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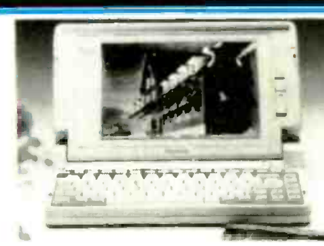

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# History is bunk?

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Looking back over the years, one might be easily forgiven for thinking that the Luddites were right. The history of electronics is a fascinating story, a mix of science and pragmatism where physicists Hertz and Maxwell laid down challenging hypotheses which were eagerly taken up by practical experimenters.

The likes of Marconi, Round and Fleming were full of optimism about their new toys. They saw only the benefits – and of course the financial rewards – promised by the technology. It appears that they never gave a moment's thought to the possibility that their inventions could be anything other than benevolent.

The politicians of the day took a broader view. They saw how long-distance communications could be used to build the Empire. Marconi's beam stations provided reliable links over which instructions to the local High Commission could be relayed and acted upon within hours. The response could be equally swift. Long after we granted this plundered warehouse its independence – an act for which nobody was grateful since it was never ours to take in the first place – we maintained our dominance in the third world through a yoke of debt, mostly incurred by the former empire in the purchase of trivial technology.

The Northern hemisphere persuaded the Southern half to sell its resources in return for arms and colour TVs. These two commodities were all that brutal, selfish regimes needed to oppress their populations; a television set sits in virtually every overcrowded room in every shanty town the world over. The torrent which pours out is always one of acquisition, false values and unattainable dreams.

This surely can't have been in the minds of the inventors whose efforts led to broadcast systems.

A cynic would find it hard to take comfort from the legacy of electronics. Computers shackle as many people as they free, automated production simply finds quicker ways to consume scarce world resources while mass communications displace individual ideas. This last misdeed is perhaps the most serious since we shall never know what we have lost.

In spite of this unpromising history, I personally believe that electronics still has much to offer. We look to it to reduce the vast appetite for world energy while computers have uses other than to automate Big Brother. Remote sensing satellites have much to tell about the way the planet deals with our refuse, about the manner in which the ocean currents influence climates and the global foodstore. Spaceborne electronics has a great deal yet to do and it is with pride that EW+WW reprints one of the most important papers in the history of electronics, "Rocket Relays" by Arthur C Clark, first published in the Autumn of 1945.

We learn from our past that we must apply conscience alongside technology: the combination stands a much greater chance of contributing to the greater good than technology alone. History is not bunk and on this, the 80th anniversary of *EW+WW* and in deference to Henry Ford, I am particularly aware of it. **Frank Ogden**

## Reader survey letter

Apologies to Frank Ogden are due. Many of you will recently have received questionnaires from the editor seeking your views on Electronics World. The document, which Frank Ogden was instrumental in creating, was subsequently infested with typesetting and printing errors. He was not responsible for these; please think no less of him and spare him your acerbity. **Robert Marcus**, publisher.

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# REGULARS

UPDATE

## Training investment "a priority" says IEE president

If Britain is ever to regain its position as a successful manufacturing nation, it must dramatically review its approach to the education and training of its workforce.

This was the message given by Mr Brian Manley in his inaugural address as president of the Institution of Electrical Engineers.

The present position, he warned, is unacceptable: "Our schools fail 50% of our children, the number of young people wishing to follow an engineering career is falling and we have one of the worst trained workforces in Europe," he said.

On the subject of secondary education the IEE president criticised a system that persuaded only some 19% of pupil to stay on at school to the age of 18 and called for an end to the partitioning of academic education and vocational education and training. "Our continuing failure to provide an adequate education to the large majority of our young people is nothing short of a national disaster," he said.

For students up to the age of 16, Manley advocated a single national curriculum incorporating both academic and vocational studies; a modular structure which would allow early leavers to "top-up" at a later date and a system of credit accumulation and transfer which would help children who move from one school to another.

Post 16 education, Manley continued, must move away from the present narrow system of A levels to a broader range of studies with the inclusion of vocational subjects.

Employers should also be legally required to provide day release to enable early school leavers to study for advanced qualifications. All these changes would require substantial increases in the number of teachers particularly in science and mathematics as "a matter of the utmost urgency".

On the issue of vocational training, Manley drew attention to the fact that Britain falls far behind nations such as Germany in the skills of its workforce. Some 60% of British workers possess no qualification of any kind.

"The link between productivity and the skill of the workforce is well established, he said.

Skill shortages have made the UK vulnerable to competiton from low wage countries making low margin products.

Mr Manley is a Partner in Manley Moon Associates, a Cambridge based management consultancy.

## CT-2: a dead line?

***The news that Phonepoint, last of the four original telepoint services, has been abandonned might seem to spell the death knell for CT-2. But it may yet survive.***

Twenty years from now when everyone is carrying around a personal communicator in their pockets, maybe a Trivial Pursuits question will ask what was the name of the first pocketphone? Perhaps the answer will be the CT2.

Friends will look on in amazement as you recall a pocketphone which would not receive calls outside the home and which would only work if you were within 200 metres of special green and blue triangles. Perhaps only the £200 price would have impressed them.

The world wants a telephone it can carry around in the pocket. But CT2 isn't going to be the one. It was strangled at birth by the prospect of new and more sophisticated competitors.

There can be little doubt that the British idea for a digital cordless telephone, the CT2, and the original plan of offering low cost mobile communications to everyone has landed on the rocks. Two and a half years after their introduction the pocket-sized handsets are a collectors' item.

Few retailers would stock models despite the obvious performance advantages of the digital technology over existing analogue cordless telephones. "If people were asking for CT2's we'd have stocked them. No one ever asked," said an assistant in one London telephone stockist.

CT2 and the low cost mobile communications it would offer has fallen foul of over inflated aspirations which had less to do with its technical capabilities and more to do with the government's desire to milk the booming mobile communications market of the late 1980s for all that it was worth.

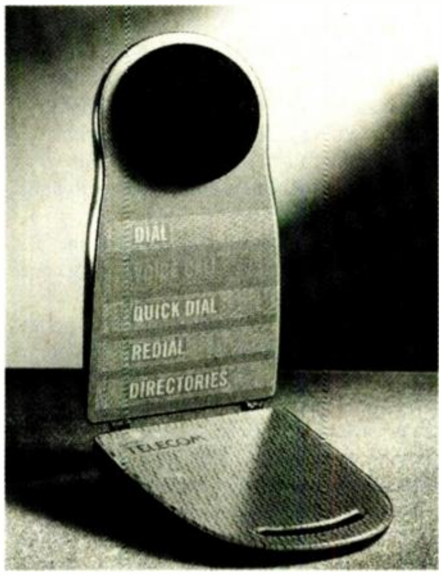
*CT-2 for go-anywhere communications: not yet ready to throw in the towel.*

The government's plan to offer mobile communications to the masses through launch of a new service called telepoint based on the CT2, like the cellular telephone only cheaper and less exclusive, nose-dived.

In 1989 four operators were licensed, three bravely launched services despite the lack of suitable handsets. The take-up of the service by the public was almost imperceptible and earlier this year two of the three were forced to scrap their services disappointing a small but faithful band of subscribers.

The last operator to offer a telepoint service was BT-backed Phonepoint and even it now admits that the original 1989 launch was severely premature. At that time says, Roger Best, managing director of Phonepoint, " a saleable product had not been created as it should." Phonepoint had planned a new launch for later this year with new handsets from US communications giant Motorola, lower prices and a £3m advertising campaign, now of course abandonned.

The future for CT2 may look dead, but the world's telephone manufacturers have not given up on it completely. American and Japanese manufacturers have at last




***There is no doubt the world wants a telephone it can carry round in the pocket. But no-one is yet sure what it will look like.***

recognised the CT2 for what it is. Not a revolution in mobile communications, but that first important technological step towards a pocket telephone which no one can afford to be without.

By the end of the century more sophisticated personal communicators will slip into our pockets. Like the British personal communications networks (PCN) operating in the empty spaces of the 1.8GHz frequency band or US systems based on digitally coded radio signals. These will have the capacity to support the tens of millions of users and literally billions of pounds will be spent on their development.

The CT2 has neither the technical capability nor financial backing to compete with PCN at the turn of the century. What it does have is a five or six year head start which means that it could still find its place as the preferred cordless handset for office PABX systems and in the home.

**Richard Wilson**

# HDTV hard sell to europublic

European electronics companies want to sell the public the new idea of widescreen, 16:9 aspect ratio TV sets as a stepping stone to HDTV. But they are adopting different compromises in the upgrade path.

Most want to see the mac system succeed. So does the European Commission, because if it fails, Europe's investment in the Eureka HDTV system, HD-mac, goes down the pan.

But crass mistakes made by the EC in past legislation left the satellite broadcasters free to transmit in pal. This guarantees a quick audience, but pulls the rug from under mac and HD-mac. So the EC is now trying to buy itself out of the hole of its own making with one billion ECUs of public money.

At the same time the terrestrial broadcasters want a widescreen, improved definition TV system which is compatible with conventional 4:3 pal. The electronics companies want to protect their interest here, too. But in developing the new system, pal Plus, they risk jeopardising their investment in mac and HD-mac.

These convoluted issues erupted into open conflict at the recent Funkaussustellung in Berlin. And, confusing the issue still further, technical problems at Berlin made demonstrations of wide screen mac less impressive than the first working demonstration of wide screen pal Plus.

By next year the Eureka 95 team will have spent over £500 million pounds on preparing an HDTV system for the Olympics. The Vision 1250 consortium, with 32 member companies and broadcast authorities, employs 1000 research engineers and is pledged to broadcast the Olympics to 1000 HDTV sets across Europe. This year, 1991, the EC will contribute 10 million ECUs to


***The ITV Association's HDTV production vehicle supplying material for the Berlin show EU95 Eureka demonstration.***

the Eureka EU-95 HDTV project. The Vision 1250 members each pay 40,000 ECUs a year.

The EU-95 HDTV system is a 1250 line version of the 625 line mac system developed for satellite. Peter Bogels, President of the EU-95 HDTV directorate, admits that the whole pack of cards will collapse if satellite broadcasters, like BSkyB, continue to transmit in pal. The EC's Directive of 1986 was intended to force all satellite broadcasters to use mac, but left loopholes for lower powered transmitters at lower frequencies.

"There was a flaw, a hole in the law, that let people start pal transmissions", said Bogels at Berlin. "Now we have to find a solution". Despite the magnitude of the EC's mistake no one in the HDTV directorate can say who in the EC was responsible.

EC Telecommunications Commissioner, Filippo Maria Pandolfi has been trying for a year to repair the damage. Recently he secretly met Rupert Murdoch, main shareholder in BSkyB in Brussels. In Berlin he joined with German Telecommunications Minister, Christian Schwarz-Schilling to announce the EC's latest plan. This doubles, to one billion ECUs, the amount of European tax payers' money available for simulcasting, simultaneous broadcasting of pal programmes in mac until January 1994. Any new broadcaster now starting in pal must switch to mac in 1994 and will not be paid the sweetener to simulcast.

Pandolfi has now asked a Working Group to report by 15 September to report on whether there will be enough satellite transmitters in orbit to cope with simulcasting.

German broadcasters ARD, ZDF, RTL Plus, Sat 1, Pro 7, Tele 5, Premiere and

VPRT have already started lobbying against Pandolfi's plan. At Berlin they issued a statement saying "No" to the proposal because "it is not fair for the EC to make this law, and not friendly for the consumer or for owners of satellites or receivers in Europe".

Although demonstrations of the 1250 line HDTV system at Berlin were impressive, parallel demonstrations intended to show how the HD-mac signals can also be received on 625 line wide screen "Cinevision" sets were disappointing.

No effort was made to explain why this was so to the million visitors expected to attend. In fact most demonstrators did not seem to know where their signals were coming from and why the 625 line mac pictures were fuzzy with ringing echoes on vertical detail.

Nokia vaguely blamed "the cable". Nordmende blamed the difficulty of satellite reception at the Berlin showground with other equipment causing echoes - clearly an absurd answer. Fortunately a Thomson engineer, seconded to Vision 1250, was able to explain all, clearly.

HD-mac programmes were uplinked from Berlin to the Kopernicus satellite, and received at Usingen.Berlin then received from TV-Sat. But the signals were distributed by cable round the enormous exhibition site. The distribution system uses the hyberband, a band of the German and French cable networks in the slot around 300 - 400MHz, which was previously unused because of fears that leakage would interfere with terrestrial services. With improved cable technology, this band has now been divided into 12MHz channels for HD-mac distribution.

The cable system at the Berlin exhibition site is far from perfect. Poor terminations introduce short group delay echoes. These were exacerbated when a mechanical digger cut through the cable the day before the show opened and the cable was clumsily joined. Whereas the digital equalisation circuits in a full-blown HDTV set can compensate for spurious short echo signals, other sets cannot.

Sadly, many visitors will have left the show wondering what all the fuss about mac quality is all about.

They will have wondered even more after seeing the first demonstration of a wide screen pal system, pal Plus, which Grundig, Nokia, Philips, Thomson and European broadcasters have been developing in parallel with HDTV. This gave better pictures than the mac demonstrations.

To avoid undermining mac's credibility, pal Plus designers stress that their system is intended only for terrestrial use. But they admit it could be used by satellites.

To transmit pal Plus, the broadcaster feeds a 625 or 1250 line wide screen signal through a filter. This reduces the number of picture scanning lines by a quarter. The remaining three quarters are transmitted as a picture which appears on a conventional 4:3 aspect ratio TV set as a letterbox picture, with black borders at the top and bottom.

To be more specific, of the 576 active lines making up the visible portion of a 625 line pal picture, 432 are left to define the 16:9 wide screen aspect ratio letterbox image.

The filtered information is converted into a digital "helper" signal, much like teletext. This helper code is buried in the black borders of the letterbox picture as a blacker-than-black signal which conventional tv sets treat as pure black. So the helper code is invisible on conventional sets, if correctly adjusted.

A pal Plus receiver will decode the helper signal and use it to rebuild a 625 line picture which fills the full area of a 16:9 wide aspect screen. Demonstrations given at Berlin prove that the "helped" signal is clearer than the original.

There is none of the cross colour patterning and shimmer that normally spoils pal pictures. The picture is bright and a lot sharper than conventional pal. On a 4:3 set the black borders show no signs of the helper signal. Resolution on the 16:9 pal Plus screen was better than on a 4:3 standard pal set receiving the same source signal.

So far the pal Plus encoders and decoders are the size of a refrigerator but the group promises integration into a set-top box by 1995. By a neat coincidence this is a year later than the "Big Bang" which Peter Bogels promises for HDTV. Thomson has also promised to integrate an HDTV decoder into a set-top box.

The depressing news all round was that punters at large seemed largely uninterested in any kind of 16:9 widescreen. Hopefully this was only because they were blinded by the light of the vast tiers of 4:3 sets that abound in Berlin. **Barry Fox.**

## Engineering add-on

In the review of the Electrical Engineering Application Pack for use with MathCad (October issue), supplier details were unfortunately ommited.

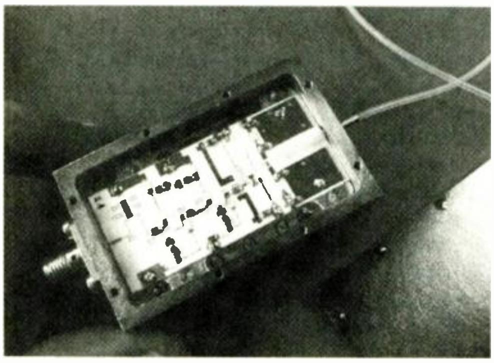
The pack (£75) and MathCad((£375) are both available from Adept Scientific, 6 Business Centre West, Avenue One, Letchwort, Herts SG6 2HB. Tel: 0462 480055, fax: 0462 480213.

# Optical heterodyne receiver tunes in thousands of channels

As part of the Race programme, Siemens has developed a low noise wide-band receiver for heterodyne optical communications.

Radio broadcasting made the transition from direct to heterodyne reception in the thirties and every effort is being made to duplicate this in optical communications. Heterodyne reception permits the use of more sensitive modulation methods and hence multi-channel operation with reduced channel spacing.

***The Siemens heterodyne receiver for optical communications. It uses a tuneable laser sto convert down to 140MHz.***



This increases the capacity of optical fibres more than a thousand fold.

Optical balanced receivers - such as continuously tunable laser diodes used as local oscillators - are key components for they largely determine the performance of optical heterodyne systems.

The heart of the receiver developed at Siemens' research laboratories in Munich is a chip on which two monolithic integrated photodiodes are connected in series. The optical input signal modulated by the local oscillator, via a directional coupler, is converted by the photodiodes into an intermediate frequency signal. The subsequent stages of the balanced receiver employ a three-stage high impedance circuit.

The first stage acts as a low-noise preamplifier for the output signal of the photodiodes. The second stage has an equalizer circuit to level the frequency response. The third stage matches the output impedance to 50Ω. The thermal noise – equivalent to a noise figure of 0.36dB in commercial RF amplifiers – was achieved without unwanted ripple in the frequency response curve.

The prototype module exhibited a sensitivity of -59dBm with a 140Mbit/s heterodyne system employing frequency shift keying. This performance is claimed to be only 2.5dB above the theoretical limit.

Initial results indicate that, at the present state of development, more than 1000 subscribers could be served by a central transmitter with broadband television services via fibre-optic systems and that the theoretically predicted increase in transmission capacity appears to be achievable.


*PL320K laboratory triple power supply*

*TS3022S laboratory dual power supply*

## PL320K laboratory triple power supply

This power supply from Thurlby-Thandar combines three, totally independent power supplies within a single unit: 0–30V at 2A, 0–30V at 1A and 4–6V at 7A for logic supply. The 30V supplies will operate in a bipolar tracking mode for ±30V operation or in a series mode to provide 0 to 60V output. Both supplies incorporate independent remote sensing and independent precision voltage/over-voltage/current-limit preset. Three 3 3/4 digit led panel meters indicate current and voltage to an accuracy of 0.05% fsd. Output stability is typically 0.01% for 90% load change. PL320K £359+VAT (£421.83).

## TS3022S laboratory dual power supply

This laboratory quality power supply from Thurlby-Thandar provides two fully floating 0–30V 2A outputs for parallel, series or independent operation. Each supply has its own metering of voltage and current by LCD display; with the output switch to off, the display can be used to preset the voltage and current limits prior to connection of the load. Coarse and fine controls permit output voltage adjustment to within 5mV of a predetermined value. The current limit control employs a log law for precise adjustment down to 1mA. Load regulation is typically within 0.01%. Both supplies incorporate remote sensing. TS3022S £299+VAT (£351.33).

## TD201 digital storage adaptor

The TD201 digital storage adaptor from Thurlby-Thandar is a low power, single channel digital storage unit which adds digital storage capability to ordinary analogue oscilloscopes. The maximum sampling rate of 200kHz permits fast transients to be captured while the lowest rate can extend the sampling period to over an hour. The unit stores over a thousand points on the X axis with 256 levels in the Y axis. The internal batteries (not supplied) allow data retention for up to four years.Other features include an AC/DC sensitivity down to 5mV, selectable pre-trigger, roll and refresh modes and a plot mode. The case measures 25 x 5 x 15cm and the unit weighs about 1kg. The TD201 provides the ideal solution for those wanting a well specified and easy-to-use DSO at the lowest possible cost. TD201 £195+VAT (£229.13)

*TD201 digital storage adaptor*


## How to order

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# How acoustic wave detectors may save the ozone?

Researchers at Sandia National Laboratories have developed a prototype sensor system to allow them to detect and measure gaseous chemicals almost instantaneously. The team hopes to use the technology as the basis for a portable sensor system for monitoring ozone-damaging chlorinated hydrocarbons.

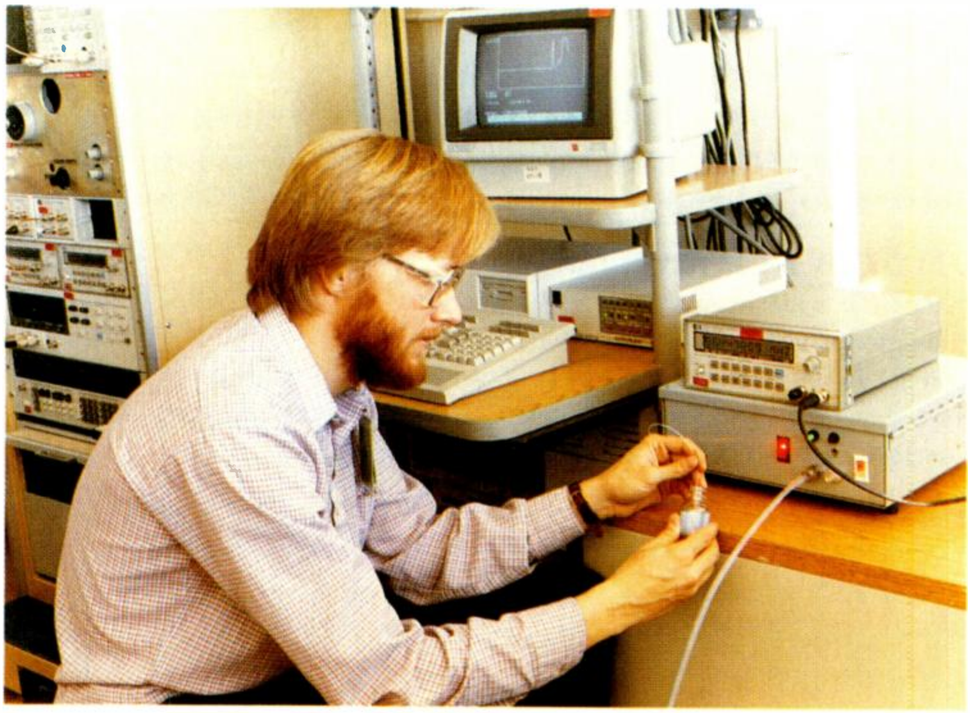
Sandia's sensor is based on coated surface acoustic wave (saw) devices, a relatively new class of sensors that measure the behaviour of acoustic waves in solids. When acoustic waves interact with solids, liquids or gases, their properties are altered in measurable ways that can provide information about the materials that the waves encounter.

Engineers have devised a way of analysing data obtained from saw devices that identifies chemicals of interest more quickly and easily. They do this by obtaining two independent responses from a single sensor and then analysing the two responses to produce a unique "signature" for a specific chemical.

Surface acoustic wave devices consist of two interdigital transducers formed on a piezoelectric substrate such as quartz. When an alternating voltage is applied to the input transducer, an alternating mechanical strain is generated, launching the acoustic wave. The wave travels along the surface, interacting with a thin film formed on the device surface before being converted back into an electrical signal by the output transducer. If the film has absorbed chemicals from the surrounding environment, the velocity and/or attenuation of the acoustic wave will be altered.

Prior to use, a coated saw device is calibrated by simultaneously monitoring wave velocity and attenuation as it is exposed to a range of concentrations of various chemicals of interest. Because the responses are independent, each chemical generates a unique set of values when attenuation is compared to velocity. Once a chemical is identified, a comparison of either the velocity or amplitude shift to the calibration curve for that substance can be used to determine concentration.

Using saw sensors coated with polymers, the team is developing aportable sensor system to monitor ozone-damaging chlorinated hydrocarbons. The system has also been used to identify organics such as toluene, acetone, methanol, ethanol, isopropanol and hexane – chemicals commonly used in industrial processes.



*Using an acoustic wave sensor's ability to detect methanol in real-time.*

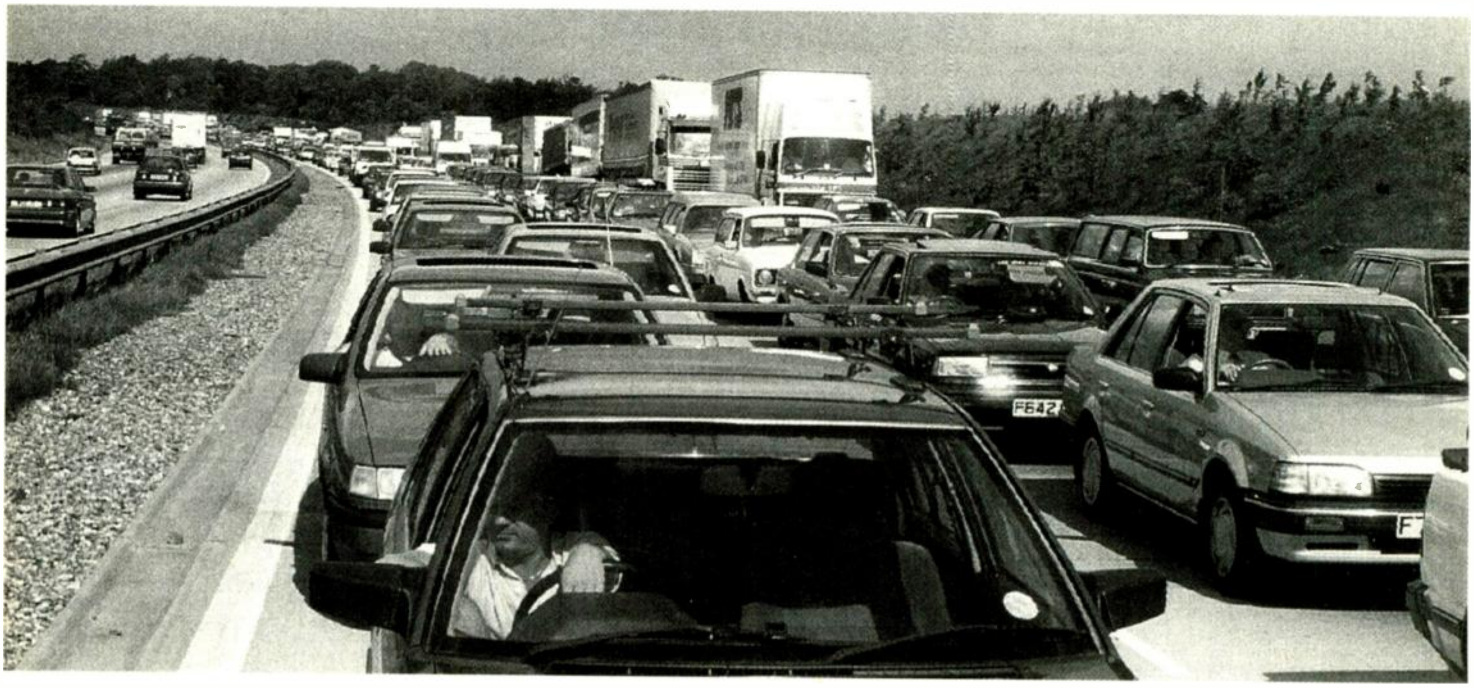
# Solving traffic jams with zener diodes

Why does the building of a bypass road too often result in worsened congestion when the obvious effect would be an improvement? Two US researchers may have cast some light on this annoying paradox of urban living – by looking at peculiarities of certain electric circuits.

Joel Cohen of New York's Rockefeller University and Paul Horowitz of Harvard describe an electrical analogue (*Nature*, Vol 352 No 6337) where the removal of a component actually reduces its impedance. This is not, as you might be imagined, some clever trick with tunnel diodes, but a very simple arrangement of very ordinary (if somewhat idealised) components.

Take **Fig. 1a**, a bridge arrangement of 1Ω resistors and 1V zener diodes. Being symmetrical it can be thought of as two paralleled diodes in series with two

*CIRCLE NO. 129 ON REPLY CARD*



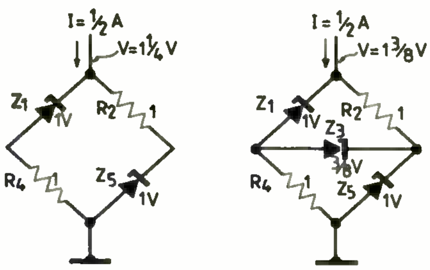
paralleled resistors. If a current of 0.5A is passed through the network the diodes will drop 1V and the parallel resistors will drop 0.25V. Total voltage drop amounts to 1.25V.

Now add a zener of 0.375V across the arms of the network (**Fig. 1b**) and see what happens. Experience suggests that ANY extra component would have the effect of reducing the voltage drop across the network. In practice, the reverse happens and the voltage rises to 1.375V.

What actually happens is that the 1V zeners in Fig. 1b do not conduct at all. All the current flows through the two 1Ω resistors and the 0.375V zener.

At half an amp, this amounts to 0.5 + 0.5 + 0.375 = 1.375V

***Experience suggests that adding an extra component will reduce the voltage drop across the network. In fact it rises.***




(a) (b)

Cohen and Horowitz point out that such counter-intuitive puzzles exist right across the spectrum of physics wherever non-linear components are found, including thermal and hydraulic systems.

Where it does not apply is in all-linear systems; purely resistive systems behave exactly as expected according to Kirchhoff's Laws.

But – and this is the interesting point – the paradox results do apply to traffic flow which, in many respects, is a perfect analogue of electron flow in wires.

The authors cite earlier work showing that non-congested traffic behaves like a current flowing through a linear resistor, while congested traffic turns the road into a decidedly non-linear impedance.

So if you take a congested city network and build a relief road or a bypass, the congestion may end up being worse than before! You may be doing to the existing network exactly what the 0.375 zener diode is doing in Fig. 1b, increasing traffic flow impedance. Cohen and Horowitz do not attempt to provide any easy answers to modelling traffic flow. But they do warn against assuming that physical networks will behave in the way common-sense appears to indicate.

The next task is to find a way of specifying the general conditions in which such paradoxes can occur.

# Super clean chips are green

A method for drying silicon wafers and glass plates, devised at Philips Research Laboratories in Eindhoven, could open the way for ultra-clean chips with no environmental effects. The method relies on the Marangoni effect where the flow along a liquid surface is induced by local variations in surface tension, due to a gradient in either temperature or concentration along the surface. Marangoni drying is of particular interest in IC production, where there are extreme demands for cleanliness, becoming increasingly more severe with the ever shrinking IC dimensions.

Manufacturing methods in the modern electronics industry for products such as ICs, liquid crystal displays and printed circuit boards, often rely on wet processing steps, usually ending with rinsing in water and subsequent drying.

During drying, dissolved or dispersed contaminants occurring in even the purest water, are left on the product's surface, with detrimental effects to further steps and final product quality.

A product withdrawn from a water bath after rinsing, is covered by a water film of about 10μm thickness.

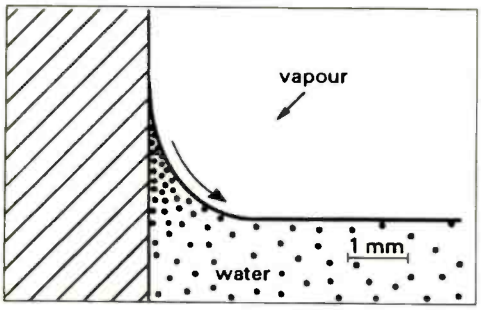



*Fig. 1. Using a vapour of water-soluble organic compound directed at the product surface to absorb water.*

Conventional spin drying reduces this film thickness by a factor of about ten, but the equipment usually generates small contaminating particles that are deposited on the surface. The method may also lead to stress-induced damage of fine surface structures.

But when a vapour flow of a water-soluble organic compound, such as isopropyl alcohol, is directed at the product surface at the point where it emerges from the rinsing bath, the vapour will absorb in the water. This leads to a larger concentration increase at the top of the meniscus (against the product) than further down where the dissolved vapour can more easily diffuse away from the surface.

The concentration gradient set up along the meniscus results in a surface tension gradient, in turn, inducing a Marangoni flow of water back into the rinsing bath.

Marangoni drying does not result in environmental pollution, consumes little energy and, when an organic compound with a low vapour pressure is used, does not require expensive safety measures. But most importantly its application warrants the highest yet attainable level of cleanliness.

# Ulysses uses radio to probe sun's atmosphere

Investigations of the sun's fiery outer atmosphere intensified when the Ulysses spacecraft passed behind the sun earlier this year. Ulysses, which is slightly above the plane of Earth's orbit, appeared to pass just above the sun and radio waves transmitted from the spacecraft travelled through and became distorted by the innermost region of the-corona.

While interference from the conjunction temporarily degraded communications with the spacecraft, the alignment created an ideal situation for radio science experiments, according to Dr Edgar Page, ESA science coordinator.

At closest approach, the signals from Ulysses crossed through the sun's corona at four solar radii, almost three million kilometres from the centre of the sun. Scientists are interested in studying the innermost layers of the corona, where gases are particularly thick and dense. Subtle changes in the character of the radio waves reaching Earth from the spacecraft can provide information on the hot gases through which the waves have passed.

The solar corona experiment, one of two radio science experiments using the spacecraft's two radio transmitters, is studying the density, velocity and turbulence of the solar atmosphere.

Dr Michael Bird of the University of Bonn, Germany, is the experiment's Principal investigator.

This radio probing of the corona has provided an opportunity to obtain information in solar regions where no spacecraft has previously flown, a flight path which is particularly favourable scientifically because the radio waves travel through a region of the corona in which the solar wind is thought to originate.

The mission operations team at the Jet Propulsion Laboratory reported routine manoeuvring of the spacecraft was not possible for about 15 days during the solar conjunction. The spacecraft was therefore placedin a mode to operate autonomously during the conjunction. The automatic conjunction mode allowed the spacecraft to carry out pre-programmed computer instructions necessary to maintain normal housekeeping operations.

Ulysses is presently travelling just above the ecliptic plane – the plane in which the Earth and sun orbit – on its way to Jupiter.

On 8 February 1992, the spacecraft will fly by the planet at a closest approach of about 375,000 km. above the cloud tops, using the gravitational pull of Jupiter to swing Ulysses out of the ecliptic plane and onward to the poles of the sun.

Ulysses, a five-year mission to study the poles of the sun, is managed jointly by Nasa's Office of Space Science and Applications and the European Space Agency. The spacecraft will begin its primary science objectives in June 1994, when it reaches 70° south solar latitude.

# The unseen attraction of VDUs

A thought-provoking contribution on the subject of VDUs and their possible health hazards has recently been provided by Walter Wedberg of the University of Bergen in Norway. Writing in *Nature* (Vol 352 no 6332) he points out that the electrostatic charges associated with CRTs not only attract particles and aerosols to the screen, but also to the operator's face.

What is significant about this is that such electrostatic fields can negate the protective effect of thermophoresis – a repulsive force due to temperature gradients near the skin. Wedberg's own research conducted in Norwegian offices shows that a combination of the charge on a VDU screen and triboelectric (frictional) charging can lead to electrostatic charges of around 100V/cm near an operator's face.

Since most airborne particles carry some sort of charge, the inevitable consequence of this is that particles are attracted quite strongly to the operator's face. Wedberg has analysed such particle deposits with an electron microscope and found them to vary in size from 0.05μm to 100μm. Deposition rates are, moreover, some five times greater on a charged surface compared to an identical neutral surface.

Wedberg's hypothesis is interesting because it could tie in with suggestions from other workers that alpha-radiation from radon decay products is responsible for some of the health complaints associated with VDUs. If the claims relate to particles electrostatically attracted to the screen, then it would be easy to dismiss such claims; alpha-radiation after all has only a tiny range compared with the usual distance between the screen and the operator. If, on the other hand, the alpha-emitting particles are located on the operator's actual skin, then the argument becomes much more plausible.

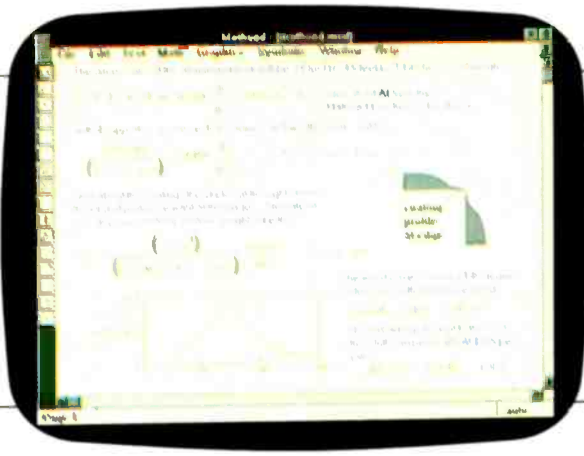
Wedberg concludes by suggesting that if static electricity can have such a powerful influence in negating the protective effects of thermophoresis, it may well influence human health to a greater extent than has hitherto been recognised.

A point not mentioned by Wedberg, but one which amplifies the force of his argument is the thought that harmful airborne particles include not only alpha-emitters but also a whole host of viruses, bacteria and allergens such as pollen.

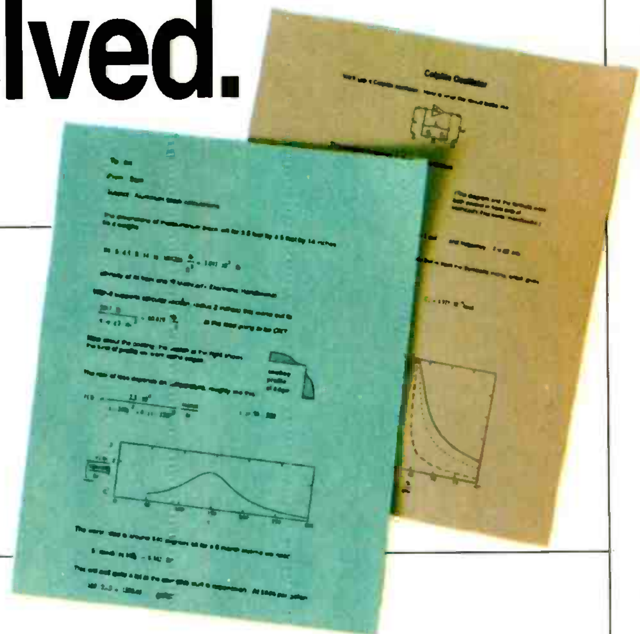
What then is to be done? Two thoughts come to mind: first what about re-examining the much-debunked ioniser which does at least reduce charge levels? Secondly, if Wedberg is right about particles adhering to the skin, what about the simple expedient of regular visits to the washroom?

**John Wilson** ■

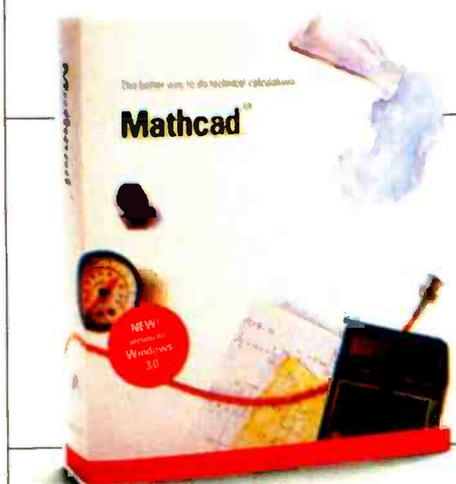
# Calculations.

# Solved.



# Easy.

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### Can Rocket Stations Give World-wide Radio Coverage?

*Arthur C Clarke*

# Extra-Terrestrial Relays

*In October 1945 Wireless World (as Electronics World + Wirless World was then called) published an article which broached for the first time the idea of satellite communications. Written in clear and concise language by innovative thinker and scientist Arthur C Clarke, the article caused a sensation when it appeared. At that time the V2 rocket was leading edge technology and there was as yet no direct experience of radio waves passing between earth and outer space.*

*As part of the celebration of EW + WW's 80th Anniversary, and as probably the most famous article ever to have appeared in our pages, we have decided to republish that original article in full. Our hope is that readers can once again sense the pioneering excitement of Arthur C Clarke's question: "Can rocket stations give world-wide radio coverage?".?*

Although it is possible, by a suitable choice of frequencies and routes, to provide telephony circuits between any two points or regions of the earth for a large part of the time, long-distance communication is greatly hampered by the peculiarities of the ionosphere, and there are even occasions when it may be impossible. A true broadcast service, giving constant field strength at all times over the whole globe would be invaluable, not to say indispensable, in a world society.

Unsatisfactory though the telephony and telegraph position is, that of television is far worse, since ionospheric transmission cannot be employed at all. The service area of a television station, even on a very good site, is only about a hundred miles across. To cover a small country such as Great Britain would require a network of transmitters, connected by coaxial lines, waveguides or VHF relay links. A recent theoretical study[1] has shown that such a system would require repeaters at intervals of fifty miles or less. A system of this kind could provide television coverage, at a very considerable cost, over the whole of a small country. It would be out of the question to provide a large continent with such a service, and only the main centres of population could be included in the network.

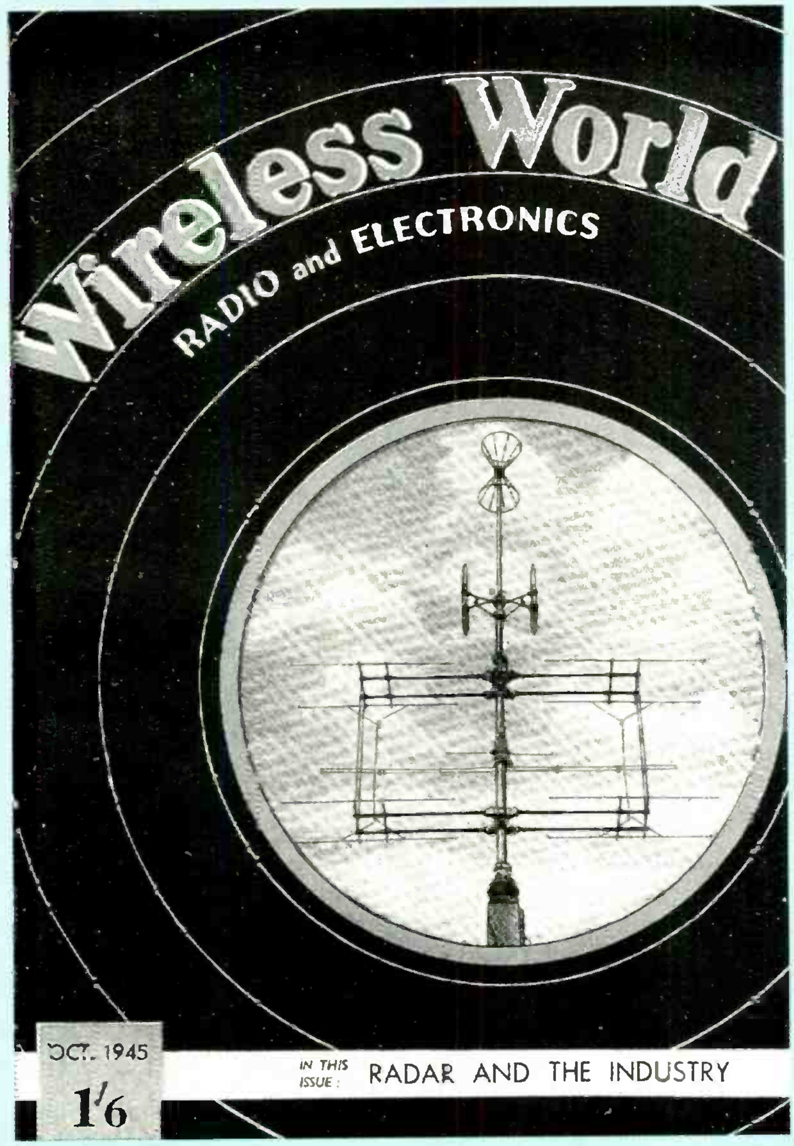
The problem is equally serious when an attempt is made to link television services in different parts of the globe. A relay chain several thousand miles long would cost millions, and transoceanic services would still be impossible. Similar considerations apply to the provision of wide-band frequency modulation and other services, such as high-speed facsimile which are by their nature restricted to the ultra-high-frequencies.

Many may consider the solution proposed in this discussion too far-fetched to be taken seriously. Such an attitude is unreasonable, as everything envisaged here is a logical extension of developments in the last ten years – in particular the perfection of the long-range rocket of which V2 was the prototype. While this article was being written, it was announced that the Germans were considering a similar project, which they believed possible within fifty to a hundred years.

Before proceeding further, it is necessary to discuss briefly certain fundamental laws of rocket propulsion and "astronautics". A rocket which achieved a sufficiently great speed in flight outside the earth's atmosphere would never return. This "orbital" velocity is 8km/s (5miles/s), and a rocket which attained it would become an artificial satellite, circling the world for ever with no expenditure of power – a second moon, in fact. The German transatlantic rocket A10 would have reached more than half this velocity.

It will be possible in a few more years to build radio controlled rockets which can be steered into such orbits beyond the limits of the atmosphere and left to broadcast scientific information back to the earth. A little later, manned rockets will be able to make similar flights with sufficient excess power to break the orbit and return to earth.

There are an infinite number of possible stable orbits, circular and elliptical, in which a rocket would remain if the initial conditions were correct. The velocity of 8km/s applies only to the closest possible orbit, one just outside the atmosphere, and the period of revolution would be about 90min. As the radius of the orbit increases the velocity decreases, since gravity is diminishing and less centrifugal force is needed to balance it.




*The cover of Wireless World's October 1945 issue gave little clue to the presence of Arthur C Clarke's pioneering article within.*

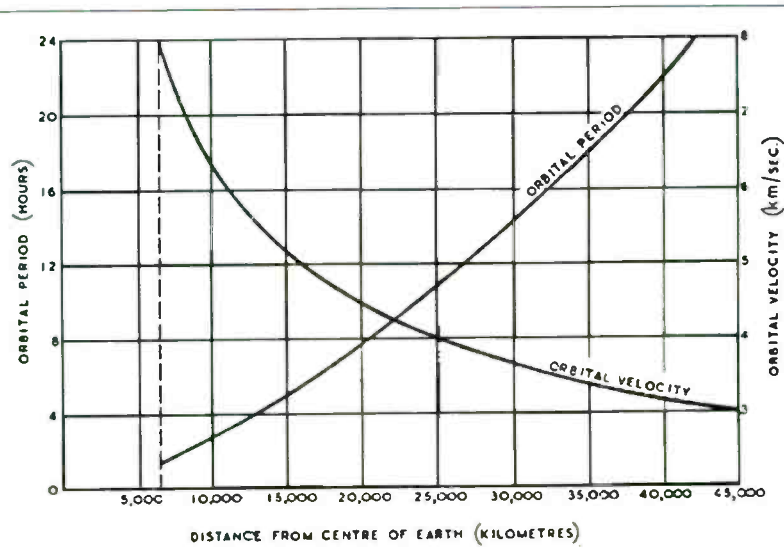



*Fig. 1. Variation of orbital period and velocity with distance from the centre of the earth.*

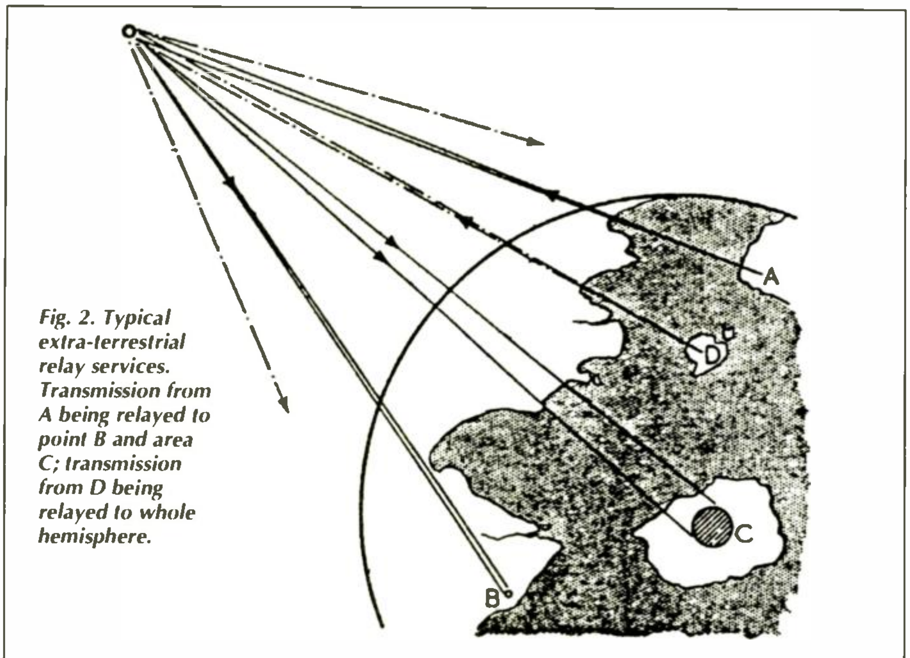



*Fig. 2. Typical extra-terrestrial relay services. Transmission from A being relayed to point B and area C; transmission from D being relayed to whole hemisphere.*

**Fig. 1** shows this graphically. The moon, of course, is a particular case and would lie on the curves of Fig 1 if they were produced. The proposed German space-stations would have a period of about four and a half hours.

