows the user to get to grips with it and a tutorial in the manual is particularly helpful.

REQUIREMENTS

Magic/L programming language

Once proficiency has been gained with Notebook users can access a feature which really enhances its flexibility: the Magic/L programming language.

Magic/L commands can be grouped into five categories: Notebook defined functions; looping command; input/output commands; branching and control and maths functions. Users can combine the block unit design strategy with a powerful structured design language containing conditional control features, paving the way for design of intelligent, decision making control systems.

Patchy but informative

In general the user's manual is readable and each section is well written. But on reading through, there is a growing feeling that the document has grown, and appended sections have been inserted where necessary.

The result is that in places it is rather patchy. A lot of information is included but somehow the document lacks coherency. Surprisingly, pages are numbered consecutively as opposed to numbering by sections (for example 3-12) preventing a whole section from been rewritten as appropriate upgrades are introduced.

More information could be provided on actual expansion boards which can be used with Notebook as this appears to be a grey area in the product.

Arguably, user's manuals are easy pickings for a critic but unless the problem of presentation is addressed in a professional manner they will remain largely unread — and in many cases unreadable.

Practice and example as a method of learning is well recognised in engineering circles and Labtech has included three tutorials in the user manual, allowing the beginner to gain confidence.

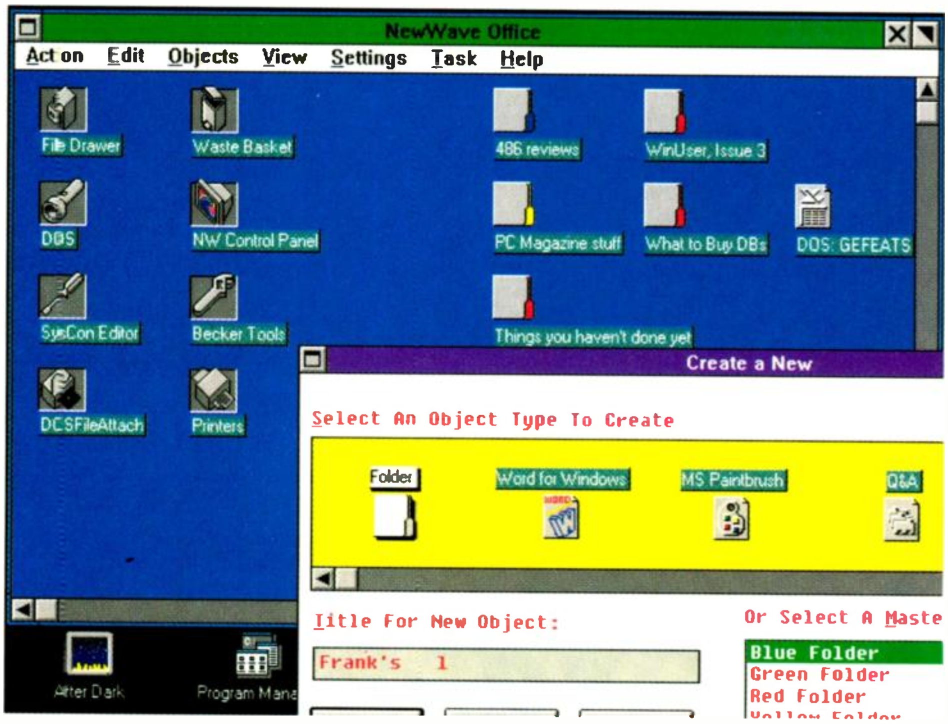
These are indeed helpful. But I feel there should be a few more examples to help in the early learning stages. However the Application Notes are certainly useful and serve to increase understanding and appreciation of Notebook's potential.

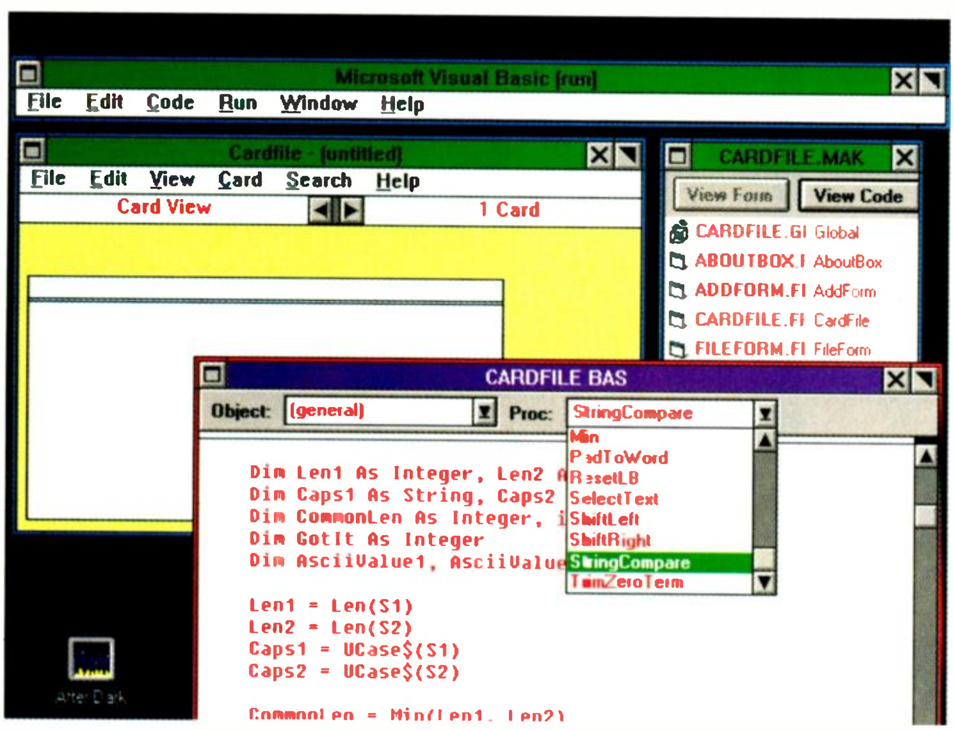
Overall, Notebook is a powerful package and worth considering for design of a small scale data acquisition and control system.

Installation is problematic and only serves to frustrate the new user. When the TSR problems are resolved and restrictions on mouse and dongle are lifted then I feel Notebook will be an attractive package which has a lot to offer the engineer working on data acquisition projects. ■

Looking out

Since the introduction of Microsoft's Windows 3.0, the PC industry has re-engineered itself with the concept of the graphical user interface, a product originally developed over 13 years ago by Xerox in its Palo Alto Research Centre. GUI promises a new look to PC based technical applications. Neil Fawcett reports from behind the screens.





Microsoft wrote the Windows 3.0 operating system to provide an extension to dos with mouse support, simulated multi-tasking, application windowing, a common look and feel to all applications, ease of use and, most importantly, ease of learning.

The common belief, and Microsoft has market research to prove it, is that GUI can make an end user more productive. Essentially stated, a user can run more PC applications simultaneously, share data more easily between them while working intuitively because they all look and feel the same.

Although Windows 3.0 sits on top of dos doing mainly what is intended, it is not the all-purpose product which Microsoft would claim

Unpleasant memory

The process of loading a PC operating system is arduous and tedious. For instance, it

Mouse powered development: Microsoft's modular Basic for power programmers. Codes and routines run in separate windows

Windows 3.0

takes around 15 disks and two to three hours to install OS/2 v1.3 extended edition. Microsoft went overboard in the other direction with Windows 3.0 by reducing installation to one finger operation.

The company may well have over-simplified the process: getting the system to deliver its promise requires a considerable amount of manual fine tuning. The system does come with get out of jail free cards. At most points during installation you can opt out and customise the procedure for yourself. However, it is very easy to make the mistake of just settling for the very basic installation which Windows 3.0 chooses for your PC.

Although the system will work on an 80286-based computer it does not perform in a productive fashion unless carefully configured.

Simply adding memory to make applications run better doesn't work: the design of the Intel architecture PC leaves a lot to be desired.

Memory management on a PC is complex. An 80286-based PC with a standard 640K of ram will enable you to run one dos application or one Windows application: all you gain is the glorified use of a mouse and a graphical interface.

If the same machine had 640K of expanded ram, the only Windows 3.0 benefit would be the ability to manipulate larger data files. The best way to use extra memory is to turn expanded memory into extended memory. Once this has been done an 80286-based PC with a total of 1MByte can be used to task switch between full screen dos applications using Windows 3.0.

This configuration will also give a reasonable performance from Windows specific applications. Multiple Windows applications can also be used but performance is poor: 1MB is not enough to simulate Windows multi-tasking. It requires around 4MB to resemble a power user operating system.

Quantum improvements in computing power make themselves felt with 32-bit 80386SX or 80386DX microprocessor chips. Although Windows 3.0 is not designed to take advantage of a 32-bit architecture — it is simply a 16-bit extension to the 16-bit dos operating system — the raw processing power of the 386 chip increases performance

The hard option

By comparison to Apple Macintosh, PC memory handling is a dog. The reason lies in the struggle for compatibility between the 8086/88 microprocessor through to the 486. The latest chip generation allows applications to address up to 64MB of memory in its virtual form.

Virtual memory is really hard disk storage space Microsoft has made Windows 3.0 adept at using the hard disk, but it falls over if there isn't enough of it.

Up to 48MB of hard disk space can be used as virtual memory. Windows 3.0 on a 386 PC can create what are known as virtual machines. In essence this is like having an 8086/88-based PC running independently within a single 80386-based PC. Providing there is enough real system memory — four MBytes should be adequate — and plenty of free disk space, the operating system will

EXPANDING MEMORY

Windows 3.0 has been written to take advantage of extended memory. To an application, extended memory looks like a seamless continuation of1MB conventional memory provided with most 80286 and 80386 PCs. A Windows 3.0 driver, HIMEM.SYS, makes the first 64K of extended memory available to Windows in either real, standard or 386 enhanced mode.

The multi-tasking part of the system is unable to use expanded memory; it is best to convert extra memory from expanded to extended form when using Windows 3.0. A Microsoft utility called 386EMM.SYS will perform this task. The problem with expanded memory occurs because it is not a continuation of conventional memory.

Standard dos applications might require extra memory in the expanded form which calls tor a separate memory manager to switch between the two. The only way that 3.0 can give dos applications access to expanded memory is to run in real mode which cuts out the advantages of the operating system.

Windows in Real Mode

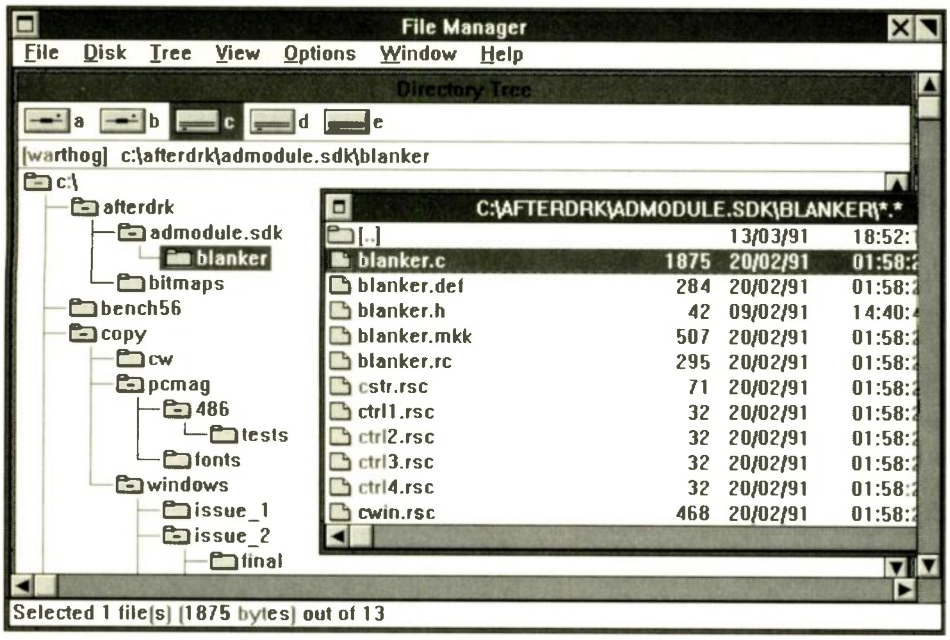
- Windows operating system runs as a dos shell
- Windows programs run in real mode
- Windows task-switches rather than multitasks dos programs
- Most of Windows is swapped out of memory when a dos program runs
- Dos programs cannot be windowed
- Dos programs run in real mode or in protected mode via dos extender

Windows Standard Mode

- Windows operating system runs in extended memory
- Windows task-switches (rather than multitasking) DOS programs
- Most of Windows is swapped of memory out when a DOS program runs
- Dos programs run in real mode or in protected mode via dos extender
- Windows programs run in a 16-bit protected mode in extended memory
- Dos programs cannot be windowed

Windows 386 Enhanced Mode

- Windows operating system partly runs in 32-bit protected mode
- Virtual device drivers use 32-bit protected mode
- Windows programs run in 16-bit protected mode
- Windows programs can partly use 32-bit protected-mode
- Dos programs can run in Virtual 86, 16-bit protected, or 32-bit protected mode
- Windows multitasks multiple DOS programs



multi-task both dos and native Windows applications.

Because of operating system complexity, the use of hard disk space can cause problems if either itself, or an application, crashes. Anybody who uses Windows 3.0 will have experienced the fatal Unrecover-able Application Error (UAE) dialogue box and cursed it (c.f. the friendly Macintosh bomb).

At the time of this crash Windows 3.0 usually leaves behind a small reminder on your hard disk drive in the form of temporary (.TMP) or swap (.SWP) files. Generally these files are kept at bay by being written to a special Windows directory, but depending upon the severity of the UAE error, these can be written to the root directory.

The location of the .SWP or .TMP file is, however, not the problem. Fragmented files on a hard disk drive slow it down which in turn slugs Windows 3.0 because it relies on the hard disk drive so much. Regular 'cleaning up' of a hard disk drive to contiguous storage space has much to recommend it.

Swap files are used by Windows on PCs with low memory, and use hard disk space to make up the shortfall. This is similar to virtual memory. However lively Windows operation requires a dedicated section of hard disk. Although you actually lose the use of this space when you are not running Windows 3.0, it does make Windows run faster.

Device drive

In the dos world, each application requires individual device drivers to control each piece of peripheral equipment attached to a PC. Windows 3.0 eases the software house's job — and eventually the end user's — by offering a single device interface to service a number of applications. For example, a spreadsheet, wordprocessor and desktop publishing application will talk directly to the system printer without the user having to specify a driver for each individual application. Print data from any of them is simply passed to the Windows 3.0 Print Manager which looks after all internal housekeeping.

File Manager: system housekeeping under Windows. This feature, rather ineffective in version 3.0, will be given much more power in the next release.

Windows 3.0 allows applications in 386-enhanced mode to give direct control of a device to an application despite the fact that it is actually being shared by another. Hardware developers realise the greatest benefits of the operating system. If Canon launches a new printer, such as its latest BJ10e bubble jet, then the company does not need to program individual drivers for each application that will use it. One Windows 3.0 device driver will offer support of the BJ10e to any number of commercial applications.

Network operation

Microsoft has attempted to improve the lot of the network user. File Manager offers a simple way to search all drives on a network, make a link and then copy or move files around by using simple mouse movement.

In the most basic configuration all Windows 3.0 files are located on a PC's local hard disk drive and simple access to other network machines is made through File Manager.

This type of installation allows for fast last file access, low network traffic and allows a user to continue working even if the rest of the network crashes. It does eat up over 6MB of hard disk space when running in enhanced mode.

A second option holds files on a server: only the initialisation files are held on the local hard disk drive. Although this setup only uses around 200k of local hard disk space, it increases network traffic. It also means that if a network goes down then so does Windows and all its applications.

Window on the future

Eventually Microsoft will turn Windows 3.0 into a 32-bit operating system combining all the features of OS/2 without the need for a dos foundation. For example uncompromised use of the 32-bit i486 microprocessor would allow preemptive application scheduling, multithreaded operating support, 2GB memory address space per application, inter-application communication and numerous graphical extensions.

The next version of Window to appear will be version 3.1. Although Microsoft does not plan this as a major product release, 3.1 will readdress several flaws in Windows 3.0. Probably the first, and the most important enhancement, will be improvements to File Manager. Improved file browsing, multiple directory trees and a modest level of drag/drop — icon movement around the screen to perform different tasks — will be on the wish list. 3.1 will also include closer to life font display and the system will be available in rom form for PC portables.

Programmers will look for additions to object linking and embedding (OLE). Already present in version 3.0 to a minor extent, it gives programs the ability to talk to each other and share data. OLE will finally end up as an object oriented file manager for the intelligent control of data files.

An object oriented file system (OOFS) will allow for the creation of compound data files. A file that knows what application created it and can also be created with links to other data files that relate to the same subject matter.

For example, imagine a word processor document created with an OOFS file manager. The document could contain a hidden link to a spreadsheet, an image from an art package and live motion video from a multimedia card. By clicking on the initial document, the data file will load the relative wordprocessor, spreadsheet, art package and initiate a video source link without further reference to the user.

A Dynamic Data Exchange (DDE) link, already a Windows 3.0 feature, could also be created by such a compound document so that when data in one application is changed, it is automatically recognised in a program with a corresponding link.

Windows 3.0 is evolving into an impressive product. Although extensions are available from other companies, for instance the object oriented NewWave file system from Hewlett-Packard, future versions of Windows should perform the task better than an extension to an extension of an old-fashioned operating system.

Apple's operating system release 7.0 includes most of the Microsoft wish list features: inter-application communication, TrueType Outline Font and an object oriented file system. Perhaps what Apple already has in an operational product will be the model for Windows 4.0 – or Windows 32 – within a couple of years. ■

Superconducting sandwich

Researchers at Stamford University have used a high temperature superconductor to grow a many layered, thin-film sandwich in which the optimum current path is at right angles to the film surface. This new superlattice structure should enable construction of sandwich type tunnel junctions, basic devices useful in the study of superconductivity and in its technological applications.

The lattice consists of alternating layers of the superconducting ceramic yttrium-barium-copper oxide ($YBa_2Cu_3O_7$) interlayered with an insulator, praseodymium-barium-copper oxide, $PrBa_2Cu_3O_7$. Each layer is 12Å thick. Structures with 400 such layers have been prepared as thin films with extremely smooth surfaces.

At least half a dozen groups previously have grown superconductor/insulator superlattices by stacking one material on top of another. In such a c-axis orientated structure, the copper oxygen planes, along which the current flows, are parallel to the film surface. This means that the supercurrent flows along the film, from one edge to the other.

But to incorporate superconductor films into integrated circuits, chip makers would like the current to flow from one face of the film to the other so that electrical connections can be made to the surfaces, rather than the edges, of the film. For this to happen, the current carrying CuO_2 planes need to be orientated perpendicular to the surface. This is the orientation of the Stamford superlattice. The end result is that each CuO_2 plane consists of alternating superconducting and insulating strips, depending on whether the neighbouring rare earth atoms are yttrium or praseodymium.

Sandford thinks a-axis oriented films will probably make it easier to construct sandwich type tunnel junctions which have not yet been made from any of the cuprate superconductors. Such junctions could be used to gain a better understanding of the physics of superconductivity, and to obtain well behaved Josephson junctions for electronic applications.

Real time nerve probe

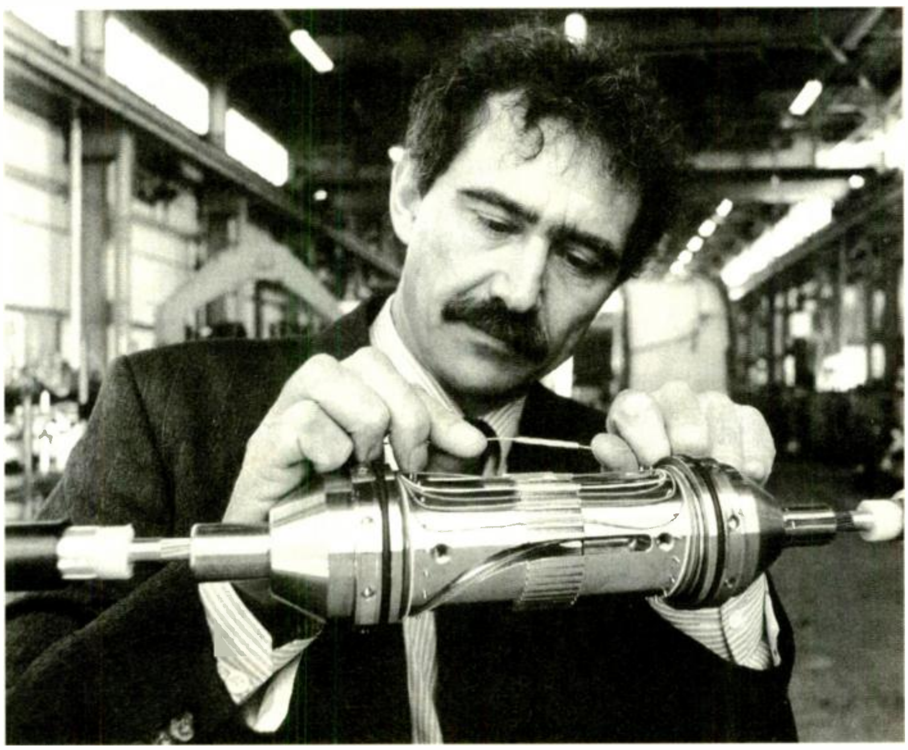
A new type of microelectrode reacts quickly enough to monitor the neurochemistry of living nerves in real time.

The concept, under development at the University of California by Paul Pantano, Thomas H. Morton, and Werner C. Kuhr, involves immobilising enzymes on carbon fibre microelectrodes using biotin-avidin coupling. To create an enzyme modified electrode, an electrode is first marinated in biotin and then dipped in avidin, which binds at one of four chemical receptor sites. Subsequent exposure to biotinylated enzyme fills the remaining sites.

In operation, the sheathed electrode is positioned inside a nerve. The immobilised enzyme covering the probe catalyses a reaction of the cell contents (substrate) with the electrode dip. The reaction liberates a redox active medium that diffuses rapidly to the electrode surface where it is reduced or oxidised. This generates an electrochemical signal proportional to substrate enzyme concentration which can be measured by a sensitive voltmeter.

Although the products of the enzyme driven reaction must be electroactive, the substrate need not be. The electrode could thus make it possible to follow changing levels of non-electroactive neurotransmitters like glutamate and acetylcholine at nerve synapses in real time.

Problems remain to be solved. For example, says Kuhr, "This electrode has never hit a biological matrix yet, so we don't know what kind of problems we're going to see in terms of immunological reactions." But Kuhr and co-workers are optimistic that their electrodes will open up new areas of neurochemistry to electrochemical investigation. **Anthony Edwards.**



Getting to the depths of the problem: BT will sink some of its profits at the bottom of the ocean in developing a universal underwater joint.

In an environment where a single repair can cost £100 000 it sees a need for a jointing system which can work with cable types from the four main suppliers. Cable repair ships can currently deal only with the single product for which they were designed. BT hopes the new system will be available in time for the laying of the TAT 9 transatlantic link which will make use of three cable types.

SAW measures picogrammes

A surface acoustic wave device has found a novel application: assessing the absorbtion of porous thin films. A sensor using SAW technology can measure thin films as small as 0.2cm^2. Previously, samples had to be about one square metre in area to make accurate measurements of gas/fluid take-up.

The surface area of a thin film with no pores can be calculated easily by geometry, but a porous thin film has a surface area greater than that given by simple equations. The total area indicates how effective a thin film will be during use. Applications include chemical and gas sensors, microelectronic devices, and anti-reflective coatings.

In a typical SAW device, a transducer at one end of a piezoelectric substrate emits an acoustic wave which travels along the substrate to a detecting transducer at the far end. Conventionally, the wave passes unimpeded to the other end where a receiving transducer converts it back into an electronic signal. The delay is fixed and depends on wave propagation. speed.

With the new sensor developed by Sandia National Labs of Albuquerque, New Mexico, specimens placed on the substrate surface change wave speed. The altered propagation delay tells much about the mass of the specimen.

To make a measurement, a thin film is placed on the surface and exposed to nitrogen gas. The film absorbs gas and increases in mass thus slowing waves travelling along the substrate. The Sandia SAW transducer forms part of an oscillator circuit. The soaking up of gas molecules causes a decrease in frequency from which the mass change may be calculated. The actual area of the film, pores and all, may be determined by calculation from the mass change and the known surface area of a nitrogen molecule.

The SAW sensor can measure mass changes as small as 20 picogrammes. The previous method used in measuring surface area of porous materials could only detect changes of about 1 microgramme. this accurate.

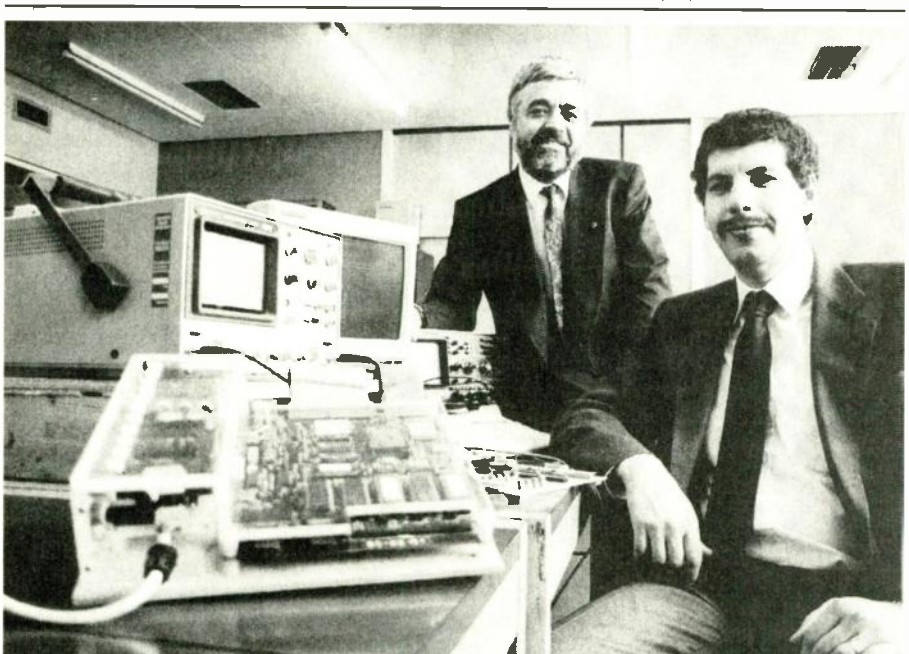
Satellites show Japanese carmakers the way

By 1993 every new Japanese car will have a navigation system, according to Rockwell Communications, developers of a low-cost satellite based system. Rockwell's Ray Mathis says Mazda is already building cars with a GPS system on-board and will start selling them later this year.

Global positioning by satellite (GPS) uses a ring of spacecraft put into orbit by the US government to help its military find its way around. There are two levels of signal. One, encrypted, allows positions to be calculated to within five metres, and a second signal, open for use by anyone, which is accurate to within 50m.

Rockwell has started selling a decoding module for the 50m signal for between $300 and $500, depending on order volumes. The NavCore V module has five channels of decoding DSP — five satellites are used to find the position — to reduce the time taken to get a fix compared with competing, two-channel systems. Calculation time is reduced because the module has to spend less time checking signals and tracking new satellite signals.

The module needs at least three channels to fix a 2-D position, one for each of three satellites, and four channels for a 3-D fix. The fifth channel is used to keep track of the "next" satellite coming up over the horizon. ■



Sponsored engineering: Intel has donated £15,000 worth of microprocessor development equipment to Swansea University's department of electrical and electronic engineering. Intel's academic relations officer Jake Nelson (left) with Swansea's Dr Salah Khanniche.

Photorefractive effect found in polymer

Researchers at IBM have discovered a polymer that exhibits the photorefractive (PR) effect, previously only found in a few small expensive crystals. Illumination by light causes electrical charges in the material to move altering the refractive index (RI).

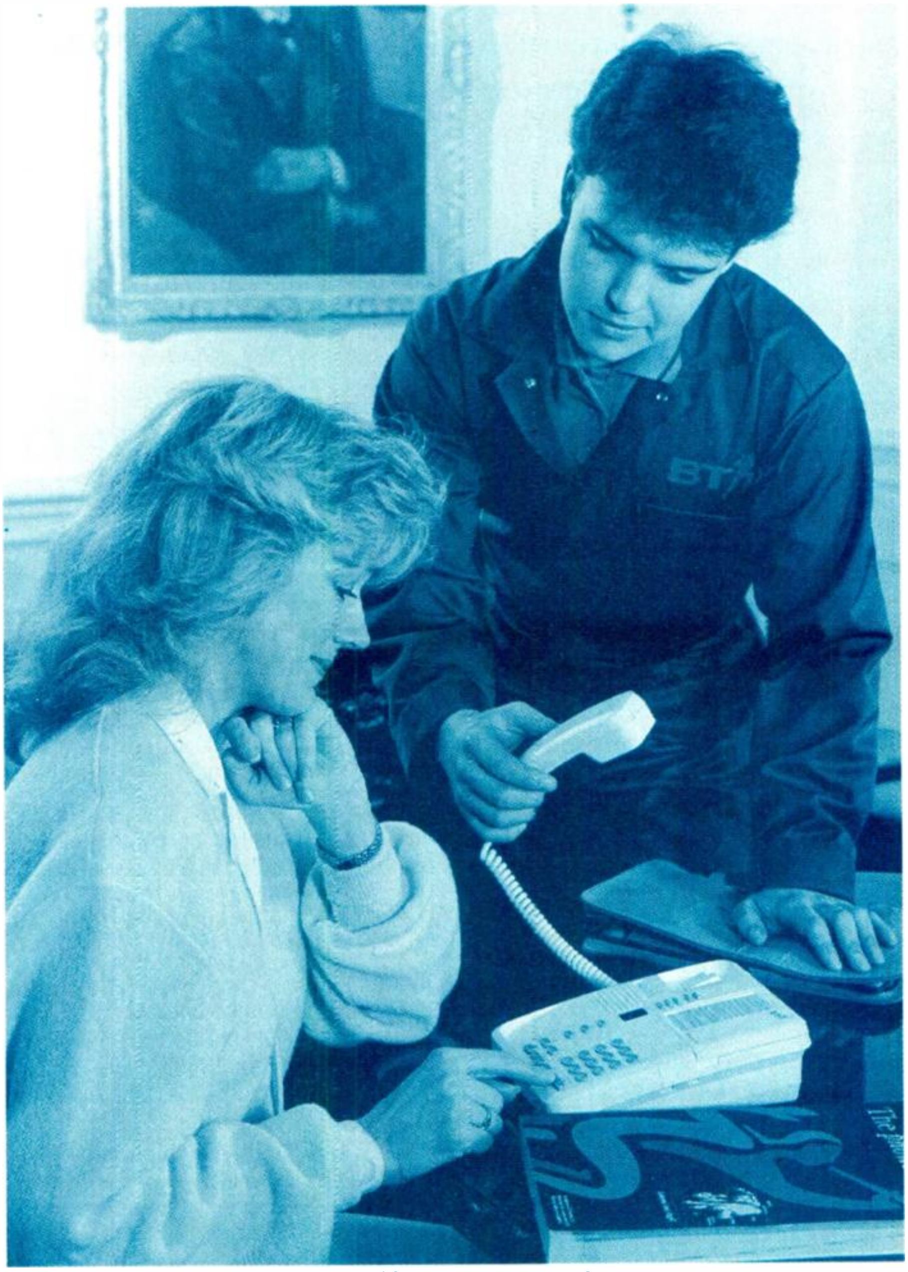
Differences in the RI between water, glass and air can result in rainbows when white light passes through. But when two laser beams cross in a PR material, they create a pattern of electrical charge similar to a hologram. In some cases this can allow the storage of 100 complete holograms each containing 1Mbit of information in a volume 2mm diameter by 1mm thick.

The effect was discovered 25 years ago but because it only worked in certain crystals applications have been limited to laboratory demonstrations such as recording simple holograms or making optical filters.

But the new polymer is made of an epoxy formulation called NNDN-NAN and an organic photoconductor material called DEH used in copiers and laser printers as the charge transport agent.

IBM believes it could lead to applications such as an instant camera that produces holograms or goggles that automatically diffuse intense light to protect their wearers from being blinded

Why is there such a gulf between the people-friendly, high-tech image BT is spending so much time (and a great deal of money) cultivating, and the sad reality of the inaccessability of some of its computer-access services? Maybe if BT's managers had to use their own services the situation would improve



BT muddle points to communications crisis

British Telecom has hit yet more problems with its jinxed Phone Base service. In theory PB lets small-business users directly access BT's directory enquiry database in Sheffield using a PC and modem, at lower cost than the 43.5p which BT has started charging for directory enquiry speech calls.

"In the light of customer feedback we have made a number of key improvements" says BT after trials with 1600 firms using Phone Base on over 2000 terminals. "Overall we've made it far more user-friendly". But many would-be users will still find using Phone Base impossible or expensive and more trouble than it is worth.

Although PB works well when presented as a working system, getting it working is a job for experts. The root cause of the problem is BT's insistence on using the antiquated V23 75/1200 baud viewdata standard previously used for Prestel.

When BT launched the trial version of Phone Base last year, criticism of the V23 decision was countered by Andy Green, general manager network services, and Michael Bett, BT's Vice Chairman and Managing Director, with vague talk of modifying the system later to work with the 1200/1200 and 2400/2400 data speeds used by BT's own Telecom Gold electronic mail service. Now Phone Base has been "upgraded" and was officially launched ahead of directory enquiry charging. But PB still only works at V23 speeds. Most important, modifications made by BT have switched off many of the trialists.

The first version of Phone Base required a dumb terminal of DEC VT-100 standard, with commands entered by "accept" rather than IBM-PC "enter" key. The Phone Base Help Line could not reliably advise callers on how to get the keyboard of a PC to emulate the "accept" command. And without an accept command, Phone Base would not work.

Soon after the trial launch BT was forced to suspend Phone Base for three weeks. One user who had successfully connected with the system had also found a way of getting the home address of subscribers with ex-directory telephone numbers. Far from showing gratitude to the trialist, BT admitted that it had already identified the security loophole and had been working on a solution "for some time".

DIALLING UP DISASTER

Bitish Telecom's viewdata system, Prestel, was conceived in the late seventies as a domestic service. Through the early eighties it failed miserably — the first mass market telecommunications idea to do so. Some business applications continue to survive.

Since the mid eighties British Telecom has offered an electronic mail service, Telecom Gold, which lets subscribers use personal computers and modems to connect with a host computer and leave messages for other subscribers. A system of passwords ensures that only the intended recipients get the messages.

Gold works well — once subscribers have learned to cope with its special requirements. For example many users had to learn by time-consuming trial and error that messages prepared in a word processor are best converted into plain ascii text before transmission to the host computer. Otherwise the control codes used by the word processor will throw the Telecom Gold system into confusion and produce crazy effects on the user's screen. Using Gold is expensive because subscribers must pay for telephone time as well as for time connected to the computer and text transmitted.

BT missed out badly on the trend by newspapers and magazines to take articles by phone line from roving reporters with portable PCs. Mercury offered a gateway from its Mercury 7500 electronic mail system into the electronic publishing systems used by virtually all national and international papers. BT did nothing similar with Gold. The result is an almost complete standardisation by the newspaper industry on Link 7500.

British Telecom has also tried making its Yellow Pages database available on line to anyone with a PC and modem. BT first launched EYP in January 1987. It was a test service covering London, Reading, Guildford and Watford. The system was based on viewdata software which uses 24 line pages. Anyone attempting to print out the results of the EYP search onto paper got a string of blank or only partly used sheets.

BT's £0.5 million campaign of full page newspaper advertisements, posters and radio commercials for EYP attracted nearly 40 000 potential users, which was around 25% of the estimated number of computer owners in the catchment area. But after a year BT admitted that there was a hard core of only 2000 regulars left. The others had given up. BT then paid market researchers to phone the drop-outs. The researchers themselves admitted that they heard again and again how users found the system incomprehensible, unfriendly and unusable.

A new, improved version of EYP was launched last year. The new service is cheaper to use, because it uses one national dial-up number which is charged at local call rate from anywhere in the UK.

But the search procedures are still unfriendly, muddled and time consuming.

When incorrect entries are made the system dumbly throws up the same questions over and over again. The short viewdata screen format wastes telephone time. Unless you are looking for non-local services it will usually be far quicker to let your fingers do the walking.

As with EYP, the idea behind Phone Base is sound. Anyone with a PC and modem can directly access the Directory Enquiry database. But again BT has based the system on viewdata software. When launching Phone Base, the BT managers responsible for it admitted they had not tried using EYP. It is thus hardly surprising that Phone Base is limping clumsily into service.

Security was tightened and Mike Bett promised that BT's research department would modify Phone Base "to enable a PC user to access it from their existing equipment with the minimum of fuss".

Faulty user guide

This has now been done. New Phone Base will work with a PC. But only if the user can cope with the V23 connection requirements and knows to ignore completely incorrect information in the new User Guide which BT mailed to over 2000 would-be users ahead of the official service launch at the end of February!

BT neglected to check the system against the User Guide and its help line has been deluged with calls from trialists who found they could no longer connect.

According to the CCITT V23 standard, the user's computer must transmit data at the painfully slow rate of 75 baud, while receiving it at 1200 baud. Modern modems designed for BT's own Telecom Gold electronic mail service transmit and receive 1200, or 2400, bits of information per second. These modems may not be able to cope with 75/1200. Communication software often has no provision for 75/1200 working.

Trialists with "intelligent" modems, which automatically adjust to any line speed, have been able to connect with Phone Base by setting their software to 1200/1200 and relying on the modem to cope with a mixed line speed. But they may also need to dial the number by keying in the raw Hayes-compatible command (ATDT or ATDP, followed by the telephone number) rather than relying on the software to dial the number.

Despite BT's promises, the "upgraded" system still works only at 75/1200. To make matters worse the vital data and parity settings have been changed and wrongly stated in the user guide.

The original version of PB worked with seven data bits and even parity. The new user guide gives seven data bits and even parity as the setting for the new version. In fact the new version of Phone Base will only work with 8 bits and no parity. As a result previous users have suddenly found it impossible to connect with Phone Base. After wasting time and money on failed calls they phone the help line and are told to ignore the new instructions.

In a desperate attempt to make Phone Base usable, BT commissioned the development of user communications software which short-circuits the confusion over vital settings. In theory at least, anyone with a modem which will cope with the odd 75/1200 speed requirement will be able to use Phone Base without understanding much about computers. Two weeks after the service launch, BT still did not have a final version of the friendly software, called Baseline, to give to Phone Base users.

BT has however been sending out beta test versions of Baseline. Well into March, two weeks after BT discovered the errors in Phone Base, Baseline still contained the same errors. The software was pre-set to the wrong parity setting (seven bits, even parity instead of eight bits, no parity) and the Baseline User Guide perpetuates the mistake by giving seven bits, even parity as the "recommended" setting. With these pre-set and recommended settings Baseline cannot be used.

Those who buy all the necessary hardware, negotiate the settings hurdles and are prepared to fire up their system every time they want to search for a telephone number must pay BT a peak rate of 13p a minute for the telephone call needed to connect with the directory enquiry database. 75 baud transmission is so treacly that you are unlikely to find a number for less than 26p.

Golden disk

The system is infuriatingly unhelpful. A simple name and address search can keep generating the same, meaningless error message: "B050: at least one word must be full or a partial word of at least length 4". Even quitting the system involves an illogical command. Instead of keying the customary "escape", users must key "Delete" and then "E" for exit.

The alternative to Phone Base is BT's Phone Disc CD rom. This works well but is far too expensive for small businesses. In addition to the cost of installing CD rom hardware, subscribers must pay BT over £2000 a year for a supply of updated discs - even though it now costs less than £1 to press a CD.

BT claims that the high cost of Phone Disc pays for the security which it has had to build in to guard against reverse searching and trawling, eg to get an address and name from a telephone number or collate lists of telephone numbers for a whole village or city street.

The root cause of BT's problem is that its managers do not appear to have tried using the systems which they intend selling to the public. If they did they could not fail to be aware of the practical problems of using them. In mid March, when BT's Director of Information Technology, John O'Sullivan, was asked about the problems with Phone Base, he admitted "I am not personally aware of the points you raise but I am having the matter looked into".

Barry Fox

This A320 is not climbing, it is flying level. The indicated airspeed is only just over 100kt as it tests its "alpha protection" system which prevents the pilot from allowing the aircraft to enter a stall.

The safety of such systems were subsequently questioned at two crash enquiries.

FLY-BY-WIRE: THE VERDICT

Two aircrashes cast doubts over digitally signalled control systems. In an update to an article which appeared in* EW + WW *in June 1990 David Learmount looks beyond the press speculation to find the true picture.

Is the air transport industry's first pure fly-by-wire (digitally signalled) system responsible for the more than 100 deaths caused in two separate aeroplane crashes?. The industry believes not.

But in the long wait for the official crash reports, press speculation fanning public concern created a nightmare for Airbus Industrie who saw two of its A320 aircraft crash in the first two years of operational life, casting doubts over the A320s control system.

Part of the nightmare was the eerie similarity between both accidents: one aircraft flew into the ground with 130 passengers on board during a low fly-past at an airshow, the other hit the ground on final approach to an airport – both in perfect weather.

Airbus had complete faith in its aeroplane and managed to convince the airlines, its customers. But airlines considering buying the A320 could not afford to ignore the public uncertainty about this new-world electronic wonder-machine which kept killing people.

Press speculation

Part of the problem was that the international press was enjoying being fed, by the French pilots who survived flying the first A320 into the ground at Mulhouse/Habsheim airfield in June 1988, with stories of electronic failure and industry cover-ups.

At the same time one of the French aircrew unions backed the pilots in their aim to blame the accident primarily on a digital engine-control system which failed to deliver power when demanded.

But did it fail, and what happened at Bangalore, India in February 1990 where, on the face of it, the final killer was identical.

Both aircraft got into a situation which all pilots are taught – from day one of their basic training – to avoid at all costs: they let their aircraft get "low and slow", running out of speed near the ground.

When the pilots demanded power to recover, it came too late to save the aircraft.

The question is did they demand power too late, or was there control delay between power selection (pushing the "throttles" forward) and power delivery?

At Bangalore the pilots did not survive to present their view.

The French pilots did not seriously attempt to blame the flying controls at Habsheim, focusing rather on the digital engine controls, the Fadecs (full authority digital engine control).

If you provide a pilot with a stall-prevention system, does that cause him subliminally to think that he is safe whatever he does or fails to do?

All jet airliners built nowadays, including current versions of older, mechanically-controlled aircraft like the Boeing 737, 747, 757 and 767, and the McDonnell Douglas MD-80 and MD-11 (and the rest), have Fadec managed engines even though they are not full fly-by-wire aircraft. So if Fadec is a killer, it is a danger in all modern airliners, not just the A320.