It will be observed that one orbit, with a radius of 42,000km, has a period of exactly 24 hours. A body in such an orbit, if its plane coincided with that of the earth's equator, would revolve with the earth and thus be stationary above the same spot on the planet. It would remain fixed in the sky of a whole hemisphere and unlike all other heavenly bodies would neither rise nor set. A body in a smaller orbit would revolve more quickly than the earth and so would rise in the west, as indeed happens with the inner moon of Mars.

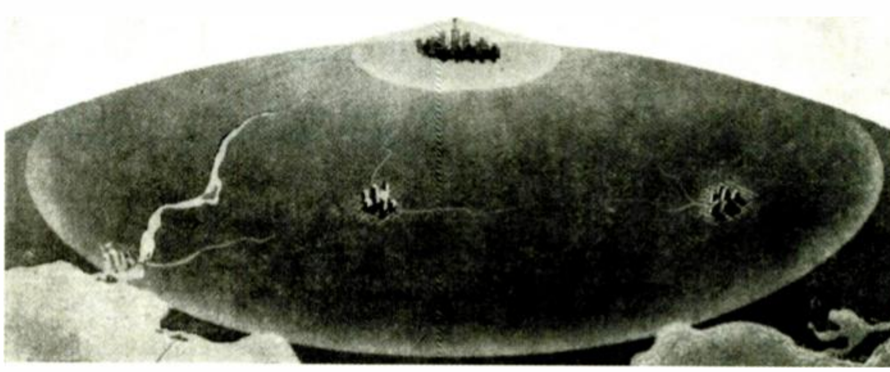
Using material ferried up by rockets, it would be possible to construct a "space-station" in such an orbit. The station could be provided with living quarters, laboratories and everything needed for the comfort of its crew, who would be relieved and provisioned by a regular rocket service. This project might be undertaken for purely scientific reasons as it would contribute enormously to our knowledge of astronomy, physics and meteorology. A good deal of literature has already been written on the subject[2].

Although such an undertaking may seem fantastic, it requires for its fulfilment rockets only twice as fast as those already in the design stage. Since the gravitational stresses involved in the structure are negligible, only the very lightest materials would be necessary and the station could be as large as required.

Let us now suppose that such a station were built in this orbit. It could be provided with receiving and transmitting equipment (the problem of power will be discussed later) and could act as a repeater to relay transmissions between any two points on the hemisphere beneath, using any frequency which will penetrate the ionosphere. If directive arrays were used, the power requirements would be very small, as direct line of sight transmission would be used. There is the further important point that arrays on the earth, once set up, could remain fixed indefinitely.

Moreover, a transmission received from any point on the hemisphere could be broadcast to the whole of the visible face of the globe, and thus the requirements of all possible services would be met (**Fig. 2**).

It may be argued that we have as yet no direct evidence of radio waves passing between the surface of the earth and outer space; all we can say with certainty is that the shorter wavelengths are not reflected back to the earth. Direct evidence of field strength above the earth's atmosphere could be obtained by V2 rocket technique, and it is to be hoped that someone will do something about this soon as there must be quite a surplus stock somewhere! Alternatively, given sufficient transmitting power, we might obtain the necessary evidence by exploring for echoes from the moon. In the meantime we have visual evidence that frequencies at the optical end of the spectrum pass through



*A project which goes part of the way towards the goal envisaged in this article has been put forward by Westinghouse in collaboration with the Glen L Martin Co of America. The radius of coverage would be increased from 50 to 211miles by beamed radiation from an aircraft flying at a height of 30,000ft and equipped with television and FM transmitters.*

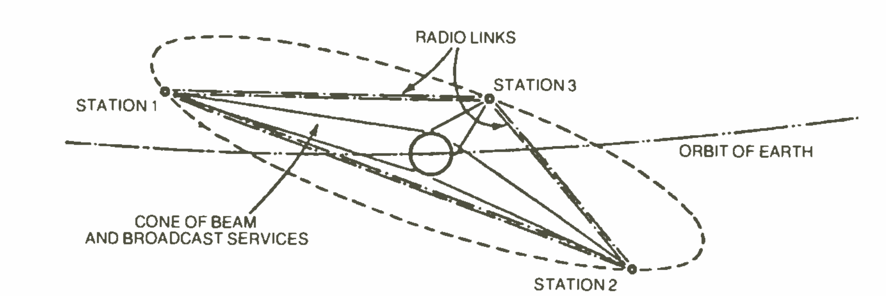



*Fig. 3. Three satellite stations would ensure complete coverage of the globe.*

with little absorption except at certain frequencies at which resonance effects occur. Medium high frequencies go through the E layer twice to be reflected from the F layer and echoes have been received from meteors in or above the F layer. It seems fairly certain that frequencies from, say, 50Mc/s to 100,000 Mc/s could be used without undue absorption in the atmosphere or the ionosphere.

A single station could only provide coverage to half the globe, and for a world service three would be required, though more could be readily utilised. **Fig. 3** shows the simplest arrangement. The stations would be arranged approximately equidistantly around the earth, and the following longitudes appear to be suitable:-

30E - Africa and Europe
150E - China and Oceana
90W - The Americas

The stations in the chain would be linked by radio or optical beams, and thus any conceivable beam or broadcast service could be provided.

The technical problems involved in the design of such stations are extremely interesting[3] but only a few can be gone into here. Batteries of parabolic reflectors would be provided, of apertures depending on the frequencies employed. Assuming the use of 3000 Mc/s waves, mirrors about a metre across would beam almost all the power on to the earth. Larger reflectors could be used to illuminate single countries or regions for the more restricted services, with consequent economy of power. On the higher frequencies it is not difficult to produce beams less than a degree in width, and, as mentioned before, there would be no physical limitations on the size of the mirrors. (From the space station, the disc of the earth would be a little over 17 degrees across). The same mirrors could be used for many different transmissions if precautions were taken to avoid cross modulation.

It is clear from the nature of the system that the power needed will be much less than that required for any other arrangement, since all the energy radiated can be uniformly distributed over the service area, and none is wasted. An approximate estimate of the power required for the broadcast service from a single station can be made as follows:

The field strength in the equatorial plane of a $\lambda/2$ dipole in free space at a distance of $d$ metres is[4]

$$e = 6.85\frac{\sqrt{P}}{d}\text{ volts / metre}$$

where $P$ is the power radiated in watts.

Taking $d$ as 42,000km (effectively it would be less) we have

$$P = 37.6e^2 \text{ watts}$$

($e$ now in $\mu$V/m)

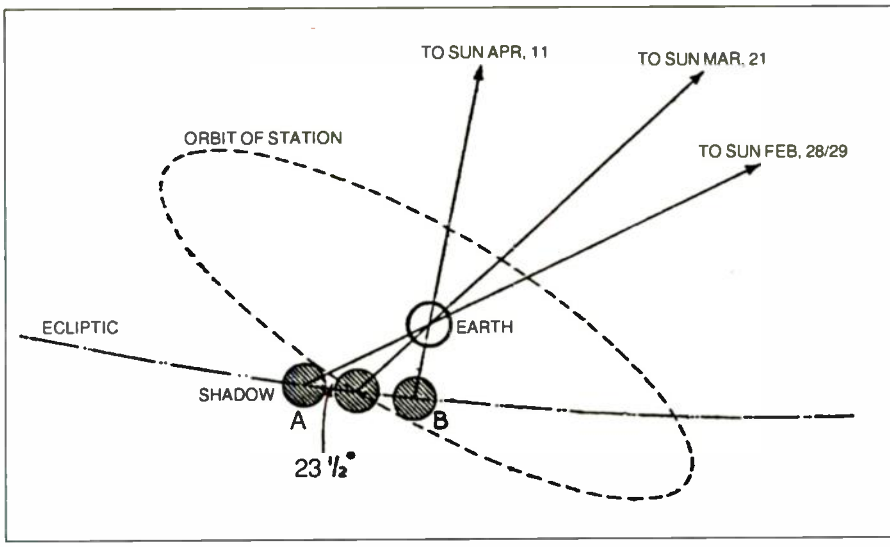



*Fig. 4. Solar radiation would be cut off for a short period each day at the equinoxes.*

If we assume $e$ to be 50mV/m, which is the FCC standard for frequency modulation, $P$ will be 94kW. This is the power required for a single dipole, and not an array which would concentrate all the power on the earth. Such an array would have a gain over a simple dipole of about 80. The power required for the broadcast service would thus be about 1.2kW.

Ridiculously small though it is, this figure is probably much too generous. Small parabolas about a foot in diameter would be used for receiving at the earth end and would give a very good signal/noise ratio. There would be very little interference, partly because of the frequency used and partly because the mirrors would be pointing towards the sky which could contain no other source of signal. A field strength of 10mV/m might well be ample, and this would require a transmitter output of only 50W.

When it is remembered that these figures relate to the broadcast service, the efficiency of the system will be realised. The point-to-point beam transmissions might need powers of only 10W or so. These figures, of course, would need correction for ionospheric and atmospheric absorption, but that would be quite small over most of the band. The slight falling off in field strength due to this cause towards the edge of the service area could be readily corrected by a non-uniform radiator.

The efficiency of the system is strikingly revealed when we consider that the London Television service required about 3kW average power for an area less than fifty miles in radius[5].

A second fundamental problem is the provision of electrical energy to run the large number of transmitters required for the different services. In space beyond the atmosphere, a square metre normal to the solar radiation intercepts 1.35kW of energy[6]. Solar engines have already been devised for terrestrial use and are an economic proposition in tropical countries. They employ mirrors to concentrate sunlight on the boiler of a low-pressure steam engine. Although this arrangement is not very efficient it could be made much more so in space where the operating components are in a vacuum, the radiation is intense and continuous, and the low-temperature end of the cycle could not be far from absolute zero. Thermo-electric and photo-electric developments may make it possible to utilise the solar energy more directly.

Though there is no limit to the size of the mirrors that could be built, one fifty metres in radius would intercept over 10,000kW and at least a quarter of this energy should be available for use.

The station would be in continuous sunlight except for some weeks around the equinoxes, when it would enter the earth's shadow for a few minutes every day. **Fig. 4** shows that state of affairs during the eclipse period. For this calculation, it is legitimate to consider the earth as fixed and the sun as moving round it. The station would graze the earth's shadow at A, on the last day in February. Every day, as it made its diurnal revolution, it would cut more deeply into the shadow, undergoing its period of maximum eclipse on March 21st. On that day it would only be in darkness for one hour nine minutes. From then onwards the period of eclipse would shorten, and after April 11th (B) the station would be in continuous sunlight again until the same thing happened six months later at the autumn equinox, between September 12th and October 14th. The total period of darkness would be about two days per year, and as the longest period of eclipse would be little more than an hour there should be no difficulty in storing enough power for an uninterrupted service.

## Conclusion

Briefly summarised, the advantages of the space station are as follows:

## Appendix - Rocket Design

The development of rockets sufficiently powerful to reach "orbital" and even "escape" velocity is now only a matter of years. The following figures may be of interest in this connection.

The rocket has to acquire a final velocity of 8km/s. Allowing 2km/s for navigational corrections and air resistance loss (this is legitimate as all space-rockets will be launched from very high country) gives a total velocity needed of 10km/s. The fundamental equation of rocket motion is

$$V = v \log_e R$$

where $V$ is the final velocity of the rocket, $v$ the exhaust velocity and $R$ the ratio of initial mass to final mass (payload plus structure). So far $v$ has been about 2-2.5km/s for liquid fuel rockets but new designs and fuels will permit considerably higher figures. (Oxy-hydrogen fuel has a theoretical exhaust velocity of 5.2km/s and more powerful combinations are known). If we assume $v$ to be 3.3km/s, $R$ will be 20 to 1. However, owing to its finite acceleration, the rocket loses velocity as a result of gravitational retardation. If its acceleration (assumed constant) is $\alpha$ m/s$^2$, then the necessary ratio $R_g$ is increased to

$$R_g = R\frac{\alpha + g}{\alpha}$$

For an automatically controlled rocket $\alpha$ would be about 5$g$ and so the necessary $R$ would be 37 to 1. Such ratios cannot be realised with a single rocket but can be attained by "step-rockets"[2], while very much higher ratios (up to 1000 to 1) can be achieved by the principle of "cellular construction"[3].

## Epilogue - Atomic Power

The advent of atomic power has at one bound brought space travel half a century nearer. It seems unlikely that we will have to wait as much as twenty years before atomic-powered rockets are developed, and such rockets could reach even the remoter planets with a fantastically small fuel/mass ratio – only a few per cent. The equations developed inthe appendix still hold, but $v$ will be increased by a factor of about a thousand.

In view of these facts, it appears hardly worth while to expend much effort on the building of long distance relay chains. Even the local networks which will soon be under construction may have a working life of only 20-30 years.

(1) It is the only way in which true world coverage can be achieved for all possible types of service.

(2) It permits unrestricted use of a band at least 100,000Mc/s wide, and with the use of beams an almost unlimited number of chan-nelswould be available.

(3) The power requirements are extremely small since the efficiency of "illumination" will be almost 100%. Moreover, the cost of the power would be very low.

(4) However great the initial expense, it would only be a fraction of that required for the world networks replaced, and the running costs would be incomparably less.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## BOOK REVIEW

### Capacitance theory of gravity

Morton F Spears

The book *Capacitance Theory of Gravity* by Morton F. Spears is an attempt by a U.S. electronic engineer, a former MIT graduate of MIT who has built his own successful high-tech communication business, to discover the true nature of gravitational force. Engineers are, of course, entitled to ponder on such fundamental issues, in spite of the resentment and scorn which relativistically-minded physicists and mathematicians confer upon intruders into their domain.

As is normal when an outsider offers his thoughts on the question of gravity, the argument is ignored and, often in frustration, the author commits his ideas to an essay in book form, hoping that it will sit on university library shelves until its merit is recognized. If the work doesn't warrant even a small dose of the kind of glory that was bestowed upon Albert Einstein, then at least the author hopes someone, somewhere, will point out the flaw in the reasoning. Spears ascribes the mutual gravitational attraction of particles to a capacitative effect, taking strength from the fact that there is an analogy between mutual attraction of plates in a charged capacitor and the fact that a corresponding mutual attraction can be induced between spherical objects immersed in a fluid dielectric medium.

The phenomenon of gravity poses two challenging questions, which Spears tries to answer. Firstly, there is the task of relating the form of the gravity force law with electrical or electromagnetic action and, secondly, there is the daunting question of explaining why the gravity force between two electrons is so minute in relation to the mutual electric force. Spears' approach to the first is his capacitance theory, by which he ascribes a notional spherical form to an electron or proton and deduces its capacitance in relation to its radius.

Perhaps the concept of capacitance having a role in gravitational theory is new, but certainly the idea of charge containment on a conductive sphere as a particle form subject to Coulomb-related forces which feature in gravitational action has its historical antecedents. All such theories are beset by the task of explaining why electric fields do not interact with gravity. Spears does not discuss this background, which leaves the reviewer feeling that a reader would be better informed by a study of the chapter on Gravitation in Sir E. T. Whittaker's book *The History of the Theories of Aether and Electricity.*

Spears' book will find little sympathy with the physics community, who will join the reviewer in judging this work principally on the treatment of that second question, namely the showing that the gravitational G-dependent force can be derived in precise numerical terms from the charge and radius properties of the electron and the proton. Using the now-standard units in which force is expressed in newtons, Spears exploits a numerical coincidence to show how on page 44 the gravitational interaction can be the same in his CTG (capacitance theory of gravity) as in Newtonian theory. Sadly, there is something amiss with his primary equations by which he appears to have overlooked a dimensional balance. If the same theory is translated into the classical cgs system of units, those equations no longer give that numerical result on which Spears relies. Somehow in his analysis he has lost a dimensional parameter, because equation (4.9), vital to his thesis, declares that the gravitational force is proportional to the dimensions of coulombs squared and this seems not to be a typographical error.

As is so often the case with projects of this kind, no one skilled in judging physical theory has taken an interest or understood the proponent's thesis well enough to focus on this fatal problem. There is a need to topple the Einstein doctrine and put gravity on a better foundation. It may be that an engineer will see this task to a conclusion, but Spears' capacitance theory of gravity is not the way forward. **Harold Aspden**

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Published by Morton F Spears

# SHEDDING LIGHT ON OPTO-ELECTRONICS

***David Bradbury, head of applications at the UK semiconductor company Zetex, explains how to get the best out of the sample opto-transistor diode pair supplied with the UK copies of this month's issue.***

Applications for short range infra-red control and data links have grown from the occasional TV to include a wide range of products: light dimmers, toys, music centre, garage door controls, slide projectors, intruder detection, automobile alarms and teaching aids to mention just a few.

Although infra-red links have become commonplace to circuit designers, the characteristics and constraints of the component elements of these links have seldom been explained. This article covers the main design considerations of such links and, with the free devices supplied with this copy of Electronics World, provides some interesting circuits for experimentation. Emphasis has been placed on the BPW41D photo diode and ZME41 infra-red emitter as these were specifically designed for such application.

Generally, infra-red links consist of a light-emitting diode radiating at a wavelength of 850 to 970nm whose output is detected by a silicon photodiode or phototransistor. The led's output needs to be modulated not only to include the required transmission data but also to provide a means of rejecting the relatively immense levels of IR light falling on the detector from other sources. The modulation is invariably digital, using either simple oscillators or coding ICs.

Light detected by the photodiode is converted to an electrical signal that is amplified and then decoded to recover the transmitted information.

All but the simplest systems use specialist ICs for decoding. Such links are usually low cost, do not require licensing, cause little interference and are affected by few interference sources.

The main difficulty with most IR link designs is to ensure signal to noise ratios adequate for reliable operation. This entails maximising the light output from the transmitter and minimising noise generation and pick up in the receiver's detector and amplifier.

## Transmitter leds

The ZME41 IR led supplied with this issue was designed with remote control applications in mind. It emits with a ±30° half-power beam width which eases transmitter aiming requirements. It has a peak current rating of 3.5A and at a continuous current of 100mA (the DC limit is 130mA) it emits useful 15mW/sr. The performance of this led is competitive with other similar cost devices on the market.

Over their intended operational range, IR leds give a light output that is proportional to operation current. **Fig. 1** shows this relationship for the ZME41 with the output given in mW/sr (a steradian, sr, is the solid angle subtended at the centre of a sphere of radius r by an area of $r^2$ on its surface). This graph shows the advantage gained by running the led at as high a current as possible. Using pulse widths of 10μs and a duty cycle of 0.01% it is permissible to use peak currents up to 2A with the ZME41. Raising the lens gain of the led's package will give further improvement in output but this will be at the expense of a reduction in beam width.

## IR Detector

The BPW41 photodiode was also designed primarily for remote control use. It incorporates a planar P type-Intrinsic-N type (PIN) chip structure with a Si-nitride anti-reflection and passivation coating. The PIN construction gives high IR sensitivity and low capacitance for high speed operation.

In order to exploit the behaviour of uncorrelated noise generators, the chip's signal-to-noise performance has been enhanced by making it as large as economically viable

(7.5mm²). Signal current from a photodiode is proportional to its area whereas its noise output is only related to the area's square root – hence the bigger the better.

It is not unusual in remote control applications for background illumination from daylight or room lighting to be 1000 times greater than the desired signal incident on the detector. Regardless of source, this unwanted illumination causes the detector to pass current and so generate noise. Since the desired signal is solely IR, receiver noise levels can be reduced by using an optical filter to eliminate all but IR light. The BPW41 photodiode incorporates a particularly effective filter, yielding the spectral response shown in **Fig. 2** (given along with the spectral outputs of common light sources). Note that although the filter is an excellent sunlight filter, it can do little with tungsten lamps whose output peaks in the infra-red (hence their low efficiency).

Photodiodes behave like a standard diode wired in parallel with a light dependent current generator. This allows the device to be used in two distinct modes. Firstly, if it is used with a high impedance load, the current generator forward biases the diode to produce an output voltage that varies as the log of the incident light level. Commonly used for power generation, this mode of operation (photovoltaic) is not of much use for IR links because large steady-state light sources can easily swamp low level signals.

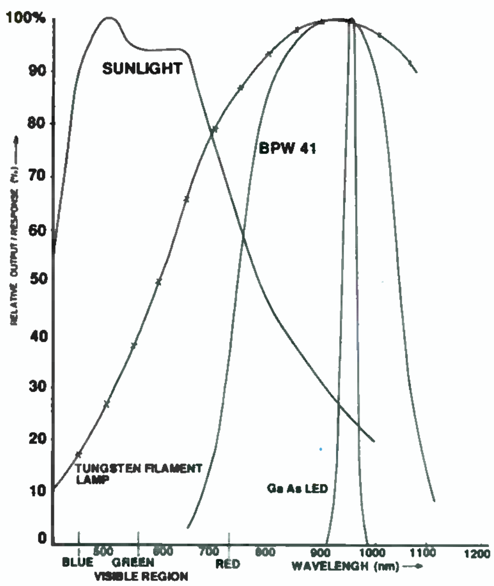



*Fig. 2. Spectral response of The BPW41 with some common light sources.*

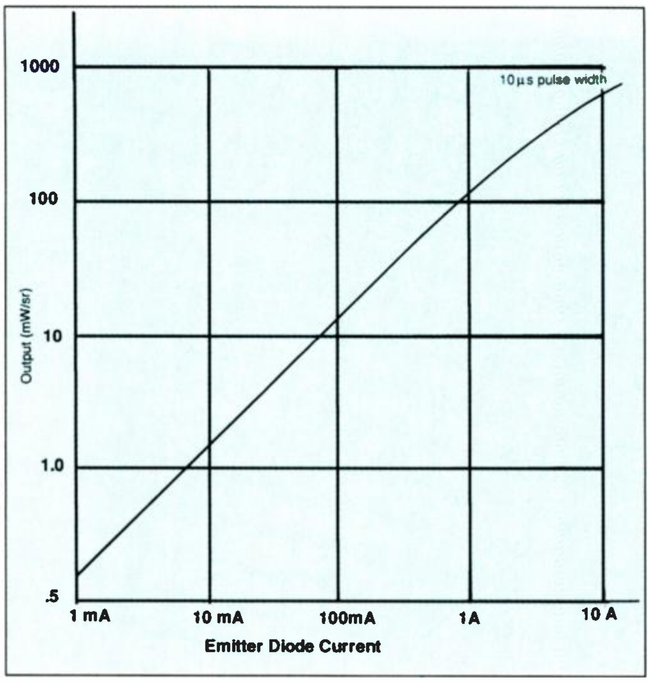



*Fig. 1. Emitter current versus infra-red radiant intensity for the ZME41 diode.*

If the photodiode is reverse-biased, it produces an output current closely proportional to light level. In this mode (photoconductive) it exhibits a high output impedance that varies little with light level. Reverse biasing alsoreduces the diode's capacitance, improving high frequency performance. With a suitable load circuit, this mode of operation works well in IR links.

### Detector Load Circuits

From Fig.1, it can be calculated that when pulsed at 2A the ZME41 will produce a light intensity of around 0.2µW/cm² at a range of 10m. With a sensitivity of typically 45µA/mW/cm², the BPW41 will generate a photocurrent of around 9nA at this illumination level. When used with an appropriate load circuit, photodiodes like the BPW41 can provide usable s-to-n ratios with signals of this order even in the presence of much stronger light sources.

As shown in **Fig. 3**, a single resistor is the simplest load that is commonly used. Several factors affect the choice of resistance. At the low end, its value is restricted by the need to keep the gain required from A at a value where the amplifier's interference rejection, stability and noise contribution do not compromise system performance.

At the high end, R's value is restricted by bandwidth limitations and overload problems from background light sources. Background light can cause enough photocurrent to forward bias the diode, leading to severe losses in sensitivity. These problems limit the use of simple resistive loads to applications where light levels can be expected to be low, for example in inexpensive TVs and lamp dimmers. Values in the range of 100 to 300kΩ give good sensitivities, turn-over frequencies in the 30kHz to 100kHz range and will work in rooms that are reasonably but not brightly lit.

Since most background light sources are either steady-state or have outputs which flicker at low frequencies, a load which is low impedance at these frequencies but high impedance at the desired signal frequency would be ideal. Such characteristics can be achieved with an inductor.

Take in Figs 4(a,b)

The inductive load shown in **Fig. 4a** can provide a signal frequency impedance of 100kΩ while giving a very low resistance path for background lighting photocurrent. Consequently it will operate over a wide range of light levels.

Figure **4b** illustrates the circuit's output waveform. It consists of a damped sine-wave whose frequency is dependent on the inductance used and the sum of the photodiode capacitance, the inductor's stray capacitance as well as the indicated capacitor. This ringing can cause multiple pulse detection if delays are not included in the receiver logic. Also there are some practical difficulties in winding a suitable inductor ie. size, cost, self capacitance and saturation current.

Inductors have been used in remote controls where good sensitivity and high background light tolerance has been required but the problems highlighted have limited the popularity of this approach.

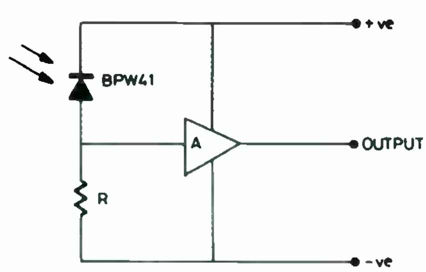



*Fig. 3. A commonly used single resistor is the simplest load.*

The optimum characteristics provided by the inductive load can be obtained without the disadvantages mentioned by using an active circuit. Two configurations of the same basic active load circuit but with differing output polarities are given in **Figs. 5(a)** and **(b)**.

In Fig. 5a, photocurrent from the BPW41 raises the base voltage of the low noise ZTX384 via the 330kΩ resistor until the transistor's base-emitter voltage reaches about 0.7V and it starts to conduct. An equilibrium point is quickly reached where the

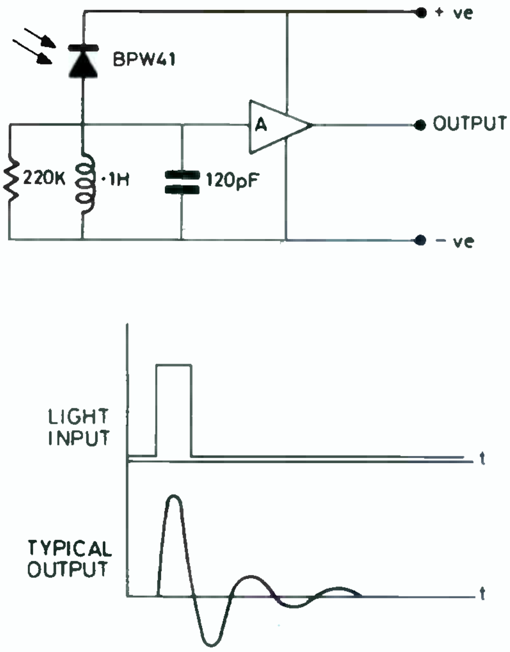
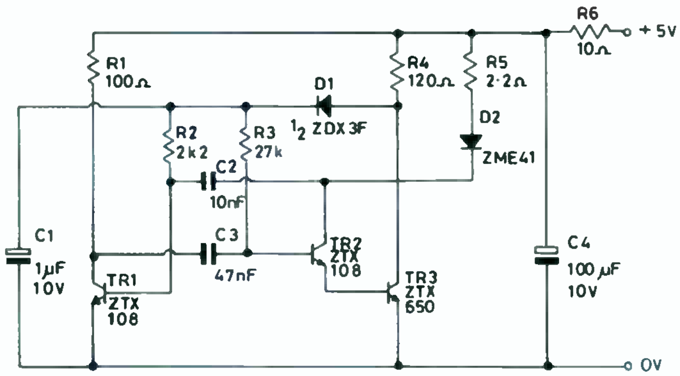
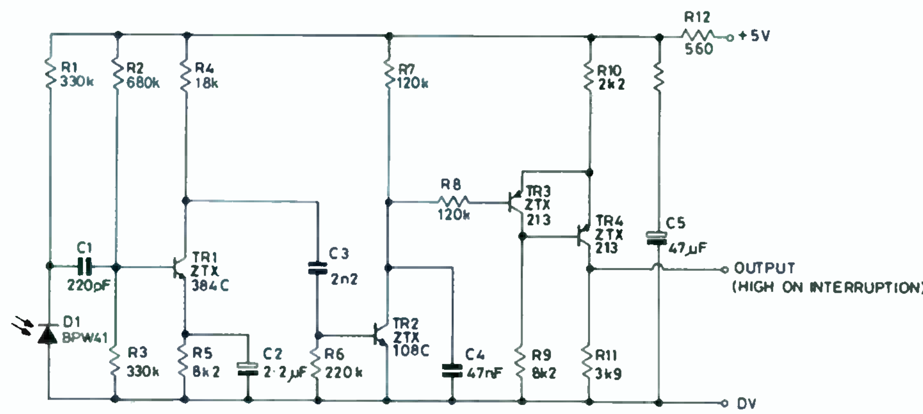



*Fig. 4. Inductive loading in (a) provides a signal frequency impedance of 100kΩ while giving a very lowresistance path for background lighting photocurrent. Output is shown in (b).*




transistor holds its collector voltage at around 0.8V by acting as a current generator that matches the photodiode current. This equilibrium is maintained

for DC or slowly varying photocurrents thus providing the photodiode with a low impedance load at these frequencies.

The base-emitter capacitor restricts the speed at which the transistor can respond to changes in photocurrent. Consequently, the current matching equilibrium is not maintained for rapidly changing photocurrents, giving the photodiode a high impedance load at high frequencies. For the component values shown in Fig. 5a, the load impedance presented to the photodiode changes from around 1kΩ at DC to approach 250kΩ at 50kHz.

The load impedance of this circuit falls a little at high light levels but the main disadvantages of the circuit in Fig. 5a are noise and interference rejection. Although at first sight it appears that high-frequency inputs to $T_{r1}$ are shorted by $C_1$, this does not apply to the small noise voltage generator within $T_{r1}$ and voltages electromagnetically induced in the wiring loop made by $T_{r1}$'s base-emitter and $C_1$. These low level signals are amplified by the transistor. The voltage gain of the transistor is given approximately by:

$$\text{Voltage gain} = \frac{R_c}{r_e} = \frac{\text{collector load impedance}}{\text{intrinsic emitter resistance}}$$

where $r_e = \frac{26}{I_e}$ ($I_e$ in mA)

These unwanted signals cause little problem with low background light levels. For instance, in a dimly lit room yielding 5μA of photocurrent, the voltage gain given to these signals will be around 50, leaving their level too low to be of consequence.

Unfortunately, at light levels approaching direct sunlight, the resulting background photocurrent of 1mA will raise the circuits voltage gain up as high as 10,000 making the noise and interference significant.

However, the problem is easily dealt with. The extra emitter resistor included in the active load circuit of **Fig. 5b** changes this behaviour dramatically. The voltage gain of the circuit now approximates to:

$$\text{Voltage gain} = \frac{R_c}{r_e + R_e}$$

At 1mA the voltage gain of the circuit has ben reduced to less than 160, leaving the noise contributions from other sources larger than those generated by the load circuit. The added resistor does increase the low frequencyimpedance of the circuit a little but it will still operate in direct sunlight.

Even with a 250kΩ load, signal photocurrents of 10nA will yield a voltage too small to be directly usable. Thus, in practical IR links all of the load circuits discussed will be followed by some kind of amplifier. These must have a high input impedance, a frequency response tailored to the desired sig-

*Fig. 6. A 70cm range infra-red system intended for parts counting.*

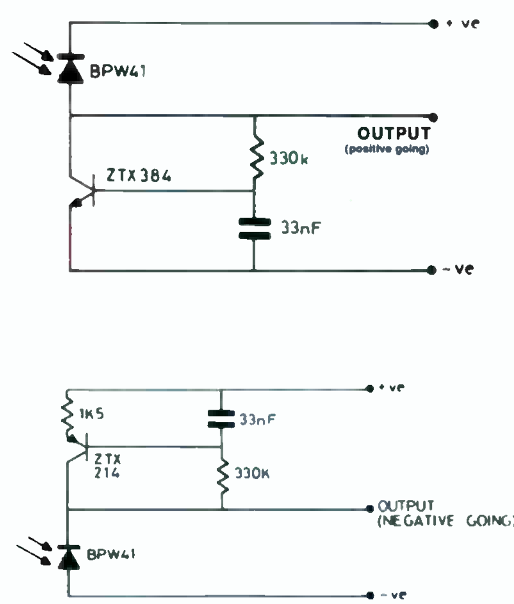



*Fig. 5. Two configurations of the same basic active load circuit but with differing output polarities.*

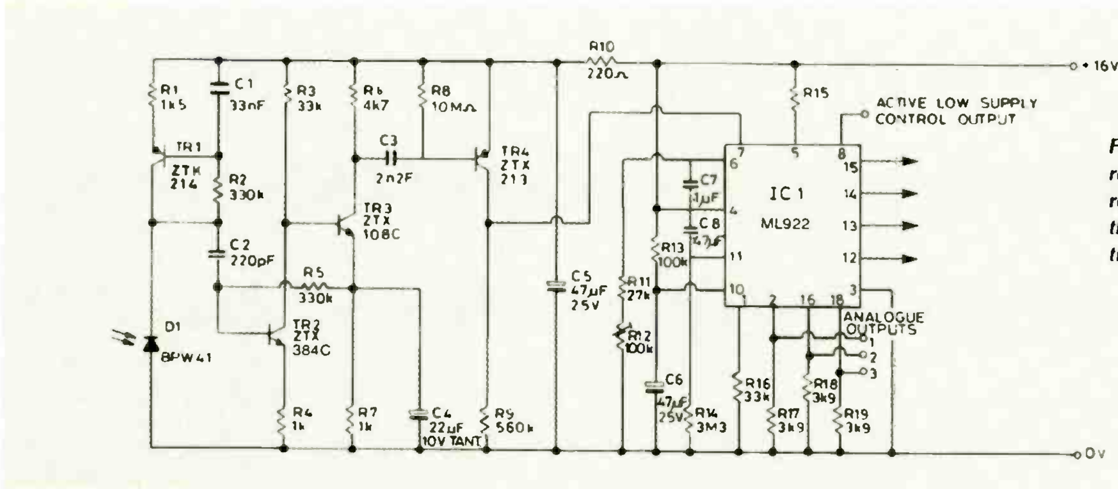
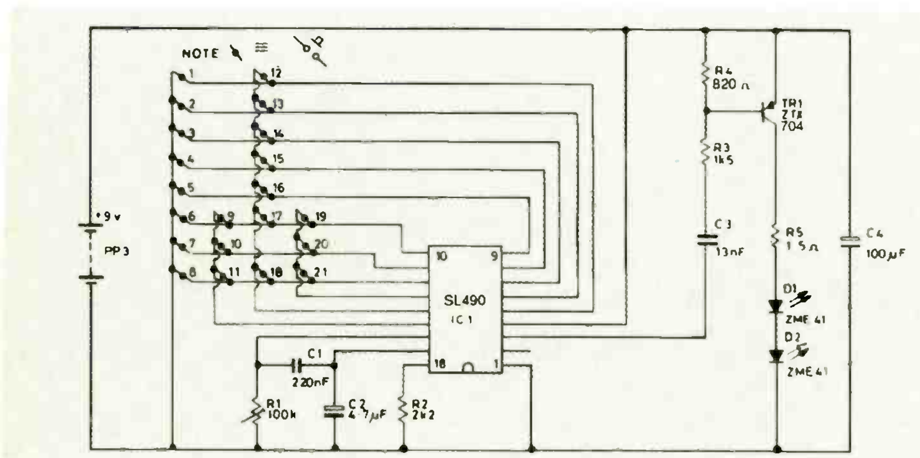
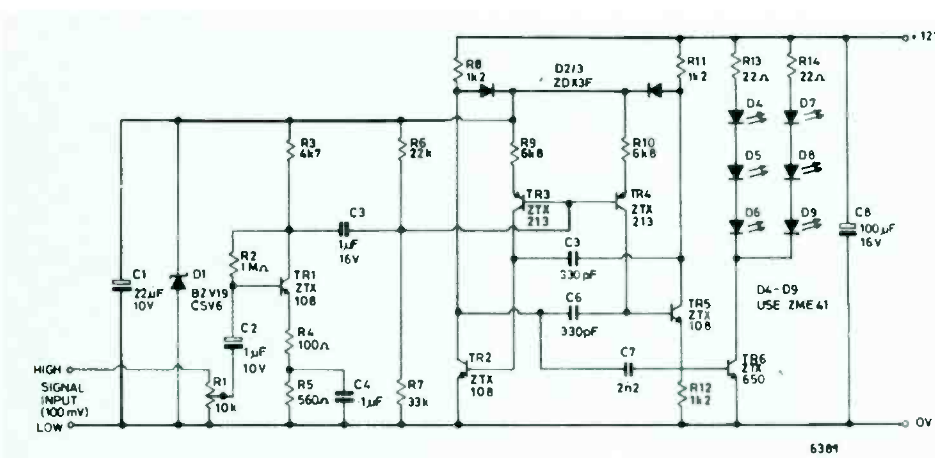



*Fig. 7. A simple IR remote control receiver (left) and the associated transmitter (below).*




nal and be reasonably low noise. Other constraints will be dependent on application so the amplifier circuits shown here are included with some IR link circuit examples.

### Beam interrupt detector

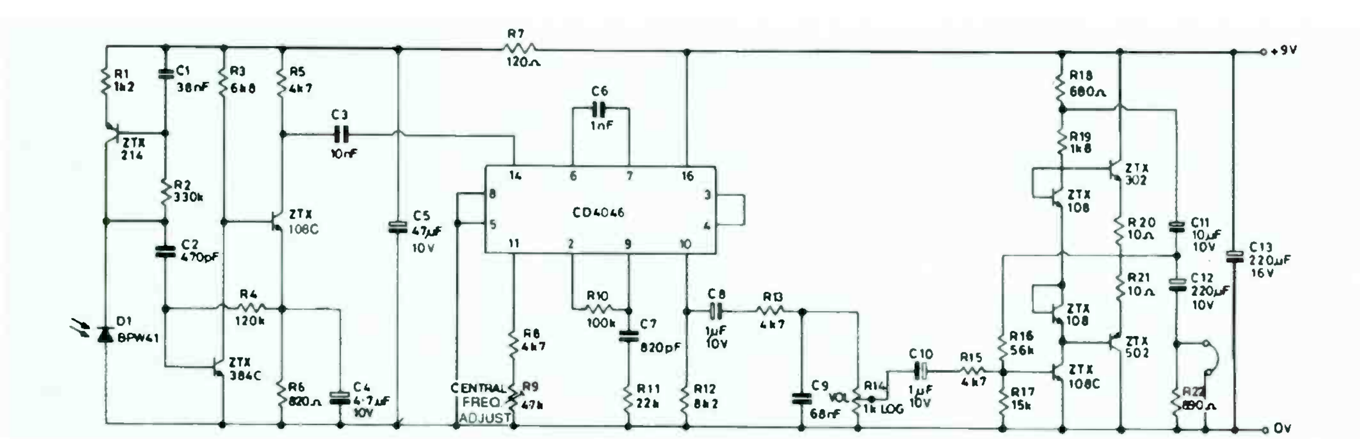
Beam interrupt detectors have a variety of applications ranging from object counting to security systems. The circuits shown in **Figs 6a** and **b** are for a short range (70cm) system intended for parts counting.

The transmitter consists of a sure-start multivibrator timed to drive a ZME41 emitter at 1kHz with a 0.15% duty cycle. The small duty cycle allows the led to operated at high peak current without degradation.

The receiver circuit is given in Fig. 6b. Screening from bright light sources was expected for this application so the BPW41 photodiode was used with a just a resistor load. Signals picked up are passed through a single stage amplifier before being fed to a pulse detector. To provide stable output states and faster level transitions, the output of the receiver is taken from a Schmitt trigger circuit driven by the pulse detector. This output is normally low when the receiver is illuminated by the transmitter beam.

The main range limitation of the system comes from the low gain of the receiver's

*Fig. 8. A single-channel cordless audio link between headphones and a television or music centre.*



amplifier stage. Consequently the range can be easily extended by either raising the amplifier gain by adding further stages or by increasing the received signal level using a lens with the transmitter led. An experimental system using both techniques operates at over 40m.

### TV remote control

**Figures 7a** and **b** show a simple IR remote control transmitter and receiver respectively. The circuits utilize a Plessey chip set for coding and decoding and code verification.

The transmitter consists merely of a matrix keyboard, an SL490 IC, clock frequency setting components and the led driver. An T092 style E-line darlington provides 2A drive pulses for the leds, the pulse width being set to about 15μs by the simple CR base drive components. Note that only 21 of the possible 32 key codes are switched because the receiver decode ignores some codes.

The receiver is rather more complex. A BPW41 used with a PNP active load circuit is followed by a simple low-noise amplifier. During signal reception, the output of this amplifier will be negative going signal pulses superimposed on background noise. The coded signal is separated from the noise using a peak detector which provides positive going pulses for the decoder IC, an ML922. This IC was designed for use as a TV controller, providing latched BCD outputs via pins 12, 13, 14 and 15 for channel selection, a mute output and three analogue control outputs.

### Monophonic audio link

Infra-red audio links are often used at international conferences to provide language translations to all those attending. The circuits shown in **Figs 8a** and **b** illustrate a single-channel audio link intended to allow the use of monophonic headphones with a television or music centre without trailing leads. Its frequency response is from 50Hz to 8kHz and depending on the environment it will give a range of about 8m.

The link uses frequency modulation to avoid potential linearity and amplitude variation problems.

Figure 8a gives the transmitter circuit. The input signal is first amplified and given 55μs pre-emphasis. The processed signal is then AC coupled to two current generators used to control the frequency of a sure-start multivibrator centred at 70kHz. One phase of this multivibrator is buffered by a ZTX650 to drive two stacks of three leds. The mark-space ratio of the multivibrator is 1:1 so the peak current in the leds cannot be as high as in the low data-rate remote control and detector systems, being set to just 300mA. The output of the transmitter is an IR carrier wave, frequency modulated by the audio signal source.

The receiver uses a BPW41 photodiode to detect the transmitter's output. This is fed through a high-gain amplifier to the Schmitt trigger input of a cmos phase-locked-loop IC. The oscillator of this IC is adjusted until it locks onto the transmitter carrier. Subsequent frequency modulation of the carrier is followed by this oscillator and the control signals generated by the IC's phase comparator reproduce the audio input supplied to the transmitter.

Output from the phase comparator is fed through a de-emphasis network which not only corrects for the pre-emphasis given to the signal at the transmitter, but reduces high-frequency noise too. After de-emphasis, the signal is amplified to a level suitable to drive even low impedance headphones. ■

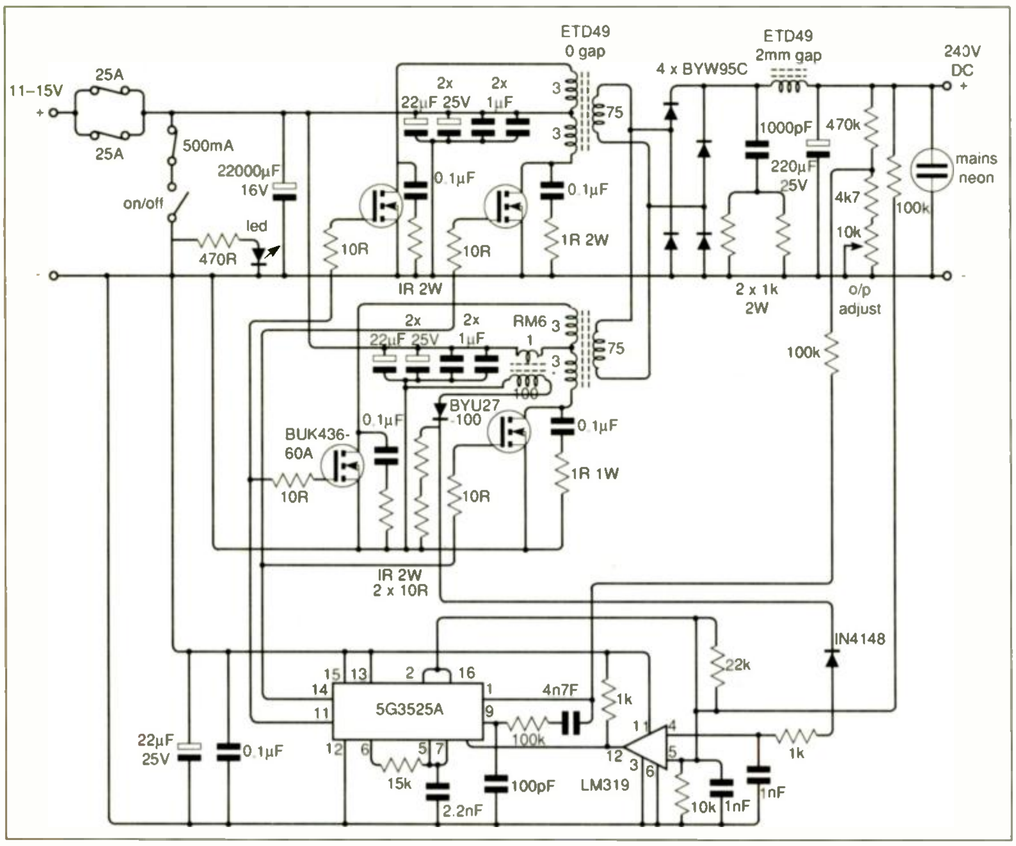
*Further information on the semiconductor devices mentioned in this article may be obtained directly from Zetex plc.*

# REGULARS

### CIRCUIT IDEAS

## DC mains inverter

For low voltages and high currents, power mosfets possess significant advantages over bipolar types. This 12V input, 240V, 500W inverter is intended to demonstrate their ease of use and will find application in power tools, lighting and universal motors.




A standard push-pull inverter runs at 25kHz, with regulation obtained from the voltage-mode SG3525A pulse-width modulator from SGS-Thomson. Current-limit shutdown is achieved by sensing the current in the centre tap of one of the transformers (not both, since they are identical), an op-amp comparator driving the shutdown IC input. Threshold of current limit at the comparator is reduced when the inverter input is very low to compensate for delay in shutdown.

On a practical note, the high primary-side currents render a ground plane more or less essential and copper tape primaries definitely essential, although 1mm enamelled copper will suffice for the secondaries.

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*Bristol*

***250V, 500W inverter using power mosfets. Equivalents to the SGS-Thomson device are obtainable from Linear Technology, Motorola, National Semiconductor, Sprague and Unitrode.***

## A different bridge

This circuit simulates a Wheatstone bridge (**Fig.1**) by an operational transconductance amplifier and avoids the need for matched resistors while providing a better signal from a strain-gauge transducer. An OTA, as shown in **Fig. 2**, gives a current output $I = G(V_+ - V_-)$, in which G is transconductance, variable by means of $R_b$, the biasing current control. If G is adjusted to be $G = 1/R$, $Vo = IR = V$, the second amplifier output being zero in this case, simulating a balanced bridge; a small variation in the value of R produces a linear output.

Responses of the two circuits for the same reference voltage and variation in resistance $\partial R$ is given for comparison. In the prototype, the OTA was a CA3080 and the op-amp an AD524 .