The "low and slow" factor was fundamental to both accidents, so is there something about the A320's cockpit and controls which makes the situation more likely to develop than in traditional aeroplanes?

The Fadec question comes second in order of chronological and logical priorities, because it would not have arisen unless the aircraft had, in both cases, been dangerously low and slow.

Pilot error?

The Habsheim captain, Capt Michel Asseline, was particularly well experienced; he was Air France's chief A320 training pilot. But the report reveals, from the time he reported to Air France's operations office that day, that he was exceptionally lax in almost all his preparations. Yet this non-standard flight, according to his personal plans, had a higher level of risk in it than a normal airline journey and therefore required *more* planning, not less.

Such behaviour would not go unnoticed. Apart from having a cockpit voice recorder (CVR) on board, the brand-new aeroplane was fitted with the very latest-technology digital flight data recorder (DFDR), recording 30 channels of aircraft flight and systems performance data. All records could be printed out after the accident, making the event the most precisely analysed crash in the history of flight.

On the day of the Mulhouse/Habsheim air show, the aircraft was chartered by the Mulhouse flying club to do two short round-trips out of nearby Basle/Mulhouse airport for people who wanted to fly in the new wonder-airliner. An A320 could not fly out of the tiny Habsheim airfield, but it was to take part in the air show there by doing a fly-past.

All the instruments on the A320's flight deck are supplied from digital sources except for a small group of old fashioned mechanical flight instruments which are the ultimate standby.

But on its first fly-past the A320 hit 80ft-high trees at the far side of the tiny airfield, having flown across the airfield at 32ft with throttles closed and speed reducing to stalling speed.

Everyone on board survived the impact but three people died in the fire caused by a smashed fuel tank.

Air France rules say that, for a fly-past, pilots may not go lower than 100ft above ground level, and then only above runways on which they could land. The overflown Habsheim runway was an 800m grass strip. Airliners are accustomed to hard runways of 2000-3000m and so the implication is that Air France rules would require the pilot to fly higher than 100ft over this kind of strip because safe landing was impossible. The intention was to fly slowly over the airfield to demonstrate how the aircraft's electronic control system will not let the aircraft stall. It did not stall, but it did crash.

Yet despite the Air France rules and the fact that he intended to fly the aircraft to its limits with paying passengers on board, Asseline briefed his co-pilot (the CVR records the briefing during the taxi-out for take-off at Basle) that the fly-past would be conducted at 100ft. Then he actually flew past at 32ft with a voice-warning telling him his height every 10ft of his descent below 100ft, let alone the visual presentations of his cockpit instruments.

Cockpit record

Basle is less than five minutes flying time away from Habsheim, which has no navigational aids or radar and it has to be found visually. The crew have never seen Habsheim before but believe they have sighted it just 1min 35s before the accident. They do not confirm the sighting until 40s after that, by which time they are descending, throttle closed, through 450ft height above ground level (AGL), with no briefed line (direction) to fly across the airfield.

Asseline calls for the undercarriage and flaps to go down - landing configuration even though he does not intend to land - and chooses to fly along the line of spectators he sees, but does not tell his co-pilot (his evidence at inquest).

The ground is coming up fast, so he levels out at 30ft (his throttles still closed). His speed starts dropping off fast. Suddenly his co-pilot warns him of electricity pylons towering ahead: "Yeah, yeah, don't worry . . ." says Asseline. He hadn't seen them, but then notices how close the looming trees are and immediately selects full power from idle.

At that moment the A320 is at 110 knots - almost stalling speed. There is no speed energy left to pull up and sail over the trees and there is five seconds to go until impact with the branches. He pulls the control level back onto its stops. A normal aeroplane would have stalled at this point but the A320 won't let itself stall – it delivers maximum nose-up available without losing lift and flies, under perfect control, straight at the trees. The engines are winding up painfully slowly, the way big-fan jet engines always do from idle. They are close to full power when they start ingesting leaves and branches, which choke them into silence.

The Inquiry ventures that Asseline saw Habsheim late and was completely unprepared for the airfield's smallness: that he was across the airfield in seconds instead of the minute or more he would have expected with a normal airport's diameter.

Asseline says there was a delay of more than a second between his pushing the throttles forward and the engines beginning to wind up.

The DFDR, which records throttle lever position and engine response, records normal engine performance, and amateur soundtracked video recordings of the event tally perfectly with the DFDR's record. Investigations following Asseline's allegations of tampering with the DFDR have failed to substantiate his claims, though normal French legal investigations continue (following the technical investigation).

All jet engines wind up slowly from idle and all pilots know that; instructor-rated Asseline would have failed any colleague who allowed engines to be at idle with the aircraft low and slow. Normal wind-up time for these CFM56 engines would be about 8s; Asseline had 5s to go to the trees when he selected power, and 50ft to climb.

Air-India

At Bangalore the pilot in the captain's seat, Capt Fernandez, was on his final check-ride before being confirmed as a captain on the A320. He and check-pilot Capt Gopujkar were flying a normal schedule into Bangalore on a beautiful Indian early spring day.

They, like the Habsheim pilots, were navigating visually and flying manually, though they had left the engines under automatic control. The control mode they had selected, coupled with the reference altitude they had programmed into the flight management system for a "go-around" in case anything went wrong, were non-standard for the phase of flight.

The result was that, in the last stage of the approach to Bangalore's runway, this aircraft, too, had its throttles at idle. The tragedy is that the crew did not notice until the aircraft was well below the glideslope and, again, very slow. When they noticed, the aircraft was only a little more than 100ft above the ground and descending very fast.

Seeing the impending disaster Fernandez pulled the control stick right back, trusting to the stall protection system (known as alpha-protection) to keep the slow aircraft flying. He did not even advance the throttles, trusting also to a system which, above 100ft, provides automatic full throttle as well as stall control when the stick is pulled fully back and speed is just above the stall (alpha-floor protection). Full throttle came in, but with a delay of 3s while the speed dropped to the edge of the stall – one of the triggers for alpha-floor. If he had positively selected full throttle simultaneously with pulling the stick back the aircraft might have climbed away safely because there would have been three more seconds for the engines to wind up. As it was the aircraft hit the ground just as it was getting control of its descent and ran into a large earthen bank. If it had not been for the collision with the bank the accident would have been simply a very uncomfortably heavy landing short of the runway. But the impact with the mound caused the aircraft to break up and burn.

Crew perceptions

The Bangalore report does not lay any blame on the Fadec, the aircraft or its systems, though it suggests a modification to remove the option of selecting, near the ground, the descent control mode which the Bangalore pilots had selected, which had allowed them descent with throttles closed. With the modification incorporated the pilots would still be able, as in any aeroplane, to close throttles manually on the approach if they wanted to, but if the aircraft was below a certain safety height they would not close automatically, however steep a descent the pilots demanded.

A common factor in both accidents was how the crews seemed totally relaxed until the last seconds, by which time recovery was impossible even with the A320's safety systems. They seemed horrifyingly unaware of their low airspeed in both cases, and speed is fundamental to flight.

> ***Airliners and their systems are becoming so reliable now that more than 75% of the time it is pilot error which causes serious accidents. It is now the pilots, not so much the machines, that the air transport is working on.***

The questions being asked are about pilot psychology. If you provide a pilot with a stall-prevention system, does that cause him subliminally to think that he is safe whatever he does or fails to do?

It is true that if the aircraft has plenty of height then the aircraft is safe however slowly you try to fly. In the A320 you could close the throttles and watch the speed fall off until it reaches stalling speed. At that point it does not matter if you pull the stick back, the aeroplane's flight management system lets the nose drop so that the aircraft glides down, maintaining its minimum flying speed by using up its height. In fact by pulling the stick back onto its stops you get alpha-floor (full power as well), so the aircraft climbs away at full power having lost minimum height.

When you are flying the last 100ft (height above ground) of the approach, with undercarriage and flaps down to land, alpha protection is still there but alpha-floor has been eliminated. The reason is simple: when settling the aircraft onto the runway to land you are literally stalling it onto the ground, and if the automatic full throttle was there you would find full power coming on at every touchdown. So the only way the stall protection system can work near the ground is to let descent continue so that minimum flying speed is maintained.

In a normal aircraft if the pilot pulled the nose up at this point the rate of descent would actually increase because the angle between the approaching airflow and the wing attitude (the angle is known as alpha) becomes inefficient and upsets the lift producing airflow. Below stalling speed an aircraft loses lift, descends even faster, and loses control.

Perhaps an A320 pilot, with his false sense of security, can forget that the aircraft's digital systems still need him for landing – that he remains more important ultimately than the microchips.

Only recently have the world's airlines and aviation authorities begun to take really seriously the matter of pilot psychology and his interface with the cockpit. Not just because of the A320 accidents, but because airliners and their systems are becoming so reliable now that more than 75% of the time it is pilot error which causes serious accidents.

It is now the pilots, not so much the machines, that the air transport industry is working on. ■

WHY FLY BY WIRE?

Fly-by-wire's attractions are many. The installation's light weight means easier maintenance (fewer mechanical moving parts) and it is more naturally compatible with modern avionics, flight management navigation systems. It will deliver more reliably the precision-programmed, four-dimensional (three dimensions plus real time) flight paths which future air traffic control systems demand. Its self monitoring self diagnostic ability far exceeds that of any digital-mechanical system, keeping the pilots better informed, and saving engineer time, cutting costs.

The computers through which pilot instructions are routed can prevent the crew asking more of the aircraft than it is designed to give, preventing high speeds or *g* forces which could break the structure and preventing low speeds which would cause the wings to stall, losing lift.

Design brief: 60W Cuk converter

Cuk power conversion offers the best of all switching power supply worlds. The boost-buck circuitry approaches 90% efficiency, requires few components yet produces minimal amounts of radio frequency interference. Terrence Finnegan sets out a practical design example.

This 60W Cuk converter produces a variable output voltage and can supply increasing levels of current as the output voltage is reduced. It was designed to provide the primary power source in a programmable system power supply, delivering a specific output power over the full voltage range, in contrast to usual supplies which produce full power only at full-scale voltage.

It acts as a pre-regulator which maintains a fixed voltage across the subsequent series regulator stage in the intended application. This produces a regulated power supply with much higher overall efficiency than is usual in a standard series regulator.

The output power is held constant at 60W over the full output voltage range. **Figure 1** defines the voltage-current relationship. **Figure 2** shows the basic Cuk converter topology (*see article in EW+WW January 1991 p69 for more detail*). The relationships between the input and output voltages and currents are given by:

$V_o/V_i = D/(1\text{-}D)$ and $I_o/I_i = (1\text{-}D)/D$

where $D=T_{on}/T_s$ and the subscripts i and o denote input and output.

The converter output voltage is controlled by turning on the power mosfet switch for a fixed duration and varying the off-time between pulses. This varies the value of D while keeping T_{on} constant. Converter operation is synchronised to the system clock frequency of 12MHz.

The fixed T_{on} interval is derived from the clock after dividing by 32, setting T_{on} at 32/12=2.67µs. The variable T_{off} interval is derived from a variable counter system, as described later.

The converter output voltage needs to vary from 60V down to 5V, as defined in Fig.1, and the supply voltage V_i was set at 85V nominal. With this input voltage, D will not exceed 0.5, even with low mains input. The reason for this is considered later.

It is also necessary to calculate the peak and the RMS currents in the switch and the diode, so that the power losses in each can be estimated. Peak and RMS currents are calculated from:

$I_s(\text{peak}) = (I_i+I_o)$;
$I_d(\text{peak}) = (I_i+I_o)$;
$I_s(\text{rms}) = (I_i+I_o)\sqrt{D}$; and
$I_d(\text{rms}) = (I_i+I_o)\sqrt{1\text{-}D}$.

To help determine the values for the capacitors and the inductance of the coupled choke, we will also need the switching frequency F_s, calculated from:

$F_s=1/T_s=D/T_{on}=12D/32\text{MHz}$.

To avoid the clutter of too many calculations, the table below summarises things appropriately for output voltages of 60V, 12V and the 5V minimum voltage. The losses given were deduced from measurements made on an operating unit.

The selection of component values for the capacitors and the coupled inductance is based on steady-state and dynamic response. To obtain a well-behaved frequency response, the original four-pole dynamics of Fig. 2 must be represented by two sets of complex poles, at least a decade apart in frequency.

$$\frac{2F_s \cdot I_o}{V_o} \times \frac{L_1 \cdot L_2}{L_1 + L_2} > 1$$

which reduces to

$$\frac{F_s \cdot L \cdot I_o}{V_o} > 1 \text{ when } L_1 = L_2$$

Fig.1. Actual output voltage-current relationship of Cuk converter.

Input corner frequency $F_{p1} = \dfrac{1-D}{2\pi\sqrt{L_1C_1}}$

Output corner frequency $F_{p2} = \dfrac{1}{2\pi\sqrt{L_2C_2}}$

Complex zero $F_z = \dfrac{\sqrt{1-D}}{2\pi\sqrt{L_1C_1}}$

Fig.2. Basic Cuk converter in which the output voltage is controlled by the power mosfet switch and varying off-ime between pulses.

CUK CONVERTER: EXPERIMENTAL RESULTS

Nominal input voltage	85V	85V	85V
Output voltage	60V	12V	5V
Output current	1A	5A	5A
Efficiency	92.3%	83.7%	84.9%
Losses	5.0W	11.7W	10.7W
Input current	0.76A	0.84A	0.83A
D	0.414	0.124	0.056
1-*D*	0.568	0.876	0.944
I_s or I_d(peak)	1.76A	5.84A	5.83A
I_s(RMS)	1.13A	2.06A	1.39A
I_d(RMS)	1.33A	5.43A	5.65A
T_{on}	2.67µs	2.67µs	2.67µs
T_s	6.45µs	21.50µs	47.70µs
F_s	155kHz	46.5kHz	21kHz

ESSENTIALS OF CUK CONVERTERS

Some 13 years ago, Dr S Cuk (pronounced Chook) was granted a patent by the US Patent Office for his design of a power converter topology that combined the advantages of other known structures without any of the disadvantages in the minimum number of components.

Until then, most switching converter topologies were conceived more or less at random, in fact often by accident. The Cuk converter was the exception, comprising a combination of boost and buck converters. Its benefits included increased efficiency, low input and output current ripple, minimal RFI, and small size and weight.

These properties closely approach those of an adjustable ratio DC-to-DC transformer. The DC voltage transformation ratio M is equal to $D/(1-D)$ where D is the duty ratio (fractional on-time) of the transistor switch and $(1-D)$ is the complementary duty ratio (fractional off-time).

For a DC input voltage V_i, the output voltage is $V_o=MV_i$. The converter thus has a step-down ratio for $D<0.5$ and a step-up ratio for $D>0.5$.

The input and output currents are non-pulsating, being smoothed by the input and output inductors. These inductors also eliminate current surges in the transistor switch at power on and off, often a difficult problem to solve.

Cuk converters are unique because energy transfers capacitively from the input to the output instead of inductively as in all previous converters. Capacitive energy transfer is more effective on a per unit size or weight basis than inductive energy transfer.

Because the input and output inductor currents are essentially constant, the switching current is confined within the converter in the transistor-coupling capacitor-diode loop. This loop can be made physically small to reduce the radiated RFI from the magnetic field. The voltage and current waveforms are particularly clean with very little ringing or overshoot.

Correct operation depends on the inductor current remaining continuous throughout the cycle (neither inductor current falls to zero), and on the energy storage capacitor being large enough to support the voltages across it throughout the cycle without appreciable droop. Continuous capacitor voltage is the dual of continuous inductor current.

In its basic form the converter has a single, polarity inverted, non-isolated output. But many applications need DC isolation between input and output, and multiple outputs of different voltages and polarities. This can be elegantly achieved by dividing the coupling capacitance into two series capacitances and inserting a coupling transformer between them.

This solution is better than other converter technologies in that there is no direct coupling in the winding and the core material can be ungapped square-loop ferrite. This will give a smaller transformer with lower losses than in the equivalent forward or flyback converter.

Cuk converters are very efficient and values greater than 90% are attainable. This can be directly attributed to the lower copper losses when compared to standard buck or boost converters and the improved operating duty ratio of the Cuk converter.

In 1983 an analysis of the structure showed that the AC current ripple in the input and output circuits could be reduced to zero if the magnetic parameters were correctly chosen. Key factors in achieving zero ripple are the relationships of the voltage across the coupled inductors and the choice of leakage inductance associated with the windings.

For a more detailed explanation of the Cuk converter, see *EW+WW*, January 1991, p68 to p72.

quency, plus a complex zero. Under this separation condition, they can be analytically described as:

Ideally, the lowest converter switching frequency should be a decade higher than the highest pole to avoid interaction. However, if this ideal is applied at the lowest switching frequency of 21kHz, which occurs when V_o=5V, then the values for L and C will be larger than necessary, since a 5V output will only be needed in unusual circumstances.

A more practical approach is to use the lowest switching frequency of 46.5kHz which occurs when the output is 12V and set the input and output corner frequencies F_{p1} and F_{p2} at 4.7kHz and 470Hz, respectively. Under this condition, the switching frequency will still be five times the highest pole, even when the output reduces to 5V, which should be satisfactory.

The energy transfer capacitor C_1 has to handle a pulsating current of 6A peak and must have low equivalent series resistance (ESR). Polypropylene would be a good choice, but these tend to be large and expensive in high values. A 3.3µF 160V polyester capacitor (WIMA MKS4) was eventually used on the basis of size and cost and has operated well with only a small temperature rise.

Ideally a value larger than 3.3µF is needed as there is some drop in the voltage waveform at the lower output voltages. Standard electrolytic capacitors were tried but these overheated: low ESR electrolytic capacitors are not yet available at the required working voltage.

Setting F_{p1} at 4.7kHz and C_1 at 3.3µF gives a required value for L_1 of 294µH. Since L_1 and L_2 are equal, C_2 needs to be 330µF for F_{p2} to be 470Hz. In practice, three 47µF capacitors in parallel were used due to space restriction without ill effect.

For steady-state conditions, L_1 and L_2 must also be large enough to maintain continuous current flow at the minimum value of output current, which will put further constraints on the values of L_1 and L_2. For continuous operation in a coupled inductor Cuk

$$R_{dt} = \frac{4 \cdot L_{1e} \cdot C_{gd} \cdot G_{fs}}{C_{gs}^{2}}$$

which reduces to

F_s

converter:

This suggests that the coupled inductor's inductance should be inversely proportional to I_o. If this can be done (up to some maximum value of L), then the current will always be continuous. This requires either a multiple-gap structure or the use of one of the newer composite core materials whose permeability varies with field strength.

Magnetic design

Previous work has suggested that a 10:1 change in inductance with current is practical using a magnetic structure with two gaps and that a 10:1 change in the value of LI^2 is also practical.

The total DC flux in the coupled inductor core is due to the sum of the primary and secondary currents, so the initial target values for the coupled inductor characteristics are:

Total current	Inductance	LI^2
5.84A	290µH	9.89mJ
0.59A	2.9mH	1.0mJ

The higher current level of 5.84A is the sum of the primary and secondary currents which will flow in the windings at 5A output. The lower current level of 0.59A is derived from the design values for L and LI^2, using the 10:1 relationship. The coupled inductor will therefore have a value of 2.9mH at a total current of 0.59A, which represents an output current of about 0.3A. This then is the minimum load current for continuous operation. The expected inductance-output current characteristics of the coupled inductor will be as shown in **Fig.3**.

The inductor will have closely coupled primary and secondary windings of equal turns, wound onto a bobbin with two pairs of cores, each with a different gap. This essentially makes a pair of parallel inductors: one which operates with high inductance at low current, and the other which operates with low inductance at high current, with both being proportionally effective at intermediate levels.

The Hanna curve for a Neosid 41x44x9 E-core is shown in **Fig.4**. From this, the required energy value of 9.89mJ is slightly too large for this core size to support, indicating that either a larger core or a smaller value of inductance is needed. Reducing the inductance and limiting the value of LI^2 to 7mJ, reduces the inductance at 5.84A to 210μH. The curve shows that a gap of about 2mm is needed and the Al value will be 100nH/turn^2, giving a required value for N of 46 turns.

For the low current condition, L=2.1mH and LI^2=0.7mJ. This gives a gap of 0.1mm and the Al value is 950nH/turn^2, giving a required value for N of 47 turns.

The two extremes of operation are therefore compatible and the basic design is complete, except for the choice of wire size and bobbin design. Unfortunately, a standard

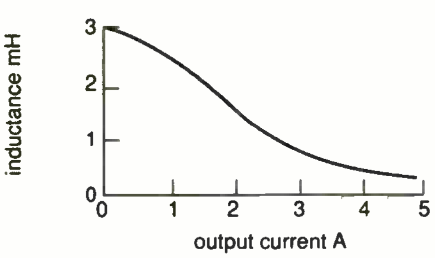


Fig.3. Expected inductance-output current characteristics of the coupled inductor.

bobbin which will take a pair of 41x44x9 E-cores side-by-side is not available, so a suitable bobbin was made from cardboard and coated with shellac varnish. The primary winding will have 46 turns and the secondary winding will have 47 turns, to allow the ripple current in the secondary to be nulled out with the balancing inductor in the primary circuit (as described in *EW+WW*, January 1991, pp69-72). The primary current is 0.84A when the secondary current is 5A maximum, so that the wire diameter cross-section ratio is 2.4:1, for equal current density.