***Promit Biswas***
*New Delhi*

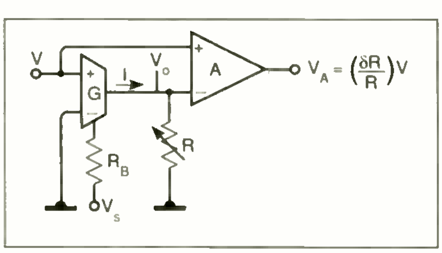
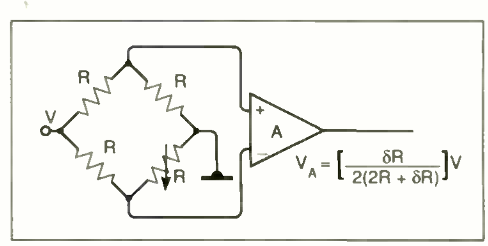



***Fig.1. Standard Wheatstone bridge needs matched resistors.***

***Fig.2. Novel bridge arrangement using operational transconductance amplifier avoids need for matching and provides better output from a strain gauge.***



# AC stabiliser

Originally designed to stabilise the supply to an over-sensitive refrigerator, this arrangement will handle a 220V supply at 20W to 2kW.

Two circuits are offered for resistive and reactive loads, the second being a modification of the first. **Figure 1** shows the layout of the resistive-load version. When the mains goes negative with repect to the diode $D_4$, all the current passes through $D_5$, control not being effective during this half-cycle. On the positive-going half-cycle, $D_4$ voltage increases, but no current passes since it is not yet triggered. Current through $Tr_1$ and $R_7$ charges $C_2$ to around 5V, at which point the n-p-n/p-n-p pair fires, discharging $C_2$ and triggering the thyristor by the voltage across $R_9$. Duration of current cut-off through the thyristor is determined by $D_1$, $R_{1,2,3}$. **Figure 2** is a graph of the relevant currents and voltages.

Components $D_{3,2}$, $R_{8,5,6}$, $C_1$ provides a supply voltage to the control circuit proportional to the mains voltage. When the mains voltage increases, the supply to $Tr_1$ decreases, extending to cut-off time of the thyristor and vice versa, average current remaing unchanged. Zener $D_2$ reduces the effect of the rectifier on the rest of the external circuit.

**Figure 3** shows the modification for reactive loads, which works symmetrically on both half-cycles, its operation being sketched in **Fig. 4**. **Figure 5** details the precautions necessary to avoid affecting the local mains supply by HF disturbances.

Transistors $Tr_{1,3}$ may be BC109s, MPSA06s or similar and $Tr_2$ a BC212, MPSA56 or the like. The resistor $R_{13}$ should be of 2W rating and $R_8$ a 1W type.

***Valery V Vershinkin***
*Avdeyevka*
*USSR*

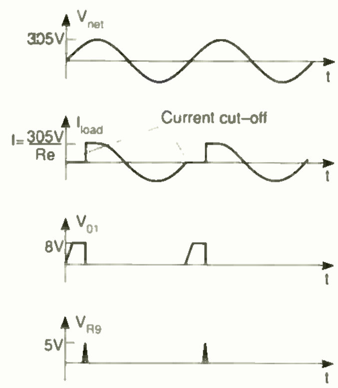



*Fig. 2: waveforms from Fig. 1*

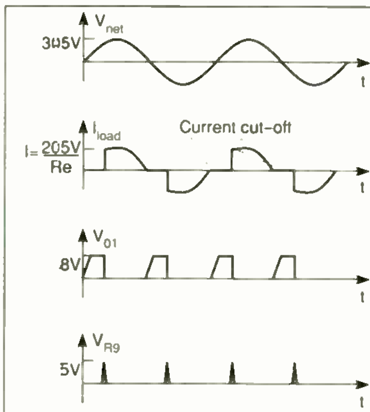



*Fig. 4: waveforms with the modifications of Fig. 3*

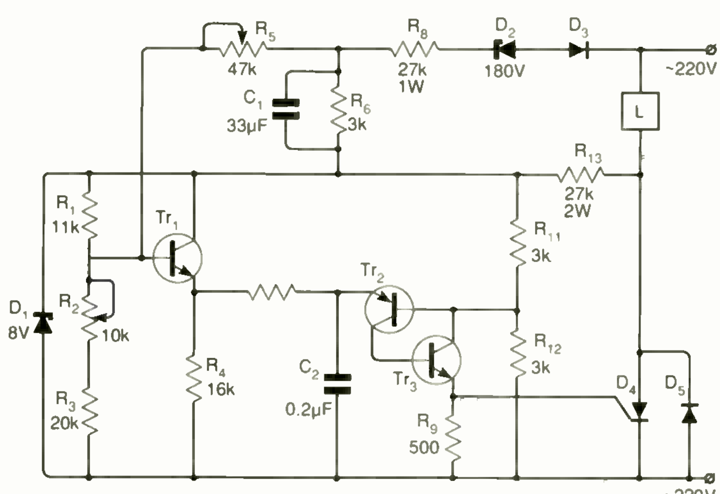



*Fig. 1 Resistive load version of AC mains stabiliser*

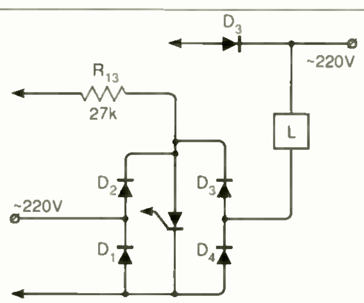



*Fig. 3: Modification to thyristor circuit for reactive loads: thyristor is set in bridge*

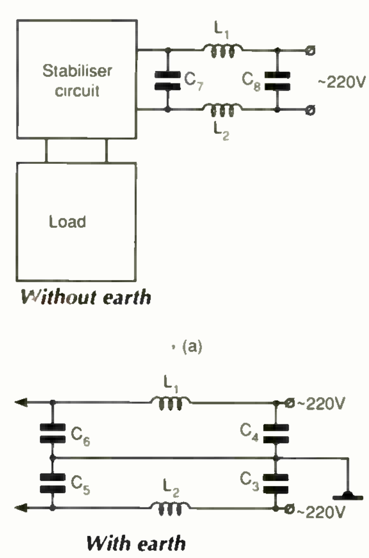



*Fig. 5: Interference suppression circuits*

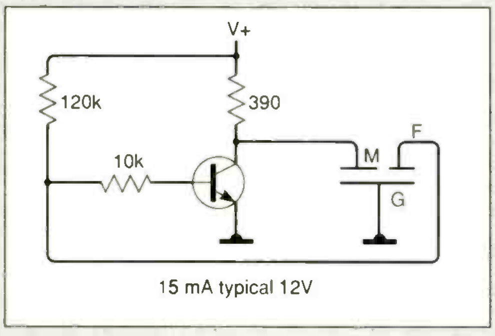



*Fig.1. Standard oscillator for use with three-terminal piezo transducers.*

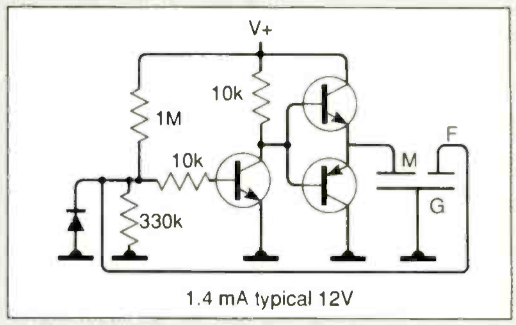



*Fig.2. Modification to reduce current drawn by oscillator, while retaining same output.*

# Low-current transducer driver

A standard oscillator driving a three-terminal piezoelectric transducer (Fig.1) may be extended by a few extra components to give the same output while drawing much less current.

Figure 2 shows the circuit, in which the diode D1 forces the oscillator to run at 50% duty cycle – the optimum ratio. Values are uncritical and the circuit is happy with a supply of 5V to 30V. Beware reducing current demand by increasing the collector resistor too much, since in that condition starting becomes unreliable.

***Mark Byrne***
*Devizes*
*Wiltshire*

## Correction

In the July issue, the Circuit Idea by PR Narayana Swamy contained errors, for which we apologise to readers. The word inputs at the top left should read as follows:

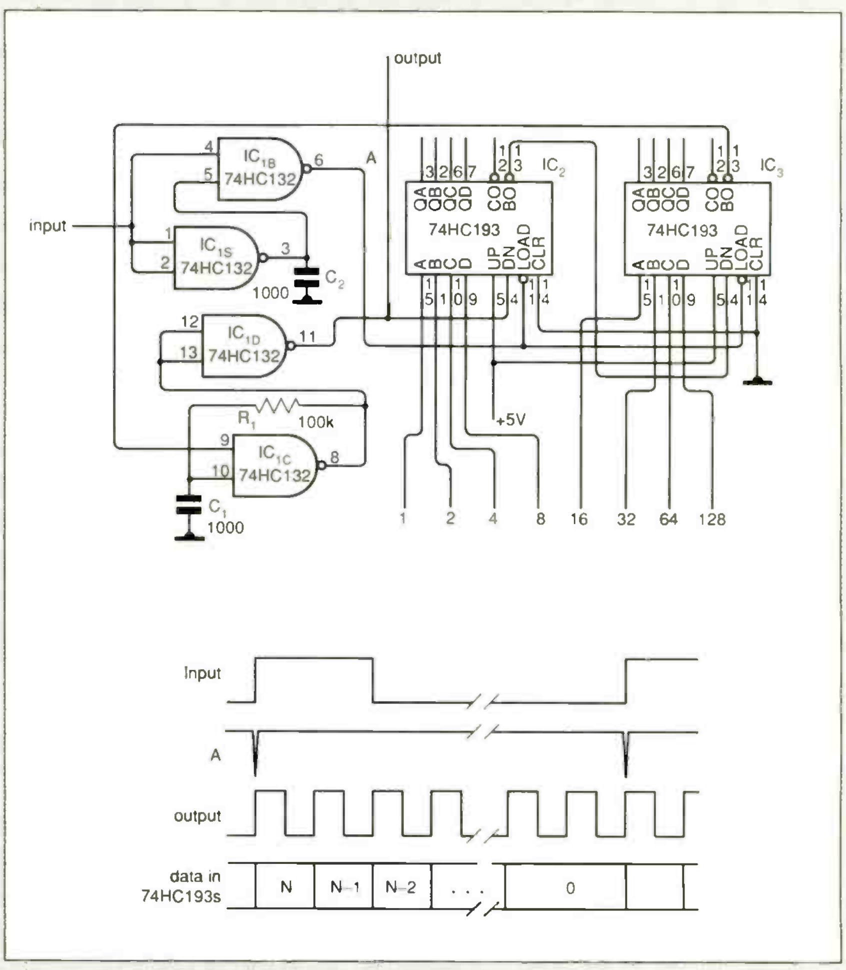
| | | | |
|---|---|---|---|
| Word 1 | A323 | Word 2 | B323 |
| | A222 | | B222 |
| | A121 | | B121 |
| | A020 | | B020 |

Also IC1 and IC3 are 7408s.

# Programmable pulse train generator

When an input triggers this circuit, the reuired number of pulses from 2 to 256 automatically appear at the output. Nand sections $IC_{1a,b}$ form the input triggers into very narrow load signals which enter the the input data (the pulse number) into the 4-bit binary counters $IC_{2,3}$. Data being loaded, the $B_0$ output of $IC_3$ is 1 and allows an oscillator $IC_{1c}$ to function and to step the two counters down until they are both at zero, at which point the $B_0$ output is 0 and the oscillator stops, having produced a number of output cycles dependent on the input data plus one count since the counters go to 0. Oscillator components $R_1$, $C_1$ determine the output frequency.

***Yongping Xia***
*West Virginia University*
*Morgantown, WV, USA*




***Number of output cycles of oscillator depends on data applied to presettable counter data inputs.***

# Taking the numbness out of PC number crunching

***"Making mathematics more exciting and enjoyable is the driving force behind the development of the Derive". So begins the 240 page manual for this esoteric program. But does it succeed? Don Bradbury reports on the package, from Soft Warehouse in Honolulu, Hawaii. It might sound like fun but it does demand a certain amount of mathematical expertise.***

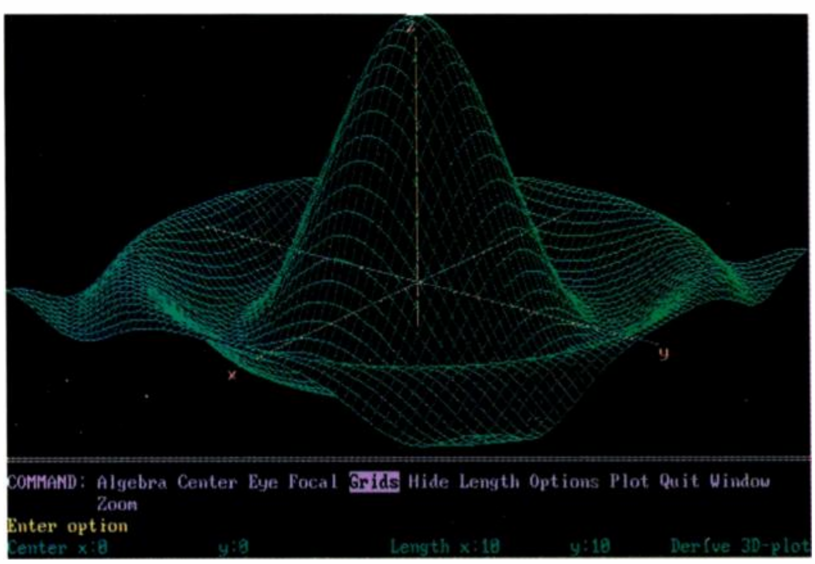
Derive offers a series of modules covering arithmetic, algebra, calculus, vectors, and matrices. Input screens allow appropriate equations or formulas to be enteredand solved, simplified or built on through an extensive range of functions and constants.

The AUTHOR option is used to enter new expressions and modify and build on certain library expressions derived from a particular module. The completed expression – provided it is syntactically correct – is transferred to the main window where it may be manipulated or graphed as appropriate.

A DERIVE.INI file contains an extensive set of default values, but it can be edited directly with any ascii line editor to set more appropriate values for work and hardware.

On-line help for the program is available as a menu option – though it serves mainly to direct the user to the relevant part of the manual. Correcting entries makes use of a Wordstar-like editor and is quite easy to do.

*Derive's plotted "Sombrero" expression.*




The program will run in 512K of ram but to squeeze maximum quality from a graphic plot, if you set the number of grids too high, (to improve the plot contour resolution) then it may run out of memory. Modern memory-hungry operating systems mean that you cannot push graphic quality too far without facing memory constraints. Undue demands on memory may cause the program to chug along for some time on a complex problem before deciding it cannot complete the requested task – a situation I faced on a mid-power 16MHz 80286 machine, without a maths coprocessor. But this is the sort of software which benefits greatly from powerful hardware.

Limitations are mainly felt while calculating graphic output, and here perfectly adequate plots may he had with quite low grid settings, say between 40 and 60. In such cases the calculations are completed fairly quickly, even on wimpish hardware. But it is best to arrange an expression, and select plot viewpoint first with a coarse setting in the graphics mode until satisfied with the output, then select better definition with a higher grid setting.

### Program operation

The screen is divided into two main areas. The bottom status line shows the percentage of computer memory currently available, the editor's present mode (insert or over-write), and the module in use in the main window;arithmetic, algebra, or whatever is selected.

Above, is a message line showing what the program is currently doing. During prolonged calculations the program can look as if it has locked up, but keystrokes stored in the keyboard buffer during that time will be executed when calculations are finished. So it's best to keep a constant eye on the message line and then wait until the menus are automatically returned.

This happens particularly when graphic plots are being constructed. Derive can plot hidden lines or omit them (the normal mode), and in the latter case there is often a substantial delay while hidden lines are plotted. The program might, with advantage, have been made to recognise that hidden lines need not be plotted.

Finally, two top-level command lines show the menu in use. This may be an extensive list, sometimes up to nineteen items long, and since selected options do not display a sub-menu as the list is traversed, each option used must be committed to memory. But this is a rapid process particularly for the most commonly-used options.

### File formats

Mathematical expressions created within the program's environment can be saved and viewed or modified with a standard ascii text editor. Options allow saving of output in various formats. If MTH format is selected data can be entered into Derive for continued work. BAS format is suitable for inclusion in a Basic program, FOR files use the Fortran format, and PAS files can be used with Pascal programs.

Files on the program distribution disk are in MTH or DMO format. Either may be read into the algebra window, or the program can be started by appending a file's name to the command line. Thus DERIVE PLOT3D starts the program directly with a series of expressions from the PLOT3D.MTH file which are suitable for demonstrating three dimensional graphing. Another option allows the merging of a different MTH file with that already in the algebra window.

All, or just a selection of the expressions created with a Derive window can be saved to a printer or disk file, but, unlike MTH files, these PRT files cannot be read into the program.

### Expressions

Most modes of expression entry to a window are straight forward. Standard operators and normal precedences are used, but parentheses do not include other than standard () brackets. The * symbol can be substituted by a space, so that 2 (3+5) is equivalent to 2*(3+5), for example, and the caret symbol indicates a power expression. Other conventions are clearly indicated in the manual.

A frequent requirement is to reuse expressions within others. Any expression in the current list (they scroll upwards as others are added to a window) may be recalled by highlighting, and then, if necessary, split into parts for further application. This is a great time saver when needing to build more complex expressions from simpler ones, although the BUILD command allows direct modification of any highlighted expression.

Standard conventions are also used for various functions such as ABS to return an absolute value, SQRT for a square root, and so on. On the PC, a SQRT entry displays as the standard symbol and may, along with other symbols, be entered by means of mnemonic characters in an Alt mode.

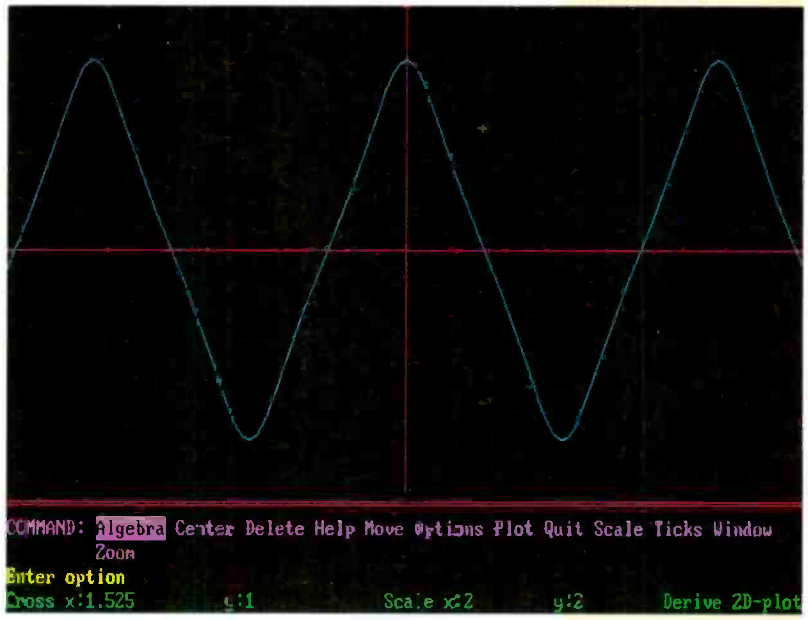
Greek letters are entered in the algebra window by using the equivalent English character in combination with the Alt key.

Finally, the order of expressions in a window may be rearranged or they can be removed altogether to reduce the clutter of no-longer-required entries.

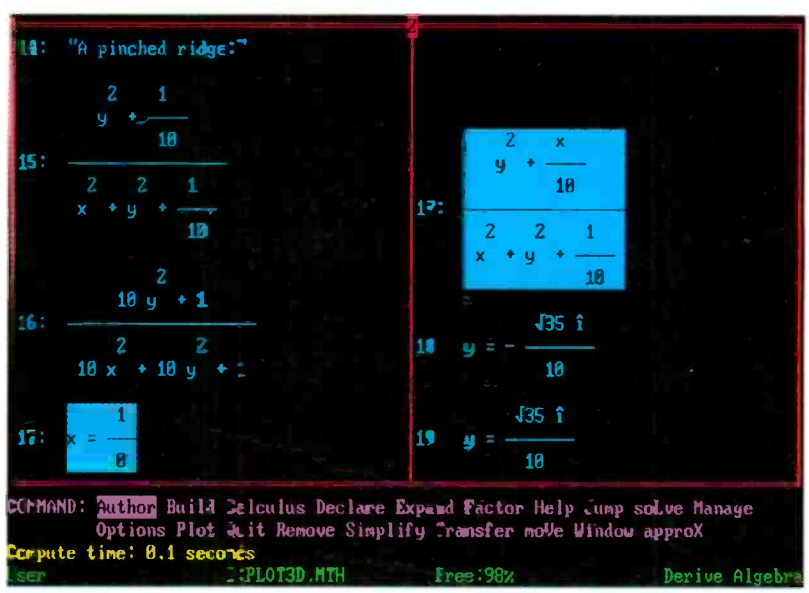
Many mathematical computer programs can substitute numerical values into formulas, and a few can solve equations to obtain numeric solutions. But Derive can also combine and simplify formulas, and can solve, algebraically as well as numerically, an equation for one variable in terms of the other variables. In this it claims to be unique. The ALGEBRA.DMO file provided can be used to demonstrate such capabilities.

Derive is able to simplify univariate and multivariate polynomials, rational and extended-rational expressions (the latter having fractional powers of variables), algebraic expressions, and elementary transcendental expressions, ie algebraic and elementary functions - exponential, logarithmic, trigonometric, hyperbolic, and their inverses.

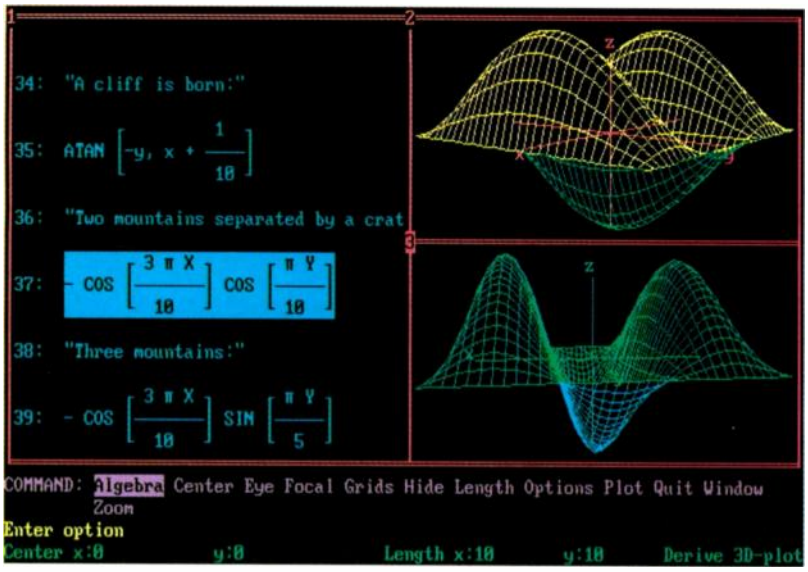
While applying the SIMPLIFY command to such




*"Near traingular waves" plotted by the package.*




*Windows showing simplifications and solutions for both example and authored expressions.*




*Three-window display showing two plot orientations*

expressions, it is often beneficial to split up the expression into parts because it can take an inordinate length of time to carry out the expansions and cancelling of common divisors necessary. Such a process can run the computer out of memory because intermediate results have to be stored in ram. If this seems to be happening it may be necessary to ESCAPE from the calculation and apply the command again after breaking down the expression into smaller parts.

In the algebra mode variables can be reordered using the MANAGE ORDERING commands, but if changing the variables order does not give the desired form of the simplified expression, you can rearrange the order manually with the BUILD or AUTHOR commands.

A Calculus module has commands and functions for performing symbolic limits, differentiation, integration, Taylor polynomial approximations, series summation, and extended products.

### Plotting

Derive can plot univariate and bivariate expressions, the resolution and colour choice of which is dependent on the display mode selected or made available.

Graphic plots can be zoomed, scaled, centred, and modified in certain other ways. They may be rotated to alter the viewpoint (particularly useful in 3D plots) using EYE, LENGTH, and FOCAL commands. The latter sets the focal point of your field of vision.

### The sum of it

Derive is a powerful mathematical tool though it might have been made to support expanded memory with advantage – but judicious use of the housekeeping commands, and restrained application of the plotting power of the program, will permit excellent work to be carried out.

At around £150 it must be considered very good value ■

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# PLD package says bye bye to breadboard

***John Anderson finds Abel-4 to be the embodiment of software description of hardware – it works well too.***

Abel-4 is an integrated suite of programs taking design of logic systems on PLDs from concept through to final programmed device. Abel (advanced Boolean expression language) is in effect a second generation PLA compiler and makes the early products such as Palasm look clumsy.

Key to operation of the package is that it allows circuit operation to be described behaviourally, through a hardware description language (HDL). This is a descriptive tool which uses software akin to Pascal or C to describe operation of the hardware of the design. It can then be compiled and processed as if the work were development of a computer program rather design of a hardware device.

### Easy installation

Main Abel-4 software is provided on five discs (though it is delivered in a huge box!) with options such as device fitting supplied on separate discs.

Installation is simple and professional, with most aspects completely automated – and it did ask before overwriting the AUTOEXEC and CONFIG files. The program is protected with a dongle on the parallel port (oh dear, not another one - there must be a better way) and be warned this package is extremely hungry for disc space. The basic Abel-4 package needs nearly 2Mbytes, with a further 3Mbytes required for the "SmartPart" device database and another 500Kbytes for work area on the hard disc.

### Integrated design environment

Operation is through an integrated design environment reminiscent of language development tools such as Turbo Pascal or Quick Basic. There is a top banner with pull down text menus – but strangely no mouse support – and the program will operate in either 25 or 43 row mode.

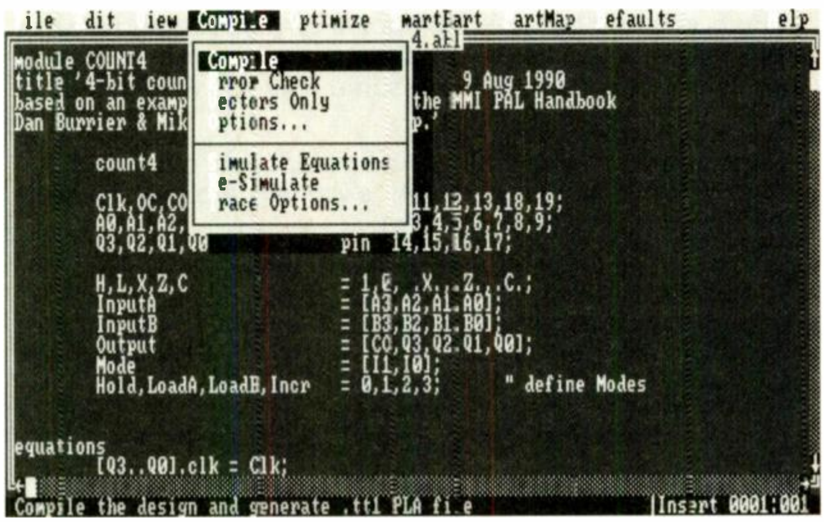
The total development process is quite complex, but as the only original work required of the designer is to define operation of the device in HDL, Abel-4 makes the rest of the task a fairly simple almost transparent procedure.

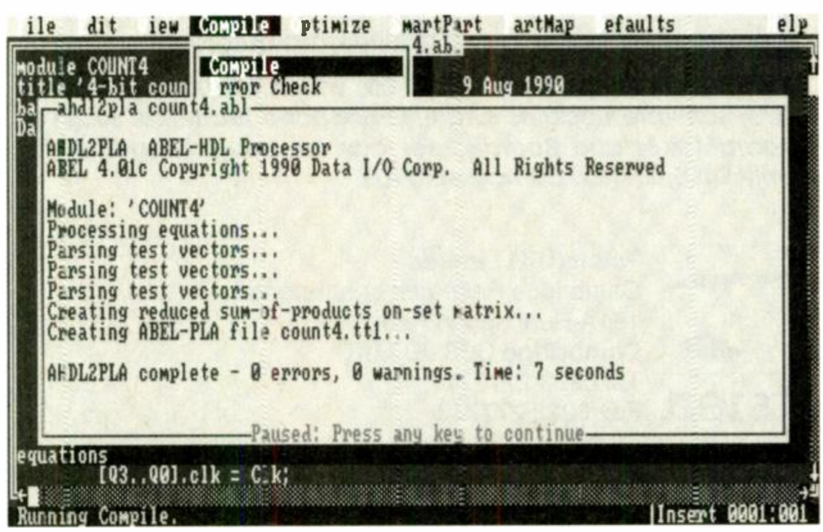
For example a considerable number of intermediate files are produced during compilation, optimisation and simulation, but these are all handled automatically by the program, with the user only specifying basic HDL text.

On entry to the program, the ascii editor is invoked. One minor moan here is that there is no file directory facility, so if you cannot remember the name of the file you want, the only way to view those available is to exit or shell out of the program. The Abel-4 editor can be replaced by another ascii editor of choice, though I found the built in one adequate for the relatively small example programs.

*Fig. 1. Edit environment with pull down compile menu - though strangely no mouse support.*

*Fig. 2. Once the HDL file is ready, compilation translates the design description into a set of Boolean equations*



# Take the Sensible Route!

BoardMaker is a powerful software tool which provides a convenient and fast method of designing printed circuit boards. Engineers worldwide have discovered that it provides an unparalleled price performance advantage over other PC-based and dedicated design systems by integrating sophisticated graphical editors and CAM outputs at an affordable price.

## NEW VERSION

In the new version V2.40, full consideration has been given to allow designers to continue using their existing schematic capture package as a front end to BoardMaker. Even powerful facilities such as Top Down Modification, Component renumber and Back Annotation have been accomodated to provide overall design integrity between your schematic package and BoardMaker. Equally, powerful features are included to ensure that users who do not have schematic capture software can still take full advantage of BoardMaker's net capabilities.

***BoardMaker V2.40 is a remarkable £295.00 (ex. carriage & VAT) and includes 3 months FREE software updates and full telephone technical support.***

## AUTOROUTER

BoardRouter is a new integrated gridless autoroute module which overcomes the limitations normally associated with autorouting. **YOU** specify the track width, via size and design rules for individual nets, BoardRouter then routes the board based on these settings in the same way you would route it yourself manually.

This ability allows you to autoroute mixed technology designs (SMD, analogue, digital, power switching etc)in **ONE PASS** while respecting **ALL** design rules.

## GRIDLESS ROUTING

No worrying about whether tracks will fit between pins. If the track widths and clearances allow, BoardRouter will automatically place 1, 2 or even 3 tracks between pins.

## FULLY RE-ENTRANT

You can freely pre-route any tracks manually using BoardMaker prior to autorouting. Whilst autorouting you can pan and zoom to inspect the routes placed, interrupt it, manually modify the layout and resume autorouting.

***BoardRouter is priced at £295.00, which includes 3 months FREE software updates and full telephone technical support. BoardMaker and BoardRouter can be bought together for only £495.00. (ex. carriage & VAT)***

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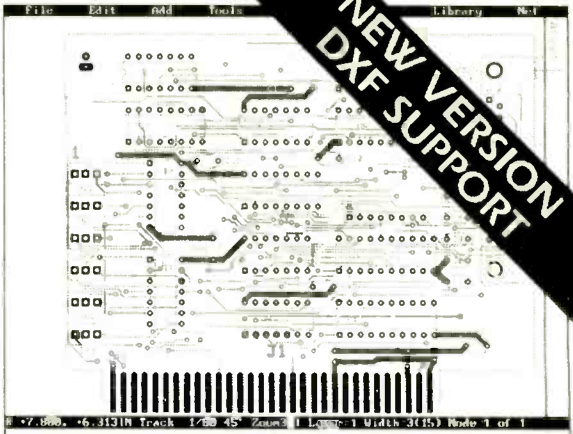
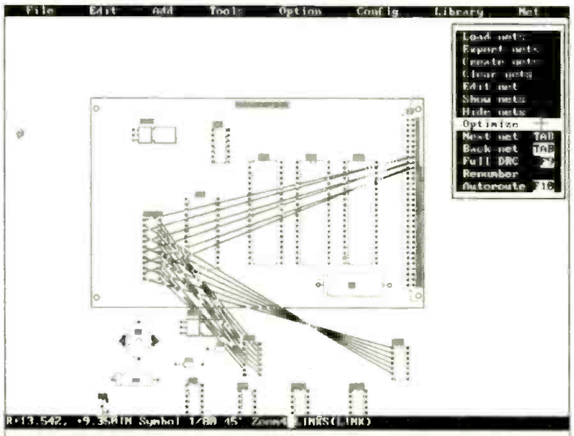



Full analogue, digital and SM support - ground and power planes - 45 degree, arced and any angle tracks with full net-based Design Rule Checking.




Optimized placement by displaying ratsnest per component. Lines indicate the unrouted nets.

## HIGHLIGHTS

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### Compile, simulate and optimise

Once the HDL file is ready, compilation translates the design description in the form of state diagrams and truth tables into a set of Boolean equations. Other operations carried out during compilation include translation of test vectors and generation of a test vector file, replacement of all operators with equivalent operations using only Not/And/Or and Xor, and Or-ing together of equations that cause multiple assignments to the same identifier.

Simulation allows correction of design errors either at an early stage when simulation of equations allows debugging of the design before even selecting a device or assigning pins. Or simulation of the Jedec file simulates design with the selected device.

Simulation output can be displayed in a table; waveform format using IBM PC character graphics; waveform format using ascii characters, and the macro cell format which shows the internal nodes and outputs.

Optimisation produces an intermediate file used by the device selector. Action of the optimiser is to reduce the logical equations based on user defined constraints.

### Few weaknesses

The program is very strong in most aspects of its operation, although a few weaknesses are apparent.

Context sensitive help is available though the index to the help file seems poor: it takes nearly 10s on a PC-AT to get the help information required. To put this in context 10s is longer than the time taken for a complete compilation.

A key area in PLD designs is timing problems through differing propagation delays in the device. Some warnings are given in the manual, together with a discussion about elimination of hazards using redundant gates, but Abel-4 does not provide estimates of propagation delays.

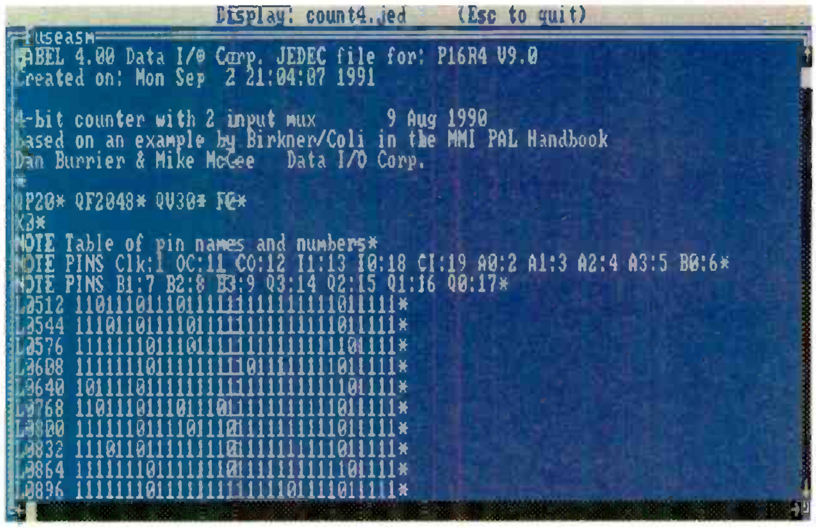
However, with the exception of the help facility, all aspects of the program ran at a perfectly adequate rate, compiling and optimising in only a few seconds. This speed of design means that for a user who knows the software well, a dramatic increase in productivity is possible.

Creative aspects of the design process are concentrated in the generation of the HDL file, and the mundane production of the Boolean description can be made completely transparent to the designer.

### Workstations

Several workstations, including Sun, Apollo and DEC Vax can run the package. So anyone starting on a PC then needing to migrate to a more powerful platform, can have the same software environment maintained with the HDL files generated on PC simply exported to the new platform.

On workstations, an alternative route (though not



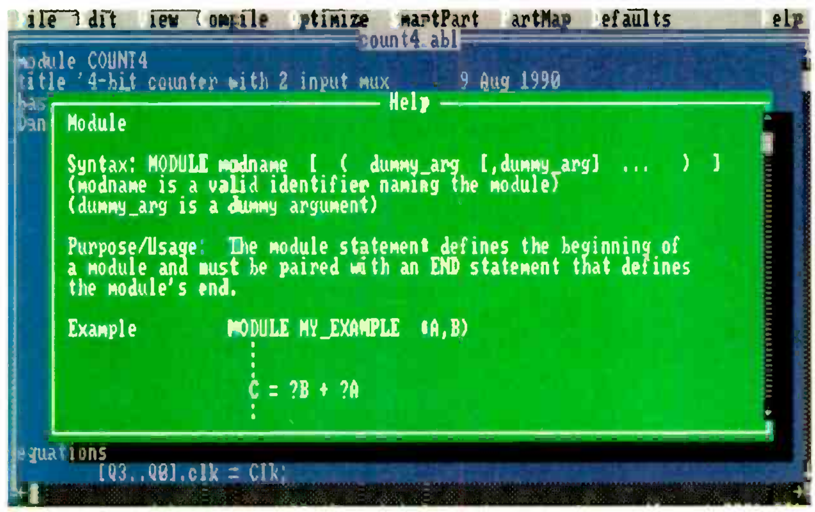
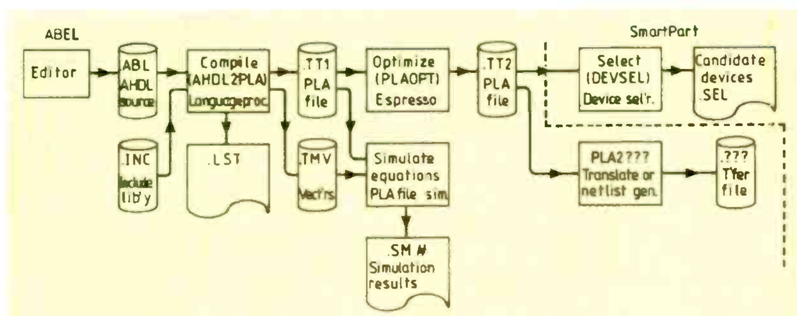




*Fig. 3. Final Jedec file for a 4-bit counter.*

*Fig. 4. Help is context-sensitive – but it can be a long time coming*

*(Below) Abel takes high-level descriptions in source files and converts them into programmer load files. Before you can create a load file that contains the fusemap of a particular logic design, you must create a source file that reflects that logic design.*




## HDL's in designing PLDs

With an HDL-based design process, production of a tested (in the simulation sense) design can be achieved from concept, entirely on computer. The process can be represented by the following procedure:

```
Design_concept
REPEAT BEGIN
REPEAT
Produce/Edit_HDL_file
Compile
UNTIL no_errors
Simulate_equations
IF simulation=OK THEN BEGIN
Optimise
Device_selection; Generate_JEDEC_file
Simulate_JEDEC;
END
END
UNTIL design=OK
Program_Device
Document
```

Although this procedure is not necessarily the exact process that would be employed – for instance the target design may not be realisable and the design concept may need to be changed or subdivided – it shows a compact and deterministic design process is possible for PLDs using HDL.

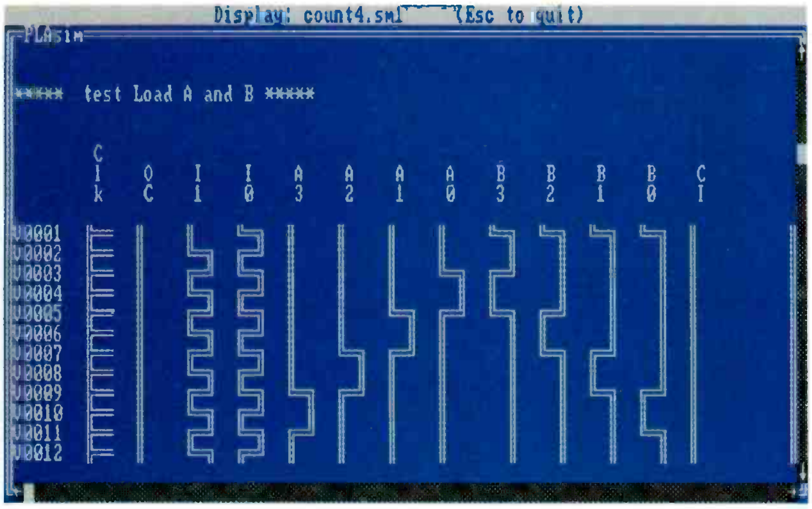



*Fig. 5. Pix simulation with waveform output is one of the display choices.*

reviewed here) to generating the HDL file is to use the Dash schematic capture program to produce the design concept in schematic form. This can then be translated directly to an HDL file.

**Professional feel – and price**

The package is a very professional logic designer's environment, offering a seamless route from the HDL description of the device through to programming of the final product. In effect it provides a silicon compiler translating conceptual designs to silicon with no intervening hardware steps.

All aspects are impressive, with the possible exception of the price. The cost is really too high for the occasional user, or the amateur, and there might be an argument for Data I/O producing a reduced performance version at a lower price.

Abel-4 is undoubtedly the embodiment of software representation of hardware, with description, compilation, simulation and programming, all on a PC, replacing the archaic methodology of design, breadboard and test. ■

**Supplier details**

ABEL-4 design software is available from Instrumatic UK Ltd. First Avenue, Globe Park Marlow SL7 1YA. Phone 0628 476741.

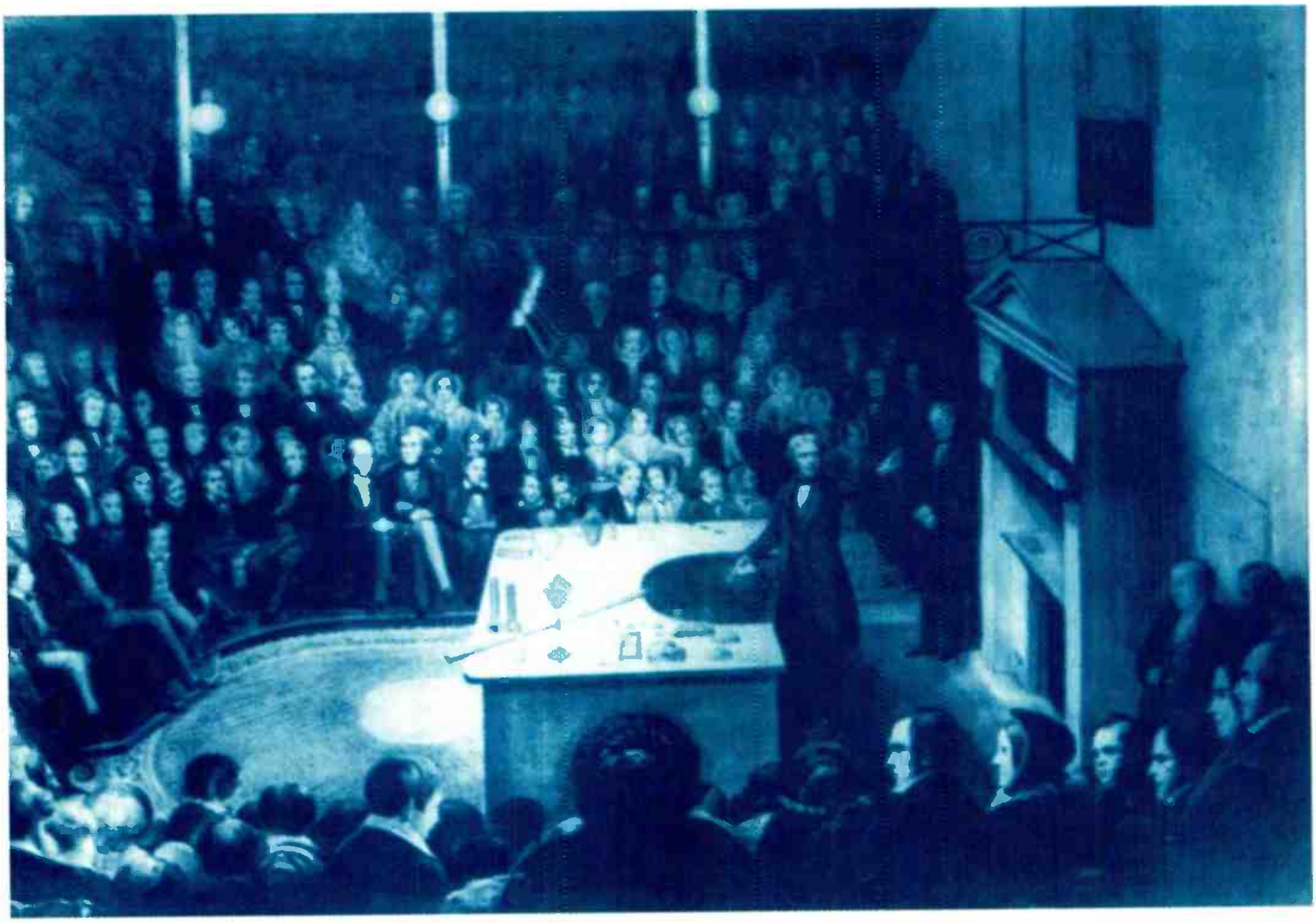
Price: Abel4 ms-dos includes 1 year update support £1695

F180-DOS fitter for Altera 1800 architecture £295

Versions for Sun and Apollo are priced from £2950

**Hardware specification**

PC running MS-dos Version 3 or higher
Standard monitor and keyboard
640K ram (384K minimum)
Hard disc drive
3.5in or 5.25in floppy drive
Parallel port (for dongle)
Serial port (for programmer interface)



# FARADAY: THE FATHER OF POPULAR SCIENCE

***Lectures so popular they were standing-room-only and words now part of everyday science are testaments to a popular brilliance. Greg Grant gives us a glimpse of Faraday the communicator.***

Michael Faraday's education, as he readily admitted, amounted to little more than the three Rs. Yet at only 33 he became a Fellow of the Royal Society. But what also sets Faraday apart was that he was the first technocrat as concerned with the communication of scientific and technological ideas as with their creation and development.

In the twenty years between discovery of the North Magnetic Pole and the Great Exhibition, he transformed electricity from a gentlemanly curiosity into a serious scientific discipline. But it was in communication of these achievements, and those of science in general, that Faraday made an even greater impact.

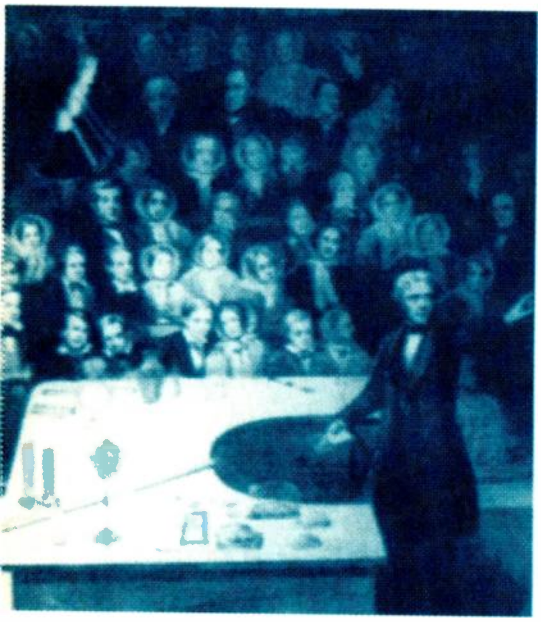
The communicative medium of the period was the lecture, and Faraday made himself a master of the genre through sheer application and dedication. He had been a regular attender at other peoples' lectures, particularly those delivered at the City Philosophical Society and the Royal Institution.

While listening, he would note the most important words and sentences, and the names of substances new to him. Later, in the privacy of his lodgings, he would write up the evening's topic from his observations.

Books too were a powerful influence on him, one particular example being "The Improvement of the mind", by hymn writer Isaac Watt. With its insistence on careful observation, the importance of known facts and the snares of rash imprecise speech, Watt's tome was the perfect guide for anyone contemplating a career in science, let alone lecturing in the subject. After his death, Faraday himself would be lauded in another self-improving tract, Samuel Smiles' late-Victorian classic "Self Help".

## Self improvement

Having given his first lecture in the spring of 1810, Faraday persuaded his friend Edward McGrath to part with two hours of his time per week, dedicated to the improvement of Faraday's grammar, punctuation and spelling. Gauging from the fact that the pro-



***Faraday giving a Christmas lecture in the presence of The Prince Consort. Lecturing was the main communicative medium of the period, and Faraday did it masterfully. Whenever he lectured, the Royal Institution's auditorium was full.***

cess continued for the next seven years this must have been badly needed. Faraday was also aware of the power of illustrations. He took lessons in drawing from a French emigre tutor, M Masguerier – hence the painstakingly accurate sketches in his laboratory notebooks, especially those of lines of magnetic force.

In 1820, he published "Analysis of native caustic lime of Tuscany", his first scientific paper, and a result of his accompanying his employer Sir Humphrey Davy on a tour of the continent. Over the next four years he published many papers, including some in the *Quarterly Journal of Science*.

Faraday also continued his lecturing throughout this period – particularly on inorganic chemistry – and seven years later, collected his investigative experiences and experiments together and published them under the title "Chemical Manipulations". This weighty, 600page publication was highly successful, remaining a standard work on laboratory methods and techniques for many years.

## Power of words

Undoubtedly one of the most significant aspects of Faraday's communicative efforts, was his coining of new descriptive terms and expressions for physical and electro-chemical phenomena he had either observed or discovered.

However his efforts were not always greeted with universal approval. He was criticised, most effectively by William Whewell, for his use of the word "pole" as a descriptive noun. Moreover the article that took Faraday to task, "Employment of notations in chemistry", appeared in the Royal Society's journal.

The piece nevertheless impressed Faraday and he wrote to its author asking for assistance. At this time Whewell was Professor of Moral Philosophy at Cambridge; he was also the man who removed the stigma associated with the term Natural Philosopher, by the simple expedient of inventing another descriptive noun for the same activity. The new term he gave to those who instigated the world about them was Scientist, which he took from the Latin *scientia*, or knowledge.

## Birth of electrolysis

Faraday had carried out electro-chemical experiments with Davy, and had watched him liberate a number of hitherto unknown metals by passing an electric current through molten compounds. This technique Faraday and Whewell called *electrolysis* – an expression based on the Greek word *lysis* meaning a loosening, and the liquid or solution in which such loosening takes place, was termed an electrolyte.

Electric current was introduced into the electrolyte through metal rods connected to the terminals of a battery and these became electrodes,from the Greek *hodos*, meaning route (cf exodus) because they formed the pathway for the electric current.

In 1834 Faraday proposed that the positive terminal be called the anode and the negative terminal the cathode, from the Greek prefixes *ana* meaning up, and *kata* meaning down. Just as a flow of water travels from a high point to a low point, it was thought that electric current flowed from positive to negative.

In electrolysis, parts of one molecule appear to travel towards the positive electrode and parts of another towards the negative. These travellers Faraday called ions, from the Greek *ienai*, meaning to go.

By 1838 Faraday and Whewell had developed what amounted to a new electrical vocabulary and words such as paramagnetic, diamagnetic and ferromagnetic could now be used to describe magnetic characteristics of specific materials.

## Unique mind

One of the principal reasons why Faraday was an excellent communicator was his cast of mind. A deep spiritual faith gave him a visionary rather than a mathematical view of nature, and he thought in pictures, seeking annotations for these images, rather than pursuing abstract explanatory indicators known as mathematics.

For example Faraday's treatment of William Gilbert's lines of force was to trace them out in space as it were, on sheets of paper with either iron filings or a compass needle.

Another old concept that appealed to his imagination was that of an atmospheric medium or "ether". Faraday tended to see his magnetic fields as lines of elastic stress in such a medium – a force field extending from its point of origin and becoming less effective with distance. Here we glimpse his quietly-determined advocacy of the unity of forces, his instinctive feeling that electricity, magnetism and indeed light itself were but different manifestations of the same phenomenon.

These beliefs go some way to explain the astringent distrust with which he and his ideas and achievements were viewed by his more mathematical colleagues.

There were some notable exceptions to this generalisation such as Lord Kelvin and James Clerk Maxwell.

Maxwell realised that there were no inherent differences in the explanatory methods of Faraday on the one hand, and mathematical physicists on the other. In the first paper of the series he wrote on the electromagnetic theory of light, Maxwell recorded a mathematical treatment of Faraday's lines of force.

## Wide appeal

Whenever Faraday lectured, the Royal Institution's auditorium was full. It was he who began the popular lectures for children, still held at Christmas every year and now reaching a far wider audience through television.

One lecture in this series, "The chemical history of a candle" became justly famous, subsequently being translated into almost every European language.

Another piece that enjoyed wide popularity was "Lectures on the various forces of matter" and both are excellent examples of Faraday's method and technique. In the first case he began simply, using the most common of household articles, a candle. In the second, he did exactly the opposite, plunging his young audience into a wide-ranging elaboration of the laws of nature.

But for me, Faraday's masterpiece is his lecture on Wheatstone's telegraph, delivered to his *alma mater* The Royal Institution on Friday 11 June, 1858. He subtitled the lecture an "Argument in favour of the full recognition of science as a branch of education", and his description of experimental techniques are crisp and fascinating. Comments on Wheatstone's workmanship are the sort that could only be made by someone with similar skills – Faraday's dexterity with his hands was the result of his apprenticeship as a bookbinder, as well as his continual experimentation in his own laboratory.

As a result his advocacy of science as a distinct branch of education is powerful, indeed irrefutable, as his belief that science teaches an individual to be "neglectful of nothing".

Many of us - more I suspect than would care to admit - write as much to explain things to ourselves as to others. Was the driving force behind Faraday's skill as a lecturer and demonstrator the fact that he regarded such activities as furthering his own knowledge as much as that of others? I like to think so. ■

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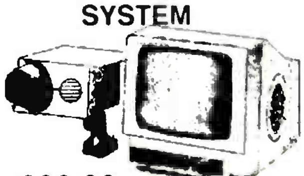

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# CROSS-QUAD QUIZZING

***The linearised cross-quad can be used as a stable precision differential output voltage-to-current converter. Terrence Finnegan provides an operational analysis of this unusual circuit which works by positive/negative feedback.***

One aspect of the linearised cross-quad circuit seems to be unique. It is essentially a voltage-to-current converter, whose transfer characteristic is linearised by a combination of both positive and negative feedback. I know of no other which uses positive feedback in this way.

Operation is stable provided that the current outputs at the collectors of $Q_1$ and $Q_2$ (**Fig. 1**) are both fed into virtual earth nodes. The AC voltages at these collectors will then be nearly zero and will not provoke instability.

The circuit is complex, but can be analysed by considering the voltage existing at the emitter of $Q_3$, – produced by the difference between two currents: the first current is generated in $Q_3$ by the voltage at its base fed in from the collector of $Q_4$, and the second current is coupled directly into its emitter through $R$, fed in by the emitter of $Q_4$.

It so happens that these two currents cancel and the emitter of $Q_3$ turns out to be a virtual earth. $Q_3$ thus provides the loop gain and the voltage at its collector (which is also the emitter of $Q_1$) is in phase with the input and larger in amplitude. This makes the output current, $i_1$, also in phase with the input and not at 180°, as one might expect at first sight.

Cascode $Q_2$, $Q_4$ also provides gain, but its main role is to provide the differencing and linearising needed to make $i_2$ equal in amplitude to $i_1$ and 180° out-of-phase. Hence $i_2$ is in anti-phase with the input voltage.

$i_1$ and $i_2$ are therefore equal in amplitude, in opposite phase and have low distortion. The circuit transconductance is given accurately by $G_m = 1/R$, provided that $R$ is larger than about 100Ω otherwise the loop gain is insufficient.

### Detailed operation

The simple looking circuit is surprisingly difficult to analyse with accuracy and what follows is a first order analysis based on a study of the observed operation. The following assumptions apply:

1. The transistors are matched and have a high current gain, so that the base currents can be neglected;
2. The DC current in $Q_1$, $Q_3$ is equal to that in $Q_2$, $Q_4$ and this current is supplied by current sources in the emitter circuits. Therefore the transistors all operate at the same transconductance, $g_m$ , and $g_m$ is a non-linear operator accounting for all transistor non-linearities.
3. Initially, point B is assumed to be a virtual earth, although the analysis will eventually prove this to be true.

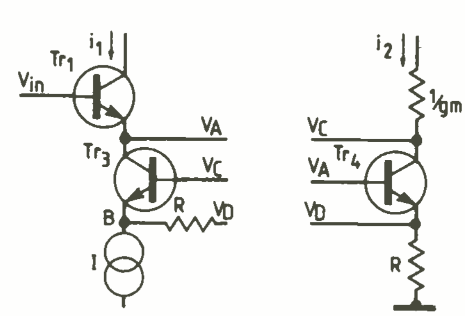


*Fig. 1. The circuit is divided into two parts, to analyse the operation of the cascode $Q_2$, $Q_4$.*

Analysis starts by dividing the circuit into two parts, as shown in Fig. 1, and then considering the operation of the cascode $Q_2$, $Q_4$.

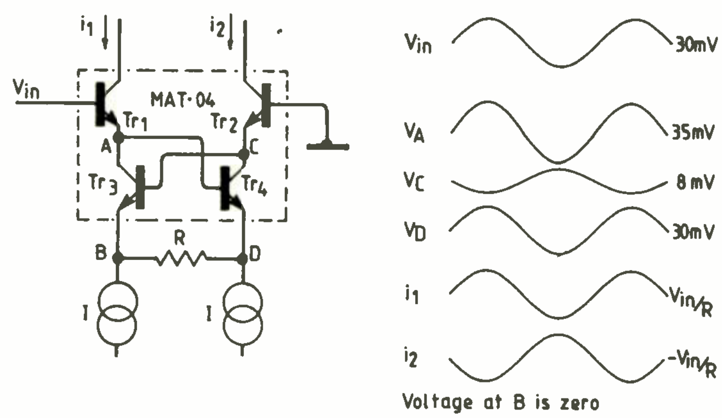


*Fig. 2. Linearised cross-quad circuit, together with some waveforms at appropriate points.*

$Q_4$ has an unknown positive voltage, $V_A$ input at its base, emitter load resistor $R$, and a collector load resistor equal to $1/g_m$, given by the emitter input resistance of $Q_2$ in common-base mode acting as the collector load.

The output signal current, $i_2$, flows in both $Q_2$ and $Q_4$ and to a first order is given by: $i_2 = V_A.g_m/(1+g_m.R)$. The voltages $V_C$ and $V_D$ are therefore: $V_C = -V_A /(1+g_m.R)$ and, $V_D = V_A .g_m.R/(1+g_m.R)$.

Turning attention now to the other half and considering operation of the cascode $Q_1$, $Q_3$: $Q_3$ has a voltage $V_C$ input at its base and a voltage $V_D$ driving its emitter through resistor $R$. Since $V_B = 0$, the current through $R$ is given by: $i_R = V_D/R = V_A.g_m/(1+g_m.R)$.

Voltage $V_C$, applied to the base of $Q_3$, will generate the output signal current $i_1$ in both $Q_1$ and $Q_3$, and $i_1 = g_m.V_C = -V_A.g_m/(1+g_m.R)$.

This equals the signal current $i_R$ flowing in $R$ and is opposite in sign.

The two currents therefore cancel and the external emitter current of $Q_3$ is zero, confirming the assumption that point B is a virtual earth. We also see that $i_1 = -i_2$ . Finally, the loop will set the voltage $V_A$ relative to $V_{in}$ so that current $i_1$ can flow through $Q_1$. This requires that $g_m(V_A - V_{in}) = i_1$ , since $V_A > V_{in}$. Hence, $g_m (V_A - V_{in}) = V_A . g_m/(1+g_m . R)$, from which $V_A = V_{in}(1+g_m . R)/g_m . R$

Substituting this value for $V_A$ in the expressions for $i_1$ and $i_2$ gives: $i_1 = -i_2 = V_{in}/R$.

The circuit transconductance is therefore independent of the transistor parameters, provided that they are matched. More detailed calculations show that the actual match conditions needed are: $g_{m2} = g_{m3}$ and $g_{m1} = g_{m4}$ . The circuit can therefore be constructed from matched pairs if necessary.

Measured waveforms for $V_A$ , $V_C$ and $V_D$ are shown in **Fig. 2**, with the input set to 30mV peak-to-peak. $V_C$ is heavily distorted and difficult to quantify. However, $V_D$ is equal in magnitude and phase to $V_{in}$ as predicted and $V_A$ is in-phase with $V_{in}$ and slightly larger in amplitude. The voltage at point B is very small and is not shown.

***Table 1. High speed instrumentation amplifier performance.***

| | | |
|---|---|---|
| Input noise voltage density | G=1000 | 1.2nV/Hz |
| | G=100 | 3.6nV/ Hz |
| | G=10 | 30.0nV/Hz |
| Bandwidth | G=500 | 400kHz |
| | G=100 | 1MHz |
| | G=10 | 1.2MHz |
| Slew rate | | 40V/µS |
| Common-mode rejection | G=1000 | 130dB |
| Distortion | G=100 | 0.03% |

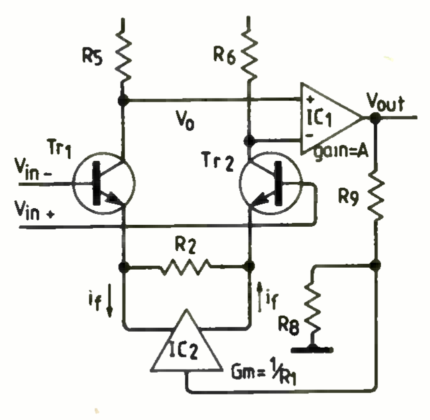


***Fig. 3. The cross-quad is represented by the transconductance amplifier $U_2$, having $G_m$=1/$R_1$, which feeds currents -$i_f$ and +$i_f$ into the input stage.***

## High speed instrumentation amplifier

The circuit finds use as a precision differential output voltage-to-current converter and is used by PMI (see reference) as described in Application Note *AN-105* to implement a low-noise high speed instrumentation amplifier.

The cross-quad is implemented by the Mat-04 matched quad to give precision performance and acts to provide differential current feedback into the input stage. OP-17 acts as an overall nulling amplifier to complete the feedback loop. The collectors of the cross-quad both feed into low impedance nodes, thus meeting the stability criterion discussed earlier. Resistor pairs $R_8$, $R_9$ and $R_{10}$, $R_{11}$ form voltage dividers to attenuate the output feedback and match the limited input range of the cross-quad.

The matched dividers also guarantee that the output voltage is at ground with zero input voltage. The REF50Z provides bias for the input stage and is used instead of a zener to give a low dynamic resistance reference. The input stage bias current is about 380µA per side. The operation of this amplifier can be studied by first simplifying the circuit to that shown in **Fig. 3**. Here the cross-quad is represented by the transconductance amplifier $U_2$, having $G_m = 1/R_1$, which feeds currents $-i_f$ and $+i_f$ into the input stage.

The differential output voltage, $V_o$, from the collectors of $Q_1$ and $Q_2$ is nulled out by the servo action of the overall feedback loop. Since the collector current at $Q_1$ and $Q_2$ due to the signal $V_{in}$ is nulled to zero, the emitter voltages at $Q_1$ and $Q_2$ must follow the base voltages exactly (to generate no collector current) and $V_{in}/R_2$ must equal $i_f$ .

But, from the output circuit, $i_f = (V_{out}/R_1).(R_8/R_8+R_9)$ and the overall gain is therefore given by:

$$V_{out}/V_{in} = (R_1/R_2).(R_8+R_9/R_8)$$

Using the resistor values shown in **Fig. 4**, $V_{out}/V_{in} = 50399/R_2$

In its application note, PMI gives a gain of $33{,}000/R_2$ for their values. This does not quite agree with the calculated gain value of $34{,}297/R_2$, which should apply with their values.

I suspect that the difference is due to the high zener resistance of $Z_1$, which allows some feedback into the opposite side of the cross-quad, thus reducing the overall gain from the theoretical value. However there is no doubt about the impressive performance as **Table 1** shows:

PMI reduces the gain by increasing the value of $R_2$, from 33R at a gain of 1000 to 3k3 at a gain of 10. This increases the input noise as the Table shows and it would be better to alter the gain by proper choice of $R_1$, $R_8$ and $R_9$, while keeping $R_2$ to a low value, say 500Ω. ■

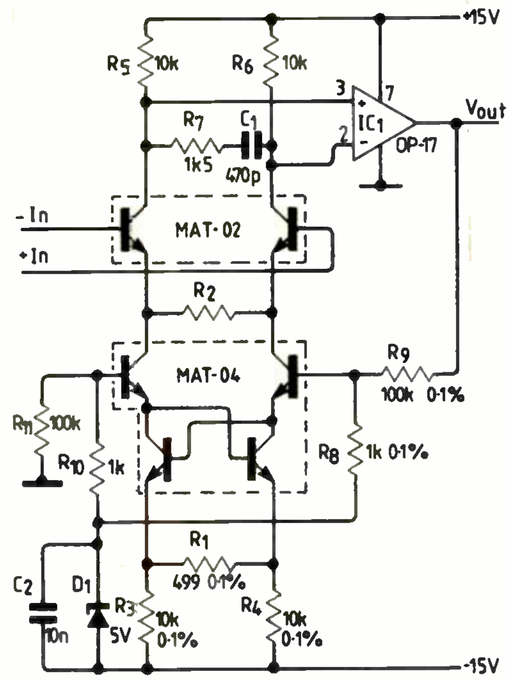


***Fig. 4. Low-noise high speed instrumentation amplifier (PMI application note AN-105) shown here, with some minor changes, is implemented by using the linearised cross-quad circuit as a precision differential output voltage-to-current converter .***

## Reference


Application Note AN-105: Precision Monolithics Inc. (now Analog Devices)

# INTERFACING WITH C

by

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# A GEM OF TECHNOLOGY?

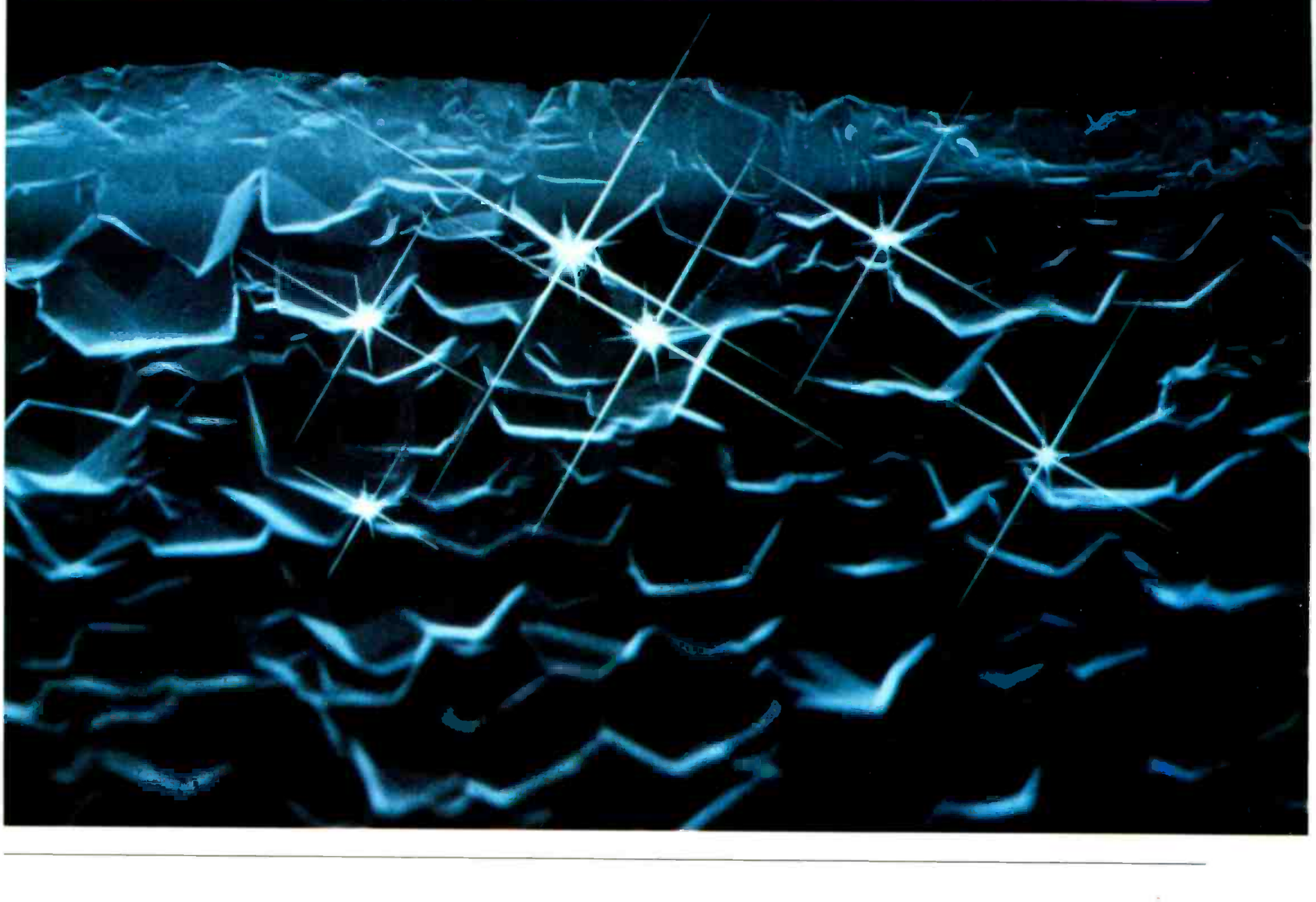
***Huge sums are being invested in research for developing artificial diamonds as a replacement for gallium arsenide in IC design. Chris Robbins traces the history of the research, and explains why diamond chips can be more effective.***

Forget gallium arsenide and indium phosphide; forget superconductors, Josephson junctions, optical computing, bioelectronics, sub-micron VHSIC, quantum-effect devices, and all the other wondrous technologies predicted to bring the computing millennium. It may not be any of these exotic approaches that make the grade when the 21st century dawns.

There is another technology, that all being well, just might be the magical one destined to revolutionize the hardware of tomorrow. That technology is based on plain old common or garden diamond. Well, it will be if the current research into its synthesis and application pans out. Worldwide there are now more than 100 laboratories working in the field. In Japan alone, in excess of $100 million a year is being spent on diamond research.

But enough of these speculations and superlatives, where does the story really begin? Well, like most branches of modern science and technology, it goes back a long way. The first really reliable account of true synthetic diamond dates from February 1955 when the American General Electric Company's F.P Bundy announced the results of the research they'd been involved in since the early 50s. The diamonds they produced were small, around 0.1 mm, and required enormous pressures and extremely high temperatures (50,000 atmospheres and nearly 2000°C) to make them. Even those extreme conditions weren't enough by themselves, so a molten nickel catalyst was used to help transform graphite into diamond.

At that time the integrated circuit (IC) had not been invented, the transistor itself was still a relative newcomer, whilst germanium ruled the semiconductor world and silicon was a difficult and little known upstart. But there was certainly no competition from GE's tiny diamonds, had anybody even sug-



gested it though the similarity between diamond, germanium and silicon hadn't gone unnoticed). GE's success didn't lead to a major breakthrough in electronics, instead it launched a new synthetic diamond abrasives business. Mundane perhaps, but profitable, and important. In fact, so important to US defence industries that diamonds were classified as a special strategic material.

Perhaps the earliest known attempt at synthesis occurred In Glasgow in 1880. One J.B. Hannay is supposed to have made artificial diamonds from lithium and paraffin. These were heated in a sealed iron gun barrel until it glowed a dull red. Hydrogen from the paraffin was supposed to have combined with the lithium leaving carbon under great pressure to crystallize out as diamonds. Although most of his experiments failed, some tiny diamond-like crystals were produced.

It all sounds very much like Victorian alchemy, though curiously, recent research has also made use of lithium in the form of lithium fluoride as substrate on which to 'grow' diamond. Even, Hannay's diamonds were supposedly examined using X-ray crystallography over half a century later and passed as the genuine article.

Thirteen years after Hannay's attempts, French chemist Henri Moissan also claimed to have made diamonds. The recipe this time involved burnt sugar and molten iron. This wasn't quite as ridiculous as it sounds; the sugar supplied the necessary carbon, whilst the iron could have acted as a catalyst. The mix was prepared at a temperature of just over 3000° C in Moissan's own invention, the electric arc furnace. To generate the requisite high pressure, the carbon-iron mix was rapidly cooled by quenching in cold water; the theory being that the carbon would separate out as diamond crystals. But did it work? Well it was a nice idea, and in several respects the process bore a striking resemblance to GE's successful process. But like so many early claims it was later discounted.

But a couple of years earlier in 1891, something did come out of E. G. Acheson's attempts to produce diamond. It was not diamond though, but silicon carbide, the third hardest substance after diamond and one of the materials which later formed the basis of the huge abrasives industry. Later still it found useful, if not gainful employment, as a crystal in the elementary 'cats whisker' detectors (primitive point contact semiconductor diodes) of early radios.

In fact, when used as a semiconductor for

## WHY USE DIAMONDS?

The answer is simply that of all known materials capable of being employed as a semiconductor, it's the best – in theory at least. Its dielectric constant is half that of gallium arsenide (GaAs); electron mobility is greater than silicon and more than twice that of GaAs, whilst the contrast in hole mobilities is even greater; thermal conductivity is at least four times that of copper (the current best); breakdown voltage is fifty times that of GaAs; power handling is some 2500 times greater.

In terms of area efficiency, when it comes to making complementary devices, it's also a winner, being three times better than silicon and six times better than GaAs, or in other words a whole lot more can be squeezed onto a chip. It is unconditionally stable in virtually any environment – ICs would not need any protective packaging, and they'd work quite happily at 600°C and even higher temperatures. What's more, unlike devices made from "conventional" semiconductors, diamond ICs would be highly resistant to radiation damage – a very real asset when it comes to nuclear reactors, satellites and spacecraft, and one that has not gone unnoticed by the US DoD (Department of Defense).

Diamond's potential for the kind of densely packed logic ICs that go into computers, is perhaps easier to grasp by combining its relevant parameters in the form of a figure of merit. If silicon is allowed the privileged status of reference material and allocated the value 1, then diamond works out at 32. By comparison, the currently highly favoured GaAs is, surprisingly, a shade less than 0.5 .

fabricating logic ICs, its figure of merit rates it some six times better than silicon and 12 times better than GaAs. Not only but also, silicon carbide was the material in which the Lossev effect was discovered way back in 1923. An intriguing scientific novelty for many decades, some 40 years later it was developed to give the now ubiquitous light emitting diode, without which no present day remote control TV would be complete. So, Acheson's experiments weren't a complete waste of time.

At the turn of the century, the real thing still posed something of a problem. Namely, where did it come from? It was generally agreed that to make diamonds intense heat and pressure were required, hence the form taken by early experiments. But where were these conditions to be found In nature? Sir William Crookes' answer was meteorites, or as he put it on more than one occasion: "a meteorite freighted with jewels has fallen as a star from the sky", whilst the vertical "pipes" in which diamonds were usually found were said to be holes made by meteorites.

It was a nice try. A bold and somewhat poetic explanation, even if a mite off course. They were found in meteorites it was true, but the real explanation lay a bit closer to home – the interior of the Earth itself – and the pipes were simply the filled in necks of old volcanic vents.

While most workers in the long history of synthetic diamond concentrated on the stressful approach, one man In the late 1940s adopted a more laid-back technique. He was William Eversole of the American company Union Carbide. His idea was to deposit diamond from methane by passing it over heated diamond dust, in a process that would nowadays be described as chemical vapour deposition (CVD). Although the method sounds a bit like alchemy, it actually worked. But Eversole's success was rather limited since only about one percent of carbon from the methane was laid down as diamond, the other 99 percent turned out to be graphite. However the method was proven and patents were granted, albeit over a decade later.

Eversole was not the only one to have been interested in making diamonds the "easy" way.

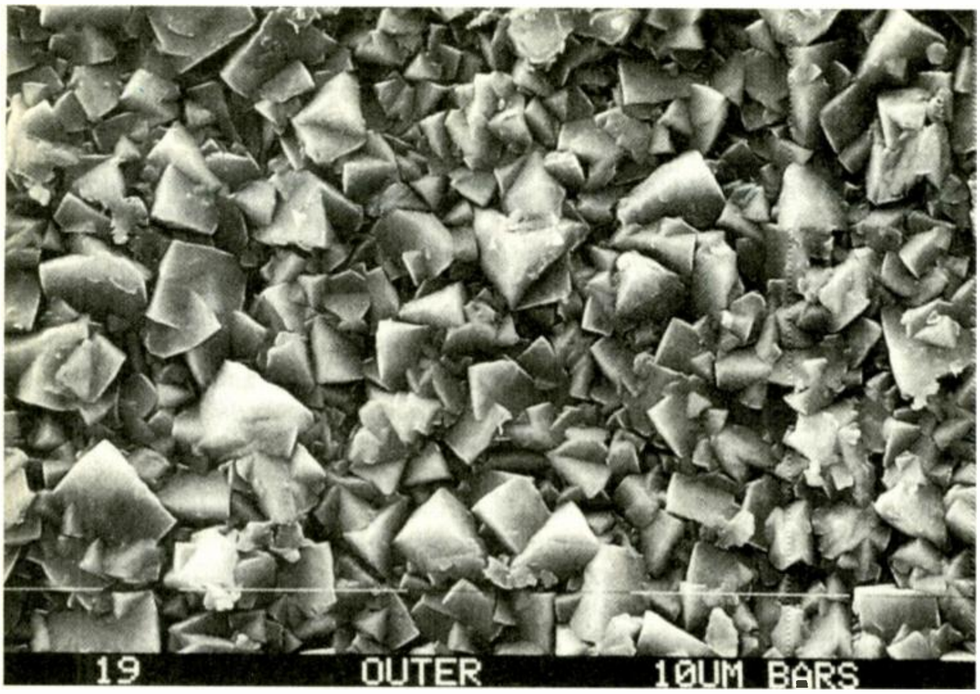
In the mid 60s another American, John Angus, also took up the CVD cause. Although by this time the commercial manufacture of synthetic diamond, using GE's process, was well established, GE had continued to develop it, and experimentally had pushed it to even greater extremes. By the mid 60s, pressures had reached upwards of 120,000 atmospheres and temperatures of 3000°C. But such extreme conditions required extremely expensive and sophisticated equipment, shortened its useful life, and of course increased the cost of the end product.

The Japanese researcher Masayaki Kondo, amongst others, had explored a slightly less fraught approach, concentrating instead on lower temperatures and pressures, but with more efficient catalysts to enhance diamond formation.

By the mid 60s, using this approach, Kondo had managed to make microscopic diamonds at an almost comfortable 800°C and 38,000 atmospheres.

Moderately successful though this and other attempts were, they weren't going to be the way for diamond to make it big in electronics. CVD on the other hand was, or more precisely seemed likely to. But by the mid 70s most Western scientists had gone

***Diamond film layers developed by Plessey's Caswell facility in 1989, provide a durable and transparent window for IR detection in missile targeting systems.***




*Pilkington Electro-optic Materials has combined high-energy plasma and chemical vapour deposition to coat variety of surfaces with polycrystalline diamond.*

off the idea, not least because one of the Russian proponents of the method had fallen foul of the scientific establishment by his supposed discovery of a new "polymer" form of water. Tut, tut!

Japanese workers, however, took the Russian work at its face value, attempted to duplicate it, and succeeded. As ever, it took a while for the West to catch on, so it wasn't until well into the 80s that efforts in the West began to get under way again. But by then the Japanese had quite a head start, and it showed in the enormous number of diamond related patents they had acquired in the meantime; nearly 500 in the period 1983-87 alone.

Despite the growing interest in diamond, research funding in the West is still considerably less than Japan's. One estimate puts total American expenditure at around $20 million a year, or one fifth of Japan's. Even so, in the last few years, considerable advances have been made in both Britain and America. In 1989 for instance, Plessey in Britain announced the development of a plasma enhanced version of the CVD process, capable of growing two inch diameter diamond films from methane. By the following year in America, four inch films were considered routine, and at least three laboratories were working to produce huge diamond films up to twelve inches across.

The latest news, at the time of writing, is that GE have made ultra-pure gem quality diamonds as large as one carat, using a combination of CVD and their well developed high pressure and temperature process. If results are to be believed they are even better than the real thing. At this rate, the interior of the average PC, could well bear a sparkling resemblance to Aladdin's cave a decade hence. ■

# Circuits, Systems & Standards

*First published in the US magazine EDN and edited here by Ian Hickman.*

## ICs simplify design of single-sideband receivers

Single sideband (SSB) transmission offers many advantages over FM and full carrier double sideband modulation schemes – more efficient spectrum use, better signal-to-noise ratios at low signal levels, and better transmitter efficiency. Unfortunately, SSB systems have historically required the use of expensive multipole filters. Today, however, some new RF and digital ICs allow you to circumvent the need for these filters. You can use these ICs to good advantage in developing a cost-effective SSB receiver. Good SSB receiver design requires that you know a little about the three basic methods of single sideband generation.

All three methods use a balanced modulator to produce a double sideband, suppressed carrier signal. The undesired sideband is then removed by high Q multipole filters (the filter method), by phase and amplitude nulling (the phasing method), or by the Weaver method. The reciprocal of the generator functions is used to develop sideband detectors. Generators accept audio inputs and produce the SSB signal; detectors receive the SSB signal and reproduce the audio signal. The sideband signal is typically in the radio frequency (RF) range, so you can amplify it and apply it to an antenna or use it as a subcarrier. It's worth noting that all three methods of removing a sideband are complementary: an SSB signal produced by the Weaver method can be reproduced by the phasing method, etc.

In a generation and detection technique using the traditional filter method, the generator (**Fig. 1a**) produces a double sideband signal, and the balanced modulator nulls the carrier. A high Q crystal type bandpass filter then removes the undesired sideband. The transmit mixer then converts the SSB signal to the desired output frequency. The detection scheme (**Fig. 1b**) simply reverses the operation. A receive mixerconverts the input frequency to the intermediate frequency (IF).

The filter has a narrow response and passes only the required SSB bandwidth. The product detector demodulates the signal.

This SSB signal generation method has one major drawback. The filter is tuned to one fixed frequency. As a result, you will need to incorporate a number of transmit and receive mixers to satisfy applications involving multifrequency operation.

### Alternatives to the filter method of SB generation and detection

Although some years old now, this article contains some useful ideas in addition to a basic review of methods of SSB generation and detection. The article describe the Weaver method amongst others. The beauty of that particular scheme is that incomplete suppression of the unwanted sideband causes no out of band interference, as it overlays the wanted sideband. **I.H.**

### Phasing method not suited to voice band

**Figure 2** shows block diagrams of generator and detector circuits for implementing the phasing method. In the detector (**Fig. 2a**), the input signal feeds in phase to two RF mixers. A local oscillator (*LO*) supplies a second signal to the mixers in quadrature. Summing the differentiated output of one of the mixers with the output of the second mixer produces an audio output.

In most cases, the mixers will have an output in the audio passband (300 to 3000Hz). Running the passband through the differentiator circuit imposes a 90° phase shift over more than three octaves. As a result, it is

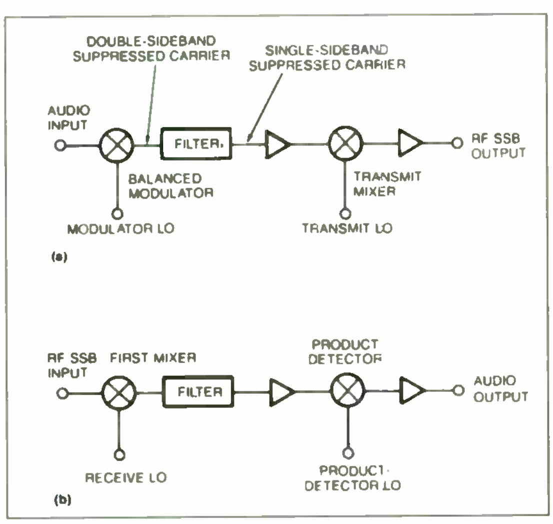



*Fig. 1. In the traditional filter method, the generator (a) produces a double-sided signal, and the balanced modulator nulls the carrier. The detector (b) simply reverses the generation procedure to develop the audio output.*

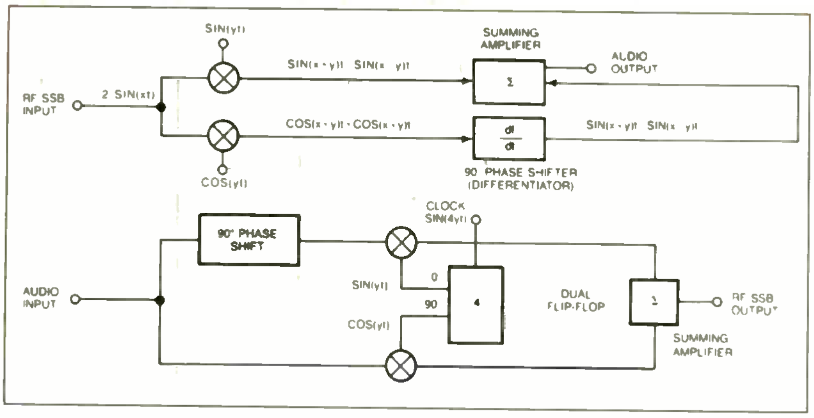



*Fig. 2. The input signal feeds in phase to two RF mixers in the phasing-method detector (a). A local oscillator (LO) supplies a second signal to the mixers in quadrature. In the generator (b), a divide-by-4 flip-flop provides the sin(yt) and cos(yt) signals for the mixer.*

quite difficult to use the phasing method for voice band SSB applications. The phasing method employs a generator **(Fig 2b)** that duplicates the circuit elements found in the detector. Note that in the generator, the differentiator (phase shifter) is located between the audio input and the mixer. In the generator circuit, a divide by 4 flip-flop provides the sin(yt) and cos(yt) signals for the mixer. As a result, the clock signal's frequency must be four times the RF output frequency.

### Versatility in datacomms systems

You can use the phasing method for FSK, PSK, and quadrature PSK data communications systems. In an FSK situation, for example, you can alternately key two discrete frequencies to correspond to ones and zeros. By tuning the receiver at the halfway point, you can let these two frequencies represent the upper and lower sideband signals. When you implement rectification and filtering, you can use the simultaneous upper/lower sideband detection concept to drive both clock inputs of a flip-flop.

This type of FSK receiver can exhibit better sensitivity characteristics than traditional FM receivers. In addition, the scheme uses discrete frequencies, so you will not have to employ a broadband phase shifter; simple discrete RC networks will suffice. The Weaver method **(Fig. 3)** eliminates the difficulty of having to maintain an accurate broadband phase shift in voice communications systems. A derivation of the phasing technique, the Weaver method does require more circuit elements (four mixers as opposed to two, for example) in both the generator **(Fig. 3a)** and the detector **(Fig. 3b)**.

### Low frequency subcarrier vs phase shift

The basic difference between the two schemes is that the Weaver method uses a low frequency (1.8kHz) subcarrier in quadrature, rather than a broadband, 90° audio phase shift. The desired sideband folds over the 1.8kHz subcarrier, and its energy appears between 0 and 1.5 kHz. The undesired energy appears at least 600Hz away (above 2.1kHz). As a consequence, you can reject the undesired sideband with a simple lowpass filter.

It is much easier to design a filter with a steep lowpass response than it is to achieve the accurate phase and amplitude balance that the phasing method requires. As a result, the Weaver method will have much better sideband rejection than that obtainable with the phasing method. Once you have chosen the manner in which you wish to develop the SSB signal, you are ready to add the other circuits that help to complete an SSB receiver. You will need quadrature dual mixer circuits for the first stage when using the Weaver method.

**Figure 4** illustrates two methods of obtaining quadrature LO signals for dual-mixer applications. Both circuits are inherently broadband circuits; they are far more flexible than designs using passive LC circuits (which fail to maintain a quadrature relationship when the operating frequency changes), and they do not require adjustments. In addition, the circuits shown in Fig. 4 are not limited to SSB applications; you can also apply them in FSK, PSK, and quadrature-PSK digital communications systems.

In **Fig. 4a**'s circuit, a divide-by-4 dual flip-flop generates all four quadrature signals. Most of the popular dual flip-flops will work in this circuit; the choice depends on the application. This example employs the HEF4013 cmos device, which consumes little power and maintains excellent phase integrity at clock rates ranging to several MHz. As a result, it will work quite well at the ubiquitous 455kHz intermediate frequency.

For higher clock rates (to 120MHz), the fast TTL 74F74 is a good choice for the flip-flop. Tests on this device at 30MHz operating frequencies show good results - greater than 20dB SSB rejection. At frequencies in the neighbourhood of 5MHz, use of the 74F74 will result in sideband rejection of nearly 40dB. The ultimate low frequency rejection is mainly a function of the audio phase shifter. You can improve performance by employing resistors and capacitors with tighter tolerances in the phase shifter.

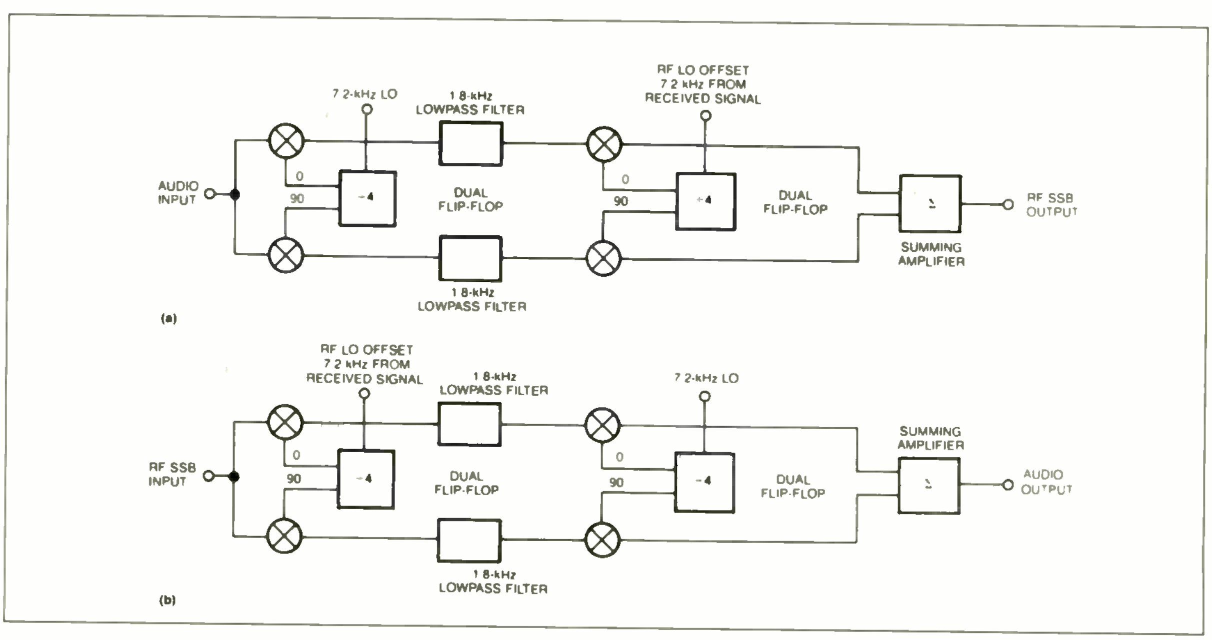



*Fig. 3. There is no need to maintain accurate phase shift when using the Weaver method in voice systems. It does require more circuit elements than the phasing method-four mixers in both the generator (a) and the detector (b), for example.*

### Match clock and operating frequencies

The circuit shown in **Fig. 4b** illustrates a different technique for producing a broadband quadrature phase shift for the LO. In this case, the clock and operating frequencies are identical – an advantage when compared with the flip-flop circuit, because you do not need the high speed components Phase accuracy, however, is more difficult to achieve.

A phase locked loop (PLL) will maintain a quadrature phase relationship when the loop is closed and the VCO voltage is 0V. The DC amplifier enhances the accuracy of the quadrature output by providing gain for the VCO control circuit. PLL circuits tend to be noisy, however, and noise can be a problem. Sideband noise is troublesome in both SSB and FM systems, but SSB transmission is less sensitive than frequency modulation to phase noise in the LO.

After developing the LO signals, you have to provide some drive circuitry. The circuit shown in **Fig. 5a** provides an effective means of driving the 74F74 (or other TTL gates) with an analogue LO. Assuming you are using 50Ω input and output impedances, the NE5205 amplifier provides approximately 20dB of gain from dc to 450MHz. External component requirements are minimal. The 1kΩ value of the resistor is about optimum for pulling the input voltage down near the logic threshold. A 0dBm output level will drive the NE5205 and 74F74 to 120MHz. By cascading two NE5205s, you can increase the sensitivity without sacrificing the wide bandwidth.

**Figure 5b** shows the interface circuitry between the 74F74 and the NE602 mixers LO ports. The total resistance establishes a conservative current drain – about 10mA – from the 74F74 outputs: the voltage divider tap optimises the operation of the NE602s. The low signal source impedance helps maintain phase accuracy. For DC isolation, use a miniature ceramic device for the isolation capacitor.

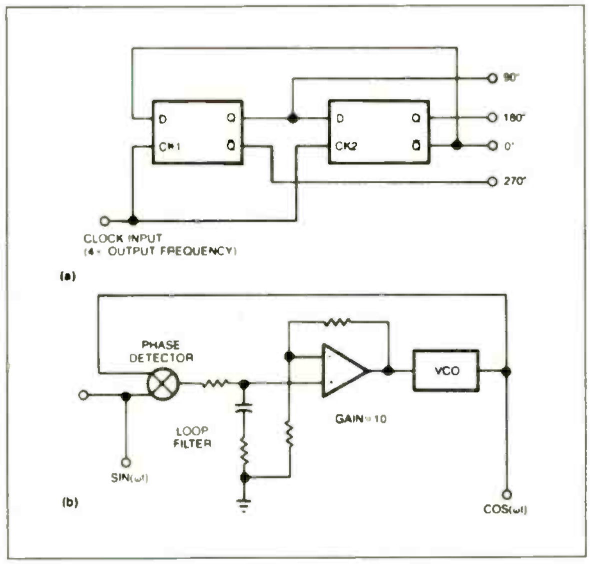



*Fig. 4. You need quadrature dual mixers whether you are using the phasing or the Weaver method. The mixer in (a) maintains good phase integrity at clock rates ranging to several MHz. Clock and operating frequencies are equal in the mixer circuit (b), which gives an advantage over the flip-flop design.*

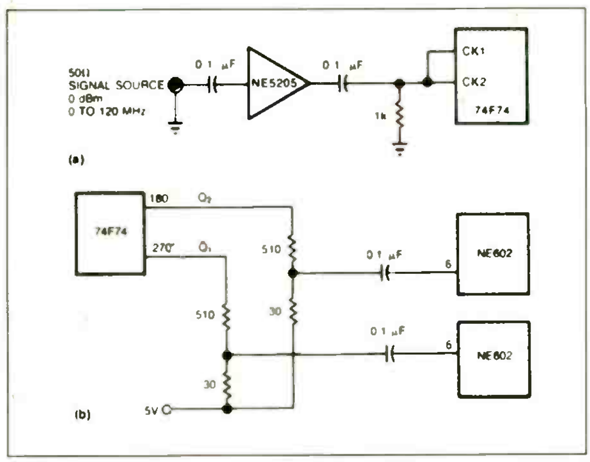



*Fig. 5. You can effectively drive the 74F74 and other TTL gates with the circuit shown in (a). The total resistance in the interface circuit (b) establishes a conservative current drain (approximately 10mA) from the 74F74, and the divider tap optimises NE602 operation.*

### Amplifying and switching functions

The use of active mixers like the NE602 will provide conversion gain – typically 18dB. In more traditional applications, which use passive diode ring mixers, you experience a conversion loss typically 7dB. Consequently, the detected audio level will be about 25dB higher when you use the active mixer approach. This fact means that you can significantly reduce the noise and gain requirements of the first audio stage and eliminate the microphonic effect. This is a great advantage in direct conversion receivers.