After some trial and error, 0.7mm enamelled wire with double silk covering was used for the primary and three strands of

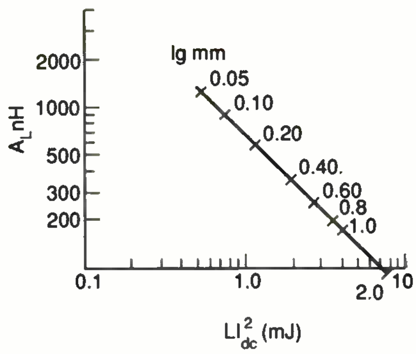


Fig.4. Hanna curve for a Neosid 41x44x9 E-core.

0.7mm enamelled wire used for the secondary to give flexibility. Lengths of 13ft were cut and twisted together into a rope, and 46 turns wound onto the cardboard bobbin. The primary wire was then removed from the bundle and one extra secondary turn added, making 47 turns in total.

The centre legs of two 41x44x9 E cores were ground to form gaps of 0.1 and 2mm. Half of the centre leg was ground by 0.1mm and the remaining half by 2mm. These were then assembled side-by-side into the bobbin opposite a pair of unground cores. Putting the gaps in the centre leg keeps the flux within the bobbin to minimise radiation.

The double-silk covering was used to give added insulation strength between the primary and secondary and to reduce the interwinding capacitance. The primary-secondary insulation is marginal and needs improving for production.

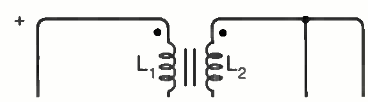
Drive/switch circuits

The power mosfet gate drive waveform must be completely defined to include both power-on and power-off: it is usually at these times that switch-mode converters fail. The circuit in **Fig. 5** gives reliable operation under all conditions and provides overshoot-free voltage and current waveforms throughout the circuit.

IC_1 is a TSC1427 dual driver, operating from the 15V supply, which provides high current 300ns drive pulses corresponding to the start and stop times of the required on-time and off-time intervals. T_1 is a small transformer capacitively coupled to the driver with a centre-tapped secondary winding. The gate capacitance of the power mosfet Q_1 (shown in **Fig. 6**) is charged via D_1, while C_1 is discharged via D_3 and the 7.5V zener D_4 by a pulse of the opposite polarity, thus turning off small-signal mosfet Q_2. The gate capacitance of Q_1 then remains charged during the on-time to about 13V, keeping the device well turned on. This is then discharged by the 300ns off pulse, which charges C_1 via D_2 and turns on Q_2. Q_2 remains on during the variable off-time and clamps Q_1 gate to the emitter, preventing any problems from spurious pulses. The 15R resistor in Q_2 drain circuit allows Q_1 gate to be turned on while Q_2 is being turned off and prevents the short-circuit which would otherwise appear across the transformer secondary. BAV10 is a high current high speed diode.

Gate isolation transformer T_1 is always presented with a balanced waveform, independent of duty ratio. The transformer only has to transmit 300ns pulses and can be made from a very small toroid with few turns. The transformer is trifilar wound with 11 turns on each winding, arranged to fit around the inside circumference. This will reduce the leakage inductance to a minimum. The core used is a 6mm SEI MM 620-T3, which is only 6mm in diameter.

The 33R resistor in series with the gate prevents ringing in the gate and drain circuits. The total resistance in the gate circuit has an optimal value and is chosen as described in IR application note *AN947* by



the expression:

where L_{le} is the leakage inductance in the drain circuit, C_{gd} is the gate-drain capacitance, C_{gs} is the gate-source capacitance, G_{fs} is the transconductance, and R_{dr} is the total resistance in the gate drive circuit.

For the IRF630, C_{gd}=80pF, C_{gs}=650pF, G_{fs}=2.5A/V and L_{le} is estimated at 50nH. Substituting these values into the above expression gives an optimal value of R_{dr} as 95Ω. The total resistance of the gate drive circuit was measured at 60Ω, so an extra 33R was added.

The circuit in Fig.6 shows the power stage, with the RFI filtering omitted. Q_1 gate and drain are protected by appropriate zener devices. An n-channel mosfet was used instead of a possible p-channel device for two reasons. First, n-channel mosfets have superior characteristics. Secondly, the circuit topology shown has no AC voltage on the drain, therefore there is no AC voltage on the associated heatsink, which prevents radiation from this potential source. The diode heatsink was also connected to the common rail, so that any capacitively coupled charge from the cathode is also returned to the input.

Inductance L_3 is made from a few turns on a ferrite rod, chosen experimentally to give zero current ripple in the output inductance

CONVERTER LOSSES

Output voltage	60V	12V	5V
Output current	1A	5A	5A
Mosfet conduction loss	0.6W	2.1W	0.9W
Diode conduction loss	0.6W	3.6W	3.9W
Total switching loss	1.8W	2.3W	2.3W
Inductor loss	1.0W	3.2W	3.2W
Snubber loss	1.0W	0.5W	0.4W
Total losses	5.0W	11.7W	10.7W

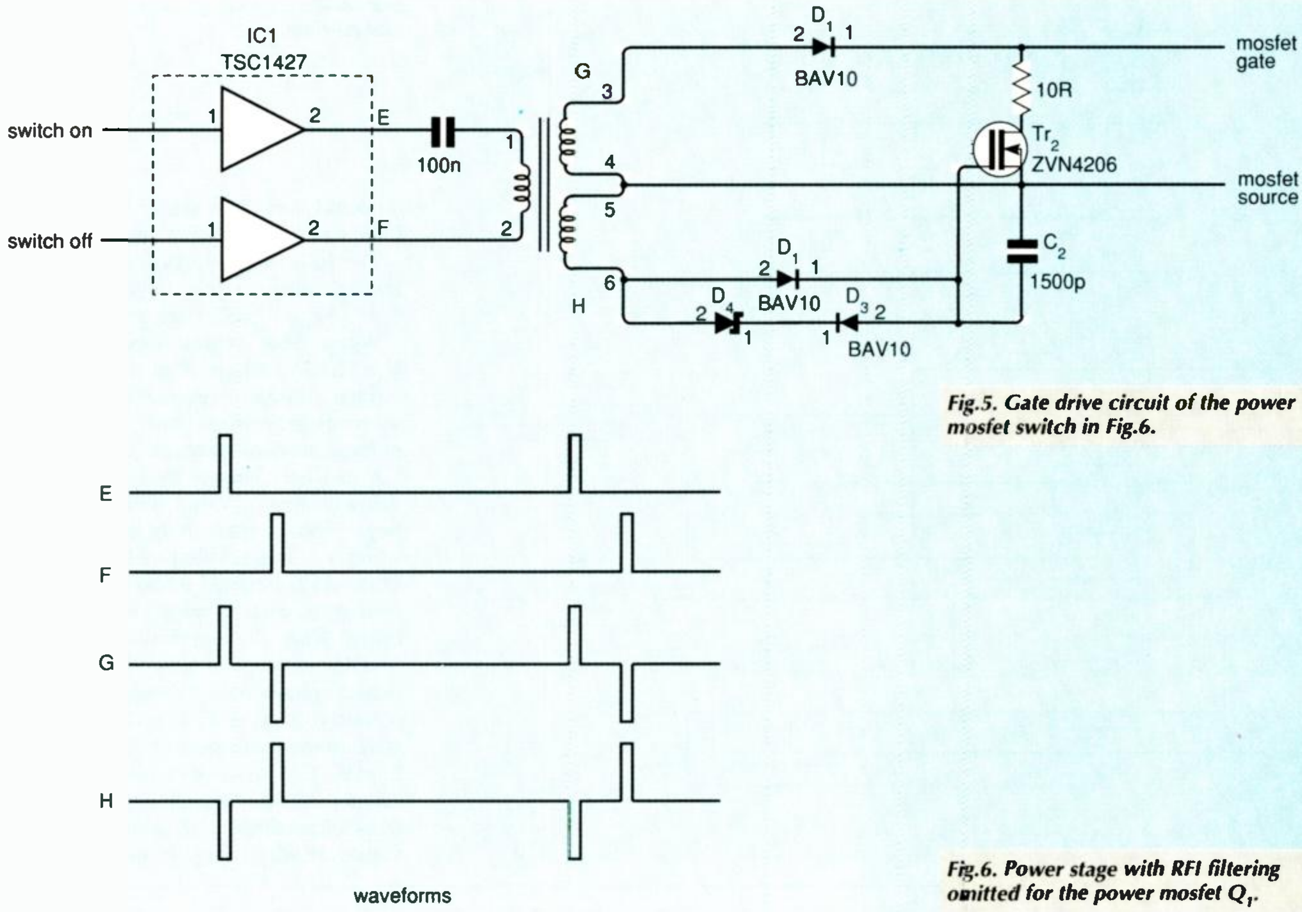
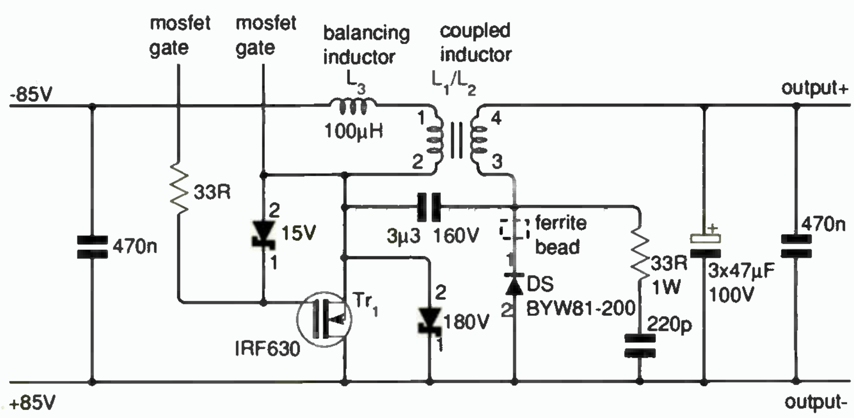


Fig.5. Gate drive circuit of the power mosfet switch in Fig.6.

Fig.6. Power stage with RFI filtering omitted for the power mosfet Q_1.



L_2. Its value was estimated as 10μH.

Switching transients

When the mosfet Q_1 is first turned on, the power diode D_5 will still be conducting and will remain so for the duration of the reverse recovery time. The mosfet therefore turns on into an effective short-circuit - with a very high peak transient current. A fast epitaxial diode is needed with a low t_{rr} to minimise this switching loss. A ferrite bead is also put onto the leg of the diode to reduce the peak current.

The bead type should have inductance and resistance at 50MHz to limit the peak current that initially flows into the diode until it has recovered its reverse characteristics. When the diode itself conducts during the mosfet off-time, the bead inductance should saturate (at least for the higher current levels) so that it does not reduce the efficiency. The bead intrinsic resistance will damp any ringing. A small resistor and capacitor snubbing circuit across the diode can be chosen to minimise the remaining transient. In this case, 33R and 220p proved adequate.

Losses

The power mosfet conduction loss during its on-time can be calculated from the RMS current and $R_{ds(on)}$. For the IRF630, $R_{ds(on)}$ is typically 0.48Ω at a design junction temperature of 100°C and a peak current of 6A.

The diode conduction loss is determined from the forward voltage at the peak forward current and is therefore the highest at the lowest output voltage of 5V, when it is conducting most of the time. The BYW80 has a forward drop of 0.76V at 5.82A at a design junction temperature of 100°C. The diode conduction loss is $P_d=V_fI_d(1-D)$. The table gives the distribution of the major losses.

Control

Control of the on-time and off-time is accomplished by using two down-counters connected into a self-oscillating loop as shown in **Fig.7**. The oscillation is started by applying a short positive pulse to the start terminal. This is refreshed regularly by the software to guarantee oscillation. Both counters are synchronous and operated by the 12MHz system clock.

Down-counter 1 determines the on-time and is set always to 32, giving an on-time of (32/12)μs, or 2.67μs. Down-counter 2 determines the off-time, and is set by the external control software loop via the data input to count between 32 and 1024. The off-time is thus variable between (32/12)μs and (1024/12)μs, that is between 2.67 and 85.3μs, depending on the microprocessor

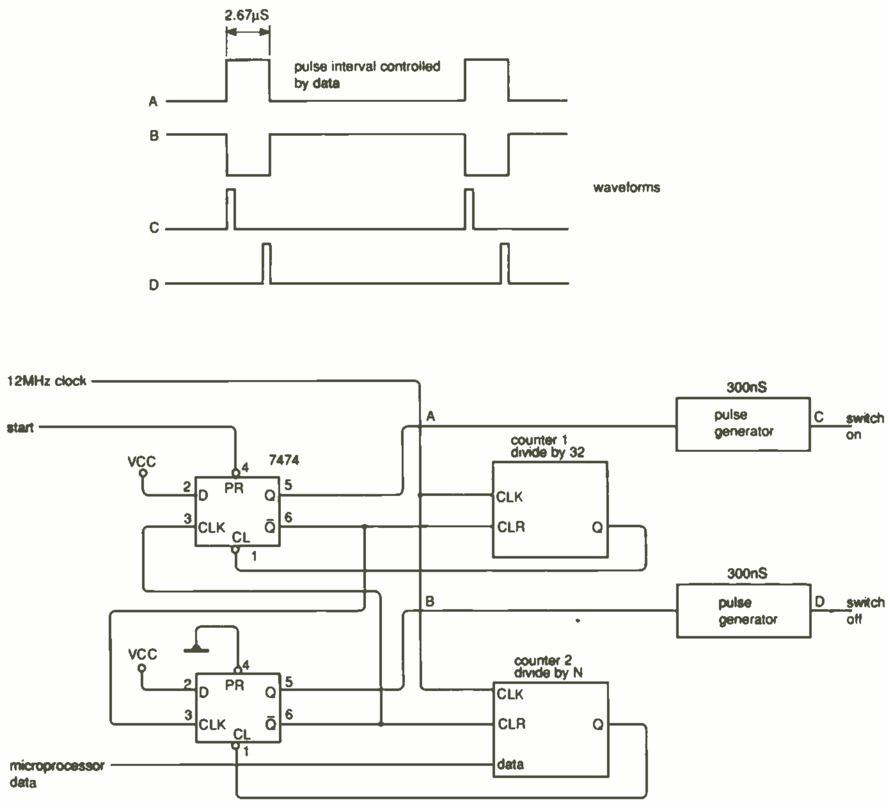


Fig.7. Two down counters connected into a self-oscillating loop for control of the on-time and off-time.

control data. This sets D between 0.5 and 0.03, which brackets the range required.

The following expressions which define the operation: $V_o=V_i.D/(1-D)$; $D=T_{on}/T_s$; $T_s=T_{on}+T_{off}$; $T_{on}=32/12\mu s$; and $T_{off}=N/12\mu s$.

When these expressions are combined, $V_o=32.V_i/N$, where N is the digital value written into down-counter 2. V_o is therefore inversely proportional to N, which has some unfortunate consequences.

N can only change by integer values, so that a change in N of 1 will change V_o by a larger voltage when N is small than it will when N is large. This problem dictated that D should not exceed 0.5 to avoid the excessive voltage steps which would otherwise occur. When the output voltage is 60V and N is 45, a change in N to 46 will change the output voltage by 1.3V. Whereas, when the output voltage is 12V, a change in N of 1 will change the output voltage by only 53mV. The software control loop takes account of this factor by setting a variable threshold control band, whose high and low values are adjusted by the output voltage. ■

Classically relative

Letters in May issue *EW + WW* suggest that several readers are uncertain about what the speed of light is when radiated from a moving source and measured by a moving (or stationary) observer. Einstein's theory of special relativity says that it is the relative speed between the two which is relevant and that the addition of the speed of any type of emission from a source to the speed of the source/observer is given by the equation:

$u = (u' + v)/(1 + vu'/c^2)$

where u is the added speeds, u' the speed of the source emission relative to the source and v the speed of source relative to the observer.

When the source emits light then $u' = c$ and the equation reduces to $u = c$; the speed of light does not depend on the speed of source or observer. The speed of light does however depend on the medium in which it propagates.

If in the equation v and u' are very much smaller than c, then the equation reduces to the classical equation for adding speeds, that is $u = u' + v$.

The Doppler frequency shift for a source moving relative to an observer at an angle ϕ is given by the equation:

$$f = \frac{f'\sqrt{1-\frac{v^2}{c^2}}}{1-\left(\frac{v}{c}\right)\cos\phi}$$

If $\phi = 0°$ the source is moving radially to the observer and the resultant equation is that of the radial Doppler shift which is analogous to the classical Doppler shift. If $\phi = 90°$ then the transverse Doppler shift equation is produced. This has no classical analogue and results from the relative nature of time which is not a classical concept.

Vernon Wynn
Department of Physics
University of Exeter

Lighting the way

I was interested to see John Ferguson's letter (*EW + WW*, March 1991) suggesting an experiment to resolve the speed of light controversy. I have for a long time felt that the Doppler effect might hold the key to the problem and wonder if the following experiment would, in principle at least, be possible.

As is well known, for a Doppler radar the signal received from a target is mixed, in effect, with the transmitted signal, to produce a difference/beat frequency which is a function of the target's radial velocity.

But what produces this change in frequency? Is it due to a change in wave velocity, as John Ecklin assumes in his examples of police radar (*EW + WW*, March and May 1991), or is it due to compression/expansion effects, as in the case of acoustic Doppler, where the wave's velocity remains unchanged, being determined by the nature of the medium? If frequency and wavelength of the transmitted and received signals were measured, then the velocity of the signals could be calculated from $v=wf$.

If the target were a high speed aircraft, I should have thought that the frequencies could be measured with sufficient accuracy. The problem would be measurement to sufficient accuracy of wavelength.

Any suggestions?

B Wallace
Tadworth
Surrey

Mystery signals

I have read the correspondence originating with Mr Pickworth's letter in February issue concerning certain low frequency signals he cannot identify. The frequencies he mentions lie mainly in the range 300 to 3000Hz used for telephone and telegraph line communication.

Since he has two earth rods 35m apart it seems possible that return earth currents to a local telephone (including telex) exchange could develop a detectable PD across these rods depending on the resistivity of the soil.

As well as the normal voice signals, signalling signals are sent from one exchange to another. Several systems are in use but in the present context those using either a single tone or a pair of tones transmitted simultaneously seem relevant.

Frequencies used vary according to system but one method is to select any two of the frequencies 700, 900, 1000, 1300, 1500 and 1700Hz. Each pair of frequencies is used to pass specific information from one exchange to another. The signal timing sequence is 68ms on and 68ms off.

The same principle is adopted with push-button dialling, using the frequencies 697, 770, 852, 941, 1209, 1336, 1477 and 1633Hz and a timing sequence of 40ms on and 20ms off. Here each combination corresponds to a number being dialled.

Other possibilities are tones generated by modems although these would tend to be continuously varying rather than short bursts of tone. Furthermore the telex system relies on a series of carrier tones spread throughout the same passband as the telephone system, and these could be another possible source.

Perhaps Mr Pickworth might like to contact the engineering staff at his local telephone exchange to see if they can help him identify any of his signals. Two useful books on the subject are "Signalling in Telecommunications Networks" by S Nelch and "Telegraphy" by R N Renton.

JJ Gameson
Basingstoke
Hants

The Luxembourg effect

I first became aware of "Cross modulation in the sky" — Anthony Garrett's article in June issue *EW + WW* as a result of going, I think in 1945, to an excellent lecture at the TRE Amateur Radio Society by JA Ratcliffe of theCavendish Laboratory, who was at the Telecommunications Research Establishment at the time.

The lecturer discussed in detail the theoretical hypotheses for explaining what had become known as the Luxembourg Effect. He referred to work on this problem by LGH Huxley, who was also at TRE.

Later these two men published a highly authoritative paper "A survey of Ionospheric Cross-Modulation", Proc. IEE, Vol 96, part III No 43, pp. 433-440 (sept 1949). Fig. 1 in this paper is almost identical to that attriubuted to Anthony Hopwood on your page 510, and their theoretical analysis took into account the effect of the earth's magnetic field and gyroresonance effects. There are 24 references.

Peter J Baxandall
Malvern
Worcestershire

Squiggly rules OK

On the subject of the squiggly resistor symbol, the editor of *Practical Electronics* insists that whether readers like it or not they are getting the rectangular symbol, on the grounds that rectangles are easier to draw - surprising because many drawings are now done by computers. This is the first time I've heard of them complaining about what theyare asked to draw. AI no longer stands for artificial intelligence, but artificial insolence.

I am writing to you to praise you on keeping the squiggly resistor in *EW + WW*. When I read a circuit diagram I want to absorb the greatest amount of information and reach an understanding as quickly as I can. Graphical devices such as shaped logic gates, Schmitt trigger symbols, and of course squigglies, are a tremendous help when finding a way round a new diagram.

In a similar vein there is another point that needs raising and that is the use of plus symbols to mark the cathodes of diodes — only *Practical Electronics* seems to do it now (until of course the computers complain about the work load and they have to leave it off).

I put the plus sign on the cathodes of my diodes because the cathodes of diodes on printed circuit boards are often so identified, and of course a bridge rectifier has a plus sign marking its joined cathode terminals and minus marking its anodes. Why should I devise a new rule when this is so well established?

Anyone using a car battery charger is perfectly happy to have the red wire and crocodile clip marked *plus* and connected to the cathodes of the rectifier inside the charger, and I would not have it any other way. But on items such as a led it is a person of great nerve (such as you or I) who can still mark the cathode with a plus when in more cases than not it is to the plus rail that the anode is to be connected.

Once we have a convention (diode cathodes marked with a plus) I think we should stick to it, but so that I can argue my case more vigorously when the odds are against me I wonder could you or anyone give me some information? Where did the convention first arise? Is it a published standard? If so where? I have consulted many current standards, but in vain; it is a convention I'd like to see continue. Talking of circuit diagrams, they are now few and far between in *EW + WW*. Please give us what we the readers want, not what you think we ought to have.