Traditional direct conversion receiver designs use passive audio LC filters at the mixer output and low noise discrete jfets or bipolar transistors in the first audio stages. Because of the conversion loss associated with passive mixers, these amplifiers must have a very high audio sensitivity, so they readily respond to mechanical vibration and produce microphony. The conversion gain available from an active mixer allows you to use a simple NE5534 op amp stage (**Fig. 6**), set up as an integrator to eliminate ultrasonic and RF instability.

You can use an HEF4053 cmos analog switch to provide the sideband select function. This triple double-pole switch drives the phase network and engages one of two amplitude balance potentiometers – one for each sideband. The buffer op amp shown with the two sideband select sections reduces the total harmonic distortion, maintains amplitude integrity, and prevents changes in the resistance values of the filter network due to switch resistance. If the gain distribution within both legs of the receiver is consistent, you can eliminate the amplitude balance potentiometers in less demanding applications.

### Phase shifting comes next

In the phasing method, the broadband audio phase shifter (differentiator) is a critical stage. The analogue all pass differential phase shift circuit shown in **Fig. 6** is one of several available broadband phase shift techniques. When you short the inputs together and drive them with a microphone circuit, the outputs will be 90° out of phase over the 300 to 3000Hz band. This splitting and phase shift action is required for phasing generator operation.

For phasing demodulation, the circuit's filters receive their inputs from the two audio detectors. The filter outputs are then summed to null the undesired sideband and reinforce the desired sideband. The filter circuit employs standard 1% values for the resistors and capacitors. You can improve gain tolerances by using 0.1% laser trimmed integrated resistors. To maximise audio performance, it's best to use polystyrene, polypropelene, or Mylar capacitors.

Two quad op amps (NE5514s in this case) fit nicely into **Fig. 6**'s approach. One section of each quad IC serves as a switch buffer, and the other three form a phasing section. The quad op amps also yield high linearity and high dynamic range. These characteristics are much easier to achieve at audio frequencies than they are at common intermediate frequencies. Audio IF systems have other things going for them as well: They have no IF tuned circuits, they have no need for shielding, and power requirements are low.

### Putting it all together

High quality SSB radio specifications call for sideband

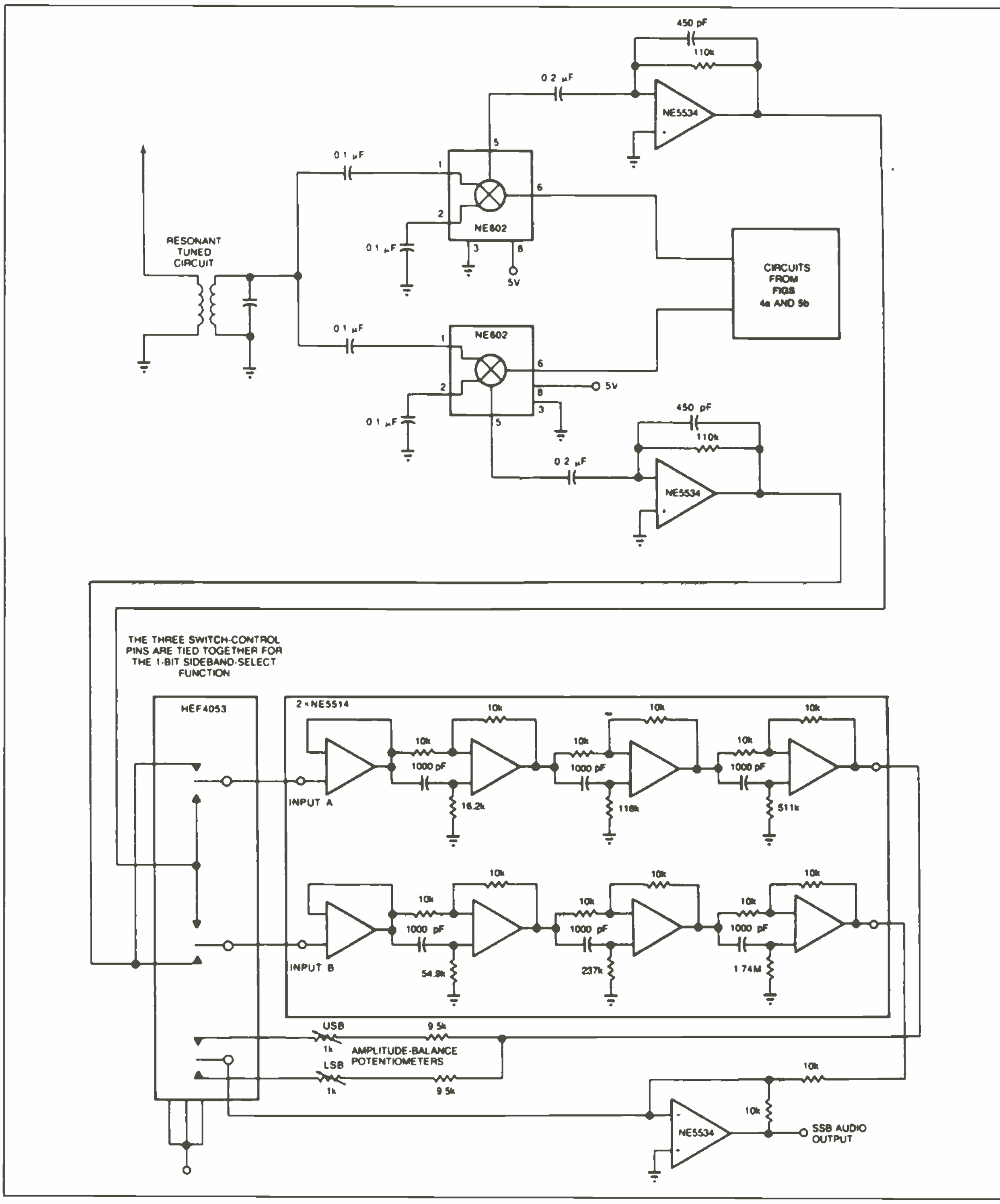



*Fig. 6. You can reliably obtain 35dB rejection levels using this circuit in direct conversion applications. Add an inexpensive 2-pole crystal or ceramic filter and you will realise the required 70dB sideband rejection levels.*

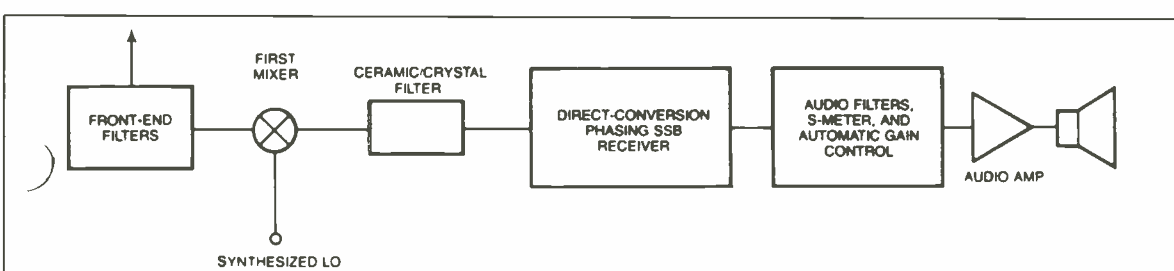



*Fig. 7. Using the phasing filter technique, you can design a complete, yet simple, SSB receiver. The antenna connects directly (via a bandpass filter) to the inputs of the NE602s' mixer stage.*

rejection greater than 70dB. Using the circuit shown in **Fig. 6**, you can reliably obtain rejection levels of 35dB. Add an inexpensive 2-pole crystal or ceramic filter, and you can meet the 70dB requirement. **Fig. 7** shows a complete SSB receiver that uses the phasing filter technique.

The block labelled "direct conversion phasing SSB receiver" is Fig. 6's circuit. The antenna connects (via a bandpass filter) directly to the inputs of the NE602s. The direct conversion phasing SSB receiver circuit has a 10dB signal/noise sensitivity of 0.5V and a dynamic range of about 80dB. Single tone audio harmonic distortion is less than 0.05%, and two tone intermodulation products are

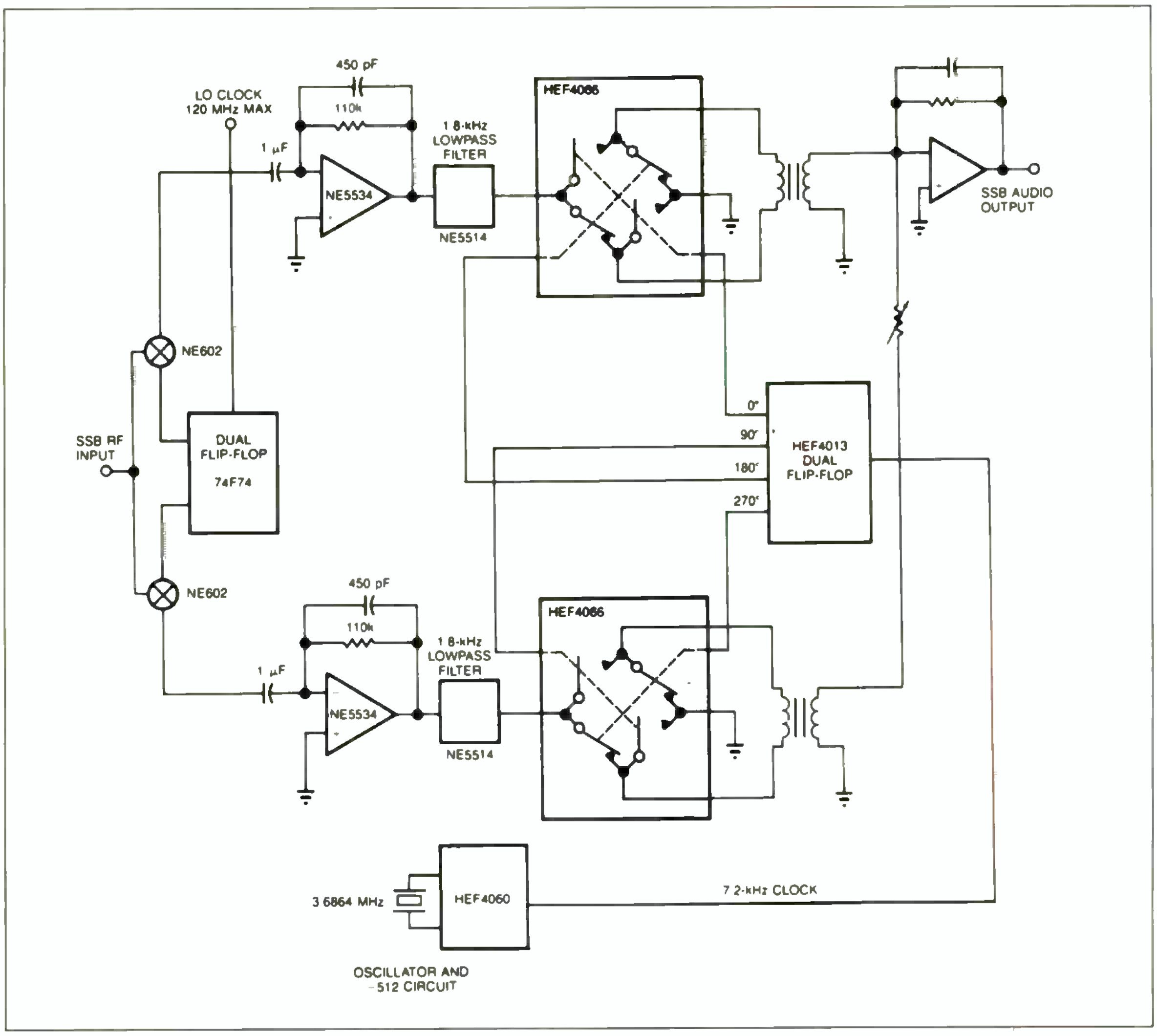



***Fig. 8.** To minimise power drain, you can use HEF4066 cmos analog switches in the subscriber stage of this experimental Weaver receiver circuit.*

more than 55dB down at RF input levels only 5dB below the 1dB compression point.

The sideband rejection is about 38dB at a 9MHz operating frequency. You can also use the same quadrature dual mixer in a Weaver method receiver. **Fig. 8** shows an experimental Weaver receiver circuit. The subcarrier stage here can use HEF4066 cmos analog switches to minimize power drain. A 1.8kHz subcarrier requires a 7.2kHz clock frequency. In the Weaver method circuit, a common 3.6864MHz crystal combines with the HEF4060 oscillator and ÷512 circuit to provide the required clock signal. When you use switched capacitor filters for the lowpass audio circuits, a single clock generator (with appropriate dividers) suffices for all circuit timing signals. ■

# CATCHING THE BUS

***Bus-based computing was developed to get around the limitations of single microprocessor systems. So when the bus standards become a bottleneck, strange things start happening. Rob Causey reports on the state of the buses.***

During the summer, Brighton-based company Amplicon started selling a PC data acquisition card controlled by its own 8086. This is the same processor used at the heart of many PCs: the company had designed a computer within a PC.

Andrew Shephard, Marketing engineer at Amplicon, said that the action was like a coprocessor chip, where the numeric coprocessor does the number crunching leaving the main micro to run the system. "The add-in card could be doing a number of things, sampling and analogue to digital conversion, which the on-board processor deals with. The host PC doesn't have to do anything about it."

Putting a PC processor on a PC add-in card is just a logical extension of what has gone before. "People want to acquire data at 100kHz. Each channel might want a filter. When you're acquiring at 100kHz and doing a Fourier transform on the board, you need a fair amount of processor power to keep it up," says Shephard.

Building a computer in a number of sections and linking the pieces together has become an accepted technique for boosting the performance of a system. Using a single board computer (SBC) to acquire and process data would tie up the main microprocessor with control tasks, slowing down its number-crunching activities. By splitting the job between an i/o board and the SBC, engi-

## Catching the right bus.

**STEbus**. The STE bus was developed to provide rugged 8-bit computer systems for industrial control. It gets its name from the standard size for boards which is slightly longer than the normal eurocard, hence StreTched Eurocard or STEbus.

A great deal of attention has been paid to the electrical characteristics of the boards. A well-designed STEbus card will have very good isolation between the power and signal lines, so that spikes in the electrical supply do not affect processing or storage of data.

Despite the availability of more sophisticated buses, STE boards carrying 16-bit microprocessors have been designed because the cost of the whole system is still cheaper than using a 32-bit bus.

**SBus** is the name Sun gives to the bus it designed for its Unix server computers. The first specification is for 32-bit communications, although there are revisions to extend it to 64-bits.

The bus is beginning to be used in other applications because of the proliferation of Sparc risc micros away from workstations. The bus is designed to avoid TTL line drivers, reducing the power consumption of the system. Sun also set out to produce mechanical specifications which would make it easier to use surface mount devices as they become available.

**Futurebus Plus** is the result of the US Navy deciding it no longer wanted to pay inflated prices for bus-based computer systems. It gave a basic specification and a deadline to a committee of computer and chip makers and the result is a standard approved by the IEEE. The first products will go on sale during the first half of next year.

The Futurebus plus specification will create the most sophisticated commercial bus-based computers yet built. The 64-bit bus is designed to transfer data at up to 100Mbit/s, which has caused a number of problems for component and connector manufacturers.

Other computer buses use ground pins on connectors to provide return paths for signals.

The speed of transfers and resulting sharp signal edges forced the use of ground planes running through the edge connectors to prevent ground bounce and ringing distorting signals.

Component manufacturers have also had to design their products from a very basic level to meet the needs of the specification. Boards will use "Backplane Transceiver Logic" devices instead of standard analogue components to create clean signals at the interfaces with connectors.

Most CPU boards will be built around 32bit risc microprocessors at first, with full 64-bit computers going on the market when the microprocessors are available. Futurebus will probably be used to link together a number of less sophisticated systems, such as VME computers, acquiring data from and controlling the "peripheral" machines.

**VMEbus**. The Virtual Machine Eurocard standard or VME was designed to provide a bus to link together boards big enough to carry 32-bit computers but based on the existing eurocard standards for physical size and connections. It is used in applications ranging from Sun's Unix servers to the electronic point of sale tills found in large supermarkets.

The standard provides for data to be transferred in 32-bit words at 40Mbit/s. The cards usually have two connectors into the system backplane and many have sockets in their front panels for links to non-VME peripherals allowing, for example, data acquisition connections.

The standard specifies that one connector is used for essential communications with the bus but leaves the use of the second to the system designer. A number of board makers have taken advantage of neers can condition and control the data rate from the i/o board, leaving the micro free to process the data.

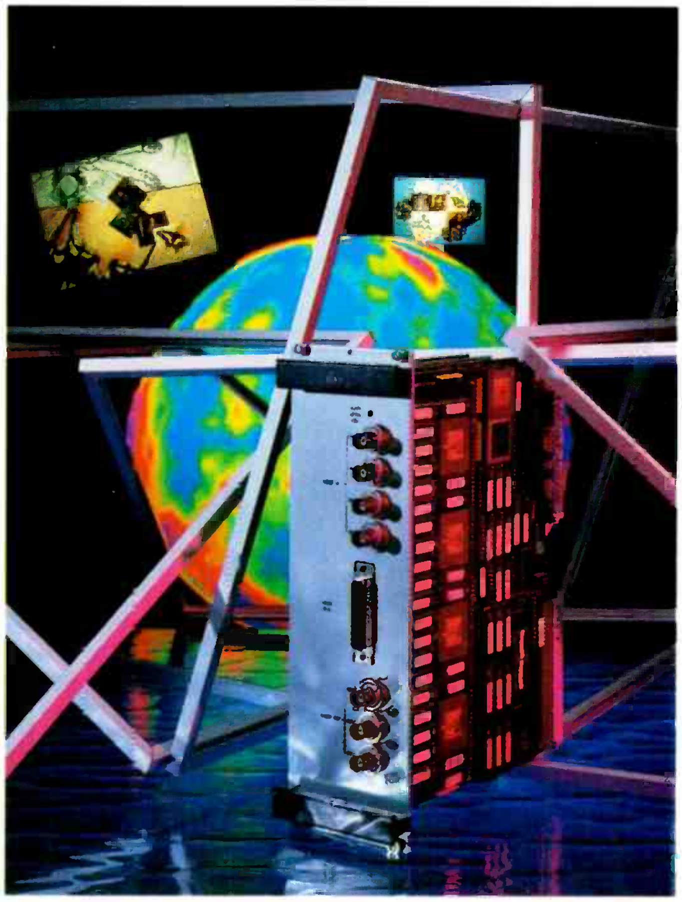
A number of bus standards have been developed to help split up system tasks. This has also helped cut the cost of the equipment needed because the engineers only have to include functions they need, instead of buying a preconfigured system.

The PC bus was designed for personal computing and never thought of as the basis for instrumentation, industrial control, image processing or many of the other thousands of tasks it is now being used for. But engineers are now so familiar with cheap PCs that they are trying to use the bus for anything and everything.

There are a number of problems with the bus. One is that it was designed for low speed data transfers and simply is not fast enough to handle the kind of 100kHz acquisition task described by Shephard. Another is that the PC is electrically very noisy and likely to interfere with weak signals coming from sensors. The physical size of the add-in cards is also a restriction for tasks which need a lot of chips, such as image processing, with its voracious appetite for memory.

At some point, even the low cost and easy system development loses its attraction, requiring a move to dedicated bus-based computer systems.

Image processing is one of the fastest growing parts of the oth-



*Radstone Technology has added image processing to its mainstream VME products. The first module is a three-board subsystem designed to capture and manipulate images in real-time.*
*Image processing is seen as the only active part of the VME market this year. Radstone's Colin Neal believes that the bus will be used increasingly for the application because it can move blocks of data around more quickly than its rivals. Until the PC makers can produce chip-level picture manipulation, which really means multimedia computers, the faster bus will win out.*

this and used the space for the so-called P2 connector to attach modules onto the VME card without passing through the backplane. This lets them increase the memory capacity of the board, or add secondary functions such as digital signal processors or dedicated communications processors.

A number of revisions due to be included next year will provide for 64-bit transfers (VME64) by sending data on signal lines originally intended for sending addresses.

A typical transfer will involve sending a 32-bit address word and a 32-bit data word during one clock cycle and then a number of other 32-bit data words.

**PCbus**. As the name implies, the PCbus is the main communications link inside IBM-compatible personal computers. However, a number of variations have been developed over the years to allow PC makers to use more powerful microprocessors and peripherals as they became available.

The original XT bus was an eight bit link, designed around Intel's 8086 micro. When the US chip company introduced its 16-bit i286, the AT bus was developed to allow all the old dos software and XT add-in cards to be used in the new machines. There are now also two 32-bit buses, Eisa and MCA, used in PCs. MCA computers have different sized slots for add-in cards to the other buses and so cannot use XT or AT boards.

The PCbus differs from other standards such as VME and STE because the CPU card itself carries the slots which give the outside world access to the computer. This so-called "motherboard" arrangement is typical for desktop computers, but rare in most industrial and scientific applications in which PCs are now being used.

The most noticeable difference this produces is the arrangement of the two connectors on PCbus cards.

Unlike backplane systems, which usually only have connectors on one side, PC cards have two links on orthogonal sidesof the card. One plugs into the motherboard and the other allows the computer to connect with the outside world.

**Multibus II** was designed for the same reason as VME, to allow a whole computer to sit on one card. The main difference between the two was the semiconductor company behind the standards, Intel drove Multibus II while Motorola was pushing VME.

Both standards provide 32bit buses and both use Eurocard as the standard board size, although the different connectors used by Multibus II made the cards slightly wider. The IEEE standards covering the two specs were both agreed at the same time, nearly five years ago.

During that time, although Intel has pushed its PC architecture into every corner of the electronics industry, it had little success in the bus-based markets. While VME grew into a $500 million commercial standard, most of the Multibus applications were in military systems.

But digital telecomms is set to change all that. Matra has based its next generation of PABXs, the kind of telephone exchanges used in large buildings, on Multibus II.

Two other Telecomms equipment makers, Alcatel and Ericsson have demonstrated prototype systems to their customers over the last few months.

The Multibus Manufacturers Group has made progress in this market by developing the "hot replacement" features of the bus. This allows system users to take out a faulty board without interrupting the operation of the rest of the computer. With the telecomms sector predicted to be the fastest growing market for the European electronics industry over the coming years, Multibus II could finally achieve the same status as its rival.

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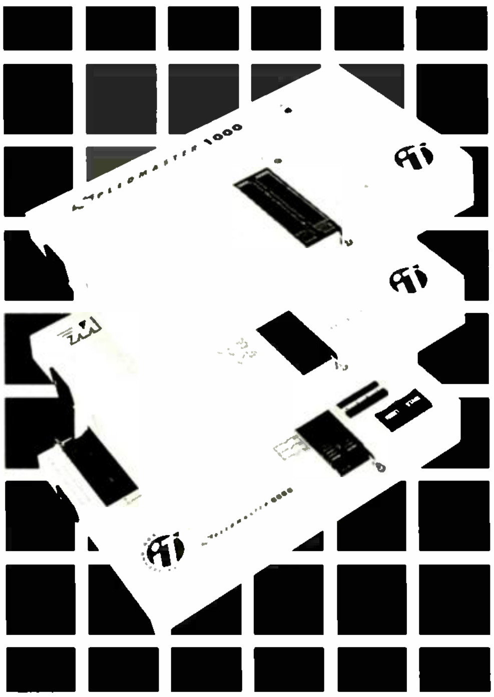

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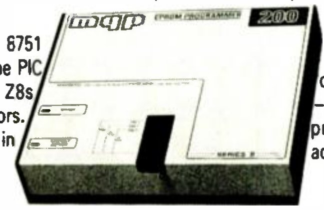


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erwise quiet VME market, according to companies working in the area. It also takes advantage of real-time operating systems such as OS/9 for image processing on VME.

VME supplier Radstone's Colin Neal believes that the company's new imaging products will receive a boost when VME64 is accepted as a standard at the start of next year. "Imaging and graphics are the applications which need lots of bandwidth," he says.

Although the performance of VME systems is not being blocked by the bus bandwidth yet, there is agreement in the industry that next year will be a time of fast change. "There is quite a lot of activity to extend the life of VME. The new revision of the VME spec will formally include 64-bit transfers. Another type of transfer doubles the throughput again, up to 160Mbyte/s. This will open up other applications as well as providing upgrade paths," says Neal.

Ken Newton, the UK managing director of Force Computers, agrees with Neal's analysis of VME64. "Basically it will give VME a mid-life kick," he says. "It will give VME a boost in any application where you're going to move blocks of data around". Newton says that this would include commercial printing as well as image processing and telecomms.

Newton believes that the biggest change to come next year will be the arrival, after two years of discussions, of real Futurebus+ products. This is a new standard which, in its most basic form, provides bus bandwidths of 100Mbytes/s. It was designed to provide a bus system to link together other bus systems, such as VME.

"We're going to announce several new products in the first half of next year and I know we're not the only one. Next year is the time when Futurebus should be renamed Nowbus," says Newton.

He believes that people were unjustifiably impatient with progress towards the standard. "It takes a long time to make a significant technical change. There were so many people working on different parts of the standard," he says.

Until Futurebus products start to ship in large numbers next year, Force is relying on VME cards based on Sparc microprocessors instead of Motorola's 68000 family. Newton believes that his customers have looked at the 68040 SBCs and at Sparc and are saying "We want a risc solution... Maybe there's going to be a better upgrade path with Sparc. There's also an element of the 040 being late," he says.

Newton believes that the VME market will continue to grow, even after Futurebus takes off. "Our estimate is that it is worth about $500 to 600 million worldwide now and will peak sometime after 1995 at $1 billion," he says. Futurebus is not expected to compete with VME for applications. Several European telephone companies are said to have expressed an interest in using it as the basis of the exchanges needed to handle the number of calls routed through fibre optic trunk routes. It will probably be used by at least one computer company as the backbone of its next generation of minicomputer system, linking together networks of PCs and workstations and communicating with mainframes. DEC has been heavily involved with the definition of the standard since the IEEE committees first began meeting.

Force's conversion to Sparc is thought by some in the bus-based computing industry to herald a move towards the risc processor. At the recent Sun User show, the US company Performance Technology showed products promising the use of SBus to develop a wider range of computer systems. "People weren't really walking around talking about it, they were doing it," says one observer.

The point about the use of the Sparc chip is very similar to the reasons for using the PC bus. Engineers are used to developing systems on workstations and it is easier for them to leave the design on the same platform than to recode into C and recompile. If engineers can build a target system using the same architecture as their development hardware, they will.

But if VME and the PC bus are gaining ground now and Futurebus will take off next year, what has happened to all the old favourites? Has STE died under the relentless march of the PC? Will anyone ever build a Multibus II system?

For years, the biggest supplier of STEbus boards in the UK has been Arcom. Many of the system's detractors have pointed to Arcom's recent launches of PCbus products as evidence of the demise of the old 8-bit standard. But according to a spokesman for the company, the new products were introduced to allow customers to build up multilevel systems with boards from one supplier.

"The PC is not suitable for rough tough environments," he says. "If you want a low cost vehicle for that, STE bus is ideal. The SBCs provide a rugged modular industrial environment for dos based systems".

The company expects its STEbus market to hold up for a few more years because of the limitations of the PCbus spec. The signal lines and power supplies are too vulnerable to electronic interference for use in industrial control unless the computer is heavily screened.

Arcom also considers the rise of unix as an operating system, even in real time applications, to be a significant factor in shaping the bus-based computing market. This month it will become one of the first companies to start selling a VMEbus SBC based on Intel's i486 microprocessor.

Arcom believes that the board will be used to run embedded dos or realtime unix software. Although at first sight neither operating system ought to have a place in a realtime VME system, the software concerned may not be controlling a critical application and so Unix's long context switch times and dos' ambiguous timing are not a problem.

Arcom's spokesman says that the company has no intention of moving away from STE. "We're increasingly involved with boards for people to do their own systems. We're trying to make the three standards (PC, STE and VME) compatible. We're looking for some kind of standard signal conditioning for all three buses," he says.

The model of a bus-based system where different buses are selected for different parts of the system is not new. But over the last few years, the PCbus has not been limited by performance but by software. VME's barriers were as a result of processing power and not bus bandwidth.

But recent changes in approach, to the increased use of add-in cards in PCs and arrangements like VME64, have moved the goals posts. As designs based on these new formats mature, the shape of systems is bound to change. ■

# BETWEEN TWO BUSES

***Frantisek Michele looks at the strengths, weaknesses and differences of the two most popular open architecture systems.***

Of all the possible open bus architectures, the Motorola oriented VMEbus and the Intel Multibus II seem to be the logical options for implementing high performance computer systems. Although they take different approaches to solving the same problems, both are sound architectural choices because they provide high bus bandwidth and make provisions for multiple bus masters and multiprocessor systems.

Both VMEbus and Multibus II meet these needs, but deciding which is better for a given system is not an easy task. Not only does each bus have unique characteristics, it has vendor and supplier proponents who make the decision even more difficult.

**Data transfer rates**

Traditionally, the data transfer rates of peripheral controllers have been comparable to the transfer rates of the peripheral devices attached to that controller. Hard disk con-

*Continued on page 970*

# SL6140 as tuned amplifier

Used in a 50Ω circuit, Plessey's SL6140 AGC amplifier exhibits a gain of 15dB — a figure that can be increased by tuning or matching the inputs and outputs, although the bandwidth is then reduced by a figure dependent on the tuned circuit Qs. This application, found in the company's 1991 Professional Products data book, describes a single-ended amplifier in such a configuration.

SL6140 is an integrated broadband AGC amplifier, giving its 15dB of gain at 400MHz into 50ohms, 45dB into 1kohm and up to 55dB with tuned input and output. AGC control range is typically 75dB.

**Figure 1** shows the circuit, in which a parallel tuned circuit is across the differential inputs. Input is capacitively coupled to one input, the other being decoupled. The coupling capacitor $C_I$ is also part of an impedance match from 50Ω to the high input impedance of the amplifier; the Smith chart in **Fig. 2** is normalised to 50Ω.

One method of tuning the output is given in Fig.1, where the parallel tuned circuit lies between one open-collector output and $V_{cc}$ with the other taken straight to $V_{cc}$. Output capacitive coupling and the tuned circuit provide a high-impedance load for the amplifier to increase gain; power gain in the circuit shown is 35dB. Input and output coupling trimmers optimise gain, but too high a reflected impedance at the amplifier terminals could give rise to oscillation. Gain is traded for bandwidth.

The other method of tuning the output is shown in **Fig. 3**, where transformer coupling is used. Since both outputs are now in use, gain is up by 6dB.

***GEC Plessey Semiconductors**, Cheney Manor, Swindon, Wiltshire SN2 2QW. 0793 518000.*

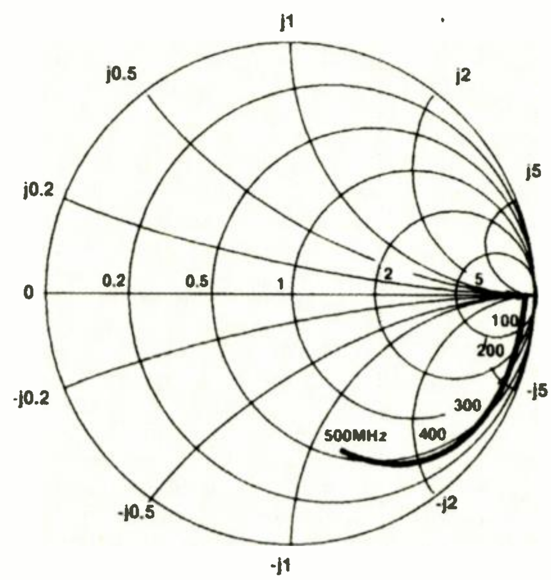



***Fig.2. Input-impedance matching network, of which $C_I$ forms a part, looks like 50ohms to the source (chart normalised to 50ohms)***

***Fig.1. Tuning and matching inputs and outputs affords increased gain in the Plessey SL6140 AGC amplifier — in this case 35dB power gain at 100MHz.***

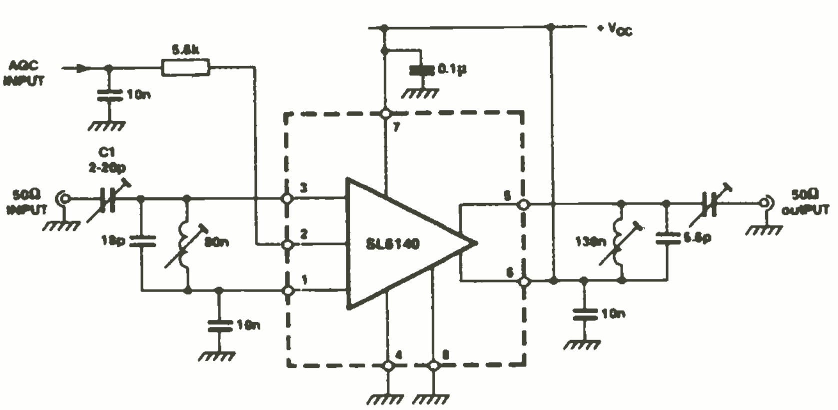
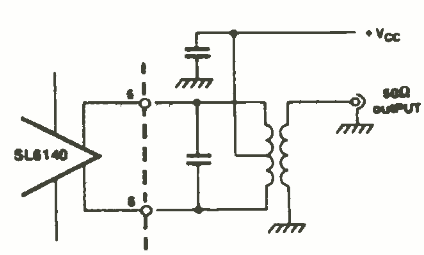



***Fig.3. Using both outputs allows increased gain by 6dB.***



# Low-power FM IFs

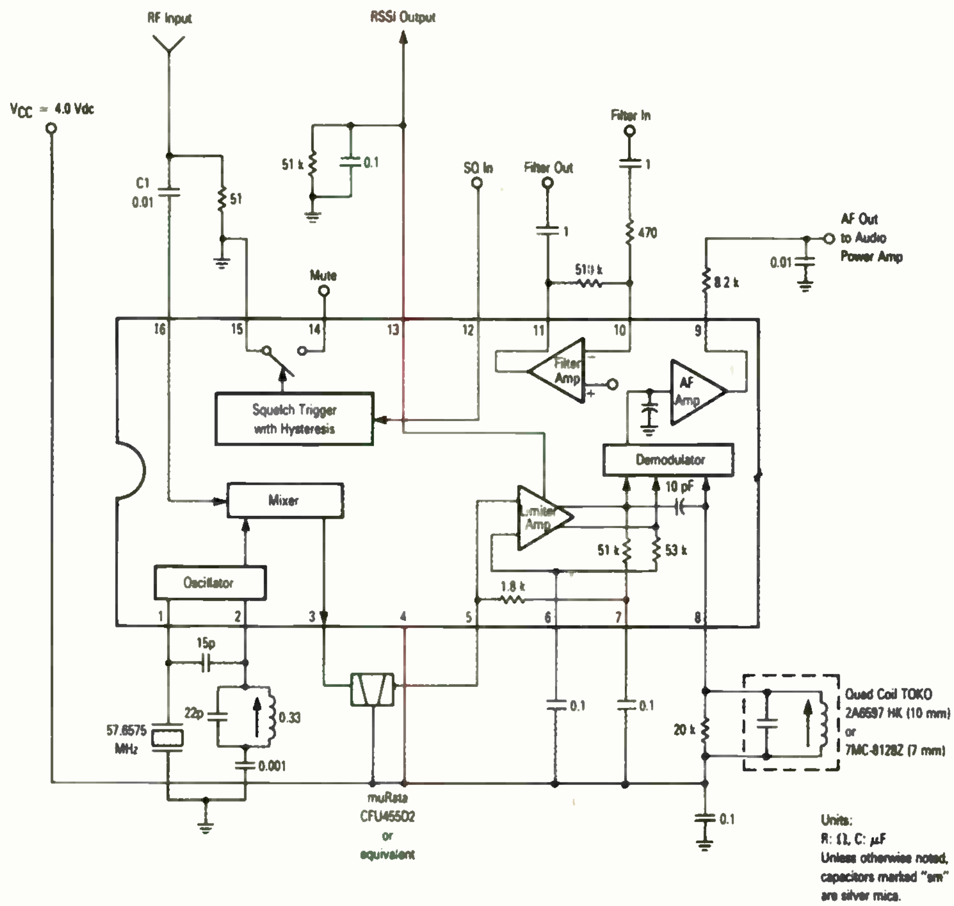
Motorola's MC3371/3372 low-power, narrow-band FM IF ICs are primarily meant as second IF and audio output stages in dual-conversion communications receivers, typically accepting a 10.7MHz signal from the first IF and working at 455kHz to a quadrature detector. There is an oscillator on-chip and also active filter, squelch switch and log signal-strength meter drive. MC3371 should have an LC circuit in the discriminator, while 3372 uses a ceramic resonator. **Figure 1** shows the internal circuit of the MC3371, taken from the data sheet MC3371/D.

A typical application is shown in **Fig. 2**. The Colpitts oscillator is a crystal-controlled type using either fundamental mode crystals or overtone types for higher frequencies up to 100MHz; inductor $L_2$ and $R_{11}$ are needed for stability. After the 20dB power gain, double-balanced mixer, a ceramic filter is the recommended type, having a bandwidth of ±2kHz to ±15kHz and feeding the 92dB limiting IF amplifier.

Different limiter and detector arrangements are needed in the two devices, to take account of the different filter types, but in both types the value of the damping resistor across the filter determines bandwidth, separation and audio output level. Recovered audio from the demodulator goes to a low-pass filter amplifier, which is followed externally by more filtering, de-emphasis and volume control before being amplified by, for example, an MC13060 low-power device.

Metering output from the IF amplifier is proportional to the log of IF input signal; the resistor $R_1$ to ground produces a 3V output for metering. Diode $D_1$ is an AM detector to provide indication of noise or tone, feeding the squelch switch whose level is set by $VR_1$. Alternatively, the amplifier may be used with the meter output to act as a carrier-level-triggered switch, $R_1$ acting as level-setting resistor.

***Motorola Ltd,*** *European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP. Telephone 0908 614614.*



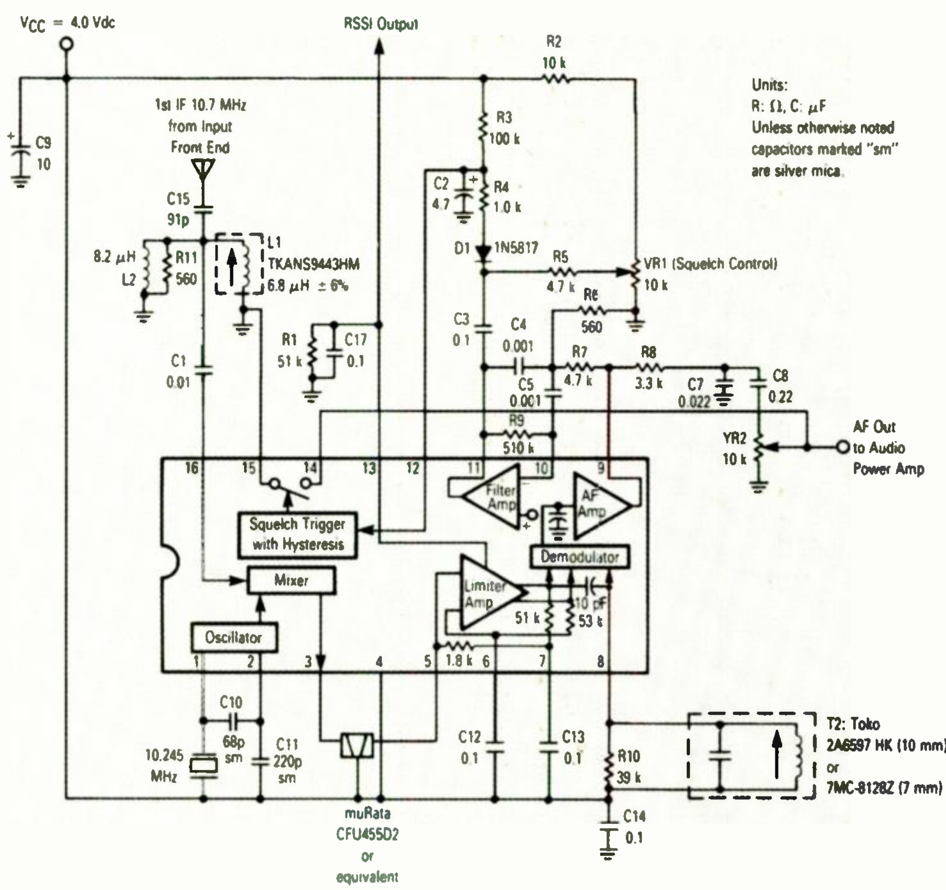




***Fig.1. Functional block diagram of the MC3371 low-power, single-conversion FM IF. This uses a parallel tuned circuit at the demodulator, the MC3372 using either this or a ceramic resonator. The devices work as second IFs and output stages in communications receivers.***

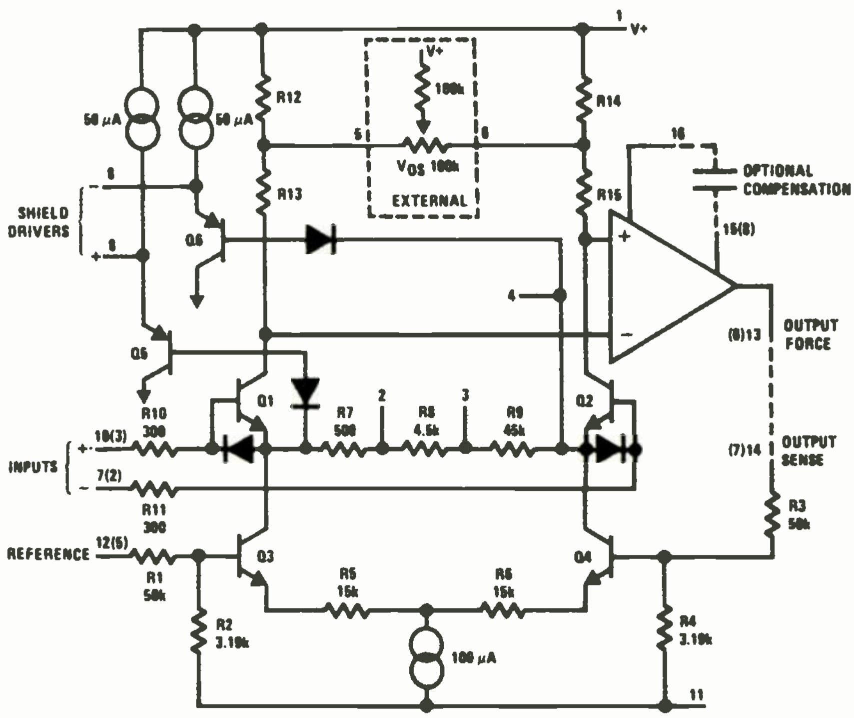
***Fig.2. Typical 10.7MHz application for MC3371. In this arrangement, an AM detector operates the squelch switch, but this can also be used as a carrier-level-generated squelch byfeeding it with the received signal-strength indicator (RSSI) output.***

# Curvature-corrected thermometer

National Semiconductor's LM363 is a true instrumentation amplifier that needs nothing extra to provide link-determined gains of 10, 100 and 1000; the precision is achieved by on-chip trimming for offset voltage and gain. Despite its open-loop gain of 140dB and GB product of 30MHz, the novel two-stage design renders it stable for all closed-loop gain settings.

Main features are 12nV/√Hz input noise, an offset of, typically, 50μV at a gain of 100 (0.5μV at G=10), offset drift of 2μV/°C at G=100, 130dB common-mode rejection ratio and 2nA bias current. Two differential shield drivers eliminate capacitance problems and output force, sensing and reference pins allow other gain settings.

**Figure 1** is the simplied circuit diagram, in which input is applied to the bases of $Q_{1,2}$, appearing across their emitters. If $R_x = R_{7+8+9}$, a differential current of $V_{IN}/R_x$ flows between emitters. The op-amp maintains equal collector currents via $Q_4$, so that emitter currents unbalance by the amount of inter-emitter current. If $R_{5+6}$ is $R_y$, differential voltage across $Q_{3,4}$ emitters is now $V_{IN}/R_x(R_y)$ which, divided by the attenuation factor $R_4/(R_3+R_4)$, is the output-to-reference voltage and overall gain is



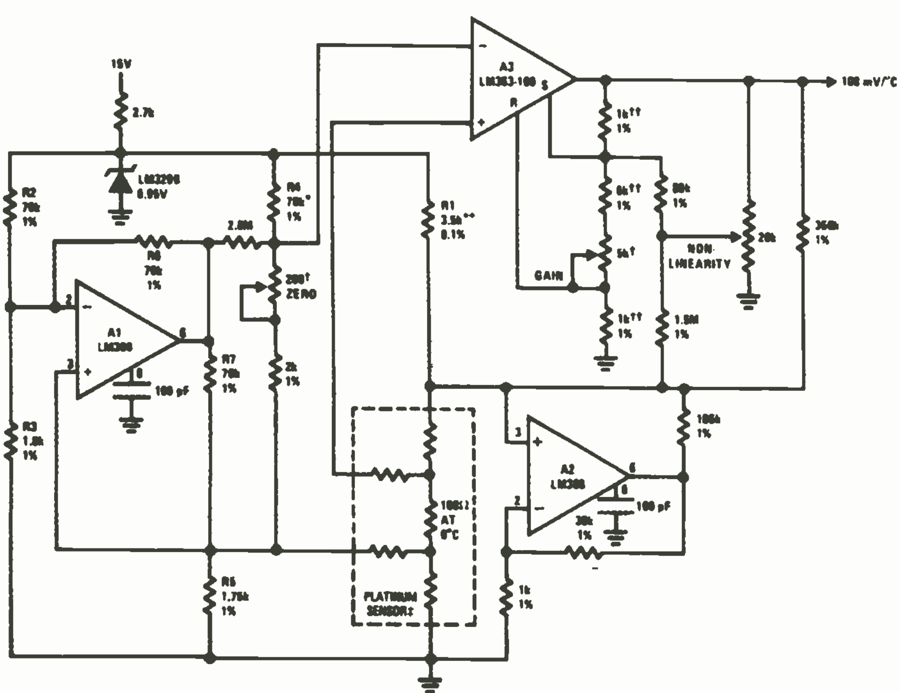




*Fig.1. Skeleton circuit diagram of National Semiconductor's LM363 instrumentation amplifier. Two-stage amplifier yields extremely high open-loop gain and gain/bandwidth product, but remains stable at all closed-loop gains.*

*Fig.2. Curvature-corrected thermometer using LM363 with extra op-amps for full Kelvin sensing without increasing drift and offset. Maximum error is 0.01% .*

$(R_3+R_4)/R_4 * R_y/R_x$.

**Figure 2** is the circuit of a curvature-corrected platinum thermometer, using the 363 and a couple of LM308s, giving 0.01°C error from -50°C to +150°C. Trimming arrangements ensure that zero, gain and non-linearity correction are not interactive and one calibration operation will suffice. The 308s give Kelvin sensing in the sensor (100Ω at 0°C) without being involved in drift and offset mechanisms and the *A2* op-amp biases the sensor with a fixed current.

***National Semiconductor (UK) Ltd,*** *The Maple, Kembrey Park, Swindon, Wiltshire SN2 6UT. Telephone 0793 614141.*

# REGULARS

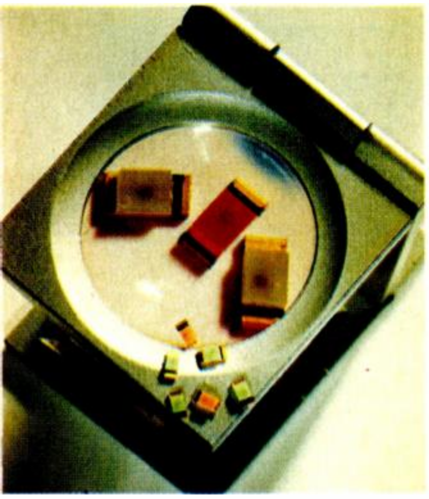
## NEW PRODUCTS CLASSIFIED

## ACTIVE

### Asic

**Asic toolset.** Compass toolset is a suite of tools and libraries for asic design; from a system level analysis tool and HDL synthesis through to back end tools for generation and verification of test programs and physical layout. Latest release, V8 R2, includes a bonding diagram editor to allow creation and management of bonding diagrams. Automatic floor planning is an option in the chip compiler and assistant. Compass Design Automation, 0908 665930.

**Boundary scan service.** Nettag is a Jtag-compatible boundary scan service for system-level testing of manufactured asics. It performs automatic insertion of boundary scan circuitry and four or five dedicated test pins as well as automatic serialisation of parallel functional test patterns. Netlist and functional test vectors will generate the boundary scan test. Gould AMI, 0272 238014.



***Looking down: Citizen led lamps are available from Pedoka.***

**Booster pack.** XPlus simulation booster package is for high quality asic, multiple asic and system designs. The booster links the XPlus environmental software with XP hardware accelerators including the XP100 with a capacity of 256,000 gates running at 2.5 million events/s. XP200 has a four million gate capacity. Zycad, 09323 53957.

### A-to-D & D-to-A converters

**14bit.** ADC00145 14bit 5MHz converter has a hybrid 40-pin hermetically sealed package containing a 200ns unit with a precision track and hold amplifier. 30.5 by 55.9mm. It contains two internal precision references and timing circuits so that only a single command input is needed to initiate the conversion cycle. Three bipolar and four unipolar link selectable analogue inputs from ±2.5 to -10V. DDC (UK), 0635 40158.

**8bit flash adc.** Harris HI5700 monolithic 8bit cmos flash converter has a rate of 20Msample/s. Parallel architecture eliminates external sample and hold circuit. Integral and differential linearity is typically ±0.75 LSB and differential phase 0.8° and 2%, respectively. Consumes 500mW from a single 5V supply. Jermyr Distribution, 0732 740100.

### Discrete active devices

**SM transistors.** Zetex transistors come in SOT223 surface mount packages and can dissipate up to 2W. The package has a thermal junction to case resistance of less than 15°C/W. Operating range is -55 to +150°C. Peak current capability is up to 8A and the range includes npn and pnp types. Celdis, 0734 585171.

**High voltage mosfet.** A low-gate-threshold high voltage mosfet comes in a SOT89 (TO243AA) package. Called the Supertex TN2540N8, it has a drain-to-source breakdown voltage of 400V minimum, an on resistance of 12Ω maximum, and a gate threshold voltage of 1.8V maximum, making it TTL compatible. Applications include solid state relays, telecommunications and medical equipment. Kudos Thame, 0734 351010.

### Linear integrated circuits

**GaAs attenuator.** Directly cascadable without inter-stage matching, HMR11000 GaAs MMIC attenuator operates from DC to 18GHz. Range is from 35dB at DC to 15dB at 18GHz. Cascading allows greater attenuation. VSWR is 1.3:1 at 18GHz. Attenuation is varied by applying two analogue voltages, from -3 to 0V, at less than 30µA current. Consumption is 500mW. Anglia Microwaves, 0277 630000.

**8bit I/O.** ZN540 analogue I/O system on a chip includes a successive approximation A-to-D converter with 5µs conversion time and double buffered latch outputs. The two D-to-As have double latch inputs and up to 1.25µs settling time and 2.5V temperature compensated band-gap reference. Main data interface is an 8bit bidirectional data bus and eight control lines. Programmable clock prescaler allows input clock speeds up to 12.8MHz. GEC Plessey Semiconductors, 0793 518000.

**Video buffer amp.** Max405 180MHz precision video buffer amplifier has a guaranteed 450V/µs slew rate on ±5V supplies. It is for Pal, Secam and NTSC systems and has a differential phase error of 0.01° and differential gain error of 0.03%. Unadjusted DC gain is greater than 0.99V/V over -40 to +85°C with loads as low as 50Ω. Input capacitance is 0.6pF. Maxim Integrated Products, 0734 845255.

**Voltage regulator.** TA7900S is a 5V voltage regulator for automotive microcomputer systems. Output is 5V ±5% without adjustment. Typical line and load regulation is 0.1%. A power-on reset timer can reset any systems being supplied; the reset signal will also be transmitted if the output falls below 92% of set level. Toshiba Electronics, 0276 694600.

### Power semiconductors

**1W power transistor.** High-gain 1W microwave power transistor MRW54602, is for use in large signal output and driver amplifier stages operating in the 1 to 4GHz range. Internal compensation and diffused ballast resistors. It is for Class A common emitter power amplifier applications. 20V DC power supply. All gold metallisation. Hermetic package is suitable for commercial, military and space communication applications. Motorola, 0908 614614.

### Memory chips

**Cache ram.** A 32K x 9bit cache ram provides a zero wait state secondary cache for the 50MHz i486 microprocessor. The IDT71589 uses internal logic to solve i486 timing problems normally handled by adding wait states. It includes a burst mode synchronised to the system clock. A synchronous write capability and a late write abort feature allow zero wait write cycles to be supported while reducing speeds required of supporting Pals, cache controllers, and cache tag rams. Integrated Device Technology, 0372 377375.

**Asynchronous fifos.** Previously only available in 25ns versions, the IDT7200 256 x 9bit, IDT7201 512 x 9bit, and IDT7202 1K by 9bit families of asynchronous fifos, in 15 and 20ns versions, can be used as buffers or in graphics and networking applications handling large amounts of data. 300 and 600mil plastic DIL and PLCC packages. Integrated Device Technology, 0372 377375.

**1Mbit sram.** 1Mbit cmos srams with access speeds down to 17ns can have 1, 4 or 8bit wide organisations. The byte-wide models have either single or dual chip enable and the 4bit unit can be configured with common or separate I/O. Increased speed and lower power consumption are achieved by eliminating address transition detection and redesigning output buffers. Micro Call, 0844 261939.

### Microprocessors and controllers

**Microcontroller.** A Hitachi microcontroller has been optimised for telephony applications and uses a dual-tone multifrequency receiver as well as its CPU, 512 by 4bit ram, timers, I/O ports and program memory. It is based on HMCS400 series architecture and has 48 bidirectional I/O pins, four dedicated input pins, two synchronous serial interfaces, 11bit prescaler, and four 8bit timers. Dialogue, 0276 682001.

**Low power processors.** Fully static cmos NEC V20HL and V30HL microprocessors can work at clock speeds from DC to 16MHz. Consumption at 16MHz is less than 100mA – calculated at 6mA/MHz for intermediate clock speeds. Pin and function compatible with 8088 and 8086 devices. 40-pin DIL, 52-pin QFP and 44-pin PLCC packages. Impulse Electronics, 0883 346433.

**4bit microcontrollers.** The SGS-Thomson series of Cops 4bitmicrocontrollers is being second sourced. Officially called the ET9400 series, it includes versions with 512, 1K or 2Kbyte of rom, up to 128byte of ram and up to 23 I/O lines. Cmos and nmos variants are available and other on-chip features include led driving, serial I/O ports, tristate outputs, and clock generation. Impulse Electronics, 0883 346433.

**Single-chip microcomputer.** Mitsubishi M37450 single-chip microcomputer – mask rom, romless and eprom/OTP versions – can be supplied in various packages including 64-pin dil and 80-pin quad configurations. Clock speeds are up to 10MHz with a 0.8μs minimum instruction time at this speed. Dissipation is 30mW from a 5V supply. RCS Microsystems, 081-979 2204.

## Optical devices

**Fibre amps.** Erbium-doped fibre amplifiers for light-wave voice, data and cable transmission can also be used as boosters. They use one or two high-power 1480nm pump laser modules, in-line optical isolators for optical isolation at input and output, wavelength division multiplexers to branch out the signal to multiple receivers, and erbium-doped fibre. AT&T Microelectronics, 0344 865927.

**Led light source.** T470 is for use on optical fibre systems from local area to long haul networks. 9V battery provides 40h of operation without recharging. Useable with wavelengths of 850, 1300 and 1550nm with an output power between -20 and -30dBm. It can be used with 50/125, 62.5/125 or 8/125 multimode and single mode fibres. BICC Cables, 0244 688400.

**Fibre optic chip set.** A 50Mbit/s chip, SP9960 encoder and led driver can accept either ECL or TTL data and output the result at either the large or small led driver output. SP9921 is a circuit for clock and data recovery from a Manchester encoded signal. It has ECL outputs and input signal detection from lock detect output. SL9901 is a transimpedance amplifier to interface between a detector diode and a decoder in a fibre optic receive system. GEC Plessey Semiconductors, 0793 518000.

**SM leds.** Citiled CL150 chip type led lamps from Citizen Electronics measure 3.2 by 1.6mm with a 1.2mm depth. Standard luminous intensity is 2.4mcd. They come in red and green with a power dissipation of 65mW. Rated current is 20mA and minimum life expectancy is 500h at 25°C ambient. They can operate from -25 to +80°C. Tape in reels of 3000 pieces. Pedoka Electronics, 0462 422433.

## Oscillators

**Quartz oscillators.** Quartz crystal oscillators made to customer specifications can be incorporated in various electronic devices including pass and stop band discrete component filters, monolithic crystal filters, electromechanical filters, clock oscillators, temperature compensated and voltage and oven controlled crystal oscillators, and dual in line oscillators. Specialtel-LEM, 0661 72497.

# PASSIVE

*Creatures of the sand: Rhophase's semi-rigid PTFE cable.*

## Passive components

**Tantalum capacitor.** TAJ0805 moulded chip tantalum capacitor can have a C/V from 4.7μF/2V to 0.1μF/20V. It has totally compliant leads and measures 2.1 by 1.4mm. Height is 1.2mm. It is expectec to be used in medical applications and in communications equipment. AVX, 0252 336868.

**SM resistors.** KDI/Triangle NPC tantalum surface mount resistors have rated powers from 2 to 15W and frequency bandwidth from DC to 18GHz. They are made using a sputtered tantalum nitride process. Gold or lead/tin terminations. Sizes range from 0.02 by 0.04in to 0 75 by 0.15in. Typical thickness is 0.1in. Anglia Microwaves, 0277 630000.

**Trimmer pot.** Model 3224 4mm multi-turn surface-mount trimmer potentiometer has a footprint meeting EIA, EIAJ and VRCI board layout standards. It is an 11 turn device with a rotational life of 200 cycles. Contact resistance variation is within 1%, temperature coefficient is less than 100 parts in one million per °C. Resistance tolerance is 10% from 10Ω to 2MΩ. Bourns Electronics, 0276 692392.

**Trimming pots.** Miniature carbon trimming potentiometers, the Bourns 3316 series, are 6mm in diameter and have a cross slot rotor design for automatic adjustment equipment. Legs are angled. Pin design stops the trimmers falling out of the board after insertion. 13 resistances from 100Ω to 1MΩ. Power rating is 0.1W. Jermyn Distribution, 0732 740100.

**Small relay.** The TQ relay measures 14 by 9 by 5mm and has two changeover contacts. It comes in monostable or bistable latching versions and has gold plated bifurcated contacts. Surface mount versions available. Maximum switched load is 100W DC. Power consumption is 140mW (mono) or 280mW (bi). Matsushita, 0908 231555.

**Electrolytic capacitors.** VR series miniature electrolytic capacitors now operate over 6.3 to 450V (250V was the previous maximum). Capacitance range is 0.1 to 22,000μF, ±20% at 120Hz, 20°C. From 6.3 to 100V, leakage current after 1min is 0.03CV or 4μA; from 160 to 450V it is less than 0.1CV or 40μA. Operating range is -40 to +85°C. Nichicon (Europe), 0276 685393.

**Solid state relays.** Relays in the Crydom E series have an optically isolated I/O to 4kV rms and an AC (90 to 280V) or DC (3 to 32V) control signal voltage. Recommended minimum load current is 50mA and their must operate voltage is 3V DC or 90V AC. Must release voltage is 1V DC and 10V AC. Response time at 50Hz is 10ms and the operating range is 25 to 65Hz and -40 to +100°C. Unitel, 0438 312393.

**Thin capacitors.** MLC surface mount capacitors can be inserted beneath plastic leaded chip carriers, being only 0.58mm thin. They are for use in smart cards, single board computers, memory expansion boards, and graphics boards. They are made with nickel barrier terminations and have capacitances from 0.1 to 0.33μF in 25 and 50V. Vitramon, 06285 24933.

## Connectors and cabling

**PCB receptacles.** BNC straight or right angled bulkhead mounting PCB receptacles comply with forthcoming EEC requirements on electromagnetic interference. This is achieved using diecast bodies rather than the normal polyester types (although polyester versions are also available). Receptacles come with serrated washers and locknuts. Coax Connectors, 081-948 7047.

**Fibre optic cable.** SL series external grade fibre optic cable has a Kevlar-reinforced all-dielectric construction. It is enclosed in athermo-plastic resin tube which is thermally and environmentally stable and filled with a thixotropic gel. Further protection is providec by corrugated steel armouring and a polyethylene outer jacket. Fibre Optech, 0767 600800.

**Zif connector.** Zero insertion force connector, DL Drawer, has an integral cam design that uses the movement of the drawer or subassembly to mate and un-mate the connector halves. Tested to 100,000 mating cycles. Crimp contacts, wire wrap or solder tails. Gold over nickel plated copper alloy contacts. ITT ElectroMechanical, 0256 23356.

**DIN connector.** Peanut-sized high-density Din connector made by Erni is available in 50 ways with contacts set on a 1.27mm pitch in a two-row format. Length is 42mm including mounting lugs. PCB height is 5mm. Depth of a mated pair is 12mm. Standard or reverse configurations with straight or right-angle spills and surface mount versions are available. Radiatron Components, 081-891 1221.

**Microwave cable.** Semi-rigid PTFE microwave cable has a pliable copper outer conductor and multi-ply laminate dielectric. It is for communications and military use and is available in 0.085, 0.141 and 0.250in diameters. All appropriate semi-rigid connectors can be accepted. Rhophase Microwave, 0536 63440.

## Displays

**Flat screen.** VGA compatible 5in flat screen monochrome monitor, compatible with 3U high instrumentation systems, is available in kit form or as a standard 3U Eurocassette. It can be driven from either 12 or 15V DC with a maximum power consumption of 15W. Maximum resolution is 640 by 480 pixel. Phosphors include P4 white, P31 green and LA amber. Digitran, 0763 261600.

**20in monitor.** 17M2000 20in multifrequency colour monitor has full autoscanning capability and scanning range of 15 to 37kHz. Three input connector types – BNC for analogue video via coaxial cable, nine-pin D-type for EGA/TTL, and 15-pin D-type for VGA can be mounted on the back panel or recessed below the cover. Kent Modular Electronics, 0634 830123.

## Filters

**Audio filter.** Yamaha YM3414 two-channel eight-times over sampling digital audio filter comprises three linear phase FIR type filters connected in vertical stages. First filter is 225 order, the second 41 order and the third 21 order. There is an in-built 19 by 18bit multiplier and accumulator. Pass band ripple of within ±0.0001dB at 0 to 20kHz and stop band attenuation of at least 100dB at 24.1kHz and higher. Barlec-Richfield, 0403 50111.

**Three-phase filters.** Arcotronics three-phase suppression filters come in four types rated at 440/250V up to 400Hz. Type AA has an IP65 splash-proof housing and a leakage current less than 30mA. AB has a high frequency dense housing with max 3.5mA leakage current. AD is compact and provides high attenuation against common and differential mode interference. Leakage current is less than 3.5mA. AE is similar to AD with a leakage current less than 10mA. STC Mercator, 0493 844911.

**RFI filters.** Large case Arcotronics filters for RFI suppression, in metal cases with ground terminals connected, have voltage ratings of 250V up to 400Hz. F.AI types for higher frequencies have Faston or screw terminations and are general-purpose devices for asymmetric RFI generated by switches and sliding contacts. F.AM power line filters are for attenuating symmetric, asymmetric, periodic or pulse shaped interference. STC Mercator, 0493 844911.

## Hardware

**Stick-on feet.** Square, domed, flat-dome and round polyurethane stick-on feet are available in various colours. To fix, peel the foot from the backing material and stick it on. They can be used for reducing component vibration or protecting delicate surfaces. Moss Plastic Parts, 0865 841100.

**Shoes.** Electrostatic footwear from Otter is ergonomically designed to eliminate generation of triboelectric charges in electronics workplaces. They are lightweight and made from box-calf leather with a polyurethane sole. Volumetric resistance is between 0.1 and 1MΩ. Teknis, 0344 780022.

## Instrumentation

**20MHz scope.** 9302 20MHz digital storage oscilloscope uses standard analogue controls and can be switched to an analogue scope. It can freeze displays, display one channel while storing another, capture fast events, display ultra-slow moving waveforms, store events before or after a trigger event, and transfer data to an external plotter. Dual triggering lets asynchronous signals be displayed. Beckman Industrial, 0384 442394.

**Digital multimeter.** DT9000 digital multimeter measures 200mV to 1kV DC, 2 to 750V AC, 200µA to 20A DC and AC, 200Ω to 3MΩ, 1pF to 20µF, and 10Hz to 200kHz. Voltage auto-range operation for AC and DC and resistance measurement can be specified. Results are displayed on a 17mm LCD (1999 counts). Features include reading hold function, REL mode for relative measurement, analogue signal or bar graph proportional to reading value, and diode and transistor hFE tests. Electronic & Computer Workshop, 0376 517413.

**X-Y recorder.** Yokogawa 3023 is an A3 size X-Y recorder using high-torque DC servomotors to give 200mm/s slewing speed and 7.6G acceleration in the Y axis and 2000mm/s and 5.1G in the x axis. Basic accuracy is ±0.2% and error between ranges is less than 0.1%. One and two pen versions and there are 16 calibrated input ranges with sensitivities from 50µV/cm to 5V/cm. Martron Instruments, 0494 459200.

**Laboratory recorder.** Yokogawa LR8100 recorder can produce eight high speed traces with pens operating at up to 1600mm/s, a performance achieved by the use of digital sampling and stepper motor drivers. A built-in printer lets date, time and measured data be printed alongside the recorded traces. Martron Instruments, 0494 459200.

**Function generator.** HCG305 function generator has frequency burst and sweep facilities and a range from 0.01Hz to 10MHz. It generates sine, triangle, square, ramp and pulse waveforms. Sinewave flatness is within 0.2dB from 0.01Hz to 100kHz and within ±2dB above this range. Distortion is 0.5% or less. Multitest, 0480 403617.

**100MHz scope.** CS5175 Kenwood 100MHz dual-channel four-trace oscilloscope has delayed timebase. Input sensitivity is variable between 1mV/div and 5V/div in 1-2-5 steps. A signal delay line allows display of leading edges. Crosstalk between channels is -40dB or lower at 1kHz. Thurlby-Thandar, 0480 412451.

**Antennas and receivers.** Schwarzbeck EMC antennas, artificial mains/line-impedance stabilisation networks and EMI/EMC measuring receivers are available in the 9kHz to 1GHz spectrum. Antennas include high power transmitting types for testing immunity to RF fields in the 22 to 150 and 30 to 300MHz bands. Receiving antennas are available as broadband and tunable devices. Schaffner EMC, 0734 697179.

## Literature

**Optical devices.** Laser diode instrumentation and other optical devices are covered in a free 76-page technical brochure. It contains technical articles and product information. Instruments covered include low noise laser diode drivers, thermoelectric controllers, and accessories. Lambda Photometrics, 0582 764334.

**Power transistors.** A bipolar power transistor selector guide and cross reference (SG48/D) covers 700 off-the-shelf devices and spans all applications categories including application specific devices such as audio and CRT deflection families. Motorola, 0908 614614.

**Quartz crystals.** Standard quartz crystals and ovenised oscillators are covered in a 136-page technical guide. It gives details of SEI's manufacturing capability and research and development and technical specifications. Salford Electrical Instruments, 0706 367501.

**Connectors.** A 127 page catalogue covers the Connectel range of DIN41617, 41612, 41652/sub-D, and 41651 connectors. Also included are recent developments in DIN41612 press-fit connectors. Weidmuller Klippon Products, 0795 580999.

## Power supplies

**Uninterruptible power.** 900 series has a VA range of 10, 15, 20, 30, 40, 50, 60, 90, and 120kVA. An on-board computer continuously monitors 52 parameters and reports operational status to its load computer or any suitable PC or dumb terminal. Avel-Lindberg, 0708 853444.

**Switching supply.** Pioneer Magnetics PM3187 multiple output switching power supply incorporates a 0.99 power factor correction and the equipment is housed in a 5 by 8 by 12.25in enclosure. 1340W output over the 90 to 264V AC range with no input strapping or switching required. Line to load regulation is ±0.25% and voltage stability is ±0.1%. FR Electronics, 0202 897969.

**2kW supplies.** Miniature power supplies furnishing 1.5 or 2kW to a densely populated telecommunications rack have been added to the Eta range. Esma units operate at about 80% efficiency and measure 20.3 by 27.9 by 12.7cm. Input voltage tolerance is 170 to 264V and outputs can be 2, 5, 12, 15, 24, 28 or 48V. A current distributing function allows parallel operation and three-phase input. Pascall Electronics, 081-979 0123.

**6W DC-DC converters.** The PM900 Computer Products series of

*Pretty pictures: electronic design automation gets a boost from Solbourne's latest workstation.*

converters has a field demonstrated MTBF of 680,000h. They deliver 5 to 6W of output power from a 2 by 2in package. Input voltages are 5, 12, 24 or 48V DC and outputs 5, 12 or 15V DC, or dual outputs of ±12 or ±15V DC. All have a Pi input filter with six-sided continuous metal shielding to VDE0871 curve B. Efficiency is at least 60%, line regulation ±0.02%, and load regulation either ±0.02 or ±0.04%. XP, 0734 845515.

## Radio communications products

**Mobile radios.** Three PMR mobile radio products in VHF high and low band and UHF and have multichannel capability. Model 1 has four channels, CTCSS and simple five-tone signalling. Model 4 has ten channels, five tones and CTCSS. Top of the range is Model 3 with an alphanumeric display and keyboard pad. A personal recorded status message can be left when the vehicle is unattended and automatically interrogated by the control network. Securicor PMR Systems, 0761 413174.

## Transducers and sensors

**Displacement transducer.** FS5000 fast linear displacement transducer has a measuring stroke of 254mm and a body length 24mm longer than the stroke. Shock resistance is 50g and resolution 0.004mm. Accuracy is 0.15% of stroke and 0.1% is optionally available. Control Transducers, 0234 217704.

**Vibration sensor.** Series 1000 vibration sensor is for machine monitoring. It is made of stainless steel and mounting arrangements include a quick-fit fixture and male and female thread fittings. Operating range is -25 to +120°C and typical output is 100mV/g via a TNC electrical connector. Monitran, 0494 816569.

**Displacement transducers.** Six models with spring-loaded probes have been added to the D5/G range of miniature precision displacement transducers. The probes have a low friction bearing that can accept mechanical side loading. Five measurement ranges are ±0.25 to ±5mm with linearity performance better than 0.5%. RDP Electronics, 0902 457512.

**CCD linear sensor.** ILX503 reduction type high-resolution CCD linear sensor has an array of 2048 pixels, each measuring 14μm square. The sensor can read documents up to B4 dimensions with a resolution of400dot/in. Total transfer efficiency is typically 97%. Sony, 0784 466660

# COMPUTER

## Computer board level products

**Single board computer.** VMIVME-7300 combines the software environment of Digital's Vax architecture and VMEbus. It supports the Vaxeln real-time kernel and development environment which provides for software development on a Vax/VMS host using languages such as Fortran, C, Ada and EPascal. Source level debugging is supported over the Ethernet. Diamond Point, 0634 722390.

**Capture and delivery.** MicroEye 2C card real-time video framestore, based on the 82C9001/A video processor, has user control of window sizing and positioning, and mask, cut out and overlay effects. It can simultaneously display live and frozen video images. Pal or NTSC video standards are selectable under software control. Any three composite inputs can be configured to be SVHS. There are also three audio channels. Digithurst, 0763 246313.

**Image processor board.** PC/IMP32C combines a 25Mflops processing engine, frame grab and display subsystem on a PC AT compatible board. It uses AT&T's DSP32C digital signal processor and is for fast image and two-dimensional array processing. The DSP chip can execute arithmetic and logical operations in a single 80ns instruction cycle time; a 3 x 3 convolution can be completed in less than 1.5μs/pixel. Loughborough Sound Images, 0509 231843.

**Analogue output card.** The DA04 is a 16bit PC plug-in card for putting out analogue signals in voltage or current form. There are four independent output channels with 12bit resolution. Each channel can be set using plug-in units and it is possible to choose one of five output voltage ranges (two unipolar and three bipolar) and one of three output current ranges. Each channel can be adjusted by a potentiometer. Mechatronic, C049 6151 26431.

**Data acquisition boards.** 98-02/03 data acquisition boards have an expandable multichannel system with true 16bit measurement at speeds up to 400Ksample/s. DMA transfer direct to VMEbus system memory is used to keep full real-time throughput up to 1024 input channels. Eight shielded differential inputs are current and voltage protected with input ranges 0 to +10, ±5 and ±10V. Radstone Technology, 0327 50312.

**G64 communications card.** SYN-ASP5 communications card for the G64 bus, based on the 82C684 quad universal asynchronous receiver and transmitter, gives four asynchronous serial ports and 20 digital I/O lines. All serial channels can be individually configured to produce any on-board mix of RS232, RS422 and RS485 interfaces without changing any driver chip. Data rates, programmed by software, are up to 115.2Kbaud. Syntel Microsystems, 0484 535101.

## Computer systems

**Unix workstation.** S4000DX (Design Xcellerator) Sparc Unix workstation desktop system has a 256Kbyte second level cache memory and a 36MHz clock speed, and uses the SGA20 Sbus graphics accelerator card to give a performance of 530K two-dimensional vectors per second. It can support up to 128Mbyte of memory or 1Gbyte of internal disc storage. Solbourne Computer, 0793 491333.

## Development and evaluation

**Futurebus+ developer.** Designed to provide an environment for the Futurebus+ system developer, the Microrack development unit supports a 128bit wide data bus with central arbitration. SMT RC termination networks minimise signal skew by equalising line lengths across the data bus. The backplane is housed in a hard metric conductive RFI-screened KM25 subrack, 18SU high and 85SP wide. There are 13 slot positions for 300 by 300mm daughter boards on a 6SP pitch. BICC-Vero Electronics, 0489 780078.

## Mass storage devices

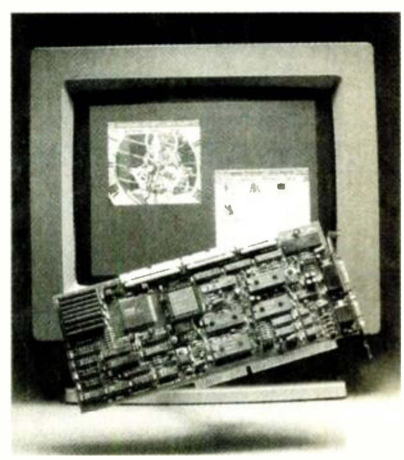
**Memory cards.** Credit-card size memory units are Jedia 4 and PCMCIA compatible and have memory capacities up to 4Mbyte. The range includes sram, eprom and maskrom versions in 8 or 16bit formats. They allow the storage of programmes or data in a rugged format and give a secure method of transportation. Hakuto International, 0992 769090.

**Optical storage.** A single optical disc drive has been developed that can operate with worm and rewritable optical discs. The SMO-E511uses 5.25in discs to store up to 650Mbyte of information in worm or magneto-optic format. The drive can read magneto-optical discs recorded on other ISO standard disc format. Sony, 0784 466660.

## Peripherals

**Laser printer.** Epson's PostScript EPL7500 printer is device independent. Standard ram is 2Mbyte expandable to 6Mbyte. It uses microart printing to control the flow of toner so that sharp edged letters and lines can be printed with consistent toner density. Toner density can also be controlled by hand. STC Electronic Services, 0279 626777

**Hard disc lock.** FastLock Plus software is a PC access control system preventing the system being booted from a floppy diskette or being circumvented through the keyboard. A log-on screen is presented to all people trying to use the PC. Before log-on can be achieved, a personal account name and password have to be entered. GuildSoft, 0752 251155.



*Smash and grab: the £1000 price barrier smashed by MicroEye 2C grabber and delivery board.*

## Software

**Engineering windows.** A range of Windows 3 engineering software packages operate across various data acquisition and control hardware platforms. Written originally for the Microlink 3000, the software can also support hardware from Arcom, Metrabyte and Data Translation. Biodata, 061 834 6688.

**Neural network.** Autonet Windows applications generator automatically builds, trains and validates a neural network without assuming any user expertise in the technology. It uses a combination of statistical data analysis and expert system rules to generate an optimal neural network for decision and prediction problems. Using the optional C code package, networks developed can be embedded directly into an application. Recognition Research, 061-449 8628.■

# HAMEG OSCILLOSCOPE OFFER FROM B.K.

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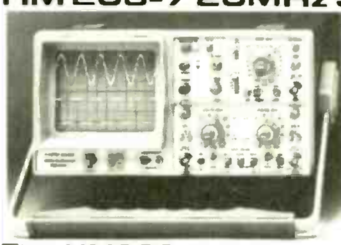
## WHY CHOOSE HAMEG?

For more than 30 years, Hameg has been engaged in the manufacture of oscilloscopes in West Germany. With a broad range of successful instruments, Hameg is known throughout the world as a supplier of attractively priced oscilloscopes based on innovative technology that continues to set new standards of quality and performance. An outstanding example of this is the new generation of digital storage oscilloscopes which has enabled tens of thousands of users to enter the world of digital storage technology for the first time. The price/performance attributes of Hameg's analogue oscilloscopes continue to be second to none on the international market. The recently introduced HM1005 is proof, once again, that high performance oscilloscopes need not be expensive. This also explains why Hameg today sells more oscilloscopes in Europe than any other manufacturer of test equipment.

**All models incorporate a clear, 8 x 10cm display and are of a compact size - 285 x 145 x 380mm.**
**Mains Supply - 110/220,240V AC, 50/60Hz**

## ANALOGUE

### HM 203-7 20MHz STANDARD



**SPECIFICATION**

* 2 Channels
* Bandwidth: DC - 20MHz
* Sens: Ch. 1, Ch. 2, 1mV/cm
* Timebase: 0.1s - 20ns/cm
* Triggering: DC - 40MHz
* Active TV - Sync - Separator
* Variable hold-off
* Trigger LED indicator
* Calibrator: 1KHz Square wave
* Component tester
* Plus many more features

The **HM203-7** is Western Europe's best selling oscilloscope because it responds thoroughly to customer demands for **reliability, superior performance** and **ease of operation.**

**PRICE £321.00 + £56.18 V.A.T.**
**FREE DELIVERY**

### HM 604 60MHz UNIVERSAL

**SPECIFICATION**

* 2 Channels
* Bandwidth: DC - 60MHz
* Sens: Ch. 1, Ch. 2, 1mV/cm
* Timebase: 2.5s - 5ns/cm
* Triggering: DC - 80MHz
* Active TV - Sync - Separator
* After delay trigger
* Sweep delay
* Delay line
* Trigger LED indicator
* Calibrator: 1KHz & 1MHz Sq. Wave
* Component tester

With its variety of operating and trigger modes, the **HM604** is a new innovative general purpose oscilloscope satisfying a wide range of exacting requirements in laboratory, education, production and service.

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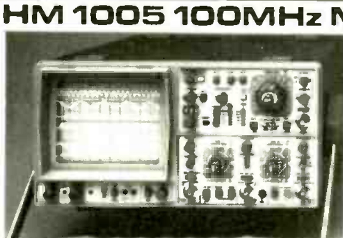
**FREE DELIVERY**

### HM 1005 100MHz MULTI-FUNCTION



**SPECIFICATION**

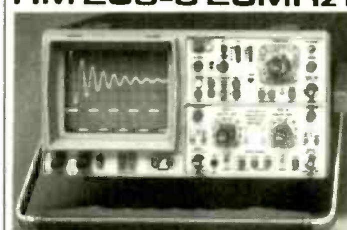
* 3 Channels with up to 6 traces
* Bandwidth: DC - 100MHz
* Sens: Ch. 1, Ch. 2, Ch. 3 1mV/cm
* Timebase A: 2.5s - 5ns/cm
* Timebase B: 0.2s - 5ns/cm
* Triggering DC - 130MHz
* After delay trigger
* Delay line
* Trigger LED indicator
* Overscan LED indicator
* Active TV - Sync - Seperator
* Calibrator: 1KHz & 1MHz Sq. wave

The **HM1005** is a multi-function oscilloscope loaded with features such as true 3 channel operation, a genuine second time base, and even a separate second trigger facility. Up to 6 traces can be displayed for evaluating waveform relationships.

**PRICE £752.00 + £131.60 V.A.T.**
**FREE DELIVERY**

## DIGITAL-ANALOGUE

### HM 205-3 20MHz DIGITAL STORAGE



**FREE DELIVERY**

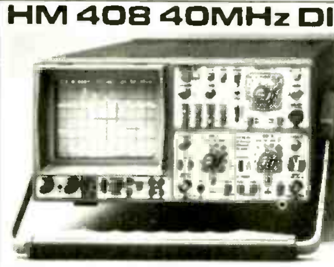
**SPECIFICATION**

* 2Channels
* Digital storage (and analogue)
* Analogue real time (as 203-7)
* Bandwidth storage: DC - 2MHz
* Sens: Ch. 1, Ch. 2, 1mV/cm
* Timebase Analogue: 1s - 20ns/cm
* Timebase Digital: 5s - 1µs/cm
* Triggering: DC - 40MHz
* Active TV - Sync - Sampling
* Max sampling rate: 2 x 20MHz
* Memory: 2 x 2048 x 8 Bit
* Dot joiner
* Component tester
* Printer/plotter output

Now with a maximum sampling rate of 20MHz and an improved storage depth of 2048 x 8 bits per channel, the new **HM205-3** has achieved a truly unique standard of performance. The HM205-3 is Europe's best selling digital storage oscilloscope.

**PRICE £579.00 + £101.33 V.A.T.**

### HM 408 40MHz DIGITAL STORAGE



**SPECIFICATION**

* 2 Channels
* Digital storage (and analogue)
* Timebase analogue: 1s-5ns/cm
* Timebase digital: 50s - 0.1µs/cm
* Sens: Ch. 1, Ch. 2, 1mV/cm
* Bandwidth analogue DC - 40MHz
* Bandwidth storage DC - 2MHz
* Max sampling rate: 40MHz
* Max storage capacity 4096 x 8 Bit
* Dot joiner
* Active TV - Sync - Separator
* Printer/plotter output

With the introduction of the **HM408** dual channel digital storage oscilloscope, Hameg is once again setting an unprecedented standard for highest performance at lowest cost. The user friendly design combines easy and convenient operation with a wide variety of analogue and digital functions.

**PRICE £1423.00 + £249.00 V.A.T.**
**FREE DELIVERY**

### HM 8148-2 GRAPHIC PRINTER

**SPECIFICATION**

* Non-impact printer
* < 20 seconds for hard copy
* Resolution > 11 dots/mm
* Built-in real time clock
* Zooming 2x to 10x
* Built-in help menu
* Same size as oscilloscope, which sits neatly on top.

Hameg's versatile **HM8148-2** Graphic Printer meets the expanding need in the world of electronics for producing fast and accurate documentation of measurement data. With both Hameg digital storage oscilloscopes (HM205-3 and HM408), the existing Hameg bus transfers stored waveform data to hard copy output.

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## Cross words

John Moseley spoiled an otherwise informative and interesting review of the IAR 8051 C Cross compiler ("Harmony in C", May 1991, pp.389-394) by persistently sniping at the program's "user interface". The criticism is misdirected because almost all cross compilers and assemblers for microcontrollers share a similar minimalist command-line-driven interface.

Instead of pointing this out, the review seemed obsessed with the notion that the IAR product has a uniquely horrible user interface. More importantly the criticism has fundamental flaws because a command-line-interface is appropriate for a product of this type.

Programmers often prefer command line interfaces to IDEs (integrated development environments), not wanting to use a different editor for every compiler or assembler. Good programmers do not spend vast amounts of time in an edit-compile-link-debug frenzy portrayed as typical in the review.

Early design and code phases of the development cycle are obviously edit only. The final integrate, debug and test phase should revert to the edit step quite rarely because the program should be 99.9% good by this stage. The mechanics of invoking a separate compiler, linker and loader are awkward, and certainly require help from the manual, but the steps are routinely automated with a batch file.

Moseley asserts that because a nice window and mouse oriented IDE is available for Turbo Pascal, such an interface is easy to implement. Comparisons with Turbo Pascal are inevitably misleading because of the difference between the markets for the two programs. Borland devotes massive resources to wrapping friendly interfaces around its development tools because it is operating in the mass market.

Additionally Borland has the luxury of concentrating on a single platform; code that implements windows and mice does not port from one platform to another as readily as core compiler technology.

I think that by concentrating effort on code generation technology and producing products with simple user interfaces porting easily to different platforms, IAR and companies like it are using resources wisely and providing good service to the engineering community.

***Bill Forster***
*Wellington*
*New Zealand*

## Cyclotron resonance

Harold Aspden makes a powerful case for his cyclotron resonance theory of cancer from power lines (*EW + WW*, "Power lines, cancer and cyclotron resonance", September 1991, pp. 774-775).

But one thing missing from his article is any data on how long it takes for the resonance to build up in the hydroxyl and hydroxonium ions in the human body when exposed to electric fields from power transmission lines. In most circumstances people will be moving around, physically, within the field. If the induction time is relatively slow – of the orders of minutes or hours – this kind of resonance might not have time to build up.

If Dr Aspden is correct one might predict that individuals who spent considerable periods relatively stationary in the fields (for example, sleeping in a house under power lines) would be far more at risk than people simply working underneath them. Perhaps this movement factor in the exposure is why the data linking high voltage fields and disease has been so difficult to establish.

A second point is that it is not clear how resonance of hydroxyl or hydroxonium ions could result in diseases such as cancer.

Mammalian cells all have a standing voltage of between 30 and 90mV (inside negative) across their cell walls – the "membrane potential". This potential, although small, is associated with an extremely powerful electric field, because the distance over which the voltage changes is less than $10^{-8}$m. The field is powerful enough to force charged molecules in the cell wall to orientate in a particular way, ie to line up with the field.

These molecules control many functions of the cell, including certain aspects of growth and development. Reductions in the membrane potential can allow realignment of the charged molecules in the wall and alter how they work. Cancer cells often have abnormally low membrane potentials, and it may be hypothesised that this reduction in wall field, by relaxing the molecular alignments in the cell wall, may disrupt control mechanisms exerted by the wall molecules on cell growth and function. Interactions of the external field from power lines and the cell wall field could make ions in the cell walls particularly vulnerable to the cyclotron resonance effects, resulting in disruption of the wall structure and opening up the way for cancers to develop.

***J Millar***
*University of London*

## On-line support

Barry Fox's criticisms of British Telecom's Phonebase on-line UK telephone directory's lack of user-friendliness are certainly justified (*EW + WW*, "BT muddle points to communications crisis", July 1991).

But he is wrong to object to the choice of the CCITT V23-standard 1200/75 bit/s data-rate.

Of course, it would be even more convenient if Phonebase were equipped (like many private bulletin boards) with auto-selecting modems able to accept all the common data rates, from 300/300 to at least 2400/2400 bit/s. But the V.23 option is one of the most cost-effective solutions for this application – evident from the fact that, just across the Channel, it is currently being used to make some 52 million Minitel calls for a total of 1.6 million hours every month to access France Telecom's equivalent "annuaire électronique".

Here in Belgium, the public videotex server RTT Videotex has just introduced the first stage of its on-line directory service, coded "AE" in French and "ETB" in Dutch, initially covering the 03 (Antwerp) and 065 (Mons) areas. RTT-VTX subscribers can search for either the telephone number, by entering the required surname and local authority area of residence, or for the name and address of an individual subscriber by entering their telephone number. The search can be extended to phonetically similar names and/or associated areas if required.

Although RTT-VTX provides subscribers with gate-ways to various private databases coded in Télétel, including those available to French Minitel users, its default system is compatible with the British Prestel system, except that the character set includes lower-case accented characters instead of fractions etc.

However, although the information printed in Belgian telephone directories includes these accented characters, the AE/ETB software does not (yet?) recognise or display them.

Perhaps at least its user interface could provide a model for other Prestel on-line directories.

***Alan F Reekie***
*Brussels*
*Belgium*

## Common basic problem

As a teacher of basic electronics at college level, there is a small point which has bothered me for some time concerning the bipolar transistor in a common base mode, shown in **Fig. 1**. In reviewing a number of American electrical engineering textbooks, I find none that adequately explains how forward collector current can flow in the saturation region — second quadrant **Fig. 2**. For transistor action to occur and majority carriers to spill over from the base region to the collector region, it would seem that the collector-base diode would need to be reverse-biased; yet in a simple common base configuration with the

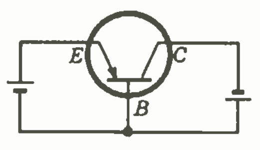


*Fig. 1. Bipolar transistor in common-base mode.*

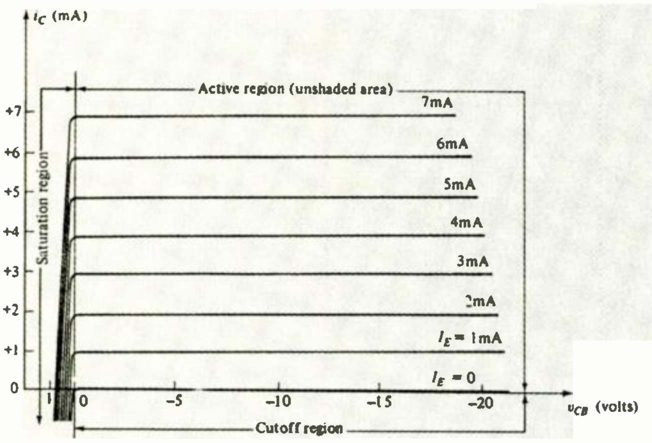


*Fig. 2. Stepped curves... (From "Electronic Devices and Circuit Theory", Robert Boylestad and Louis Nashelsky, Second Edition, 1972, p. 126, Prentice-Hall Inc, Englewood Cliffs, NJ.)*

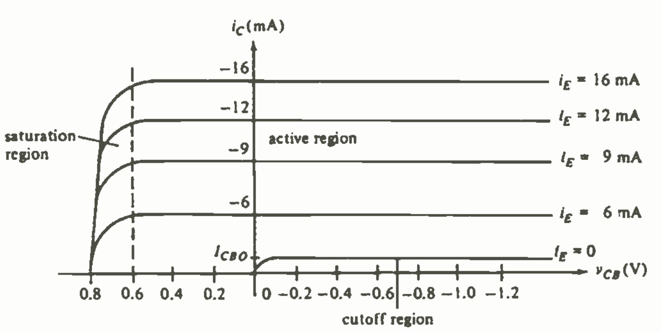


*Fig. 3. ...or convergence. Which is right? (From "Fundamentals of Electrical Engineering", Leonard S. Bobrow, First Edition, 1985, p. 364, Holt, Rinehart and Winston, Inc., 111 Fifth Avenue, New York, New York, 10003, USA.*

base solidly grounded, this diode is clearly forward biased in the second and third quadrants.

With the base solidly grounded and both the emitter-base and collector-base diodes forward biased, the emitter-base loop would appear to be independent of the collector-base loop.

If base resistance is considered, the picture becomes clearer. Emitter current flowing in base resistance raises the potential of the internal P-N junctions with respect to the base terminal; when this potential exceeds the collector supply voltage, the collector is reverse-biased, allowing forward collector current to flow. But I would like to hear some expert confirmation, or correction of this hypothesis.

I have also been intrigued by the collector characteristics for common base which appear in various texts. About half the books I reviewed showed the family of curves "stepped" in the second quadrant, as shown in **Fig. 2**. The others showed all curves converging at about 0.8V, as in **Fig. 3**. It is hard to see how both versions can be correct.

***Frank W Smith***
*University of Tennessee at Chattanooga*
*USA*

## Analogue watch

Your Comment September issue ("Analogue changes") is a timely reminder of the importance to electronic engineers of having a working familiarity with analogue techniques. My lifetime career has been in the communications industry and some of your older readers may remember that I have made some minor contribution in the specialised area of high quality audio design.

One of my responsibilities was the provision of music grade circuits for the broadcast authorities and I remember vividly the time when a young graduate was assigned to me for field experience.

I decided to send him out to line up such a circuit. Sensing some hesitation when asking him to plot a response curve in dBs I was prompted to ask if he understood dB notation.

His reply: "Well, I think so...but I did that in my first year, so you can't expect me to know now, can you?"

I have been told that many universities running electronics courses do not include analogue techniques at all.

This is a gross error. To me, digital techniques are an adjunct and not a replacement for analogue. In wide areas of signal processing, they have freed designers from many problems in the analogue domain. But digital signal processing is a human invention and at the end of it all, there has to be a reversion back to analogue; here is where an understanding of the many problems is vital, such as interfacing to transducers.

I find, an increasing tendency to assume that for every design problem, there is a digital answer. There may well be, but it may prove quite uneconomic and unnecessarily complex.

***Reg Williamson***
*Kidsgrove*
*Staffs*

## Cuk champion

I must congratulate Terrence Finnegan on his assessment of the benefits of the Cuk converter, compared to the more traditional power converter topologies. However, Brian Pollard, in his letter, (*EW + WW* September 1991), raises points that require to be addressed.

As one of the few people who has actually built integrated magnetic Cuk converters into real equipment, I feel I am in a position to dispel these often repeated myths. Although the initial design of a Cuk converter is more complex than the more conventional type, requiring real knowledge of magnetics and control theory, the final product does indeed deliver all that is claimed.

The first myth is that the energy transfer capacitors are physically large. When the Cuk topology was first proposed some 17 years ago, capacitors were indeed a limiting factor, and physically large polycarbonate or polyester types had to be used, not for their high value of capacitance, but for their low ESR. This is no longer the case due to advances in multilayer ceramic capacitor technology.

Now, because of their very low ESR, tens of amps can be carried with low loss, in a small volume. (Mr Pollard is probably using them in the input and output filters of his Buck converter for exactly this reason ). It is important to realise that the energy transfer capacitors are for just that, transferring energy; they are not for bulk energy storage. As the energy is transferred in a few microseconds, and considerable droop is permitted, relatively small values of capacitance is required, resulting in small in-rush and rebalance currents.

The second myth is that efficiency of a power supply is dependent on quality of the components, and is independent of the choice of topology. TS Finnegan showed in the first part of his article, as others have elsewhere, that choice of topology determines the attainable efficiency at the outset. Using the same components in different configurations produces quite different losses. Although the basic Cuk converter is shown to be superior to other topologies in this aspect, it is when the integrated magnetics solution is considered that the full benefits are realised.

Because of zero ripple in both the input and output inductors, very much reduced values of inductance are required. The magnetic structure is therefore small, resulting in low iron losses; and the number of turnsrequired is reduced, allowing heavy gauge wire to be used, (without eating into the window area), further reducing copper loss.

Another benefit of the lower inductance values found in the integrated version is the effect of simplifying the loop stabilisation. The small inductance of the input choke, coupled with low capacitance of the energy transfer capacitor, causes the complex poles and unpleasant right half plane zeros to move up in frequency, well above the usable bandwidth of the power supply. Damping of the energy transfer capacitor is simple, and may not be required at all.