David M Parkins
Greenbank Electronics
Merseyside

Mr Parkins, along with some other readers, also noted the poor quality of diagrams in our May 1991 issue. This was due to teething problems with our new desk top publishing system. We have taken steps to rectify the situation - Ed.

A perfect note for music lovers

Absolute or perfect pitch (AP) has been referred to twice in the lastfew issues of *EW + WW* and readers may be interested to know a little more about this remarkable phenomenon.

An accuracy of 1% was quoted in May issue (Can you believe your ears? p. 365-366). This is a little misleading as people can have AP and be out on the piano scale by up to a semitone (26Hz at A=440Hz).

The important parameter which categorises AP is consistency of AP judgments of a musical tone which, even though biased away from the tone, is consistent to within 1%.

An AP subject's bias away from the piano scale does vary through the day and fluctuates from day to day. In women these fluctuations appear to be connected to the menstrual cycle. It is uncertain as to what causes the cyclical fluctuations observed in men!

Variations of this type can fluctuate by about 8Hz over an approximately two week period even though consistency of the AP estimates is still 1%.

Stress can also shift the AP bias, and shifts of a semitone have been observed in subjects suffering from stress caused by illness or examinations.

There has yet been no conclusive proof that AP can be acquired after early childhood. This has led to the controversy as to whether AP is learnt or inherited.

I believe that the ability has to be acquired very early in life and may involve an imprinting mechanism.

Vernon Wynn
Department of Physics
University of Exeter

Security scramble

Ever increasing security at international airports gives rise to problems for those of us who regularly travel with electronic equipment. It seems most airline staff regard a signal generator with the greatest suspicion and express a wish to take it to pieces looking for hidden explosives. Security guards have a strong desire to bombard anything in sight with X-rays, neutrons or whatever.

Having had a number of floppy discs corrupted in transit by some unknown force, I have always kept them out of the way of these machines, just in case, after all the contents are usually worth quite a lot and I have yet to hear exactly who would accept financial liability for destruction of a disc.

Looking at the sort of consumer equipment around me, some of which I would like to travel with, I also wonder how resistant to airport security machines is the myriad of microprocessor components inside the average modern handheld VHF radio or video camera.

I am now fed up with the whole situation, to the point of avoiding flying as I resent being treated-like a criminal and having my possessions damaged without recourse. Undoubtedly readers of *EW + WW* will understand what I mean; I doubt people at the airport will do.

Jim Watt
Interactive Systems Ltd
Gibraltar

Aerial assault on quality

I read with interest the recent articles by JL Hood on development of FM circuit design techniques from the 1950s onwards. But it is appropriate to comment on some of the consequences of the BBC's change-over to FM broadcasting which started last year.

Most people listen to radio programmes on portable transistor receivers. They want to do this easily in their own homes.

Prime concern of these listeners is the content of the programme, not the highest possible fidelity or stereo; those who are worried form a minority specialist group.

Will the change-over turn out to be better or worse for the men and women in the street who belong to this silent listening majority?

Ironically at the same time as FM began to develop in this country, AM radio also underwent a quiet revolution — the ferrite rod aerial was born.

Many of the German AM/FM sets imported here before our industry got into production in the mid 1950s had a rotatable ferrite aerial for medium and long wave reception. Some features of the initial UK set makers' FM designs, similar to some in Mr Hood's articles, owed much to those German sets.

A properly designed ferrite rod aerial has a very high Q, allowing a quite deep null be obtained. It also has a signal-to-noise ratio superior to the crude wire aerial typical of that era. It was this introduction that paved the way in the next decade for the success of the transistorradio.

The aerial is the critical component in all reception. No aerial — no reception, bad aerial - bad reception. Although Mr Hood's article was not concerned with this, many of the benefits of modern day circuitry are lost if the receiving aerial is inadequate.

Dependency on the aerial makes it the Achilles heel of FM radio. Unfortunately this modern day Achilles has a weakness in both heels. The whip aerial is mechanically fragile as well as being electromagnetically weak lacking directional discrimination. The directional property of the fixed dipole aerial installation is also its major weakness, as reception is restricted to that of transmitters in the direction that the dipole is aligned.

The ferrite rod aerial is electromagnetically non-directional, it works equally well indoors and outdoors whereas the FM whip aerial needs to be in a benign electromagnetic environment free from the dreaded standing waves found in all our living rooms.

With the ferrite rod aerial, advantage can be taken of its very sharp null to minimise interference thereby optimising reception of weak or distant stations. On the other hand the reception indoors of weak FM stations is compounded by the capture effect, it only takes someone to walk across the room for a favourite programme to be transformed into a hated one and the decibel level to be unfavourably altered thanks to the change induced in the standing wave patterns.

A typical portable set can easily pick up clusters of up to four separate transmissions of each of Radios 2, 3 and 4. Due to multi-path effects it is not always possible indoors to get distortion free reception.

The average listener objects strongly to all that hissing, the cure for which is a strong dose of top-cut bringing the audio passband back to AM standards. A full scale deflection on the signal strength meter is no guarantee of a perfect signal.

People generally are not interested in technicalities and treat a radio merely as something to listen to. How are they to know that in each of those clusters of signals only one signal is going to give optimum reception? It will just confuse them. They will end up with reception inferior to that which they would previously have got on medium and long wave.

But what about the listener who uses FM for its originally intended purpose — high quality interference free reproduction of music?

If he or she wants to take advantage of the plethora of BBC local radio stations then the expensive dipole aerial installation won't pick them up satisfactorily, if at all, as it is unidirectional. The next door neighbour with a low-cost portable can hear more than with anexpensive fixed installation.

Surely the answer here is wired wireless, Rediffusion, relay or whatever you prefer to call it.

Certainly one advantage of FM reception is that it is interference free; however on balance the severe disadvantages I have described seem to outweigh this advantage.

What we need is an innovation comparable to the ferrite rod aerial for FM. Would some knowledgeable reader like to tell us what the prospects are?

JJ Gameson
Basingstoke
Hants

20-bit audio D-to-A converter

At full-scale output, the Burr-Brown PCM63 20-bit D-to-A converter exhibits a -96dB THD, by virtue of its dual D-to-A per channel arrangement. It also possesses a 116dB s:n output (A weighted) and a settling time for a 2mA step of 200ns. Main applications envisaged are low-distortion frequency synthesis and professional digital audio.

The block diagram shows the layout of the system, which abandons any suggestion of noise shaping or high-frequency oversampling as used in bitstream or 1-bit D-to-As, which suffer from reduced s:n performance and need care in the design of succeeding circuits to avoid problems with intermodulation and channel separation.

In the PCM63, two D-to-A converters combine to produce an extremely linear output, particularly at around zero. They use a common voltage reference and R-2R ladder and, by interleaving the bits of each converter and by laser trimming ladder resistors, matching is highly accurate. Using the two converters ensures the absence of glitches or

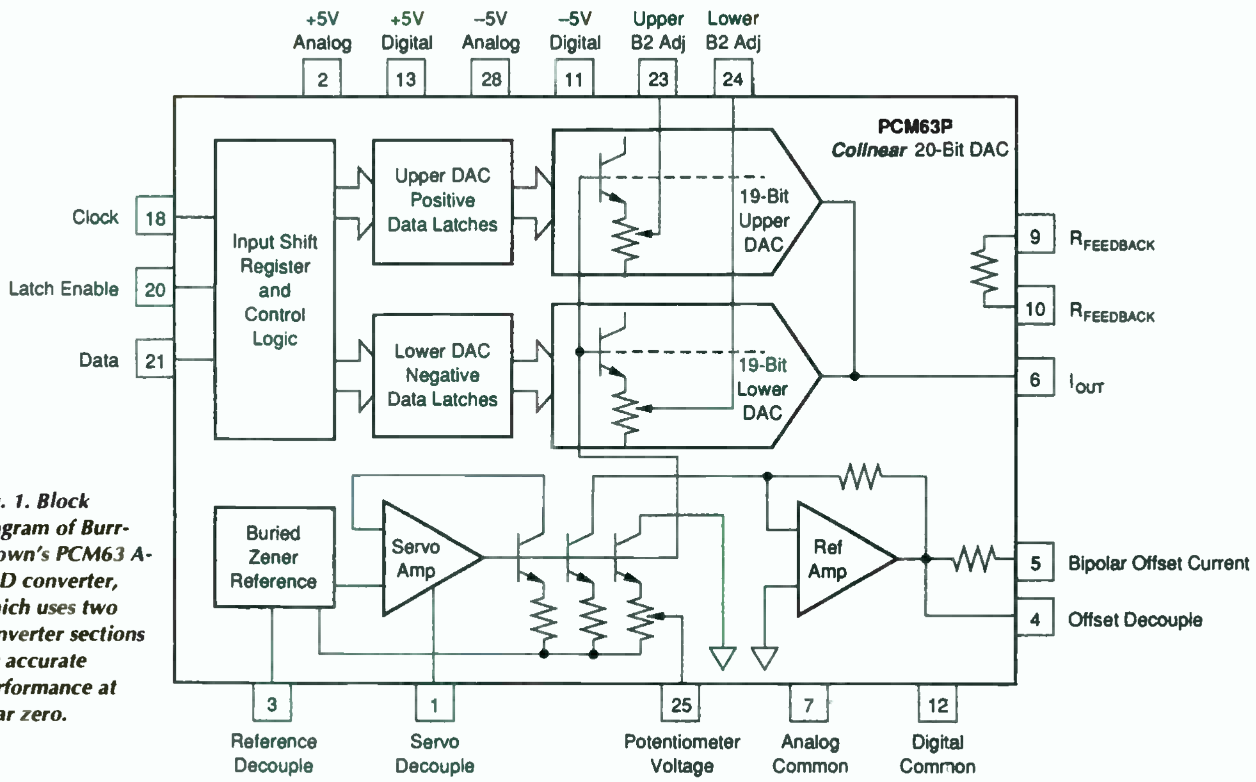


Fig. 1. Block diagram of Burr-Brown's PCM63 A-to-D converter, which uses two converter sections for accurate performance at near zero.

Conversion chart showing twos-complement to internal converter code.

ANALOG OUTPUT	INPUT CODE (20-bit Binary Two's Complement)	LOWER DAC CODE (19-bit Straight Binary)	UPPER DAC CODE (19-bit Straight Binary)
+Full Scale	011...111	111...111 + 1LSB*	111...111
+Full Scale – 1LSB	011...110	111...111 + 1LSB*	111...110
Bipolar Zero + 2LSB	000...010	111...111 + 1LSB*	000...010
Bipolar Zero + 1LSB	000...001	111...111 + 1LSB*	000...001
Bipolar Zero	000...000	111...111 + 1LSB*	000...000
Bipolar Zero – 1LSB	111...111	111...111	000...000
Bipolar Zero – 2LSB	111...110	111...110	000...000
–Full Scale + 1LSB	100...001	000...001	000...000
–Full Scale	100...000	000...000	000...000

*The extra weight of 1LSB is added at this point to make the transfer function symmetrical around bipolar zero.

gross non-linearities; 20-bit resolution is genuinely obtained — even around bipolar zero.

In the table, the twos-complement input is converted to input code to the converters, only the LSB areas of either D-to-A changing around bipolar zero. As an illustration of the monotonicity of the PCM63, **Fig. 2** shows a test using a 16-bit code from a compact disc, which provides 10 periods of bipolar zero, 10 periods of alternating signal of 1 LSB above and below zero, then 10 of 2 LSBs and so on up to 10 of 10 LSBs. This test was carried out with no external adjustment and shows near-perfect graduation with good step definition. In many other designs, noise at this level would be too high to see the steps.

Figure 3 shows a typical application — high-performance digital audio playback using a Yamaha YM3623 digital interface format receiver, a Burr-Brown DF1700P eight-times interpolating digital filter and two third-order, low-pass anti-imaging filters using B-B OPA2604APs. The use of an eight times filter increases the number of samples to the converter by eight and reduces the need for a higher-order reconstruction or anti-imaging analogue filter at the output.

***Burr-Brown International Ltd,** 1 Millfield House, Woodshots Meadow, Watford, Hertfordshire WD1 8YX. 923 33837.*

5V-to-±15V DC-to-DC converter

A dual-output, 3W switching regulator IC, the MAX743 from Maxim, will produce ±15/±12V at 100/125nA from a single 5V supply. Two power mosfets are contained in the package, with all active components needed for a working power supply. Laser-trimmed outputs are independent and within ±4% against all conditions of load, line voltage and temperature.

Switching is at 200kHz for economy in external components and, with a small LC filter, noise is down to 2mV pk-pk. Both evaluation and production kits are available.

The block diagram in **Fig. 1** shows that the main part of each current-mode controller is a three-input summing amplifier, its inputs being the current waveform from the output fet, V_{out}/V_{ref} error signal and a ramp for AC compensation from the oscillator. A flip-flop takes its trigger from the amplifier via a soft-start/thermal shutdown gate and drives the power fet switch.

Both switches are synchronised by oscillator pulses, coming on at the same time when the flip-flops are set and being turned off when switching currents reach a level set by the error signal resetting the flip-flops. Duty cycle of the switch is therefore determined by error signal and peak current in

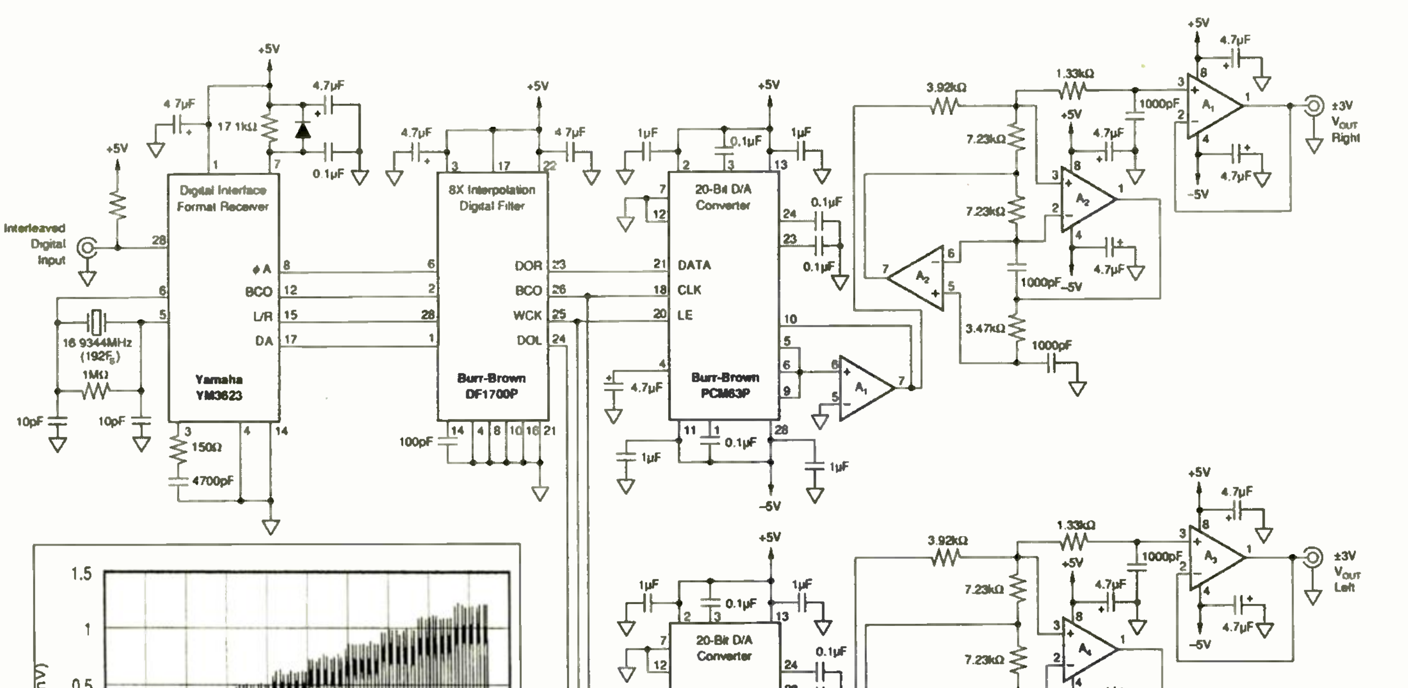


Fig. 3. Circuit diagram of a professional audio stereo playback system.

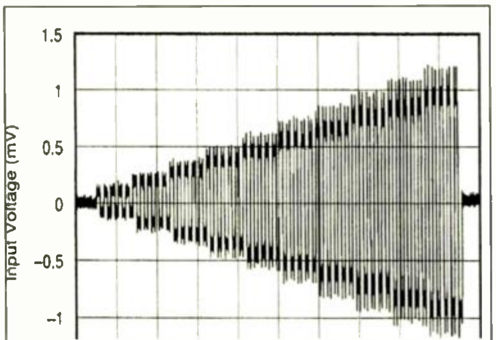


Fig. 2 shows monotonicity around bipolar zero. Other types of converter would conceal the lower steps in noise.

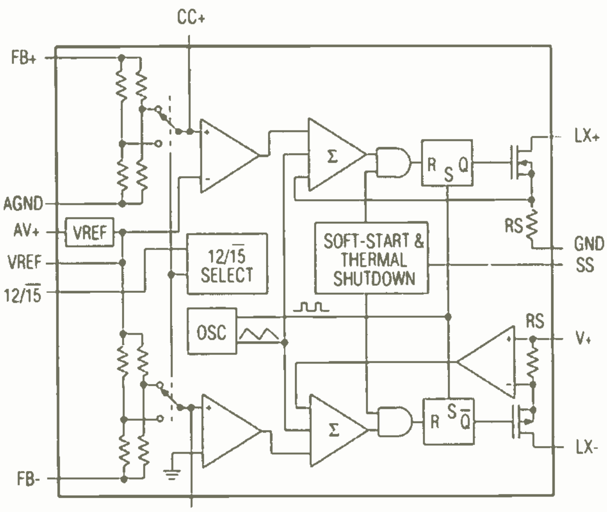


Fig. 1. Block diagram of Maxim MAX743 regulator. Output switches come on together and turn off individually when switch currents reach preset values.

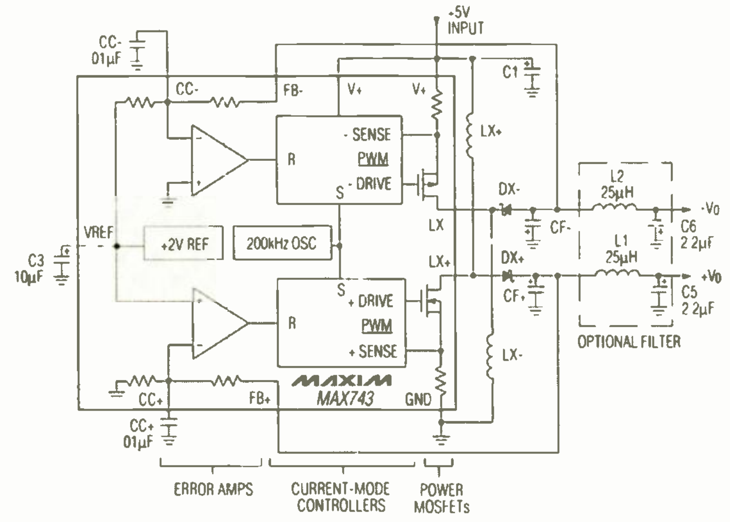


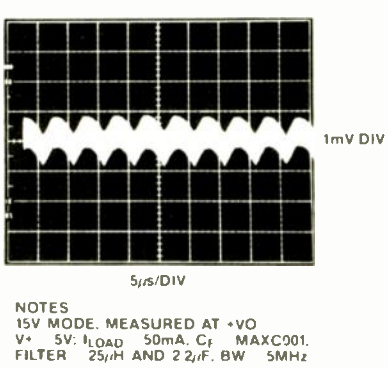
Fig. 2. Evaluation circuit, for which kits are available. Filter is optional, but reduces ripple and switching noise to millivolt level.

LX (**Fig. 2**) and can be up to a maximum of 90%.

Figure 2 shows the evaluation circuit with an optional pi-section filter. Without the filter, output voltage ripple at 200kHz is around 75mV pk-pk and about 250mV transient noise is at the LX switch transitions. The filter reduces both types of noise: **Fig. 3** shows the noise level with the filter in circuit. Maxim's application note on the MAX743 gives details of a choice of components for varying practical requirements. Soft starting is obtained by connecting a capacitor to the SS pin, which is normally left open.

Maxim Integrated Products (UK) Ltd,
21c Horseshoe Park, Pangbourne, Reading RG8 7JW. 0734 845255.

Fig. 3. Noise level at the output, measured with the pi filter in circuit.



Mosfet/IGT half-bridge driver

To interface low-level logic to power half bridges, Harris has produced the SP600 high-voltage IC for up to 230V AC line-rectified operation, described fully in application note AN8829.1. Its main function is to drive n-channel current-sensing power mosfets or insulated-gate devices in the totem-pole type of arrangement. The device provides overcurrent shutdown, simultaneous conduction protection and undervoltage lockout, and will operate at up to 130kHz with a peak drive current of 0.5A.

Since easy-to-drive p-channel mosfets are relatively expensive, the use of n-channel devices, which operate at higher voltages, appears attractive. One snag is that a floating gate supply at around 10V higher than the upper rail link is needed. But the SP600 surmounts this by providing such a supply on the chip.

In **Fig. 1** filtered cmos logic signals at top and bottom turn the upper and lower drivers

Fig. 1. Basic layout of the Harris power half-bridge driver IC containing its own floating bias supply for upper-rail mosfets.