Mr Pollard claims there is no

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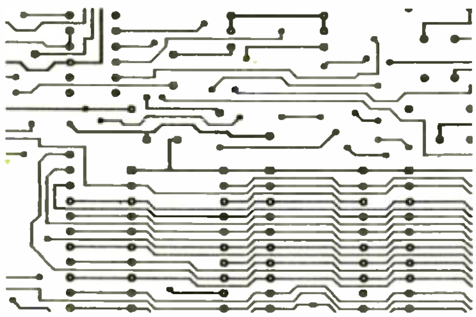

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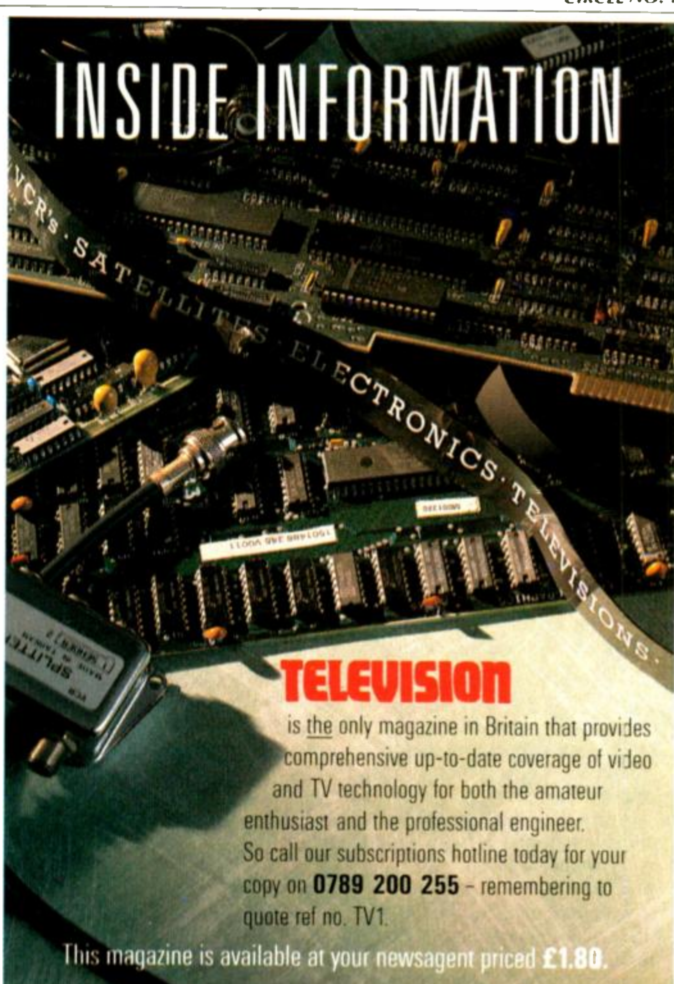


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evidence that there is an advantage in volume, weight, and cost in using the Cuk topology. Dr Cuk has himself shown prototype power supplies that he has designed for the Boeing Corporation, and for the Hughes Aircraft Corporation. These are built in the form of hybrids, and have a power density of 50W/in$^3$. It is the integrated magnetic approach that makes this power density possible at moderate switching frequencies. To get this power density with conventional topologies requires switching frequencies in the MHz region, with all the attendant problems that this brings.

The difficulty in manufacturing the integrated magnetic element that Mr Pollard highlights is indeed perceived to be a fundamental drawback to producing a low cost power supply. Costs incurred depend on the level of mechanisation that can be employed. Although it is a more complicated structure to produce, it replaces two much larger inductors and a transformers. The total number of windings to be produced is the same, and if these are wound as self supporting bobbinless windings and assembled on one core later. I cannot see why they should cost more than three much larger windings required for the conventional topologies, assembled on to three separate cores. Without bobbins it becomes more difficult to terminate the windings, and an additional terminal carrier may have to be used. The slightly added complexity in producing the magnetic element is more than compensated for by the benefits that it brings.

The new EMC directive from the EC, originally due for implementation in 1992, (but now delayed until 1994 ), will have dramatic impact on all electrical equipment offered for sale. It will be an offence to sell equipment that has not passed a rigorous EMC test by an accredited test house.

The vast majority of power supplies currently on the market will not pass this test without substantial additional filtering. Wound component manufacturers, and the suppliers of filters, are excited with the prospect of increased sales to manufacturers of Buck and Flyback converters.

Mr Pollard states that the input filtering requirements of the Cuk are similar to that of the Buck. This is most definitely not the case. Even the non-integrated version of the Cuk, with its non-pulsating input current, is much easier to filter than the Buck, with its pulsating input current. With the integrated structure, and near zero ripple, the task of filtering the residual differential-mode input current noise is almost trivial. Very small components are required for the Cuk, while substantial inductors and capacitors, (and damping ), are needed for both the Buck and the Flyback converter. In addition, Dr Cuk has demonstrated that by splitting the input inductor into two windings, with the appropriate ratio, a very effective common-mode noise filter is obtained at no extra cost.

Mr Pollard wonders why, with all its apparent advantages, the Cuk converter is not more widely used.

There are several reasons, the main one being that the technology is relatively new, and is still undergoing rapid improvements. Perhaps engineers were frightened off by a bad experience several years ago when the dynamics were not fully understood, or perhaps it is just because designers are unwilling to risk a design that is perceived to be too radical, preferring instead to stick to well tried and tested topologies.

The increasing pressure from the market place for higher power densities and improved efficiencies, coupled with the new EMC regulations, will force designers to consider alternative topologies, and the Cuk converter would seem to be an obvious candidate.

***Alastair J Stanley***
*Aberlady*
*East Lothian*

## Telepoint – not telepointless

With regard to Mr Peter Johnsonn's letter that appeared in your September issue ("Telepointless"), I am writing as a member of the Phonepoint team to answer to Mr Johnsonn's claim that the telepoint system is ill-conceived. Phonepoint fills the gap for a mobile communications system, positioned between pay-phones and cellular, offering convenience and cost effectiveness. We do not see the fact that telepoint is at present only one-way as a detriment to its success. It is a low-cost service to meet the needs of telephone users who do not want the expense of cellular equipment and calls. Making it a two-way public service would require adding intelligence to the system, driving up the cost. For those who demand two-way telepoint, we will be offering an integrated pager and handset, and users can then decide whether they want to call back on telepoint.

Phonepoint is backed by some of the world's most powerful telecomms companies (BT, Northern Telecom, France Telecom, Deutsche Bundespost), and so is in a strong position to invest in the emerging telepoint technology and support the common air interface (CAI) launch. Telepoint cannot be dismissed on the grounds of cost. Handsets will be priced close to £100, with the complete package of handset, private base station and subscription for around £300. Call charges will be the same as making a call from a public payphone. On the subject of competition, we have always maintained that four players were too many for a start-up technology like telepoint, and produced much fragmentation of effort. This has been proved with Phonepoint and Hutchison the only two operators intending to launch a public service.

I hope my letter will answer many of Mr Johnsonn's queries.

***Susan Sherring***
*Phonepoint*
*London*

***I still say it will never sell – Ed.***

## Challenging viewpoint

Anyone trying to call the invariant-velocity-of-light dogma into question, is invariably attacked by Einstein's supporters who will use any method to defend the prevailing view (cf subsequent correspondence to John W Ecklin's letter, March 1991). The fact that light is a physical phenomenon, behaving as it does independently of Einstein's theories seems to make no difference.

Light travels very fast and that is one of the problems behind performing measurements with high accuracy, especially if moving light sources or moving observers are involved. So Doppler shift measurements are used, whereas in fact distance measurement would be the most suitable.

Doppler wavelength/frequency shift measurements are indirect methods and can be rejected as invalid by Einstein's supporters who say that the product of frequency and wavelength is always equal to $c$.

But distance/time measurement would be possible using satellites.

Consider satellites A, B and C moving in the same orbit around the earth, A and B moving in the same direction with constant relative distance and with the same velocity, and C moving in the opposite direction. C satellite emits radio or light pulses continuously and A and B catch these signals and register their arrival time in computer data registers.

The local time registrations of each pulse in each satellite is continuously transmitted to Earth and the time differences of received data is calculated.

When C satellite approaches A and B, the time A–B will be: $t_1=S/(c+k.v)$ and when receding $t_2=S/(c-k.v)$, where $k=0$ if Einstein's invariant light hypothesis is valid and $k = 1$ if the emission theories ($c'=c+-v$) is valid. S is the relative distance between A and B.

Calculated time difference will be $t_1$-$t_2$ equal to :

$dt = 2.S.k.v/(c^2 - k^2.v^2)$ or $dt = 2.S.k.v/c^2$ approximately.

Inserting figures – where $v$ = 30,000km/h or 8333m/s, $c$ = $3\times10^8$m/s and $S$ = 100km – $k$ = 1 gives approximately 18.5ns. If the distance is increased to 1000km, the difference will be 185ns, or nearly 0.2μs, easy to detect and establish. As everyone can see, if Einstein's hypothesis were true, the time difference would be zero.

Who will believe on that?

By this experiment, the question of the velocity of light and the velocity of radio wave propagation would be solved once and for all, relegating this tiresome question and Einstein's theories to the lumber room of failed scientific ideas where it belongs.

***Ove Tedenstig***
*Maersta*
*Sweden*

## Clearer signal

Further to my letters published under the heading "Signally strange" *EW + WW* February and March 1991 and readers letters, I now realise that some of the trains of exponential damped waves were actually generated by the tuner as the result of an initiating pulse.

The effect of the pulse is essentially the same as that of the spark in a spark-type oscillator whereby the frequency of the actual oscillations is set by the time constants of the tuned circuit while the period between each train of oscillations is set by the spark frequency. So, in the above observations, the frequency of individual oscillations comprising the train is not significant; it is the length of time between each train that is, because that corresponds to the period of the initiating pulses.

In field experiments, I have been able to demonstrate that a large capacitor discharged in the vicinity of my earth probe antenna, where it presumably generates a magnetic pulse can initiate a train of oscillations. On my workbench I have found that trains of waves with a frequency up to 1.0kHz can be initiated by low frequency (5 to 50Hz) square waves. The fact that a pulse or square waves can set up oscillations at the frequency to which the receiver is tuned, may throw light on the origin of some of the "strange" signals.

The pulses that seem to initiate the damped wave trains do not look to be oscillatory, if they are, they consist of so few oscillations as to be non-tuneable with my basic equipment and simply break-through. So, assuming that electromagnetic pulses do actually initiate the trains of strange waves, the question is from where do they originate.

If pulses arrive from several sources it would be impossible for me to differentiate them; the receiver apparently responds to any pulse that happens to be strong enough to initiate a train. If the tuner is in resonance with a steady signal, possibly originating from ELF military stations, the trains seem to be superimposed to give the characteristic waveform (Fig. 3, *EW + WW*, Feb 1991). So, to observe the trains, the tuner had to be set to a frequency not occupied by a steady signal and best results were obtained with the tuner resonating at about 1.0kHz but this was not critical.

With the earth probe antenna installed in farmland near a village, trains with a 10 or 20ms period were conspicuous and were assumed to originate from "spikes" present on 50Hz power lines. However, with the receiver set up in a more remote area, about a mile from power lines, and the oscilloscope powered by a portable generator, trains were at times aperiodic, possibly caused by distant lightning discharges.

However, quite unexpectedly, at other times, trains occurred in groups of three with about 1.0s period (extremely difficult to estimate with my CRO) while at other times trains with 150 to 300ms period (3.3 to 6.6Hz) were occasionally observed; I suppose these could be caused by sub-harmonics of 50Hz but this seems unlikely.

I hope these notes will be of interest and at least throw some light on this intriguing subject.

***George Pickworth***
*Kettering*

## Levitation or levity?

Most scientists regard talk of anti-gravity or gyroscopic levitation as nonsense. But the minority with open minds seek, by enquiry and correspondence – some through the pages of *EW + WW*, more information.

As the author of "Anti-gravity electronics" (*EW + WW*, pp. 29-31, January 1989) and at the risk of engendering more levity, I offer the following references as an update for this minority interest:

(a) A fundamental theoretical account: "The theory of anti-gravity", H. Aspden, *Physics Essays*, vol 4, pp.13-19, 1991, University of Toronto Press.

(b) A claim to have demonstrated solid-state electronic anti-gravity technology: "Utilizing scalar electromagnetics to tap vacuum energy", F Sweet and TE Bearden, to be published by American Nuclear Society inproceedings reporting IECEC - 26th Intersociety Energy Conversion Engineering Conference, Boston, Mass, August 4-9, 1991. An electrically excited device weighing 6lbs loses weight progressively as a continuing function of electrical power throughput (90% weight reduction at 1 kW).

(c) As evidence that, contrary to learned opinion, academia still has something new to learn about "gyroscopic dynamics": p. 23 of recently issued "Report of the Head of the Department of Engineering, Cambridge University, Academic year ending 1990". This lists a cooperative research effort with Smiths Industries Aerospace and Defence Systems Ltd on a new design of rate gyroscope sensitive about two orthogonal input directions and having a rotor which "floats" in space. "Unexplained dynamic characteristics are being examined in order to understand its behaviour more completely and certain mechanical failures for which there is no present explanation"

***H Aspden***
*Department of Electrical Engineering*
*University of Southampton*

## Can anyone help?

**1155 request.** For sentimental reasons I would dearly love to get my newly acquired R1155 working again. Can anyone help?

Many years ago, in the fifties I guess, Wireless World published data on WWII radio equipment, in particular on an aircraft radio receiver type R1155A.

I am sure I recall issues of WW detailing various modifications and a circuit diagram. Could I engage your sympathetic interest in my problem to help track down a photocopy of the circuit?

This is something of a *cri de couer* as all efforts up to now in radio clubs etc have drawn a blank.

***Douglas Berry***
*Ward of Turai*
*Rescobie*
*By Forfar*
*Angus*

**Datalogger.** Can any *EW + WW* reader help me locate a data-logger to help me complete some experimental work.

I've been running a simple Geiger tube experiment on a pole to measure background since last year. This has shown that if you align the tube to the magnetic field axis, it becomes a potent solar and geomagnetic disturbance logger, because the incoming particles from solar flares are organised by the electrodynamic effect of the geomagnetic field into definite alignments which can be readily detected by an appropriately oriented detector.

My work seems to break new ground, because I'm not using the normal heavily screened tube favoured by researchers into high energy particles. My tube is unscreened except for a chunk of aluminium, so it responds to much lower energy particles, and shower products from high energy collisions.

Initially I need a datalogger which can take the digital pulse rate from a fixed or portable GM tube(s) and record it on disc or ram, for processing into bargraphs, charts etc. At the moment I run a fixed analogue system which drives an integrator chart recorder plus a digital counter which gives me an average count over 12h, but needs to be manually read and reset each time.

Ideally, I would like to take an hourly rate or better – hence the interest in a data logger.

I do have an Amstrad PCW8512 and Commodore Amiga 500 available, but nothing better than the standard Amstrad dot/matrix printer, and don't want to spend a fortune. Can anyone help?

***Anthony Hopwood***
*Close Cottage*
*Holdfast*
*Upton-on-Severn*
*Worcester WR8 0QZ.*

**Valve output transformer.** I have a hitherto secret passion for designing, building and renovating valve RF comms equipment. Unfortunately, some parts are becoming so scarce that they don't even show themselves as one of the unsold lots at the end of a radio club junk sale. Can anyone supply me with a single-ended audio output transformer, ideally with a primary impedance of about 8000Ω and a power handling of 1W?

***Frank Ogden G4JST***
*Editor, EW+WW*
*081-661 3128.*

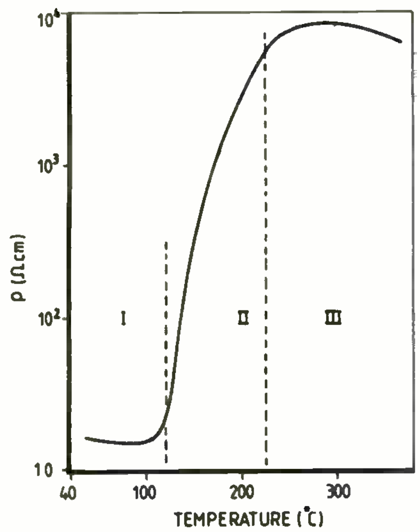



*Fig. 1. Resistance - temperature characteristic, divided into three regions: Region I, temperature region where resistance is approximately constant with temperature. Region II is the PTC, where resistance increases dramatically with temperature. Region III has typical NTC characteristics, where resistance falls with increasing temperature. In heating applications, region I is used to obtain high current and therefore heating, and region II to balance the circuit and maintain a self-regulated temperature. In over-current and over-temperature applications, region II is utilised, where the high resistance resulting from the high ambient temperature is used, essentially to cut off the current.*

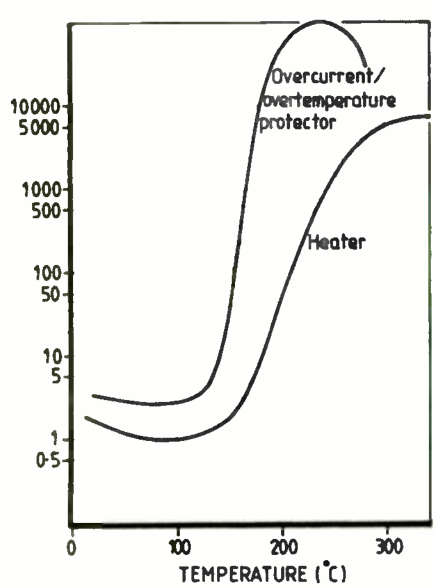



*Fig. 2. PTC applications. The steep PTC curve is required for over-current and thermal fuse applications, where the current needs to be switched off quickly. The shallow curve, on the other hand, is more suitable for heaters, where there is a gradual reduction in current as temperature rises.*

# Semiconducting ceramics

***It is not only silicon and germanium that exhibit semiconducting properties. New materials promise a generation of rechargeable batteries with virtually infinite charge/discharge cycle lives. Rob Deverson explains.***

Thirty years ago it was found that doping barium titanate with certain compounds caused the resistance to fall to 1-100Ω and the resulting material was semiconducting. Subsequent heating of the device demonstrated that, at approximately 130°C, the resistance rose sharply by up to six orders of magnitude over a temperature range of up to 100°C. The switching temperature could be tailored to match the system requirement by the substitution of compounds that either lower or raise the operating points.

Most positive temperature coefficient thermistors are based on the ceramic compound barium titanate. The material in its pure form is an insulator and is commonly used in multilayer and other miniature capacitor manufacture.

Most heating applications have PTCs which stabilise between 150 and 250°C and therefore require doping to create performance at this higher temperature. Alternatively, over-current protectors may be required to switch below 100°C and the ceramic formula is adjusted accordingly. The composition of the PTC - the relative amounts of the additives to pure barium titanate - must be carefully chosen to obtain the required PTC characteristic. For example, a heating application requires the PTC to balance the circuit at a given temperature.

Any fluctuation in current load or external temperature is accompanied by a resistance charge (**Fig. 1**) which can cause a sudden surge in the current requirement, which may not be available. If the characteristic is fairly shallow the resistance change with temperature is gradual and no sudden effects take place. Where the application is for over-temperature protection a steep resistance rise is required to ensure no further heating takes place.

**Figure 2** shows typical PTC characteristic requirements for different applications.

Conditions of application are important. A PTC which works well under 5 or 10 volts will not work under mains or similar voltages. Each application has its own PTC formulation, ensuring that the customer gets the best device for the application.

### Contact materials

Conventional electrical contacts for low voltage switch-gear, such as contactors or circuit breakers, consist of silver, copper, gold or a composite of silver and oxide materials. These materials are chosen for a number of reasons, particularly their high conductivity and mechanical properties, but each has associated drawbacks. Metallic contact elements are restricted in their use with regard to their atmospheric and design sensitivity: low temperatures are required to prevent oxidation or corrosion and contacts must be small enough to prevent contamination from the presence of air-borne particles: they must also be sufficiently large to prevent welding due to the self-heating effect at high current densities.

A new range of ceramic materials which, after suitable processing, have conductivity similar to that of most metals, has now been developed. Electrical contact elements made using the new material demonstrated superior performance to conventional composite and metallic contacts.

The ceramic elements are formed using high temperature techniques which renders the material immune to the atmosphere, mechanically very strong and electrically and mechanically resistant to the effects of arcing.

In addition, the particulate nature of the ceramic means that the surface is inherently rough and any airborne contamination can be naturally accommodated in the surface of the contact. Self-welding is also eliminated since the ceramic does not melt: therefore higher current densities and temperatures can be used with no danger of deterioration of the contacts.

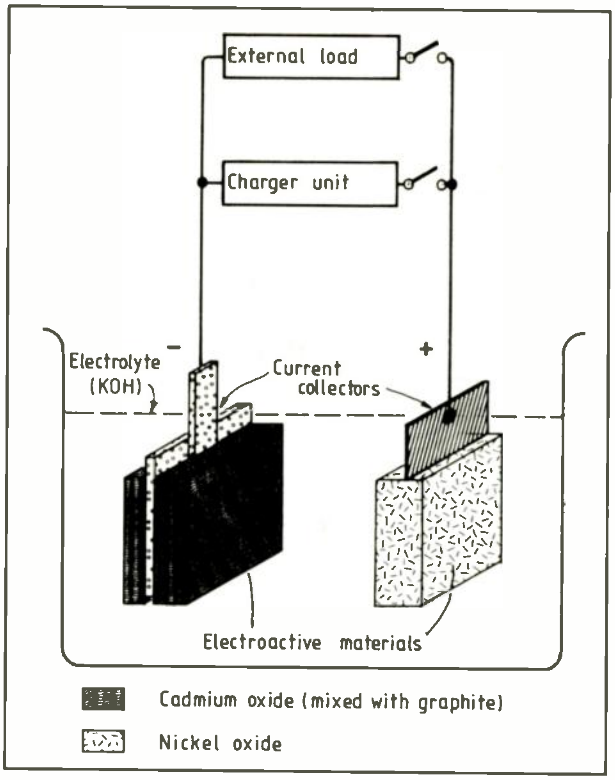



*Fig. 3. Sketch of typical Ni-Cd battery. A conventional Ni-Cd battery consists of the two electrodes, mixed with conductive fillers to increase the conductivity of the electrode, in a solution of potassium hydroxide. The new battery uses sodium hydroxide, which is much less toxic, and because the electrodes are themselves electrically conductive, conducting fillers are not required. Ceramic electrodes do not change their physical dimensions with charge giving rise to a virtually infinite charge/discharge life. The result is a simple arrangement which is more efficient and directly interchangeable with primary batteries – and much longer lasting..*

## Electrochromic ceramics

There is a group of metal oxides which change colour, in an electrochemical cell, from a colourless or white state (bleached) to blue or brown (coloured) as a result of a partial reduction of the compound by an electric current passing through the cell. These conventional materials are found in thin film form as smart mirrors and windows as well as displays, warnings, and other devices.

But the colour change is not strong (often filters and colour gatherers must be included to obtain a suitable reaction) and control circuitry must always be included to prevent reduction of the material to its base metal during the colouring cycle.

Now ceramic materials have been developed which are a compound of two metal oxides. These new materials demonstrate dramatic colour changes, from white or pale yellow to black or dark green, depending on their exact formulation.

Unlike the more common electrochromic materials, being a mixture of two compounds reacted to make a third, they are very stable and reduction to the metallic state is not possible using the electrochemical treatment.

So there is no requirement either for filters to detect colour change or control circuitry to prevent excessive reduction.

These superior properties of the new material permit more simple application, thereby introducing many more opportunities where a rapid and dramatic colour change is required.

**PTC thermistors**

A thermistor is a temperature sensitive resistor – its resistance changes as temperature is increased or decreased, in a controlled manner so that, at a particular temperature the thermistor has a known resistance. There are two types of thermistors - those whose resistance decreases with temperature (NTC - negative temperature coefficient of resistance) and those where the resistance increases (PTC - positive temperature coefficient).

Main characteristic of ceramic PTCs is their sharp increase in resistance at a given temperature, giving a step-like resistance - temperature performance not unlike a switch .

## Longer life rechargeable batteries

Experiments with the electrochromic materials revealed that they were capable of holding their electric charge providing they remained within the electrochemical cell.

Subsequent development of this observation has resulted in rechargeable battery electrodes which are chemically inert and superior to existing secondary battery materials.

Conventional nickel cadmium batteries utilize toxic cadmium metal and highly corrosive potassium hydroxide electrolyte.

During the charge-discharge cycle the cadmium reacts and changes its state between the metal and oxide, which results in a small volume change.

Over a large number of cycles (700-1000) the battery eventually becomes unable to withstand the stresses built up as a result of the volume change: it can no longer accept any charge and catastrophic destruction of the battery becomes possible. Nickel cadmium batteries have another major disadvantage in that their output voltage is slightly lower than that of conventional primary batteries, at 1.2V compared with 1.5V. Charge gatherers need to be included when these batteries are used, adding to their cost and reducing their range of application.

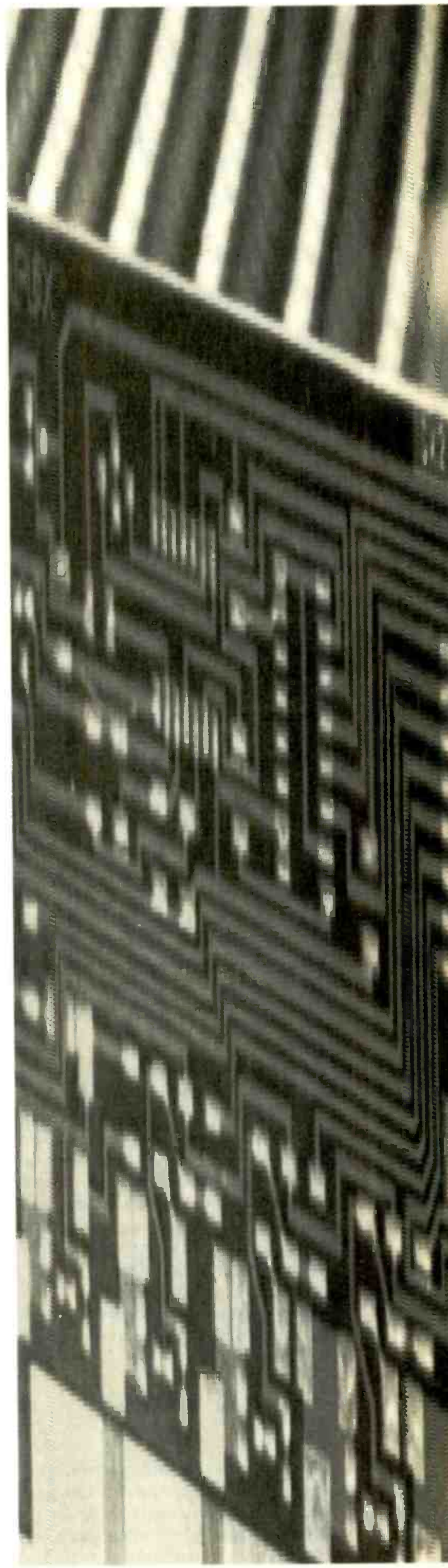
The battery obtained using Elmwood's new material (**Fig. 3**) results from a partial reduction of the ceramic, without any reaction (phase change) - the molecular structure of the charged and discharged electrodes is identical. Therefore there is no associated volume change and the battery has an almost infinite life.

In addition, the ceramic nature of the new electrodes suggests that they may be compatible with solid electrolytes, giving rise to an all solid battery.

Finally, the output voltage of the new battery, using less corrosive sodium hydroxide electrolyte, has been measured at up to 1.8V, demonstrating a much greater application potential than the Ni-Cd system and direct compatibility with primary batteries.

No phase change during cycling also translates into far longer life expectancy - a simple laboratory arrangement demonstrated a life of over 6000 cycles with no significant effect on the efficiency or voltage output. In summary, by combining the conductivity of metals with chemically inert ceramics, a rechargeable battery has been found which overcomes all of the disadvantages of conventional systems andwhich, ultimately, performs better. ■

*Rob Deverson works for Elmwood Sensors Ltd.*



# Structured analogue electronics

***Analogue systems have so far defied the standard cell approach long available to digital designers. David Grundy and Julian Raczkowicz promise an easy route to analogue chip building through standardised hardware and software.***

On picking up any modern text book on analogue electronics it is easy to see why there are so few analogue designers. Almost without exception, they go directly to the circuit component level, which calls for years of experience to solve the simplest of problems. All problem solving requires a degree of experience but a novice analogue designer will almost certainly be overwhelmed by the sheer scale of the design idiosyncrasy.

There is no doubt that if high performance in terms of bandwidth, low current, noise and in the case of integrated circuit design, smallest chip size is required then some degree of specialised knowledge, however idiosyncratic, will be required.

It is our contention that not all problems are of this type. Sure enough if big volume producers like National or Motorola want to introduce a new analogue IC for a highly competitive marketplace, the chip will have to offer the highest performance obtainable for a given current consumption and chip size. This however is not true for every analogue design. In the majority of cases a relatively small but strategically critical quantity of analogue functions are required to sit alongside a much larger quantity of digital functions. Design ease is probably more important where speed to market is paramount.

If highest performance is the goal then there is no option but to design at the component level and verify designs with Spice[1], or its derivatives. This is time consuming.

Structured analogue electronics solves the computer aided design problem by moving away from component level to a higher level of abstraction, which can be accommodated by software languages such as C, Ella, VHDL or even Basic

### Design principles of SAE

In SAE the number of unique functions are reduced to a minimum. These fundamental blocks have a simple but explicit mathematical description which is without ambiguity, both in its statement and implementation. The design process consists of interconnecting these functions in such a manner as to satisfy the fundamental application equations.

The building blocks have to be independent of the eventual silicon technology: it should be equally applicable to bipolar, cmos or indeed bi-cmos. This in itself is a tall order and enforces the basic principle of restricting the number of functions to an absolute minimum.

We hesitate to use the words "analogue computer" since this has connotations of unreliability, arising from problems associated with early analogue computers built with thermionic valves. We prefer a notion more in keeping with Alan Turing's[2] universal machine associated with digital computing. As always with universal machines, it is necessary to define an instruction set. The structure is largely a matter of personal choice, and the following is based on our own experience of analogue design:

1. addition 2. negation 3. multiplication 4. division 5. raise to the power 6. rectification. Also the time dependent forms: 7. differentiation 8. integration.

This completes the set. We believe that most analogue signal processing (asp) problems can be solved with these eight basic instructions. Just in case anyone is thinking

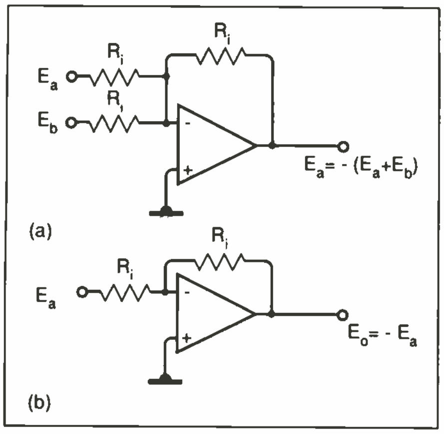



*Fig. 1. Basic SAE functions; (a) addition and (b) negation.*

"why not use a digital computer or digital signal processing?" the answer of course is that analogue processing is expected to provide a very significant improvement in speed allied with simpler architecture, lower power consumption and a greater reduction in costs.

Instruction 1, addition, is straight forward. It can be achieved in the usual manner with an operational amplifier as shown in **Fig. 1a**. Next comes negation shown in **Fig. 1b** which is implicit in the previous adder, and if required as a separate function, then a single input adder will of course suffice.

So far so good... the problems start now. Progress in analogue design standardisation can be largely attributed to the functions of multiplication, division and raising to a power. There are countless methods to implement these functions. If SAE is going to become a practical reality, then something must be done to standardise on these three functions in particular. A freely available solution rests in the characteristics of the basic p-n junction. Given the importance, we intend to digress slightly to explain just what is meant.

### Logarithms: do it with diodes

Analogue designers generally struggle to remove distortion caused by the non-linear transfer characteristics of active devices. The first step is to bias the device into its most linear region and the second – usually – is to apply negative feedback. If instead of using negative feedback, etc. to linearise junction characteristics, we take a closer look at the fundamental properties, then a few surprises are in store.

The basic relationship for current and voltage, associated with any semiconductor junction[3] is given by:

$$I = I_0 \exp\frac{qV}{nkT} \quad \text{or} \quad V = \frac{nkT}{q}\ln\frac{I}{I_0} \qquad (1)$$

where $I$ = forward conduction current, $>> I_o$; $I_o$ = reverse saturation current; $q$ = charge on electron; $V$ = voltage across the junction; $n$ = a constant near unity[2]; $k$ = Boltzmann's constant; $T$ = absolute temperature.

This equation holds true for all semiconductor junctions whatever the technology, be it bipolar, cmos or bi-cmos and also for all materials, silicon, germanium or gallium arsenide.

A further important attribute is its remarkable consistency, that is at least for silicon. This is due in part to the fantastic amount of effort and money that has been spent on bringing silicon to its present state of refinement. A long lasting experience of this diode equation and information gathered from other sources[3] has shown, that (1) is typically accurate to 1% over at least eight decades of current.

Further to this, junctions in n-p-n transistors with high values of $h_{fe}$ connected as diodes ($V_{cb}$=0V) have been seen operating down to$10^{-14}$ amps. We contend that (1) can be used to resolve the fundamental problems of standardised analogue design.

The basic logarithmic behaviour of semiconductor junctions (when not being linearised) is currently used in multipliers, AGC circuits, etc. However, it is not applied consistently and often the wheel is re-invented with each new application. Also, the division capabilities of p-n junctions are often not fully appreciated.

SAE proposes the extensive use of logarithms. If instead of linearising the exponential behaviour of a p-n junction, one simply converts signals into logarithmic form by use of this fundamental and consistent characteristic, then a great number of our problems will disappear. Multiplication for example can be achieved simply by addition of logarithms, division by subtraction and raising to a power by multiplication of the logarithm by the required exponent.

### Practical logarithmic functions

As anyone with hands on experience of silicon junctions knows that the change in junction current compared with the rate of change of junction voltage is extremely rapid. According to (1), a room temperature plot of $\log_{10} I$ against $V$ gives an almost linear characteristic of:

$$\frac{2.3kT}{q} \approx 60\text{mV}$$

per decade change in current or 480mV per eight decades change in current. Such large rates of change need special handling.

A further problem is variation of current with temperature. The basic junction current has two temperature dependent terms: (i) The saturation current $I_0$ has a marked non-linear temperature dependence, and approximately doubles for every 10°C change in temperature; (ii) The energy based function $2.3kT/q$ has an almost linear temperature coefficient of +0.3%/°C.

The physical theory behind these temperature dependent terms is quite complex and covered to a high degree in the references. Our main interest, from the design viewpoint, is to eliminate the effects of temperature.

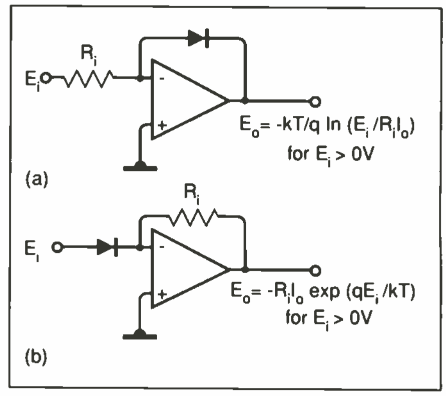



*Fig. 2. (a) Logarithmic ampl;ifier with junction connected into negative feedback loop; (b) antilog amplifier.*

A single p-n junction in isolation is of little practical value in manipulating logarithmic functions. The reason for this is that it is essential to separate voltage and current terms. In taking a logarithm, a current derived from one variable can be used to feed a p-n junction, but this value of current will of course depend upon the voltage across the junction, especially if a simple resistive feed is used. The easiest way around the problem is to connect the junction into the negative feedback loop of an amplifier as shown in **Fig. 2a**. Since the junction feeds into the virtual earth input of the amplifier, the current through it depends only on that provided by the source voltage $E_i$ and not upon its own voltage drop.

The output voltage is in fact given by:

$$E_o = \frac{-kT}{q}\ln\frac{E_i}{R_i I_o} \quad \text{for } E_i > 0V \qquad (2)$$

This arrangement shown in Fig. 2a provides a means of generating the logarithm of an input voltage variable $E_i$, at least for positive values.

If negative values are required then this may be achieved by reversing the p-n junction of the diode.

The complementary version of Fig. 2a is shown in **Fig. 2b** where the position of junction and resistor have been interchanged, this is an antilog amplifier and its output is given by:

$$E_o = -R_i I_o \exp\frac{qE_i}{kT} \quad \text{for } E_i > 0\text{V} \qquad (3)$$

The output from Fig. 2a after inversion is now used to define the input to a positive polarity antilog amplifier as shown in **Fig. 3**. The ultimate output $E_o$ will be an inverted replica of the input signal $E_i$. The logarithm of $E_i$ will be taken by the logarithmic amplifier of Fig. 2a, and subsequently the antilog will be taken by the antilog amplifier, and the output will be the input signal $E_i$. Mathematically:

$$E_{o1} = \frac{-kT}{q}\ln\frac{E_i}{R_i I_{o1}} \quad \text{for } E_i > 0\text{V} \qquad (4)$$

System output:

$$E_o = -R_i I_{o_2} \exp\frac{-qE_{oi}}{kT} \quad \text{for } E_i > 0\text{V} \qquad (5)$$

Substituting (4) and (5) produces:

$$E_o = -R_i I_{o_2} \exp\frac{q}{kT}\left[\frac{kT}{q}\ln\frac{E_i}{R_i I_{o_1}}\right] \qquad (6)$$

for matched IC diodes

(n-p-n transistors with $V_{cb} = 0$) then

$$I_{o_2} = I_{o_1} = I_o \qquad (7)$$

so (6) now reduces to:

$$E_0 = -\frac{R_i I_o E_i}{R_i I_o} = -E_i \qquad (8)$$

Therefore by using identical resistors for the log and antilog functions, the output voltage becomes exactly equal to the input and also completely independent of temperature. Both the saturation current and – for lack of a better name – the energy based functions of temperature, are cancelled out in the antilog process. For more complex functions, this simple log/antilog function will not suffice. The process of taking antilogs will usually remove the energy based functions but not necessarily the saturation current term.

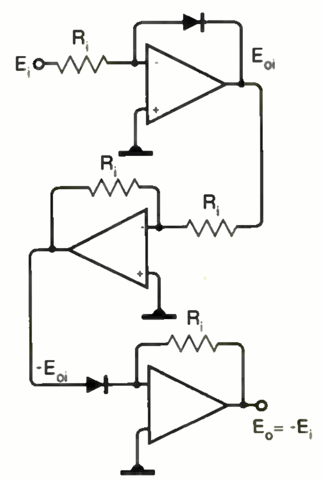



*Fig. 3. Taking logs and antilogs.*

| $E_i$(mV) | $-E_o$(mV) | $(E_o/E_i)$% |
|---|---|---|
| 222 | 231 | 1.04 |
| 297 | 310 | 1.043 |
| 373 | 390 | 1.045 |
| 473 | 494 | 1.044 |
| 572 | 596 | 1.041 |
| 671 | 701 | 1.044 |
| 772 | 805 | 1.042 |
| 872 | 909 | 1.042 |
| 971 | 1015 | 1.045 |
| 4040 | 4220 | 1.044 |
| 6020 | 6310 | 1.048 |
| 7040 | 7350 | 1.044 |

*Table 1. $E_o/E_i$ measured on SAE cells, set up as in the configuration of Fig. 3.*

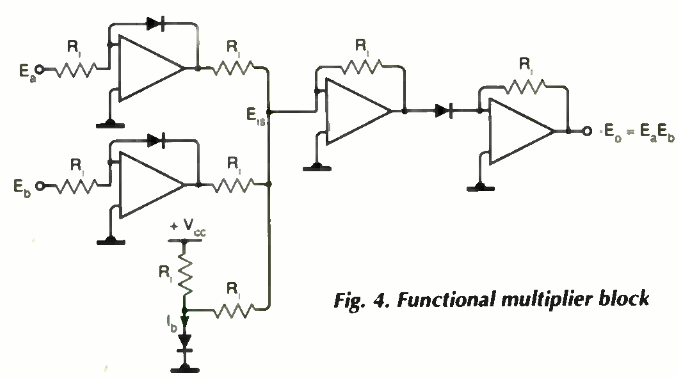



*Fig. 4. Functional multiplier block*

To see how things work out in practice, a table of $E_o/E_i$ measured on SAE cells, set up as in the configuration of **Fig. 3**, is shown in **Table 1**. It can be seen that $E_o/E_i$ is accurate to better than 1%, neglecting any scaling errors due to non optimisation of such things as resistor ratio's and amplifier offsets.

## SAE multiplier design

Before detailing multiplier operation, it is necessary to define the range of numbers over which the circuit has to operate. This is a more complex subject than might at first be appreciated. First of all it is necessary to decide on the exact mode of operation. The off line application for example, where the conditioning of numbers and the rate at which they are presented and managed is very different to the real time environment of signal processing. A functional multiplier block is shown in **Fig. 4**.

The range of numbers for off line applications is, relatively speaking, an arbitrary problem. The first decision is the choice of silicon technology be it bipolar, cmos or bicmos. Having done this, the next factor is to fix the current range to be used in the p-n junctions associated with the basic logarithmic amplifiers. Since speed is not critical for off line applications, there is an inclination to opt for the lowest current possible with the attraction of long battery life for portable applications.

While operation at $10^{-14}$A is possible, it does require amplifiers with compatible input current. This is a practical option in mos technologies but highly impractical in straight bipolar. In addition to amplifier input current problems, extremely low currents can cause difficulties in defining them accurately.

Against this background the lowest practicable current level is set by the input current requirements of bipolar operational amplifiers, about 1nA. This infers a minimum design signal level current of 10nA. The upper limit is set by the accuracy of the junction equation at high levels of injection. With these factors in mind, the upper current limit is set at 10μA, a signal range of 1000 to 1.

With a maximum signal current value of 10μA, the antilog amplifier feedback resistor can be defined once a voltage range has been established. Assume a voltage signal range of 1V at both input and output. This of course is quite arbitrary, and on this basis, the feedback resistor becomes 100kΩ.

Moving to the penultimate stage in the multiplier, the summer, its purpose is to add the logarithms of the two numbers to be multiplied (*a* and *b*). It must provide the antilog function with the voltage required to produce 10μA of current when a full scale input *a**b* product is provided. If we now assume that *a* and *b* are equal, then the output from each log amplifier will be similar and equal to one half of the full scale antilog amplifier requirements. The voltage requirement of a typical p-n junction for 10μA of current reveals that this will be approximately 600mV.

This infers 300mV output from each of the two log amplifier inputs. Unfortunately this creates a dilemma, if the input log amplifiers are operated at currents which would produce only 300mV of output, then they would be well below the minimum for our selected range.

Since junction currents vary at the rate of 60mV per decade, the current would be 0.1nA, five decades down on 10μA and ten times more than the minimum input current requirement.

The resolution of this dilemma is not obvious. If, for example we were to increase the current in the input diodes and then simply reduce the voltage with a potentiometer, this would then be equivalent to exponentiating the input numbers to the power of the division ratio since the operations are being applied to logarithms.

The solution to the problem is to let the input junction run at the required current level of 10μA maximum and then remove the excess voltage by a scaling operation. This consists of subtracting a signal from the input logarithms, which is equivalent to the mathematical process of division. The most convenient place to do this is at the input to the summer.

The net effect of all of this can best be appreciated by looking at the actual mathematical output. First of all the input to the summer:

$$E_{is} = \frac{-kT}{q}\ln\frac{E_a}{R_iI_o} - \frac{kT}{q}\ln\frac{E_b}{R_iI_o} + kT\ln\frac{I_b}{I_o} \qquad (9)$$

The output of the summer then becomes:

$$E_{os} = \frac{kT}{q}\ln\frac{E_a}{R_iI_o} + \frac{kT}{q}\ln\frac{E_b}{R_iI_o} - \frac{kT}{q}\ln\frac{I_b}{I_o} \qquad (10)$$

Adding logs is of course equivalent to multiplication whilst subtracting is equivalent to division. On this basis (10) may be rewritten as:

$$E_{os} = \frac{kT}{q}\ln\left[\frac{E_aE_b}{R_iI_oR_iI_o} - \frac{I_o}{I_b}\right] \qquad (11)$$

$I_b$ is the current flowing in the junction which is used to provide a source of voltage for the scaling function. It will soon become apparent why a diode has been used for this function. Taking antilogs of (11) the output becomes:

$$E_o = -R_iI_o\left[\frac{E_aE_b}{R_iR_iI_oI_o}\right] \qquad (12)$$

which simplifies to:

$$-E_o = \frac{E_aE_b}{R_iI_b} \qquad (13)$$

If scaling factor $R_iI_b = 1$ then

$$-E_o = E_aE_b \qquad (14)$$

From (14), the output voltage $E_a$ is the exact product of the input signals $E_a$ and $E_b$ and, in addition, completely independent of temperature. Temperature correction, for the energy term, has been obtained simply by the process of taking antilogs.

The process of junction multiplication resulted in squaring the saturation current, whilst taking antilogs dropped the power by one. If no other action had been taken, the output would have varied with temperature due to the residual $I_o$ term. This is the reason for using a junction to create the scaling voltage. The voltage which it provides is a function of temperature through its $I_o$ dependence and this provides the necessary compensation.

The practical performance of the multiplier using SAE cells is summarised in **Table 2**. Inputs *a* and *b* have been strapped together to simplify testing and evaluation. This results in the multiplier performing the squaring function. A square root of the output provides a check on the accuracy which, in this case, is better than 1%, with no attempt to optimise the performance. Far from being a nuisance the basic logarithmic behaviour of the silicon diode is a powerful building block for a structured approach to design.

## Raising to a power

There are certain well known circuit tricks for functions such as squaring and square rooting, but exponentiating arbitrarily is difficult. The technique is avoided as a result which is unfortunate since alternative solutions are equally problematic, particularly from the cad point of view.

A common requirement is to generate the sine function for example. There are many alternative solutions to this problem but, if a large period range is required with stable amplitude, then all forms of L/C or R/C sinusoidal oscillators will pose problems. An attractive solution is to use a power series.

The series for a sine function for example is:

$$\sin C = C - \frac{C^3}{3!} + \frac{C^5}{5!} \ \ldots \text{etc} \qquad (15)$$

Expansion of this series clearly needs the ability to raise to a power. A scheme for achieving this is shown in **Fig. 7** where it is required to raise the power of an input signal represented by voltage $E_a$ to the power of a second input signal represented by voltage $E_b$. There are to be no bounds applied to $E_b$ and it is entirely continuous.