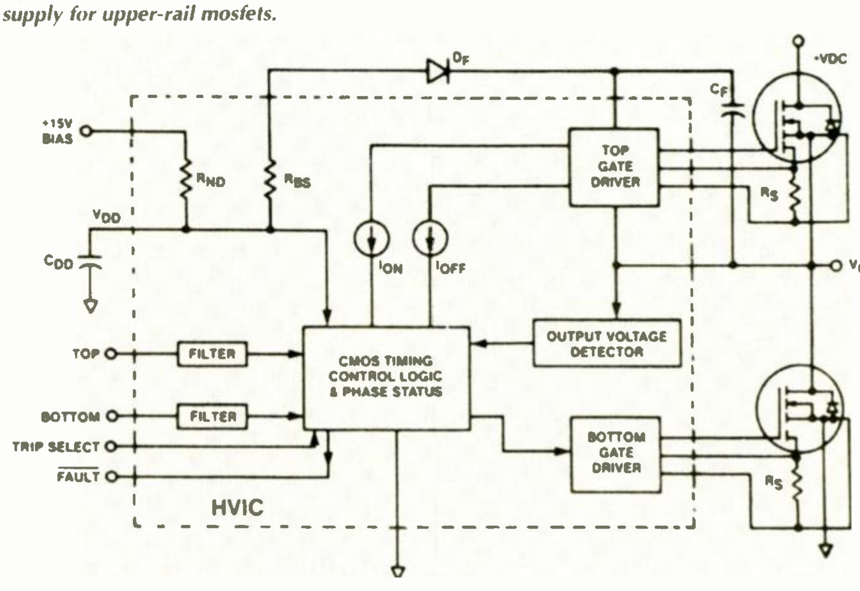
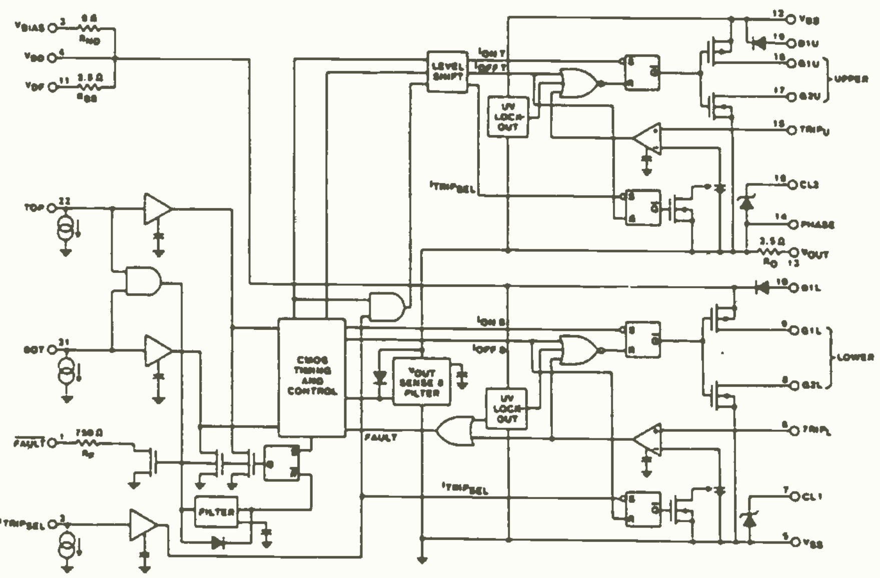


Fig. 2. Functional diagram of the SP600 driver. The diode and capacitor for the floating supply are external components.



on or off, the inputs being decoded to drive the correct output transistors via current-mirror level shifters.

Capacitor CF and diode DF constitute the floating supply. Every time V_{out} goes low due to the conduction of the lower output device, CF charges to about one diode drop less than the VDD of 15V through the current-limiting resistor RBS. Noise voltages are reduced by RND which, in conjunction with CDD, filters the supply.

Output devices are protected from over-current by the system shown in **Fig.2**, where $trip_u$ and $trip_l$ feed 100mV-level voltages derived from the current-sensing resistors R-S in Fig. 1 to comparators, which instantly disable the output when a fault condition is detected.

Harris Semiconductor Ltd, *Riverside Way, Watchmoor Park, Camberley, Surrey GU15 3YQ. 0276 686886.*

Teletext board

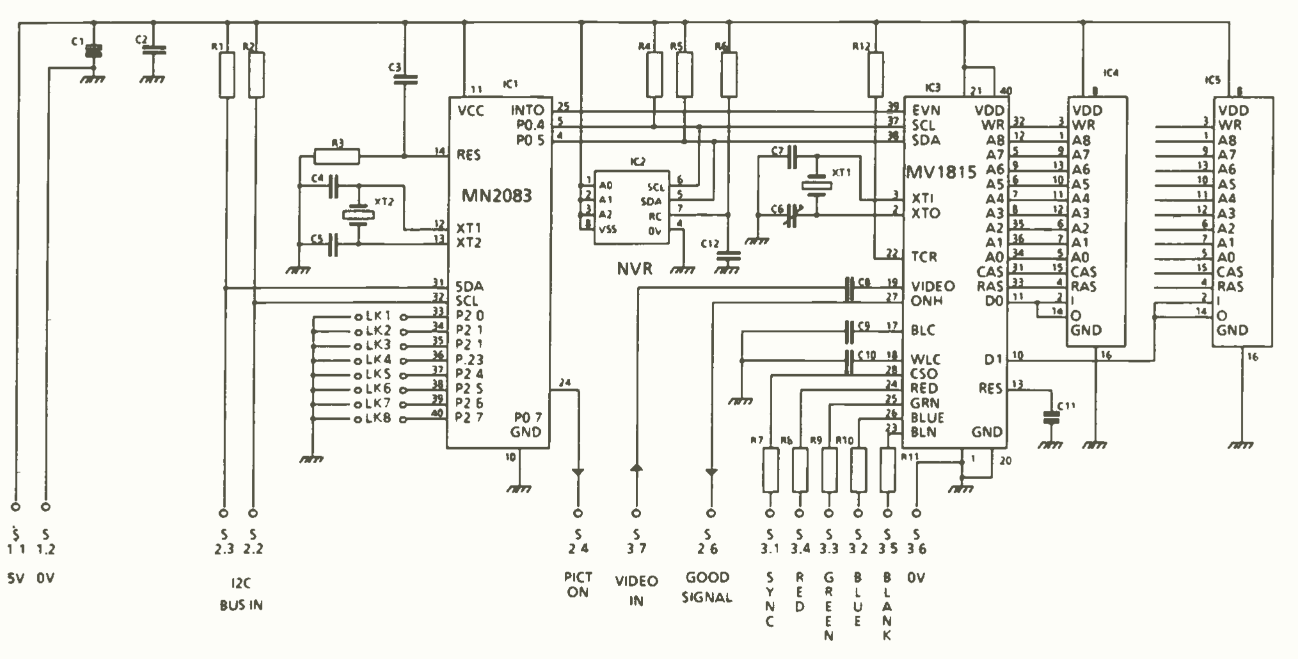
To demonstrate its Plato software and MV1815 advanced teletext chip, Plessey has made available an applications board which implements a full Level 1 Fastext system, favourite pages and Spanish. It fits easily into an existing receiver, being only 110 X 68mm,and is controlled over an I²C bus. Application Note AN90 is a full description.

An 8051-based microprocessor, the MN2083, controls the teletext chip and contains the Plato software in a masked rom. The primary I²C bus takes commands to the Plato board, which acts as slave receiver or transmitter, the secondary bus controlling the MV1815. This is at a higher speed for fast page access. Two 256K X 1 d-rams store either 14 or 62 pages. The board puts out high-power RGB, blanking and composite sync., with control lines for signal quality and status.

The diagram shows a full circuit diagram of the board; link functions are described in the application note, along with full details of its operation. ■

Plessey Semiconductors, *Cheney Manor, Swindon, Wiltshire SN2 2QW. 0793 518000.*

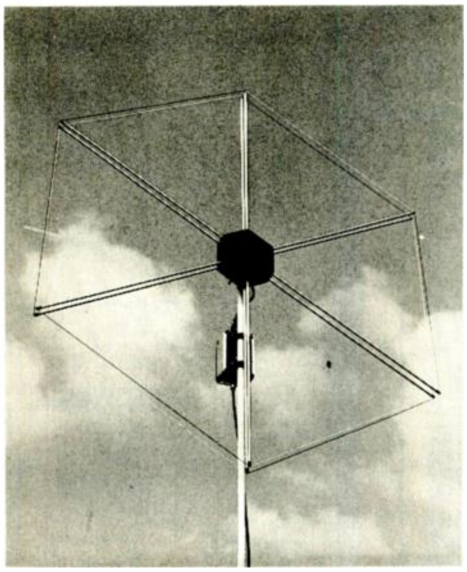
Plessey's Plato advanced teletext operating system.



R1	=	10k	R7	=	link	C1	=	470uF	C7	=	0pF	IC2	=	PCF8582AP (256 x 8 NVRAM)		
R2	=	10k	R8	=	470R	C2	=	100nF	C8	=	10nF			or PCF8572AP (128 x 8)		
R3	=	10k	R9	=	470R	C3	=	1uF	C9	=	10nF	IC4,5	=	TMS41256 (256K x 1 DRAM)		
R4	=	10k	R10	=	470R	C4	=	39pF	C10	=	10nF			or TMS4164 (64K x 1 DRAM)		
R5	=	10k	R11	=	link	C5	=	39pF	C11	=	0.1uF	XT1	=	27.7500MHz		
R6	=	56k	R12	=	10k	C6	=	3-20pF	C12	=	3.3nF	XT2	=	12MHz		

LINIPLEX

Loop Antenna



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Compacted array. A compacted array turbo series of gate arrays is made in drawn 0.7µm hcmos and has 20,000 to 200,000 usable gates with a customer designed memory capability of up to 36Kbit of ram and 160Kbit of rom. It is called the LCA200K series. LSI Logic, 071-497 8728.

Custom design. Memec has formed a new company to design and supply asic devices as part of a partnership with Harwell Instruments which has its own U2 silicon compiler software. The firm claims that U2 can help lay out an asic that is smaller, faster, and uses less power than those produced by standard design tools. The devices have clock speeds above 100MHz. Logical Integration, 0844 261853.

Single-chip asics. Based on a 0.8µm channel length cmos process, the CB-C7 asic technology allows integration of microprocessors, microcontrollers, ram, rom, intelligent peripherals, system support units, and user-defined logic on a single chip. Integration levels are in excess of 180,000 gate equivalents per chip. Power consumption is 8µW/gate/MHz and propagation delays are 0.44ns for a standard internal gate and 0.34ns for a power gate. NEC Electronics, 0908 691133.

A-to-D and D-to-A converters

18bit. The DSP101 and 102 18bit devices have internal sample/holds and references and provide full sampling and conversion at rates up to 200kHz. Signal to noise and distortion ratio is 90dB and spurious free dynamic range 94dB. 101 single channel unit allows driving of 16, 24 or 32bit DSP ports; 102 has two complete conversion channels with either two full 18bit output ports or the ability to let the user cascade two 16bit conversions into a 32bit port as one word. Burr-Brown International, 0923 33837.

Deglitched converter. DAC02320 is a fully integrated single package 12bit deglitched D-to-A converter. Update rate is 15MHz and it has a track and hold output to remove glitches as well as input registers and a precision DC reference. It is suitable for vector-stroke CRT applications and comes in a 24-pin metal hybrid package. Data Device Corporation, 0635 40158.

CD applications. A low-cost converter for portable CD players and other digital audio equipment is claimed to dissipate less than a third the power of competing ICs and works with supply voltages down to 3V. The TDA1545 dual continuous-calibration device fits in an eight-pin DIL or SO package. Total harmonic distortion including noise at full signal is -81dB (0.0089%). Power dissipation is 6mW at 3V and 15mW at 5V. Philips Semiconductors, +31 40 724340.

Linear integrated circuits

Power supply IC. The Max743 DC-DC converter IC has all the active circuitry needed to build a dual-output switch-mode power supply. It will generate ±12V at 125mA or ±15V at 100mA from a single 5V supply. Output voltage is specified by a logic level on a control pin on the device. It can regulate both outputs to within 4% over all conditions of supply voltage, temperature and load current and can typically provide around 80% efficiency over most of the load range. 2001 Electronic Components, 0483 742001.

PWM motor driver. A full-bridge PWM motor driver IC, the UDS2954V, complies with MIL883C and is for the bidirectional control of DC servo motors and is rated for continuous output currents up to ±2A. For chopped mode use output current is determined by selection of a reference voltage and sensing resistor, while off pulse duration is set by an external RC timing network. 15-pin flange mount TO3 or TO204 style hermetic package. Allegro MicroSystems, 0932 253355.

Driver IC. The UDN-2993B dual H-bridge driver IC is for controlling DC servo or DC bipolar stepping motors at up to 40V and 500mA per phase. Each of the full-bridge drivers has input-level shifting, internal logic, source and sink drivers, and internal clamp diodes. An internally generated dead time prevents crossover currents during changes in load-current phase. 16-pin dual-line plastic package with a copper lead frame. Allegro MicroSystems, 0932 253355.

Accelerometer. The 3031 is a 7.5mm 2 surface-mount single-axis piezoresistive silicon accelerometer available from ±2 to ±500g. Made by ICSensors, it is a three-layer silicon sandwich with suspended mass and sensing bridge in the middle. Self test electrodes provide calibration by simulating a known force to the internal mass. The unit is critically damped and has mechanical stops. EuroSensor, 071 405 6060.

Precision op amps. Three op amps have a low offset voltage of 1mV maximum, gain of 20,000 minimum and input bias current of 300nA maximum. The LT122x family operate on supplies from ±5 to ±15V and can drive unlimited capacitive loads. The 1220 is a unity gain stable 45MHz amplifier with 250V/µs slew rate, the 1221 is for closed loop gains of four or more, and the 122 is stable for gains of ten or more. Micro Call, 0844 261939.

High power op amps. A range of op amps with an output current of 15A can drive capacitative, inductive and other sensitive loads in, say, audio systems and motor control servos. Called Micropac Miop, they come in TO3 cans, tolerate input voltages from ±10 to ±50V and dissipate 125W at 25°C. Pascall Electronics, 081-979 0123.

Demodulator. A differential quadrature phase shift keying (DQPSK) demodulator for Nicam 728 systems integrates single-pin carrier and bit-rate oscillators. The TDA8732 works in Pal B/G and I transmission systems. Typical power consumption is 130mW. It provides data synchronised to a 728kHz clock which is either supplied externally or by the on-chip oscillator. Philips Semiconductors, +31 40 724340.

Digital stereo decoder. Performing all the digital decoding functions for EBU Nicam 728 digital stereo systems, the SAA7280 terrestrial digital sound decoder needs only three other ICs to build a complete Nicam decoder. The chip integrates a selectable 3x digital oversampling filter with seven-sample interpolator. On-chip ram allows de-interleaving and 10 to 14bit word expansion. The IC can be controlled by either a microcontroller across the two-wire I 2C bus or by direct access to the IC pins. Philips Semiconductors, +31 40 724340.

Cmos op-amp. TLC2202 from TI uses a complimentary output stage to drive its load almost from rail to rail. It is for battery powered applications and any circuit where supply margins are narrow but accuracy and low noise cannot be compromised. 12nV/Hz noise maximum and a worst case offset of 500µV. It comes in either an eight-pin PDIP or small outline package. Quarndon Electronics, 0332 32651.

Bus driver. The Si9200 bus driver IC is a physical interface between a controller area network (can) and the Intel 82526 controller. It is the direct interface for the can bus at each can bus node and has self protection and also protects the controller from spikes on the bus such as shorts and spikes. Common mode range is -2 to +7V for operation and -3 to +16V continuous for non-operation. It can stand ±60V transients. Siliconix, 0635 30905.

Bi-cmos logic ICs. Toshiba has developed what it claims to be the world's fastest Bi-cmos logic ICs. They can be used as bus driver ICs for data transmission between computers and peripherals such as printers and disc drives. Made using 1µm design rules, the 74ABY devices have typical propagation delays of 3ns and an output drive capability of 64mA. Toshiba Electronics, 0276 694600.

Memory chips

Content addressable memory. From Music Semiconductors is a 1K x 64bit content addressable memory (cam) for filtering applications in local area network bridges to allow a network station list to be searched in a single memory transaction. 64Kbit of static cam and each data field can be partitioned into a cam and a ram subfield on 16bit boundaries. It can also be used in lan routers, optical and magnetic disc cache memories, data base accelerators, machine vision, and target acquisition. Mogul Electronics, 0732 741841.

256Kbit sram. A TTL compatible 256Kbit Bi-cmos fast sram operates at 10ns access time. The family includes the 32K x 8bit MCM6706, the 64K x 4bit MCM6708 and the 64K x 4bit with output enable MCM6709, made using 1µm triple level metal technology. They can be used as high-speed cache memories for 32bit workstations. They are suited for systems running at 33MHz including burst cycles up to 83MHz. Motorola, 0908 614614.

Microprocessors and controllers

Single-chip microcomputer. Dialogue has introduced two versions of Hitachi's HD647180 Z80 single-chip microcomputer — a romless type and a mask rom unit. The latter is functionally identical to the 647180 except for the replacement of the 16Kbyte eprom by a 16Kbyte mask rom. Dialogue, 0276 682001.

Optical devices

Photodiodes. OSD series 7 UV sensitive silicon photodiodes work in the 190 to 400nm wave band and have active areas from 1 to 100mm 2. Quartz windows are available with all packages, UV transmitting glass with metal packages, and open frame with ceramic only. They operate with a reverse bias up to 5V and can conduct a peak current of 10mA DC and withstand a peak pulse current of 200mA for 1μs at 1% duty cycle. Centronic, 0689 42121.

PASSIVE

Passive components

Carbon resistors. Hot moulded carbon resistors from Allen-Bradley are each made as a solid one-piece construction. They are tested to MilR11 and MilR39008. They are rated between 0.125 and 4W at 70°C They can be supplied either taped and reeled or loose packed. Crydom Special Products, 081-763 0550.

Resistor network devices. Micro Divider packaged resistor network devices for surface mounting have a footprint of 9mm 2. They comprise a ratio pair of resistors in a SOT23 package and can dissipate up to 500mW at resistor values up to 1MΩ. Ratio tolerance is 0.01%, TCR tracking 0.5ppm/°C and time stability 50ppm for 1000h at 125°C. Ratios from centre tapped to 100:1. Thin film on silicon or ceramic planar resistive elements etched as a tapped resistor, wire bonded with two, three or four wires. Electro-Films, 0784 246273.

Connectors and cabling

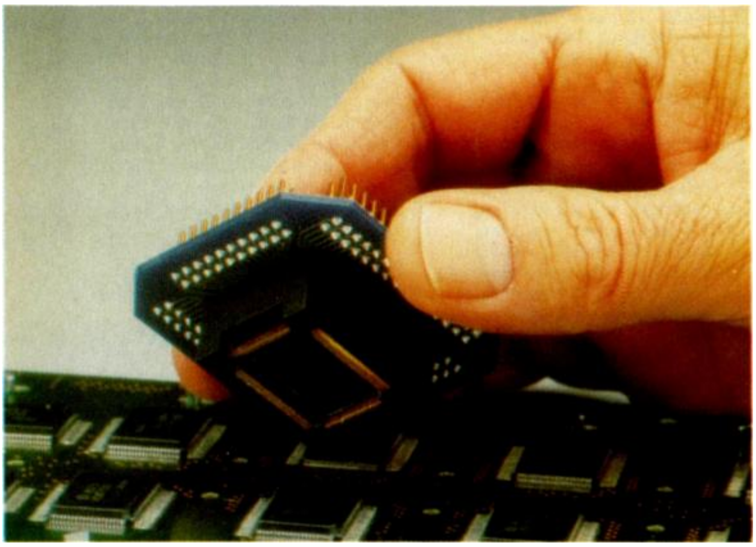
Test clips. 5640 series clips fit EIAJ ICs spaced on 0.65 and 0.8mm centres. Clips allows easy test probe access to high density leads of surface mounted plastic quad flat pack (PQFP) devices with 100, 120 or 160 pins. Clips slot over surface mounted devices and connect the leads to gold-plated phosphor bronze 0.64mm square posts on top of the clip positioned on a 0.256mm grid. ITT Pomona, 0256 473171.

Coaxial connector. An SMT coaxial connector has a maximum profile of 4.2mm and a footprint of 4.5 x 4mm. Ultra-thin coaxial cable gives the assembly a maximum VSWR of 1.2 at 2GHz. It comes in two parts — a straight receptacle for PCB mounting and a right-angle plug and cable assembly. DC to 2GHz range. Voltage rating is 250V and nominal impedance 50Ω. Murata Electronics, 0252 811666.

Displays

EL display. Sharp Electronics LJ64ZU49 display is 3.4cm thick; without its removable DC-DC converter it is 2cm thick. The converter can be installed on a separate flexible connection. Resolution is 640 x 480 pixel, each measuring 0.33 x 0.33mm. It covers 16 grey scale levels. At maximum wavelength of 585nm, luminance is 30ftL. Viewing angle is 160° and screen size is 19.2 x 14.4cm. Sharp Electronics, +40 23775-0.

ITT test clips ease in-situe testing of PQFP surface mount devices.



Filters

Phase shifter. Merrimac PWM84C digital phase shifter for IF signals has full TTL compatibility and centre frequencies between 20 and 3000MHz. It has a minimum of 360° of phase shift to a resolution of 1.4° per step. Phase shift is generated using frequency independent analogue phase shifters driven by an 8bit D-to-A converter. Pascall Electronics, 081-979 0123.

RFI filters. Arcotronics cylindrical RFI filters are rated at 250V up to 400Hz and meet the climatic requirements of HPF (25/085/21) for -25 to +85°C. F.AT series is for lighting and white goods with induction motors, while F.AB and F.AC units are for white goods with brush motors as well as optical appliances, photocopiers and facsimile machines. STC Mercator, 0493 844911.

RFI filters. Arcotronics RFI filters have a voltage rating of 250V up to 400Hz. The F.AH and F.AA types provide good attenuation and LF and MF and can be supplied either for PCB mounting or with fast-on terminals. F.LH are for PCB mounting only. F.AL types come in metal cases and are for high frequency applications. F.AI series is for use with asymmetric RFI generated by switches and sliding contacts. STC Mercator, 0493 844911.

Hardware

Brushless fans. Two ranges of subminiature DC units have body sizes measuring 25 and 40mm. 12V DC supply but versions are available that work from 5V DC supplies. Airflow is one way and varies from 0.8 to 4.2ft 3/min. Noise level is 35dBA. Smaller models weigh 8g and larger ones 20g. Pedoka Electronics, 0462 422433.

Instrumentation

Multitester. TMK600, available from Alpha Electronics, has a combined analogue and 3.5-digit display and can measure AC RMS voltage to 750V in five ranges with an analogue sensitivity of 1MΩ/V. DC voltage is to 1kV also in five ranges. There are seven current ranges up to 10A. Resistance with audible continuity uses six ranges to reach 20MΩ. Other tests include diode and dBs. Alpha Electronics, 0942 873434.

Industrial multimeter. True RMS measurement, 10,000 count resolution, on-screen menu function selection, four-digit display with analogue bargraph, autoranging on every function, and full fusing are available on the RMS225 hand-held digital multimeter. Other features include autoranging maximum and minimum recording mode, relative mode offset measurement, probe hold measurement capture, range lock, and visual and audible dangerous voltage indication. Beckman Industrial, 0384 442394.

CD test system. CDQC-2 is a compact CD test system including a Studer A725QC CD player for radio, archive, CD-write-once, and CD-rom applications. CDs with major defects can be detected and replaced even if there are no audible faults. It can also check if a fault lies with the CD or player. If a printer is connected several option reports can be chosen. FWO Bauch, 081-953 0091.

Waveform digitiser. Series 2000 waveform sampling system can read, measure, analyse and store signals. It can analyse signals from radar, VLSI validation and other pulsed or transient phenomena at up to 2Gsample/s with 12bit digitising resolution and greater than 60dB dynamic range. Hytec Electronics, 0734 697973.

Spectrum analyser. Available for rental is the HP 8590B spectrum analyser with a frequency range of 9kHz to 1.8GHz and an amplitude range from -115 to +30dBm. Frequency drift is less than 75kHz over 5min, dynamic range is 70dB, and resolution bandwidth is from 3kHz to 3MHz. Own power source for field service. It has 32Kbyte of nonvolatile memory and a built-in clock/calendar. IR Group, 0753 580000.

TV measurement receiver. VX600 is a compact portable TV measurement receiver for use by TV and broadcast engineers installing aerials, cable systems and satellite receivers. It has three functions: TV field strength measurement for all VHF and UHF bands as well as satellite and FM radio transmissions; a TV monitor for video and sound quality testing, and a spectrum analyser. ITT Instruments, 0753 511799.

Indicator/controller. Microprocessor based ADP15 is an intelligent indicator/controller which can scale all transducer inputs from the front panel for display, measurement or three-term control purposes. It accepts DC and AC voltages down to ±20mV full scale and AC currents, digital inputs and 20mA current loops. It can also provide alarm and monitoring functions. Data display is a 4.5 digit led and all scaling and I/O definition is performed by four front panel touch buttons. Amplicon Liveline, 0273 570220, or Mantracourt Electronics, 0395 32020.

Battery oscilloscope. OS-615S is a 15MHz dual-trace unit operating from mains or internal NiCd rechargeable battery with two hours continuous operation per charge. 5.5kg and 113 x 223 x 298mm. Vertical sensitivity is 2mV/division. Rise time is 24ns and is less than 3%. Timebase is from 0.5μs to 0.5s/division in 19 steps. x5 magnifier for all ranges gives a fastest sweep of 100ns. Multitest, 0480 403617.

Network analysis. An optional computer function has been added to the ZPM scalar network analysis system that combines a network analyser with a sweep generator. Called ZAM23, the function adds the capability of writing measurement, control and evaluation programs in Basic. It lets the unit behave like an independent process controller Rohde & Schwarz, 0252 811377.

Data logger. Rustrak's Ranger data logger, with four times the internal memory of its standard model, has 256K of on-board battery backed ram letting to store about 120,000 readings. This memory can be further expanded with removable data packs available with 64K, 128K or 256K. Stored data can be downloaded to a PC for analysis directly from the logger or data packs can be removed for analysis while the logger remains on site. Rustrak Instruments, 0273 606271.

General-purpose instrument. Leader LCD300 portable battery/mains instrument combines a digital storage oscilloscope, digital multimeter and logic scope. The digital storage section has two channels with 30Msample/s rates and 10MHz bandwidth. The LCD has 128-point (7bit) vertical resolution and 180 or 1800-word resolution on the horizontal axis. 240 x 44 x 165mm, 1.2kg. Thurlby-Thandar, 0799 26699.


Leader LCD300 multipurpose instrument from Thurlby-Thandar.

Literature

Designer handbook. The AME designer handbook and catalogue has information on PIN detectors, UV enhanced detectors, linear and quadrant arrays, and nuclear radiation and particle detectors. Information is given on principles and parameters of design as well as application details. Hero Electronics, 0525 405015.

Power supplies

Benchtop unit. Improved version of BNOS' A series fixed voltage output benchtop supply units can deliver 600W of continuous DC power up to 40A. Inputs are 220/240 or 120/240V AC and outputs 13.8 and 28V DC, offering safety margins for 12 and 24V operation. Output can be adjusted between 10 and 15V and 20 and 30V, respectively. BNOS Electronics, 0371 856681

DC-DC converters. Calex has introduced 7.5W DC-DC converters for low-noise telecommunications, industrial control and medical applications. The three 48SxFW units are 120kHz mosfet designs with efficiencies approaching 80%. Nominal 48V input and DC outputs can be 5V at 1500mA, 12V at 625mA, or 15V at 500mA. Calex Electronics, 0525 373178.

150W supply. A 150W unit, added to the 7000 series of high voltage power supplies, works at output voltages to 30kV in five ranges. Maximum height is 45mm. Features include voltage and current control, voltage and current metering, polarity reversal, interlocks, protection against short circuit and flashover, full remote monitoring, and control facilities. Hartley Measurements, 0752 344606.

Evaluation kit. An evaluation kit to demonstrate the performance of the Max655 +3 to +5V DC-DC converter contains a printed circuit card and all the passive components needed to build a 300mW supply powered from two AA cells. The kit is designed to simplify prototyping. Maxim Integrated Products, 0734 845255.

DC-DC converters. Made by Electronic Measurements, the EMQ series of DC-DC converter modules uses twin forward converter topology to cut voltage and current stresses in the power mosfets and a fixed frequency of 250kHz for reduced EMI. Outputs are 50 to 200W. Nominal inputs are 12, 24, 48 and 300V DC and output voltages can be selected from 5, 12, 15, 24 and 48V DC. Powerline Electronics, 0734 868567.

DC-DC converters. The RM converters come in industry standard 2 x 2in cases and are claimed to be about 40% cheaper than previous PM units. Inputs are 5, 24 and 48V DC and the range has four models with outputs of 5 and ±15V. All have a no derating performance between -25 and +71°C with a typical efficiency of 66%. Isolation of 500V DC, short-circuit protection and a Pi input filter are standard features. XP, 0734 845515.

Switches and relays

Push button switches. Miniature PCB switches with no springs, when used in a bank, all interconnected switching functions can be handled electronically via the PCB rather than by mechanical linkages. A harpoon device is used for self retention during soldering and for mechanical holding during operation. They are available in two, four, six and eight change over contacts for impulse or latching action. 0.1A 250V. ITT Switches, 0256 473171.

High side switch. A second generation Profet monolithic protected high-side switch series offers one step microprocessor-to-DC power switching capability while being fully protected and giving status feedback of fault conditions. Designated BTS410D, E, F or G and BTS412B, operating supply voltages range from 4.9 to 42V. Siemens, 0932 752313.

Transducers and sensors

Linear displacement transducers. Control Transducers has added five models to its range of fast linear displacement transducers. Nominal linear range is 19 to 254mm. Non-linearity is 0.1% and operating range is -50 to +125°C. Frequency response is 15kHz. Applications include hydraulic cylinders, roller position control, automated production gauging, vibration analysis, robotic motion control, and X-Y positioning feedback. Control Transducers, 0234 217704.

Pressure transducers. 8510-2M14 and 8510B-2M9 miniature pressure transducers are for low-level differential pressure measurements in down-hole well logging applications. They can measure ±1psi in a 10,000psi common-mode environment. Using a sculptured piezoresistive pressure sensing diaphragm, sensitivity is 200mV/psi, nonlinearity is 0.2% of full scale output, and over-pressure capability is 40psi. Endevco, 0763 261311.

SM pressure sensor. The 1431 pressure sensor uses a Wheatstone bridge piezoresistive chip mounted in a miniature plastics case on a ceramic base with footprints for surface mounting. Ranges are from 2000kPa down to 300mmHg. Applications include air pressure monitoring in telephone cables, altimeters, tyre gauges, vacuum cleaners and washing machines. EuroSensor, 071 405 6060.

Humidity sensor. The Humitter is an integrated sensor/hybrid module that needs a 7 to 28V DC supply and gives an output of 0 to 1V representing 0 to 100% relative humidity. Accuracy at 20°C is better than ±5% over two years. Vaisala, 0223 420112.

Vision systems

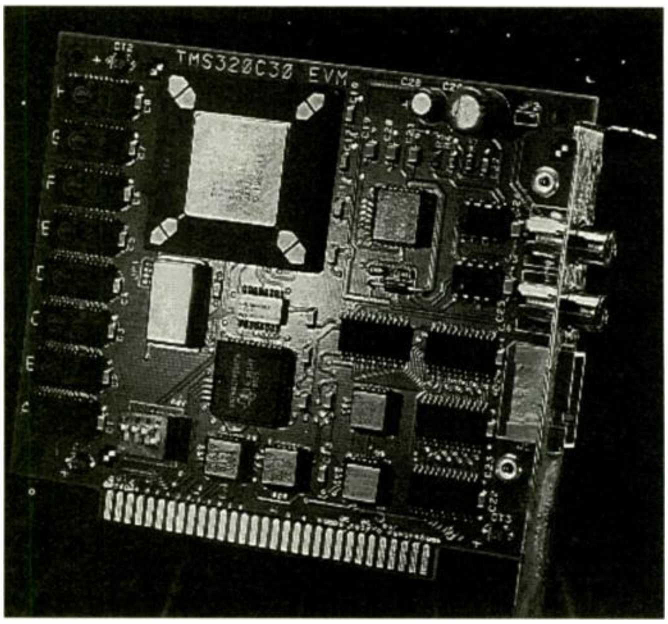
Miniature camera. Consisting of camera head, cable and controller, the iEC862CR/A is a miniature camera for military reconnaissance, remote sensing and colour monitoring in hazardous environments. The controller weighs 2kg and can operate from -55 to +50°C. An electronic iris provides automatic sensitivity adjustments inside a 10 to 60,000 lux light variation range at F1.4 with less than 5% of video signal relative change for light gradients up to one aperture per second. Data Cell, 0734 333666.

COMPUTER

Computer board level products

Data acquisition card. AD3100 data acquisition card for the PC ISA bus has up to 128 differential or 256 single ended inputs with dedicated ground planes. Features include programmable gains, 12bit A-to-D conversion, independent pacer clock, on-board fifo interface, DMA transfer, four conversion modes with four channel select options, and compatibility with Atlantis and Pegasus data acquisition and data analysis software package. Lighthouse Electronics, 0825 768849.

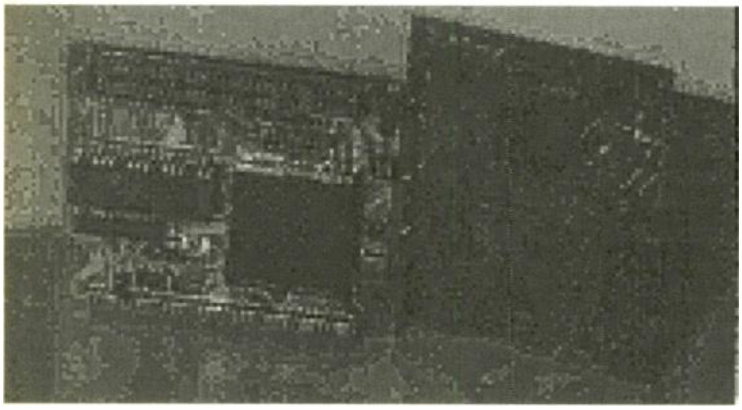
Development board. TMS320C50/51 application development board for the IBM PC and compatibles, using TI's DSP chips, will accommodate rom and ram based C50 processors. On board memory is composed mainly of zero wait state sram with 32K x 16 fitted as standard, expandable to 128K x 16. PC interface is a 4K x 16 block of dual-port ram. Loughborough Sound Images, 0509 231843.



This C30 DSP card is available from Quarndon Electronics.

DSP card. The TI TMS320C30 evaluation module is based on a PC/AT compatible half card. At its heart is the 320C30 clocked at 30MHz. As well as the chip's own ram, there are 16Kword of zero wait state sram allocated to the primary bus. Analogue I/O is by the TLC32044 analogue interface circuit brought out to standard audio phone sockets. It comes with TI's third generation assembler/linker, C source debugger and a hardware and software applications pack. Quarndon Electronics, 0332 32651.

16bit computer. The TDS microcontroller gives users access to H8/532 16bit microprocessor technology without using expensive development tools. On the board is Forth, but it can be used with other languages via a cross-compiler. It interfaces to LCDs, scans up to 64 keys and has a non-volatile real-time clock. Memory is up to 512Kbyte and ram, eeprom or flash devices can be used. There are eight 10bit A-to-D channels, three channels of 8bit D-to-A, up to 41 parallel inputs or outputs, four counter/timers, and two serial channels. Triangle Digital Services, 081-539 0285.



TDS microcontroller gives cost effective access to H8/532 16bit microprocessor technology.

Colour graphics board. CatsEye is a colour graphics controller board for cad, DTP and other PC applications. Based on the Western Digital PWGA-1 chip set, it is compatible with the IBM 8514/A display adapter including hardware register compatibility, but some 30 to 100% faster on graphics intensive operations. Software drivers are included for Presentation Manager, Windows 286/386 and 3.0, Gem, AutoCad, Computervision, and Microstation. Westec, 0258 456165.

Computer systems

Supercomputers. GT860 parallel processing supercomputers built around Intel's i860 operate under MS-dos or Unix, and have fully optimising compilers for ANSI, C and Fortran 77. The standard PC/tower chassis will accept up to eight i860 processors delivering 640MFLOPS. Division, 0454 324527.

Industrial PC AT. Crellon has introduced TI's 3014 rack-mount 33MHz 80486 based industrial PC AT. At its heart is the C486S CPU card with built-in maths coprocessor. There are 14 slots in the rack and it is suitable for use in harsh environments. Gothic Crellon, 0734 788878.

Rack-mount PC. The WR3102 is an industrial 19-in rack-mount 386PC for rugged and hostile environments. It has a single-board 80386X 16MHz microprocessor or can use a 386 DX CPU at 33MHz. Up to 8Mbyte of high speed ram can be supported for the SX and 32Mbyte for the DX. Both CPUs have a socket for an 80387 math coprocessor and contain on-board a hard disc controller, floppy controller, two serial ports and a parallel port. The graphics card supports VGA emulation and VESA compatible Super VGA resolution up to 800x600 and up to 256 colours. 3.5in 1.44Mbyte floppy drive and 40Mbyte hard disc drive with 19ms access speed. Lighthouse Electronics, 0825 768849.

Data communications products

Modem controller. The SC11091 universal modem controller performs standard interpretation, MNP error correction, and compression levels 2-5, CCITT V42 and V42bis. Support is provided for the Sendfax fax transmission system and the SK9698 send/receive fax chipset. It has an on-board uart for PC bus interfacing and usart for synchronous communications. Sierra Semiconductor, 0793 618492.

Software

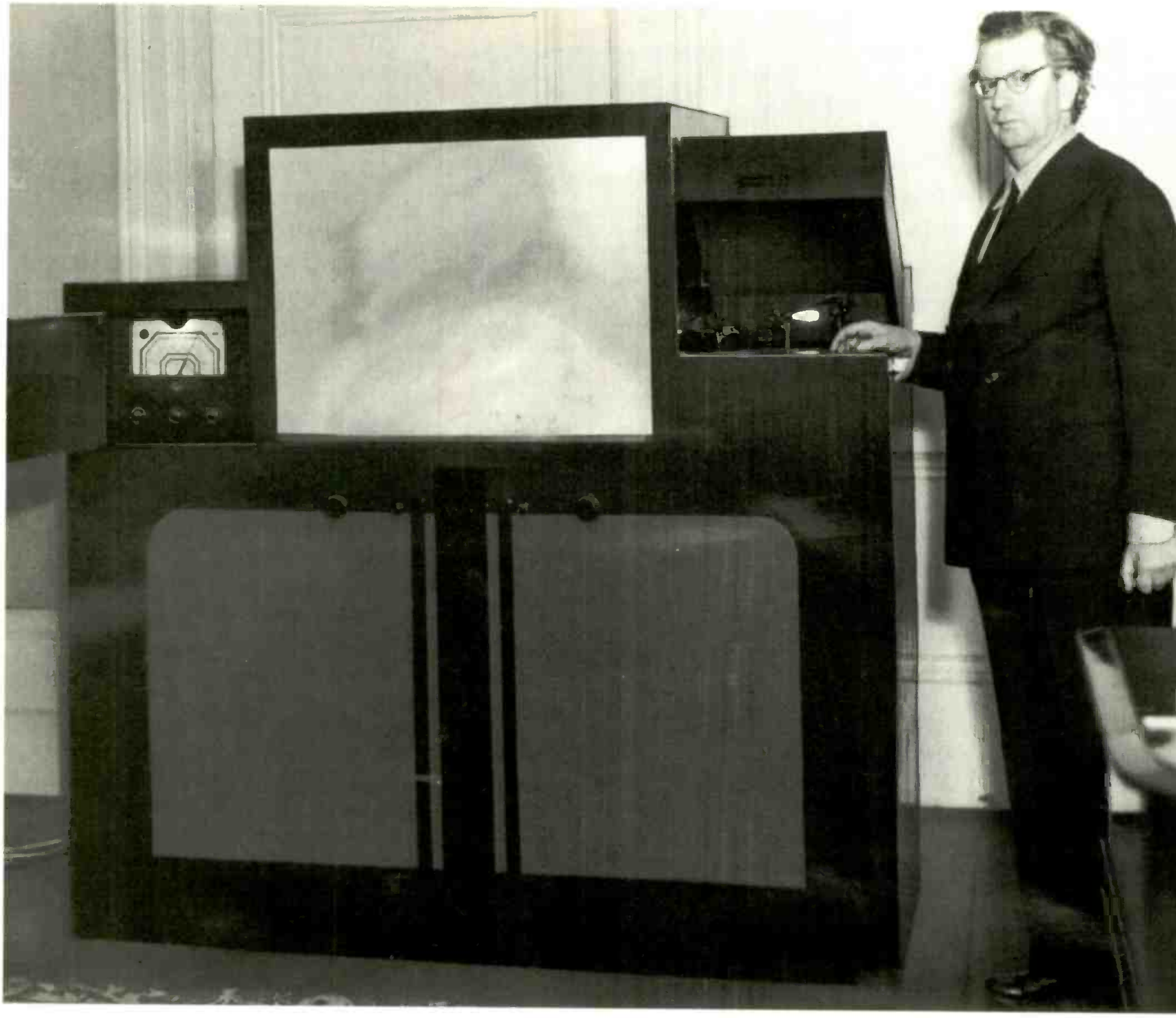
PC to VME link. Software from Compcontrol allows PCs and compatibles to work as real-time user interfaces to multiprocessor VMEbus systems running OS-9. Communications use TCP/IP (transmission control protocol/internet protocol). The system can be linked using IEEE802.5 Token ring hardware, Arcnet, Ethernet, RS232/422/485 serial interfaces, and VMEbus backplanes. Compcontrol, +31 040 414025.

X-Window port. Compcontrol has released an X-Window port to OS-9 (68020 and 68030), making the user-friendly communication style of the X-Window system X11.4 available for real-time control. Several processes can be displayed on screen simultaneously, which means more virtual terminals on a single X11 screen. Compcontrol, +31 040 414025.

Netlist translator. Quickpath translation program gives IC designers fast access to prototypes through graphics systems such as Mentor Graphics, LSI Logic, Viewlogic and other cae systems. It translates them into a data format used for the physical layout. There are two translators — a netlist translator and a simulation data translator. Both run under the MS-dos user interface. Eremue Associates, 0983 760377.

Routing and editing. Ares routing and editing software ranges from budget level schematic drawing and PCB drafting to high power schematic capture, autorouting and back-annotation. Basic packages can be upgraded without problems of porting designs from one system to another. It has design rule check, connectivity check and highlight, power plane generation, and EMS memory support. Labcenter Electronics, 0274 542868.

Design updates. Pads-PCB version 4.0 and Pads-Logic version 2.0 are available from Lloyd Doyle. Pads-PCB 4.0 new graphics and user interface has simplified data entry through pop-up menus, a user definable command macro language, and support for VGA, Elsa and Metheus graphics cards. There is support for H-P and Postscript laser printers, parts library database with over 600 standard parts, networking support, on-line part editing, library shape browsing, and a data resolution better than 1μm. Pads-Logic 2.0 also has the graphics interface, plotter outputs and library capabilities, better hierarchy support, the ability to create and edit complex data buses, and netlist outputs to Valid, Mentor and Dazix PCB design systems. Lloyd Doyle, 0932 245000.



John Logie Baird with the 1940 38in colour television receiver, which had the means to receive BBC transmissions and contained an automatic-changer radiogram in the one cabinet.

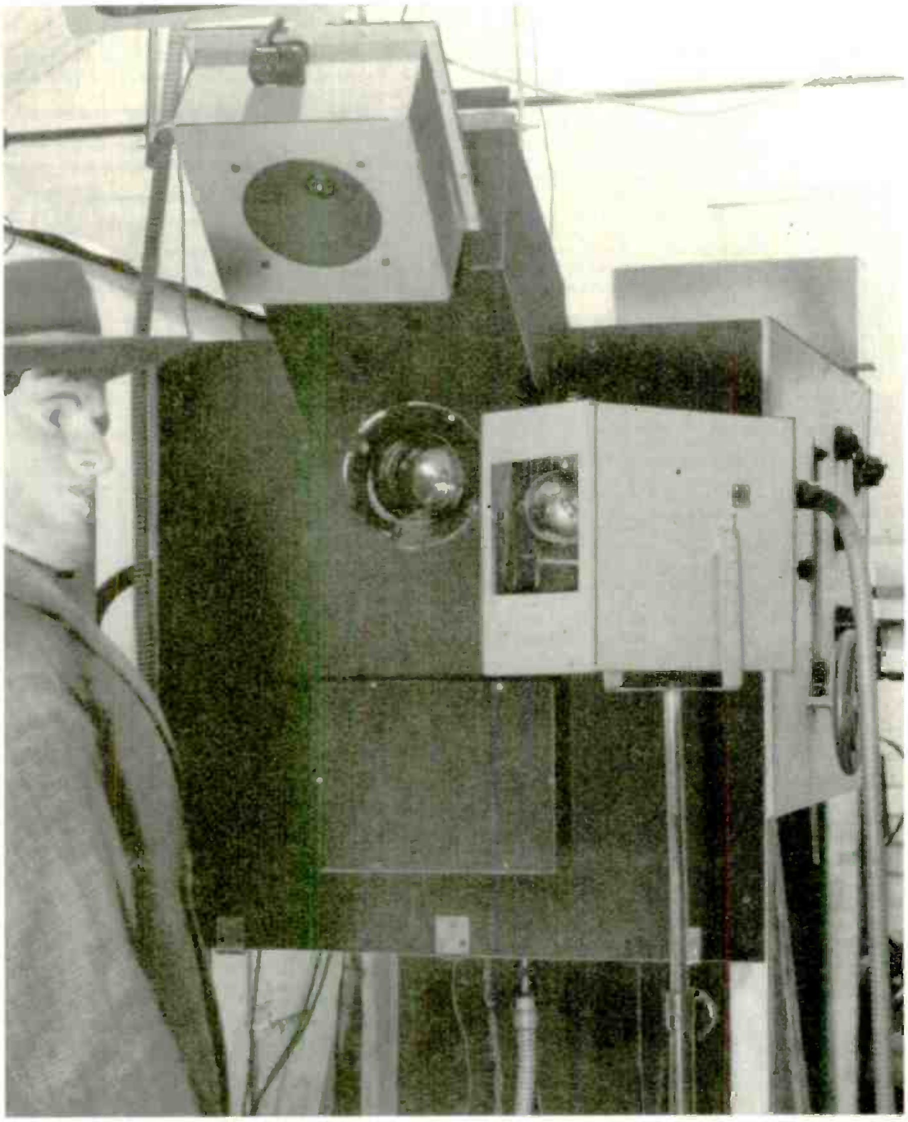
BAIRD — FIRST WITH COLOUR

John Logie Baird was not well in with the Establishment. His work was usually looked upon with a certain amount of suspicion, even when it worked without fault in demonstration — and it did not always rise to the occasion.

But there was no doubt about the demonstrations of his colour television system on July 27, 1939 and December 20, 1940. On both occasions, the equipment worked perfectly and, in the later demonstration, to a higher standard than the BBC used for its 405-line black-and-white transmissions.

Baird had first shown colour television at a British Association annual meeting in Glasgow in 1928, both that and the 1939 equipment using at one or both ends of the system the mechanical Nipkov disc scanner that had rightly given rise to many of the misgivings. He did finally manage to make the scanning system synchronise properly over a reasonable time, but it was clear to most observers that it would never make the grade in commercial use.

In 1940, therefore, he used flying-spot scanning at the transmitter and a CRT for display, although the colour was obtained by means of another, different kind of spinning disc. This time, Baird showed a 600-line picture on a 2ft by 2ft 6in projection screen in what was described by our observer as "full natural colours". Not content with the colour television, he also put a radio receiver, BBC-compatible black-and-white television reception and a record-player with an automatic record-changer in the same cabi-



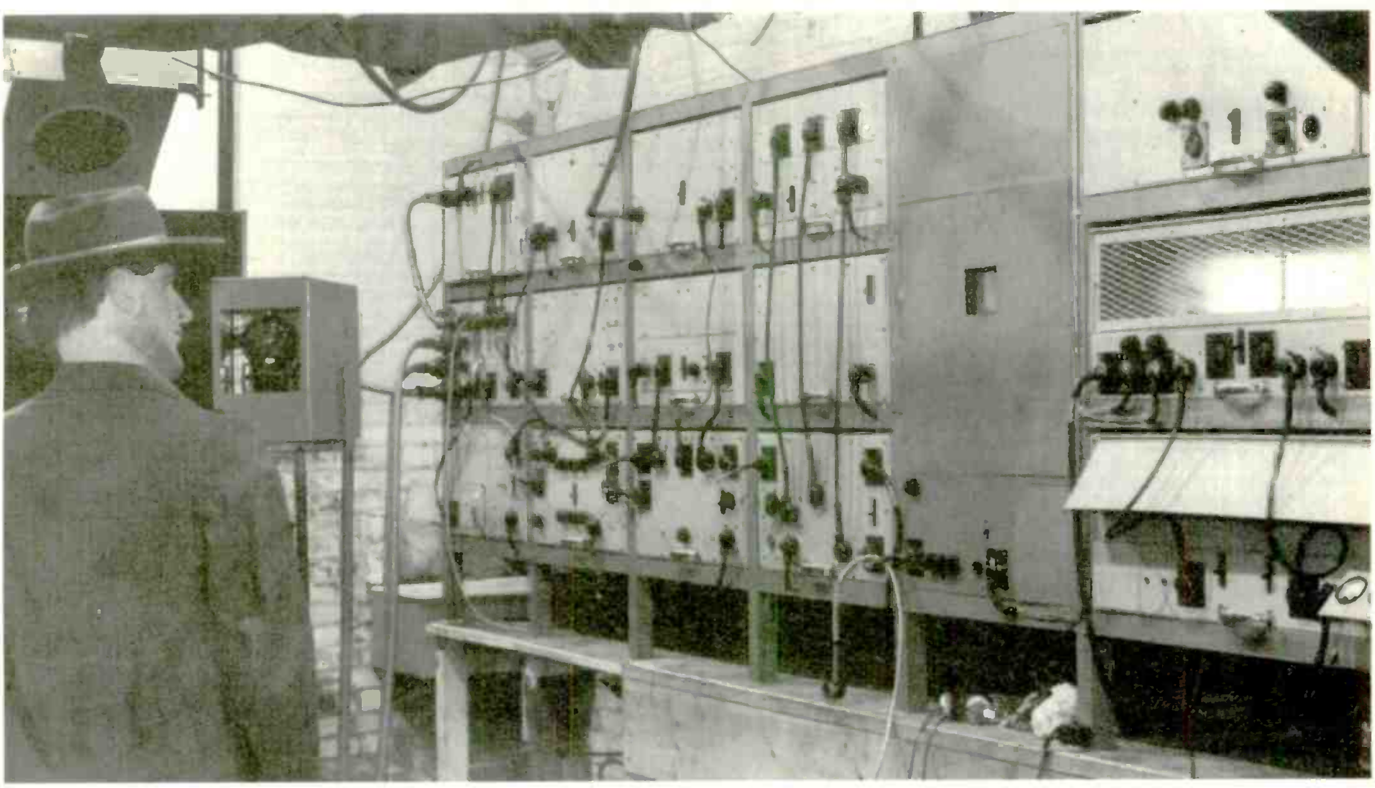
One of Baird's somewhat bewildered-looking dummies in front of his colour scanner. The restricted movement available to the subject would have made for a wooden performance. In the centre is the lens to focus the scanning spot onto the figure, the sloping box over its head being the photocell.

net — and all this in war-time, since he maintained that if Britain abandoned development work on television for the duration, our leadership in the field would be lost.

The diagram shows Baird's system. Light from a flying spot goes through a spinning colour disc, is focussed on the subject and reflected from the subject onto a photocell. Only red and blue-green sectors were used on the disc, since Baird claimed that these two gave the same effect as RGB sectors. At the receiver, the reverse procedure was followed, transmitted sync pulses keeping transmitter and receiver discs in step. The picture was produced by a mirror reflecting the focussed output of the tube after it had passed through the colour filter onto a projection screen. To convert to the BBC standard, he simply by-passed the disc and changed scanning frequencies by means of a single push-button.

In our February, 1940 article, the picture was described as being "of more than adequate brilliance" and colour values were rendered with "a degree of truth comparable with Technicolor films" ■

Another view of Baird's premises in Sydenham, this being the transmitter control and power supply. The little square aperture in the middle of the large panel is the screen of a colour monitor receiver.



HIGH POWER AMPLIFIER For your car, it has 150 watts output. Frequency response 20HZ to 20 KHZ and a signal to noise ratio better than 60db. Has builtin short circuit protection and adjustable input level to suit youe existing car stereo, so needs no pre-amp. Works into speakers ref 30P7 described below. A real bargain at only £57.00 Order ref 57P1.

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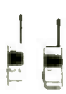

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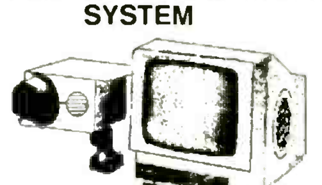
VIDEO AND AUDIO MONITORING SYSTEM



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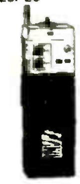

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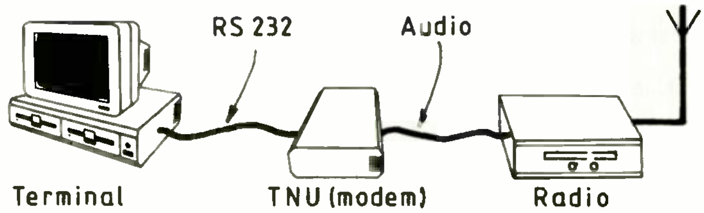
Packet radio poised for major comms role

Growing activity by regional and national organisations to introduce microwave backbones making more effective use of nodes and mailboxes could mean packet radio will at last take off as a powerful communications system. This very positive view of the development of packet radio was put forward by Captain D J Burden describing in *The Journal of the Royal Signals Institution*, the growth and structure of the amateur radio packet network in Southern England.

Amateur radio has so far been the main user of packet radio (AX.25) technology but the system is gaining greater attention from commercial, military and government agencies and is currently a contender for the data bearer of the Ministry of Defence "Bowman" project.

Even within the amateur community the system is seen as becoming more structured and organised and heading towards implementation of large on-line databases. Access will be possible through gateways to other existing electronic mail systems and very fast live links, potentially extending worldwide through fast satellite store-and-forward repeaters (PacSat).

Moreover more people are recognising that while packet radio does not always appeal as a primary mode of communication to those wedded to more traditional amateur radio modes such as speech and manual CW (morse), it is well suited as an auxiliary, practical method of providing a data communications network capable of exchanging a great deal of information and linking home computers.



Packet radio mailbox: for global communication?

	Flag	Address	Flow control	pid	Information data	FCS	Flag
BYTES	1	14 or 70	1	1	up to 256	2	1

pid Protocol Information Data

FCS Frame Check Sequence

Address is 14 bytes when only sender/addressee callsigns are used and 70 bytes for up to eight routing callsigns

Format of the AX.25 packet .

The detailed description by Captain Burden of the development of the amateur radio packet network in Southern England — including the mailbox and network node (GB7SIG) of the Royal Signals Amateur Radio Society at Blandford, Dorset, and links to the satellite uplink terminal at Surrey University — appears in the Winter 1990 issue of the *JRSI*.

Burden points out that while during the 1980s, the amateur packet networks developed on a fairly uncontrolled basis with relatively little system management, this is now changing with regional and national organisations seeking to introduce microwave backbones that will make the use of nodes and mailboxes more effective.

The 1200bits-per-second (bps) speed on VHF/UHF is being augmented with trunks having 9600bps modems for user access, and up to 56kbps along trunk lines. While most UK packet links have been on 144.650Mz, some are changing to the 70, 432 and 1296MHz bands .

Perhaps the least successful aspect so far has been the long-distance HF packet links; in theory these have much to offer for international links but often fail to deliver because of the low level of error detection employed and the AX.25 ascii protocol which rejects all packets containing errors.

On HF, the 32-character Amtor Baudot/Murray ARQ rtty, system has proved very much more effective. Currently

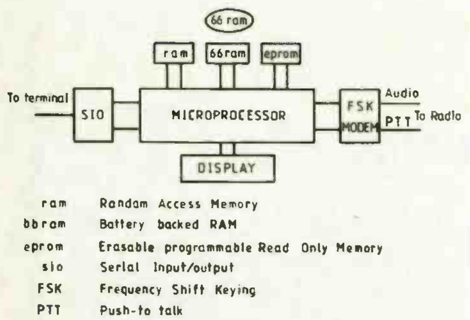
DEVELOPMENT

Packet radio (X.25 protocol) was originally developed in the 1970s at the Xerox Palo Alto Research Center (Parc) to link, without wires, computers and terminals in local and wide area networks.

Commercial support was slow in coming but it was soon taken up and developed for use on HF as well as VHF by a number of North American radio amateurs. Its value for store-and-forward mini-satellites was later recognised at the University of Surrey, investigating the feasibility of using a hand-held VHF transceiver to send a message from the UK to almost anywhere in the world.

Packet radio is proving very attractive to organisations, such as the US Forestry Service and disaster relief agencies, working in areas where a full communication infrastructure does not exist.

The ability to mix HF and VHF/UHF links, and to use the network and mailbox facilities, combined with transportable and even portable stations can be invaluable. Transition from the amateur world into the commercial world is likely to dominate packet radio development in the 1990s, especially since licensing of a number of national commercial packet radio networks by the DTI in 1989.



Building blocks of the basic node controller.

the US government is encouraging and partly funding US amateurs, through the ARRL, to develop a more robust HF packet protocol for use by some of its agencies.

Even for VHF/UHF there are some operational problems with the standard AX.25 protocol, though some of these are minimised in the PacSat protocols. Packet collisions occurring through greater use of a channel can be reduced by modems that wait longer between each transmission as a channel becomes busier.

Rejection of all corrupted packets means that the user does not see the packet on screen unless it is received perfectly and the modem is unable to overlay succeeding retransmissions.

The standard protocol does not provide conference/broadcast facilities but only one-to-one links: but these facilities are catered for in PacSat.

With a simple "digirepeater", the intermediate relay does not carry out any error checking and where several such relays are used, there is a high likelihood that the packet reaching the far terminal will be corrupted. Use of "nodes" rather than "digirepeaters" is helping tackle this problem.

Nodes have either dedicated stand-alone modems, or standard modems connected to microcomputers running special software (usually multitasking). They not only relay the data but also carry out error detection/correction and routing functions and thus form an essential part of a National Traffic System.

The standard "mailbox" comprises a dedicated microcomputer usually with a hard disc drive, acting as a store-and-forward message switch for a large number of users. Personal mailboxes may have an answerphone facility built into the modem.

Modems for packet radio in amateur practice are usually termed TNC (terminal node controller) and many of the TNCs now offered on the amateur-radio market are multitasking, allowing the station operator to use other modes such as morse (with automatic decoding), rtty., radio telex, facsimile on HF as well as packet on HF and VHF. Since the modems function with audio tones to/from the transceiver, no modifications are needed to standard amateur transceivers.

Capt Burden believes that packet radio represents a novel and potentially powerful communications system. But as he says: "That almost all this work and development has been carried out on a voluntary and generally uncoordinated basis makes the achievement of a global electronic mail system quite remarkable." ■

Dashing to right the record

The recent 200th anniversary of the birth of Samuel Morse brought forth a spate of articles, special issues and special events in the amateur-radio world.

But few noted that many historians now recognise that it was Morse's partner, Alfred Vail who first conceived and devised the alphanumeric "Morse" code, based on using the shortest symbols for the most frequently used letters, as part of a printing telegraph system. Early operators found that the sound emitted by the receiving instrument when energised was distinguishable from that when released and it was they who, in practice, turned the Morse/Vail system into a manual audio code.

The original code proposed by Morse was for transmission of numbers-only, for use in conjunction with a code book of phrases.

It is highly likely that Vail's code will still be in use, if on a reduced scale, well into the 21st century. But I wonder how many will be celebrating the 200th anniversary of the birth of Alfred Vail on 25 September 2007?

Youth support sought for amateur radio

Amateur radio has made a bid to inject fresh blood into its ranks with the establishment of an examination aimed at encouraging the younger enthusiast. The first City & Guilds examination for the new UK amateur radio Novice Licence was held in June for candidates who had completed an RSGB instructional course.

Novice Licences are available to persons of any age, but the licence is intended primarily to encourage more youngsters to enter the field, especially those under 14 years old, too young to qualify for existing Class A or Class B licences.

Examinations for Novice Licences will be at a rather lower level than the standard Radio Amateur's Examination and a Morse test at five words per minute (instead of 12wpm) will give access to limited HF facilities with no Morse test required for the VHF licence.

Novice licences were first proposed for the UK around 25 years ago and their introduction now is seen as an attempt to overcome the "ageing" of the hobby apparent in many countries with a rapidly rising percentage of amateurs over 55 years old.

The US has also introduced a "codeless" licence for VHF/UHF akin to the Class B licence in the UK since the mid-1960s in response to the belief that manual Morse code (CW) operation is of declining interest — a belief that tends to be hotly disputed by those who continue to find this mode offers a unique fascination once proficiency has been gained.

Annual cost of a DTI Amateur Radio Licence in the UK has recently been raised from £12 to £15, which most amateurs regard as not unreasonable.

Fees have never been demanded for amateur radio licences issued in the US by the FCC, but a fee proposal for US fiscal year 1990, which failed to be ratified by the Congress, has been re-introduced among the proposals for FY1992.

The proposal is to impose user fees amounting to $65million for a variety of radio users,including $2.91million from amateur licences.

Applicants for new or renewed (10-year) licences would be charged $30 — $3 per year.

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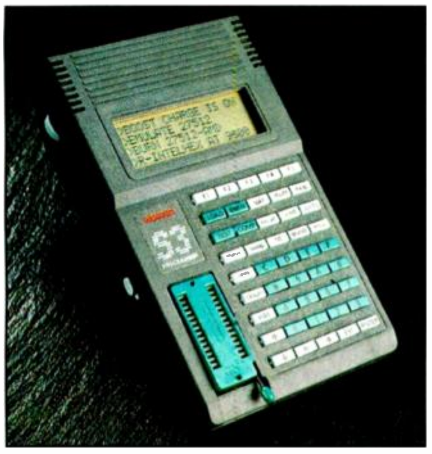

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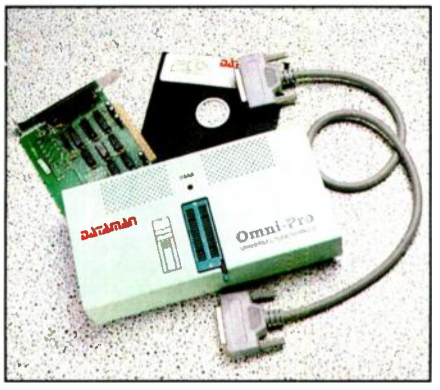

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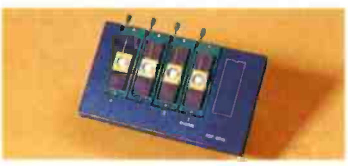

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DEVICE GUIDE	PC82	PC84
EPROM N/CMOS 2716-27010 (1 mBit) Vpp 12.5,12.9,21,25	√	√
EPROM 27513,27011,572000/4000,8764-87256,CYC2XX SERIES	√	—
EEPROM 2816,2816A,2817,2817A,2864A	√	√
EEPROM 9306,9307,9346,9356,93CS06,26,44,56,66,28256A	√	—
BPROM 32×8 to 4096×8, incl. 63S080,7C28X,29X.	√	—
PAL 10,12,14,16,18,20-L,R,X,P,1,2,4,8,10 (20&24-pin)	√	—
GAL 16V8,18P8,20V8,22V10	√	—
EPLD 20G10,22V10, EP310,320,600,610,900,910,5C031,32,60,90	√	—
CMOS EPAL C16L8,R8,R6,R4,C18V8,C20G10,L8,R8,R6,R4, C22V10	√	—
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