First of all take the logarithm of the signal $E_a$, and the output from the first logarithmic amplifier has the familiar form:

$$E_o = -\frac{kT}{q}\ln\frac{E_a}{R_iI_o} \quad \text{when } E_o > 0\text{V} \qquad (16)$$

The two temperature terms are once again in evidence; the energy term may be ignored since this will be removed by subsequent antilogging operations. At this stage however, it will be necessary to do something about the saturation current $I_o$, since it can't be done once exponentiation has occurred. In addition to temperature compensation, there is the problem of scaling as for the multiplier. Both factors can be accommodated by dividing the term under the log sign with a signal derived from a suitably biased junction. This will generate a voltage:

$$E_s = \frac{kT}{q}\ln\frac{I_b}{I_o} \qquad (17)$$

The output from the summer which the two inputs subsequently drive is:

$$E_{os} = \frac{kT}{q}\ln\frac{E_a}{R_iI_o} - \frac{kT}{q}\ln\frac{I_b}{I_o} \qquad (18)$$

Subtraction of the logs is of course equivalent to division which results in:

$$E_{os} = \frac{kT}{q}\ln\frac{E_a}{R_iI_b} \qquad (19)$$

The saturation current and its associated temperature sensitivity has been removed, and in addition, a scaling term $R_iI_b$ has been introduced. The value of this function will depend upon the range of numbers to be adopted, and also on the size of the exponent. Next, the scaled and temperature compensated term, together with the voltage $E_b$ (the exponent), are fed into a multiplier. The output from this becomes:

$$E_{om} = -E_b\frac{kT}{q}\ln\frac{E_a}{R_iI_b} \qquad (20)$$

The minus sign is associated with the output polarity of the multiplier, which is inverting. Since multiplying a logarithm is equivalent to exponentiating, it produces:

$$E_{om} = \frac{-kT}{q}\left[\ln\frac{E_a}{R_iI_b}\right]^{E_b} \qquad (21)$$

| $E_i$(V) | $E_o$(V) | $\sqrt{E_o}$(V) | %Error |
|---|---|---|---|
| 2.64 | 7.03 | 2.65 | 0.38 |
| 2.55 | 6.50 | 2.55 | 0 |
| 2.45 | 6.02 | 2.45 | 0 |
| 2.33 | 5.46 | 2.34 | 0.43 |
| 2.23 | 5.01 | 2.24 | 0.45 |
| 2.11 | 4.49 | 2.12 | 0.47 |
| 1.99 | 4.00 | 2.00 | 0.50 |
| 1.85 | 3.47 | 1.86 | 0.54 |
| 1.22 | 1.50 | 1.22 | 0 |
| 1.10 | 1.22 | 1.10 | 0 |
| 0.69 | 0.48 | 0.69 | 0 |
| 0.49 | 0.24 | 0.49 | 0 |
| 0.42 | 0.18 | 0.42 | 0 |
| 0.17 | 0.03 | 0.17 | 0 |

*Table 2.. Measured Multiplier results.*

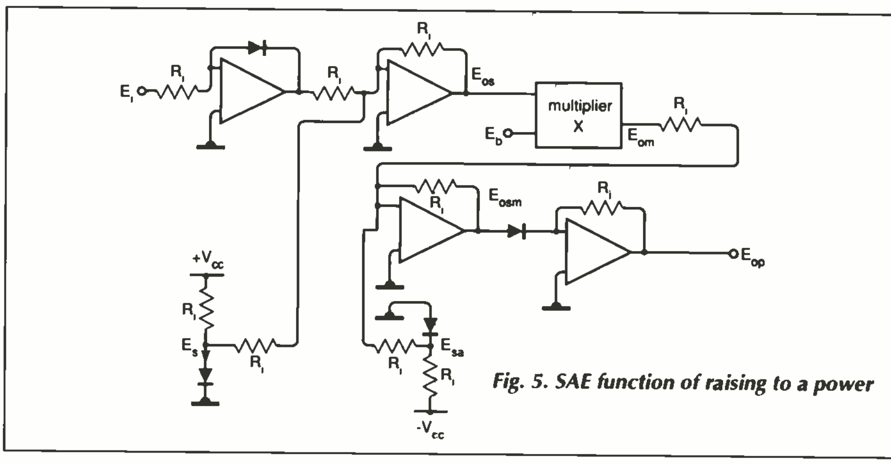



*Fig. 5. SAE function of raising to a power*

(The next stage is to take antilogs, and remove temperature terms. While the energy term will fall out nicely, the antilogging process will introduce its own saturation current term, since if we recall from (3), for $V_{in}$ > 0V, that: **(maths 22)**

$$E_o = -I_o R_i \exp\frac{qV_{in}}{kT} \qquad (22)$$

This can be anticipated by dividing the logarithmic term at the output of the multiplier by $I_o$. Once more a junction can be used to generate this, and also to provide scaling for the antilog operation. Output voltage from the junction is:**(maths 23)**

$$E_{sa} = \frac{-kT}{q}\ln\frac{I_{ba}}{I_o} \qquad (23)$$

The output from the summer $E_{osm}$, which drives the antilog amplifier, is a summation of (23) and (21), and has the form:(maths

$$E_{osm} = \frac{kT}{q}\left[\frac{I_{ba}}{I_o}\right]\left[\ln\frac{E_a}{R_i I_b}\right]^{E_b} \qquad (24)$$

Finally, the output from the antilog amp is:

$$-E_{op} = R_i I_{ba}\left[\frac{E_a}{R_i I_b}\right]^{E_b} \qquad (25)$$

The minus sign is associated with the output polarity, and $R_i I_{ba}$ and $R_i I_b$ are system scaling factors.

This completes the description of the basic building blocks. If it seems complex, you can be sure that the number of components used in creating SAE functions is absolutely trivial when compared with the number involved in equivalent digital functions.

The only instructions now remaining from the original set of eight are those of rectification, differentiation and integration. These functions are straightforward and don't require coverage here. However one or two points are still worth making. While the emphasis has been on off-line computation, there is no doubt that the main benefits arising from SAE will come from asp where real time signals are to be processed. Under these conditions, it may be easier to process signals on a polarity basis: processing occurs before the two halves of the signal are combined prior to the antilog operation. This will call for halfwave rectification, and a suitable precision block is shown in **Fig. 6a**.

The time dependent forms of integration and differentiation should be used sparingly if cad problems are to be minimised. There is no doubt however, that they will be required on occasions. **Fig.6b** and **6c** have been included to show their basic forms using operational amplifiers.

Ideally, an SAE design will comprise of a core of programmable standard cells from which any of the processing functions may be obtained. There are no time dependent forms simplifying the design functions considerably. Surrounding the core would be the time dependent programmable standard cells, for example, integrators for generating signals which increase or decrease linearly with time, or differentiators for extracting frequency information in the context of signal processing. ■

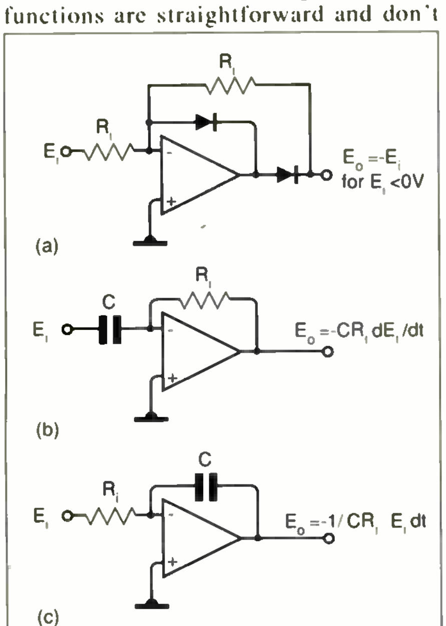



***Fig. 6. (a) Suitable precision block for halfway rectification. (b) differentiation (c) integration.***

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## BOOK REVIEWS

**AC and DC Network Theory** by A J Pointon and H M Howarth is the third volume in the Chapman and Hall series *"Physics and its Applications"*, some of which are said to be suitable for final year degree courses and postgraduate work, although this particular one seems to be intended for slightly earlier work.

Widely used theorems are treated – Thevenin, Norton, Millman –and the book begins in a fairly peaceful way by covering DC and AC current theory, j notation and the complex-frequency s notation.

Mesh and nodal analysis take up a chapter, before the foregoing is used to explain the network theorems from Thevenin to star-delta, by way of superposition and reciprocity. Resonance and coupled circuits each have a chapter and the final section is on two-port networks, including transmission lines and artificial delay lines.

No great mathematical demands are made on the reader, who should find that simple calculus and a familiarity with matrices will be enough. This is a dead-pan, straightforward book, with no attempt at lightening the subject and, as such, is a workmanlike production. I saw no "It can be shown ..."s.

**Chapman and Hall, 160 pages, paperback, £11.95.**

**The Radar Army**, by Reg. Batt, is the practical man's story of radar, from the inside. Batt saw almost the whole development of military radar, joining the Worth Matravers team in Dorset in May 1940 as a junior scientific assistant.

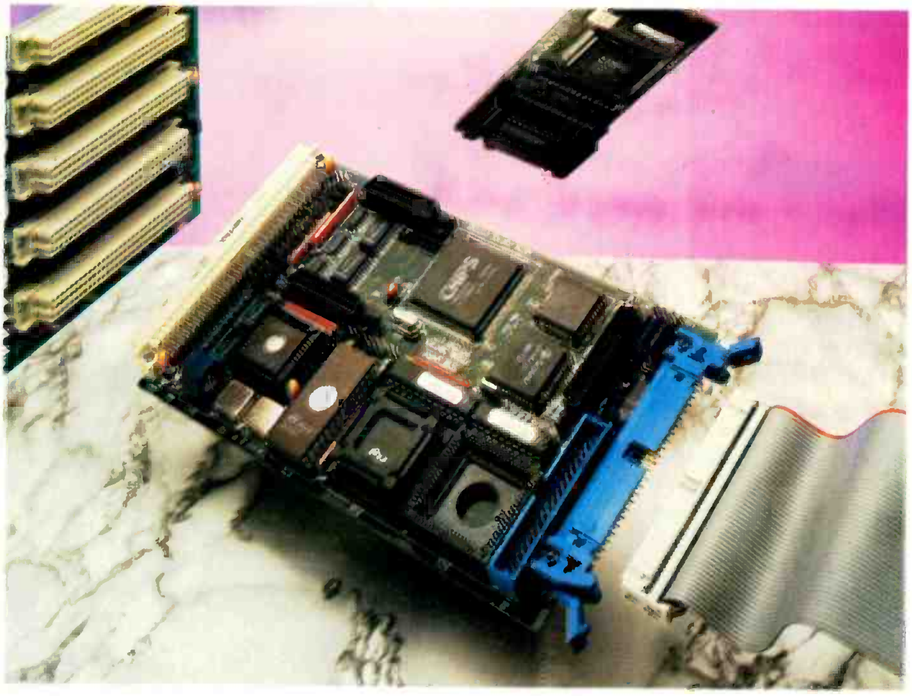
Some of the best known names in the field were there and Batt was accepted as an equal, since these people were from the universities, not the Civil Service, where "...a junior grade would know his place". As a result, what he has to tell is not hearsay.

But the book tells not merely of the technical struggle, waged under enormous pressure, sometimes by scientists who knew nothing of electronics, but also the human background, the personalities who miraculously were able to surmount their antagonisms and commonplace differences in temperament to achieve the results we all now know.

And there is the humour. Since tracking an aircraft even as slowly moving as the Anson was found to be impossible in the early days, Batt was reduced to riding around the Dorset countryside with a sheet of aluminium strapped to his bike so that a team of visiting sceptics would be convinced that a 10cm beam could work, even though it may have been dreamed up by "a bunch of academic nuts who knew nothing about radio". Apparently, a 25cm transmission was considered the minimum for the purpose at that time.

This is a fascinating book for anyone interested in those unique wartime days, when people would work as a team towards a common end – and the end was survival, not profit.

**Robert Hale Ltd, Clerkenwell House, 45/47 Clerkenwell Green, London EC1R 0HT, hardback, 207 pages, £15.95.**



*Arcom's latest VME single-board computer uses Intel's i486 as the central processor instead of the Motorola devices at the heart of most of its rivals. The company hopes this will help it to supply boards for VME, PC and STE buses which can work with each other in large systems.*

# BETWEEN TWO BUSES

**Continued from page 947**

trollers generally perform fast DMA transfers, tape controllers less fast, and serial or parallel I/O controllers – if they are bus masters at all – are usually very slow. In many cases, a peripheral controller is still only as fast as it needs to be for its associated class of device. Unless the engineer knows that slow DMA transfer lowers bus bandwidth and therefore overall system performance, it is too easy to yield to the urge to make the DMA transfer as slow as is reasonable for the peripheral device in question.

Obviously, a controller must be able to transfer data to and from system memory faster than it transfers data to and from the peripheral. If the peripheral passes data to the controller faster than the controller can handle it, system performance suffers. A disk controller will incur huge delays waiting for an additional revolution of the disk if the controller misses a sector, or a tape controller will have to wait while the tape stops and repositions itself after an overrun.

As peripheral devices become faster, controllers have the difficult task of keeping up.

A modern controller, which moves data to and from system memory at the same time as it moves data to and from the device, must be able to sustain data throughput rates that are much faster than those of the peripheral device.

An additional problem that arises in the calculation of a controller's DMA transfer rate is to determine the number of DMA devices that will be operating within the system. When a controller must co-exist with other DMA devices, its ability to keep up with its own peripheral devices is no longer sufficient.

If an SMD disk controller has to transfer data over the system bus at 3Mbytes/s and must co-exist with a second controller of the same type, it should transfer that same data over the bus at well over 6Mbytes/s.

Since data is usually transferred to or from the system CPU memory, there is a good argument for having all peripheral con-

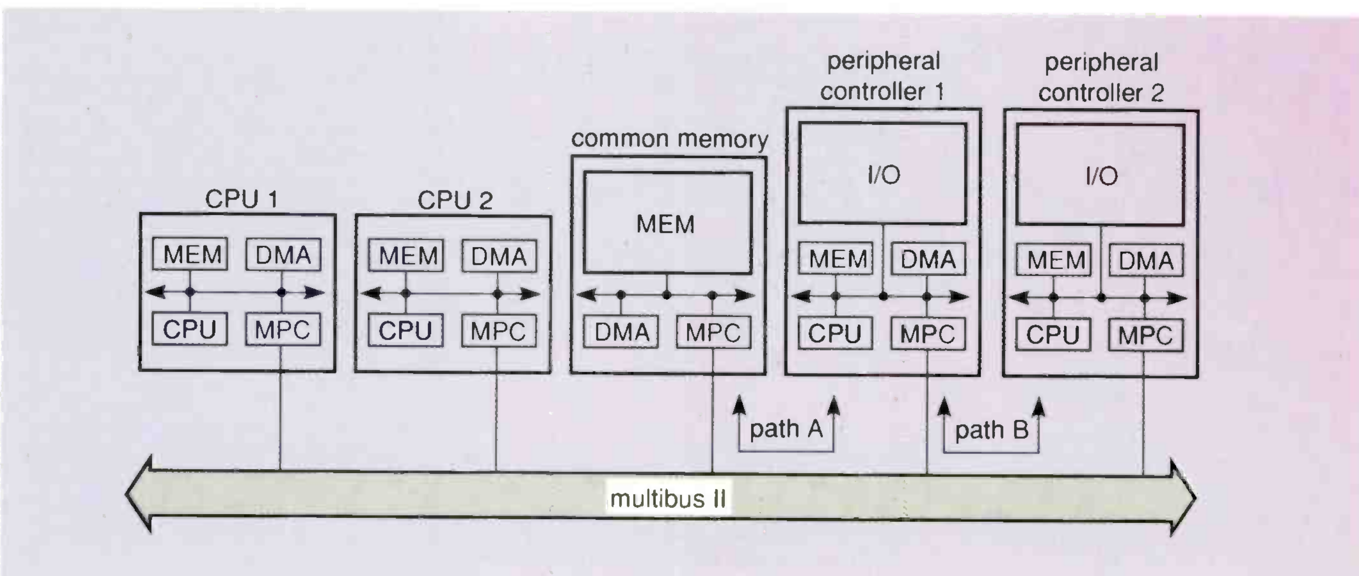



*Fig. 1. Multibus II defines transfers between a device controller and memory (path A) as well as transfers between device controllers (path B)*

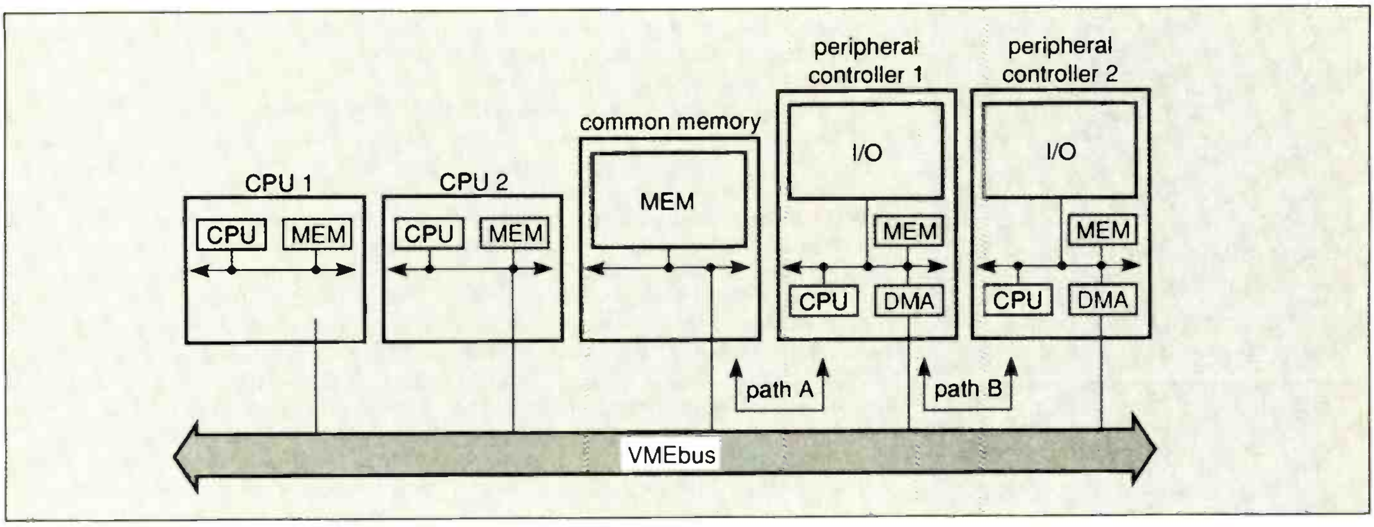



*Fig. 2. The VMEbus also defines device memory transfers (path A) but implementing device-device transfers (path B) is left to the controller manufacturer.*

trollers transfer their data as fast as possible to conserve bus bandwidth and not take time away from the CPU. This speed is particularly important with a multiuser, multitasking operating system such as unix.

**Bus structures**

VMEbus and Multibus II structures differ in one important respect: VMEbus is asynchronous, while Multibus II is synchronous. Although neither architecture is better than the other, both have built-in benefits and limitations.

The biggest criticism of an asynchronous bus is that it is subject to metastable conditions. Such temporary instabilities result when a signal is sampled during a transition state, so that the sampling result is not necessarily valid. Although it is theoretically impossible to eliminate a metastable condition, it is possible to design a reliable asynchronous bus interface that can tolerate it.

This solution is achieved by double sampling the asynchronous signals and using a synchronous state machine to control the bus. Naturally, the bus speed is adversely affected because the signals are sampled twice.

A more efficient way to eliminate the metastable condition in an asynchronous bus is to use an edge-driven asynchronous state machine for control. This approach not only eliminates the metastable condition, it enables the bus to run as fast as the particular components in the system will allow. The only draw-back is that an asynchronous state machine is usually more complicated and requires much more real estate to implement than a synchronous state machine.

The main advantage with a synchronous bus rests in the common system clock that control bus signals: it eliminates the possibility of metastable conditions. Against this, the timing of bus control handshaking is constrained by the speed of the system clock because signals on the bus can change only on a specific edge of the system clock.

For example, with the 10MHz system clock specified by Multibus II, a signal can only change states every 100ns. That means a 110ns memory is no faster than a 200ns memory when used in the system, and such improvements in system components will often go unnoticed.

VMEbus and Multibus II differ also in the manner of data transfer. The latter uses a multiplexed data and address bus, while the VMEbus uses separate data and address buses. A multiplexed bus requires considerably fewer signals to implement the same addressing range and data width as a non-multiplexed bus. When a 4Gbyte address space is implemented with a 32-bit wide data path, the Multibus II requires only 32 address/data signals, while the VMEbus requires 31 address signals and 32 data signals.

However, when the non-multiplexed bus is operating in a random access fashion, it can perform faster than a multiplexed bus given the same memory access time and clock speed for the controlling logic. The reason is that on a multiplexed bus, the address cycle must occur before the data cycle, whereas, on a non-multiplexed bus, the address and data cycles take place almost simultaneously. This disadvantage is exaggerated on Multibus II due to its synchronous nature.

**DMA transfers**

For peripheral controllers capable of performing DMA transfers on the bus, there are two different types of data that need to be handled. The first type is control/status information, which is traditionally handled with i/o transfers. Control and status information for peripheral controllers is usually 8-24 bytes long and must be written/read by the host CPU. As a result, this information usually resides in registers on the controller board that are mapped into the system's i/o space.

The other type of information is pure data – the actual information being transferred to/from the peripheral – and is usually moved via DMA transfers. The controller must gain access to the system bus and then perform the transfer to/from the system memory. This type of transfer generally consists of a number of similar transfers (reads or writes) to contiguous locations in system memory.

The Multibus II specification defines several address spaces as memory and message and provides separate mechanisms for the two types of data transfer. Control/status information is passed to/from memory in messages, while the pure data can be transferred via normal DMA. While both types of transfer involve the parallel system bus, a message is a special type of transfer that uses the message address space – **Fig. 1**.

Multibus II's message passing protocol serves several functions, the first of which is to act as an alternative to hardware interrupts on the bus. Although interrupts must eventually be passed to a microprocessor, the message passing protocol eliminates the interrupt lines and the interrupt-specific hardware that has to be duplicated on every device. Consequently, the number of interrupting devices is not limited to either the number of interrupt signals available or to the length of a daisy chain.

Fifos are built into a message passing co-processor (MPC). Short-term transfer rates over the bus are decoupled from the access time of the system memory and, even with slow memory devices, a message can be transferred at the 32Mbyte/s rate of the MPC. However, to take full advantage of this speed, data transfers must be performed using the message passing protocol, because normal DMA transfers can not be used. As a result, it is necessary to suggest using the message passing protocol to move all data.

One of the disadvantages of the MPC is its complexity. A microprocessor and possibly a DMA controller are almost a necessity in order to send and receive messages. This extra hardware tends to drive the costs of dumb peripheral controllers higher than they would otherwise be.

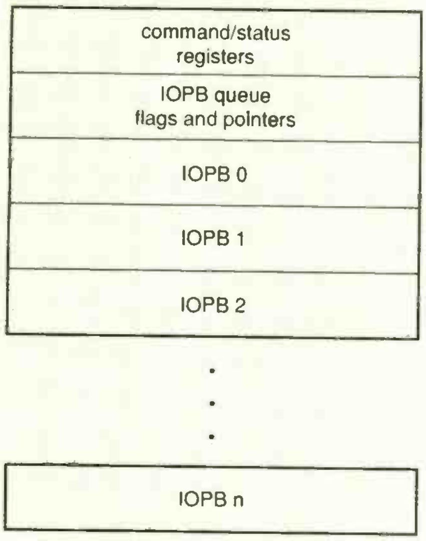



*Fig. 3. The i/o parameter block queue resides in the short i/o space of the VMEbus.*

### Data transfers

For normal data transfers, Multibus II provides two addressing modes: random access and sequential. In the first, the random access (single transfer) mode, each transfer over the bus consists of an address cycle and a data cycle. In this type of operation, the maximum transfer rate of the bus is 20Mbytes/s, since every second bus cycle must be a data cycle.

The other mode of operation is sequential. It is intended to take advantage of the nature of DMA transfers and multiple transfers to sequential addresses. In this mode, only the first cycle of a transfer is an address cycle, and the following cycles are all data cycles. Thus, the starting address is provided by the master and after that it's the slave's responsibility to increment the address for each transfer. Since this scheme permits back-to-back data cycles on the bus, the maximum transfer rate is 40Mbytes/s.

In the VMEbus, the control/status information is passed through the short I/O space defined by the address modifier codes, while the pure data is usually transferred via normal DMA.

For random access transfers, the master must assert and de-assert both the address and data strobes for each transfer. For sequential addressing the master must assert the address strobe once, and it remains asserted while multiple data strobes are asserted. While the performance difference between two addressing modes is not as great for the VMEbus as for Multibus II, a properly designed slave board can allow much faster data transfers with sequential addressing.

### Device-to-device transfers

Another area of comparison is direct device-to-device transfers. In most applications, a controller will transfer data between itself and system memory. However, in some instances, the ability to transfer data from one controller to another can greatly affect system-level throughput.

For example, in many systems, data is read from a disk and then written to a tape drive. If the disk controller could transfer data directly to the tape controller, it would eliminate a DMA transfer across the bus.

More important, if the tape controller could be governed by the disk controller, performance would be improved substantially because that eliminates operating system overhead. This scheme allows the disk devices, tape drives, and controllers to remain closely synchronised and eliminates many of the mechanical delays in the peripherals themselves.

The Multibus II message passing protocol defines mechanisms for device-to-device data transfers. Although the VMEbus specification does not include anything that rules out such transfers, it does not make provisions for them or offer suggestions about how to implement them. ■

*Ford Audio's 2007 RDS radios are now fitted as standard to Escorts and Orions.*


# RDS on the road

***As the BBC pushes hard for commercial acceptance, with so far only limited success, Philip Darrington reports on how RDS is being implemented in practice.***

Radio data system (RDS), originally developed from the Swedish PI system, has now been in existence for a number of years. But it is only recently that there has been any sign of its being taken up commercially. Volvo was probably the first automotive manufacturer to step in and now some of the new Ford cars have RDS radios fitted as standard.

### What is RDS?

There are already several thousand FM stations in Europe and by the end of this century over 20,000 are expected to be broadcasting. Tuning to one of them, in particular searching for a programme being transmitted on many frequencies, is already difficult for some listeners and is bound to become harder.

For some years the European Broadcasting Union has been developing a method by which each station is made unmistakably identifiable. Eventually the Swedish system was chosen from several submitted for evaluation. Since then development has continued so that the radio data system is now in place with many more facilities than were initially envisaged.

Data is now carried on all FM transmitters in the UK. An additional ±2kHz deviation subcarrier at 57kHz (three times the frequency of the pilot tone) is phase-locked to the pilot tone to avoid interference and is amplitude modulated by a shaped bi-phase code, the subcarrier being suppressed to prevent problems with stereo decoders.

The German ARI system also has its carrier at 57kHz which is another reason for suppressing the RDS subcarrier, both systems being usable together, even from the same transmitter.

RDS data is transmitted in blocks of 26 bits, 16 of which carry data and the remaining 10 bits forming a checkword for sync and error correction. Four blocks combine to form one of nine types of group, each being used for a different information content: for example the type 2A group is for the facility known as radiotext.

Block 1 of any group has the programme information code. The first four of the five bits in block 2 indicate which type of group it is and the fifth bit is present to specify which version of the data is transmitted.

A stream of bits in the form 00000 is group 0 version A, and 00001 is group 1 version B.

Block 1 is the main reason for RDS and is transmitted most frequently. Block 2 also carries several RDS services. Alternative frequencies are in block 3 and the programme service name in block 4.

### Exploitable facilities

RDS offers a total of fifteen facilities not all of which need be exploited; indeed in some of the earlier embodiments of the system only the non-executive functions such as station identification were present, automatic tuning and station switching for example not being used. Facilities are identified by two or three-letter codes.

Drivers are the main beneficiaries of the system since one of its main features is the possibility of automatic channel change when signals fade. Another is the presentation of traffic information regardless of which station is tuned – or even whether the radio is receiving a programme.

Facilities are:

*Programme identification (PI).* PI is not meant to be displayed but allows the receiver to find areas in which a given programme is being transmitted and to identify the programme itself – all programmes carrying the code. If a received signal becomes unacceptable as the car moves, the receiver will use the code to search for the same programme on a new frequency with a better signal. The receiver could be either a scanning type, muted during its search, or one equipped with memory containing a list of alternative frequencies which it would scan when necessary. This code is repeated at less than 8s intervals to reduce the search time in a scanning receiver.

*Programme service name (PS).* A message of up to eight characters is transmitted and displayed by the receiver. It gives the name of the programme being transmitted by the tuned station, in the form "Radio 3" for example. The code is kept short to cut down on the expense and is not meant to do anything but provide information to the listener. The message is capable of showing characters from Latin-based languages, Greek upper-case Cyrillic, Hebrew and Arabic, although cheaper receivers will not avail themselves of all these possibilities.

*Programme type (PTY)* is both an identification signal and a specification facility. It shows an eight-character message to indicate which of 31 types of programme is being received (pop, rock, news, education etc) and could be used to search for the desired programme type. The PTY will also allow receivers to tune to only the type of programme specified by the listener. Code number 31 is an alarm to switch the receiver out of a standby mode to receive warnings of hazards ahead.

*Traffic-programme identification (TP)* is a single bit which provides a switching signal to indicate to the driver that this programme normally carries traffic announcements. Again this signal could be used during a station search to select only these stations.

*Alternative frequency list (AF)*. When receivers are equipped with memory this list of station frequencies in the area reduces switching time between stations. Two methods can be used: in method A a list of up to five frequencies relevant to the area is transmitted by each station and its repeaters; in method B all transmitters and repeaters broadcast the same set of different lists in sequence. The correct list is selected by transmitting the tuning frequency and one other in the set.

*Programme item number (PIN)* gives the scheduled starting time and day of the month of the programme which may be used to switch the receiver on automatically.

*Enhanced other networks information (EON)*. EON is a newer development which updates the receiver's memory about other services on other networks which are cross-referenced by their PI codes. For example, one can listen to music on one station and still be able, automatically, to receive traffic information from another – the receiver being switched in response to a series of transmitted bits. Services transmitted under the EON facility are AF, PS, TP, PTY, PIN and traffic announcements.

*Traffic announcement (TA)* is another single-bit code intended to switch the receiver from any audio function to the announcement, or to switch the announcement on when the receiver is in standby. The code will even switch from a non-TA programme to one carrying the announcements.

*Decoder identification (DI)*. This indicates which type of decoder operation is needed in the receiver; for example mono, stereo, stereo recorded with artificial head etc.

*Music/speech (M/S)* is a single-bit code to show whether music or speech is being broadcast so that two volume controls can be switched into circuit, with the volume for each preset by the listener.

*Radiotext (RT)* is text transmission mainly intended for home receivers. In a car it is suggested that the text display might be replaced by a speech synthesiser. The Cenelec specification dealing with RDS points out that "details of operation in this mode require further study".Up to 4 characters can be used but the message is often scrolled or displayed sequentially to avoid the need for a large display panel.

*Transparent data channel (TDC)*. A form of radiotext which would provide a display similar to teletext on a television receiver. Text and graphics can be transmitted or perhaps computer programs and other data not meant for display.

*Radio paging (RP)* is similar to an ordinary paging service, subscribers needing a special paging receiver in which the address code is held. Simple bleeps or message display are possible.

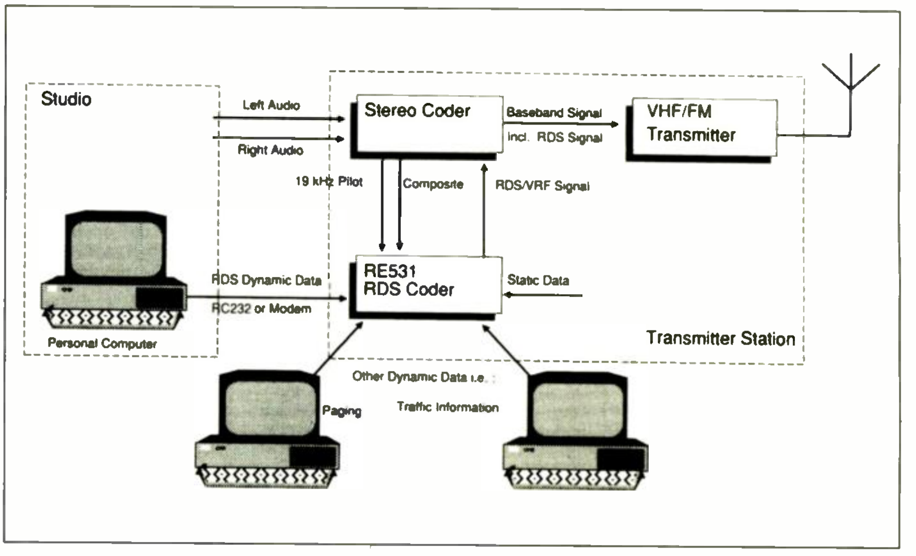



***Fig. 2. An RDS network configuration downloading data from PCs to the coder.***

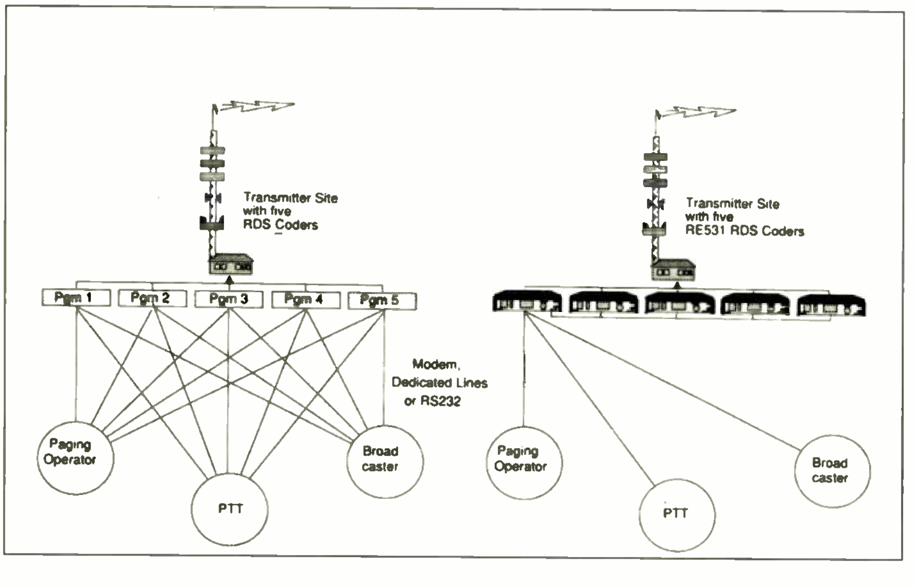



***Fig. 1. Efficient method of distribution developed by RE Instruments in which one coder acts as master, distributing data to the rest. The number of dedicated lines is reduced, from 15 – in the case of three sources each connected to five coders – to three. Traditional RDS network (left) and RE instruments solution (right).***

## RDS networks

Dynamic data such as traffic information, as opposed to the static type such as PI, comes from many sources. There is programme material from a studio, traffic information from traffic organisations or the police or input from news sources. **Figure 1** shows a typical configuration. The coder needs to be flexible and RE Instruments RE531 is one such design that uses a PC to download data.

RE has also developed an efficient distribution system. If each data source is to be connected by dedicated lines to several RDS coders, cost and complexity have a tendency to get out of hand. In the RE method one of the coders at each transmitter acts as a master and receives all incoming data modem signals so that each data source needs only one line to each transmitter. This master then distributes data to its slaves by an IEEE488 bus, as shown in **Fig. 2**. ■

# MEASURING DETECTORS

***RF level measurement looks deceptively simple. Ian Hickman outlines the circuit complexities.***

A detector of some sort is required in order to measure the amplitude of an AC signal. In the case of an amplitude modulated carrier, e.g. a radio wave, measuring its amplitude on a continuous basis will extract the information which it carries.

One of the earliest detectors was the coherer, a glass tube filled with iron filings which, when an RF current passed through them, tended to stick together. This reduced the resistance in the circuit containing a local battery causing it to operate the tape-marking pen of a morse inker.

A tapper was also needed to re-randomise the filings after the received dot or dash, to re-establish the initial high resistance state.

I have never played with one of these primitive but intriguing devices, but I early gained some practical experience of a later development, the crystal detector. This permitted the demodulation of amplitude modulated waves carrying speech or music, something beyond the capability of the coherer. The crystal detector - usually a lump of galena, an ore of lead - held sway for some years, but by sometime around the mid-thirties, the standard domestic receiver was a superhet mains table radio.

The detector circuit generally looked something like **Fig. 1a**, where the same diode (thermionic of course) is shown used both for demodulation and to produce a voltage for automatic gain control (AGC), a common arrangement - although often a second diode section of a double-diode- triode was used for the latter function.

This deceptively simple circuit is not a particularly desirable arrangement, being fraught with various design compromises, the unravelling of which is an instructive and (I hope) interesting exercise in practical circuit design. The first concerns the time-constant $C_sR_d$ formed by the detector load resistor and the RF smoothing capacitor. Demodulation of the peaks of the RF envelope presents the circuit with no particular problems. However, with the typical values shown, $C_sR_d$ has a 3dB corner frequency of 8kHz; not much above the highest frequency components of 4.5kHz found in medium and long wave broadcasting. Consequently, in the case of a large amplitude signal at a high audio frequency such as 4.5kHz, the detect-

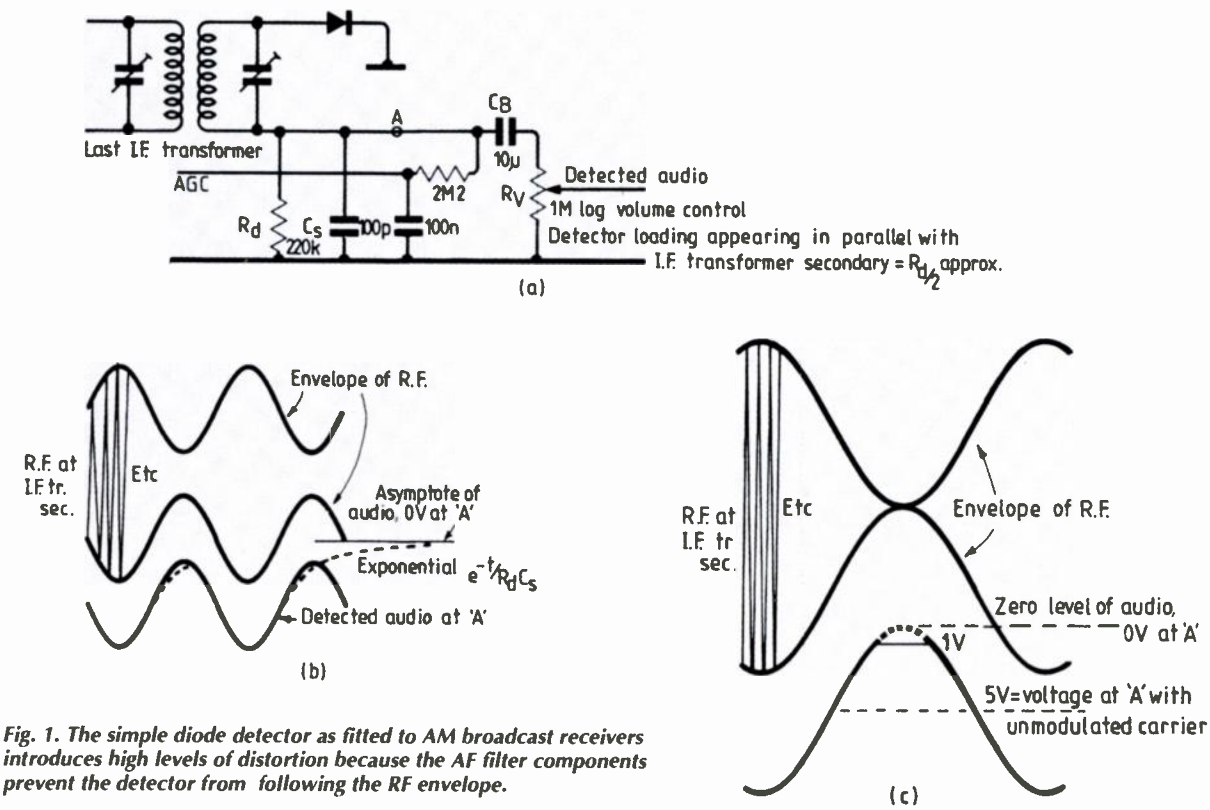



*Fig. 1. The simple diode detector as fitted to AM broadcast receivers introduces high levels of distortion because the AF filter components prevent the detector from following the RF envelope.*

ed output could come "unstuck" on the troughs of modulation, $R_d$ being unable to discharge $C_s$ rapidly enough, **Fig. 1b**, resulting in second harmonic and higher even order distortion products.

One could of course reduce $C_s$, but there are only six and a bit octaves between 4.5kHz and the intermediate frequency of around 465kHz (still in common use) in which to achieve adequate suppression of the RF ripple. A further subtle problem centres on the blocking capacitor $C_b$ and the volume control $R_v$. The DC load on the detector is 220kΩ but at AC the 1MΩ resistance of the volume control appears in parallel with it as well. $C_b$ will be charged up to the peak level of the unmodulated carrier, say -5V at its junction with $C_S$, and being large in order to pass the lowest notes, it will simply appear in the short term as a 5V battery. At the trough of, say, 100% modulation, +4V will appear across the volume control whilst -1V appears across $R_d$. Thus the circuit can only cope with a maximum of 80% modulation and, $C_b$ being large, this limitation applies equally at all audio frequencies. In fact, the situation is rather worse than this as the AGC line contributes another AC coupled load, further reducing the AC/DC load ratio and thus compounding the even order harmonic distortion which results.

A circuit very similar to Fig. 1a but with different component values, e.g. a 4.7kΩ volume control, was used in transistor portables implemented with discrete PNP transistors, with similar problems. Thus the simple diode detector is adequate for domestic entertainment purposes, but some improvements are needed if it is to be used as the basis of a measuring instrument. Indeed, the basic diode detector circuit is so poor, that at frequencies where alternative circuits employing op-amps are feasible, they are usually preferred.

The advantage of the diode detector is that it can be used at much higher frequencies, fairly successfully where suitable circuit enhancements are used to avoid some of its limitations. Its restricted dynamic range is probably the most serious. As the cathode (when used to provide a positive output) is connected to an RF bypass capacitor across which the peak value of the RF signal is stored, the peak-to-peak RF input voltage must be restricted to less than the diode's reverse voltage rating. This sets an upper limit to the dynamic range, though where the detector is preceded by an amplifier, the output swing available may in practice be the limiting factor. But not always; some schottky diodes suitable as UHF detectors have a maximum reverse voltage rating of only 5V or even less.

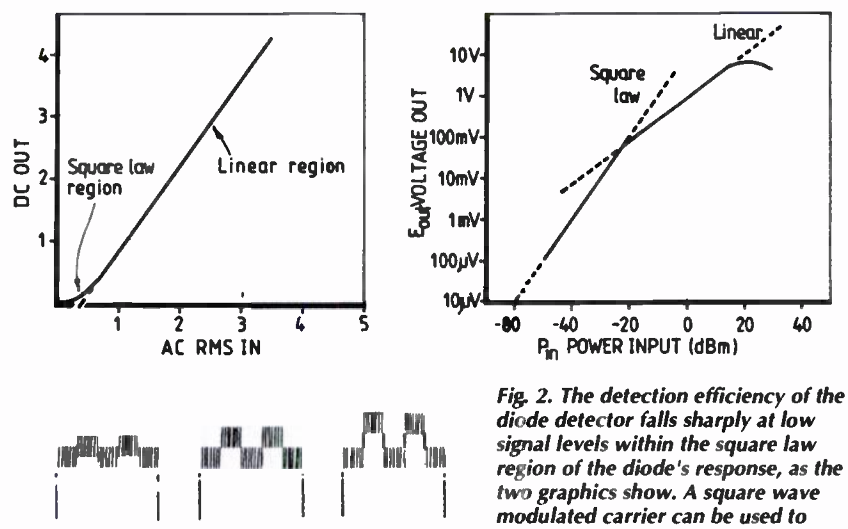



*Fig. 2. The detection efficiency of the diode detector falls sharply at low signal levels within the square law region of the diode's response, as the two graphics show. A square wave modulated carrier can be used to determine sensitivity. See text.*

## Large inputs

For large inputs, the relation between the detected DC output amplitude and the amplitude of the AC input is linear, that is to say that equal increments in the AC input result in equal increments in the detected voltage. However, this is not to say that the detected voltage is strictly proportional to the AC input; in fact it isn't quite. For the detected output is less than the peak value of the AC input voltage by an amount roughly equal to the diode's "forward drop". So the relation, though linear at high levels, is not proportional: projected backward as in **Fig. 2a** it does not pass through the origin. The characteristic looks, indeed, very like the static DC characteristic of the diode.

The non-linear portion at the bottom of the curve exhibits a square-law characteristic, so that at very low inputlevels indeed, doubling the AC input results in four times the detected DC output. The diode can still be used in this region, provided due allowance for the changed characteristic is made.

In fact the only limit on how small an AC signal the diode can be used to detect is that set by noise. Obviously the less noisy the diode, the more sensitive the equipment employing it as in a simple diode/video radar receiver. A convenient, practical method of measuring a diode's noise-limited sensitivity uses a signal generator with a pulse modulation capability. Squarewave on/off modulation is used, and the resultant detected output is displayed on an oscilloscope, **Fig. 2b**. The carrier level which just results in no overlap of the "grass", but in no clear space between the two levels of noise either, is called "tangential sensitivity".

This is not an exact measurement, since the measured level will depend to some extent upon the oscilloscope's intensity setting, but in practice the variation found when a given diode is measured on different 'scopes by different people is not large, and since it is so simple to carry out, the method is popular and widely used.

In some applications, a diode detector may be used in the square-law region without any linearisation, or with some approximate linearisaton over a limited range, using an

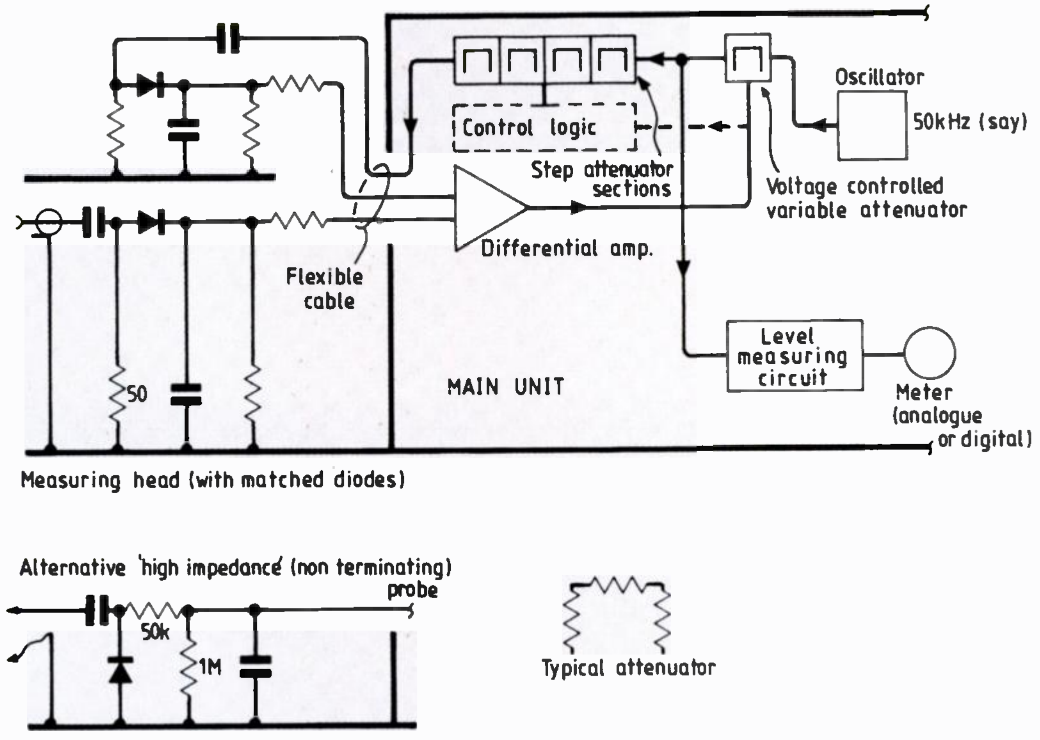



*Fig. 3. Accurate RF level measurement requires linearisation of the diode response. This can be done by using a dummy diode and separate RF reference source for comparison with the rectified level of the signal under test.*

inverse square-law circuit. This can provide useful qualitative information, as in the diode-video receiver already mentioned. But to obtain quantative information, i.e. to use a diode as a measuring detector down in the square law region, some more accurate means of linearising the characteristic is needed.

Nowadays, what could be simpler than to amplify the resultant DC output with an op-amp, pass it through an A to D converter and use some simple DSP on the result? This could take into account the output of a temperature sensor mounted in the same head as the detector, together with calibration data for the characteristic of the particular diode fitted.

However, an alternative, venerable and very elegant scheme is shown in **Fig. 3**. Here, two matched diodes are employed, fitted close together in the measuring head, but screened from each other and kept at the same temperature by the surrounding metal work. A differential amplifier compares the outputs of the two diodes and controls an attenuator situated between an oscillator and a level indicator. The former works at a convenient comparatively low frequency and high level, so that high linearity is easily achieved in the latter. Further attenuation can be introduced in steps to allow for ranging down to the tangential sensitivity, either manually by the operator (in which case the need for a range change is indicated by the meter's reading above or below the calibrated part of the scale), or automatically.

Provided the loop gain is high, the stability of the output level of the oscillator is not critical, the accuracy of the measurement depends only upon that of the level meter, the step attenuators and of course, the matching of the diodes.

Useful though this scheme is in an RF millivoltmeter working up to a few GHz, it is mainly used for static level measurements as the speed of response is limited.

Where a faster response, covering a large dynamic range is required, other schemes, no less ingenious, can be used. These will be covered next month. ■

# Space mission saved by home computers

*Computer expert and astronaut **Dr Ron Parise** was one of four scientists attached to the Astro-1 project which spent eight days in orbit, observing 135 stellar objects. On a visit to London, he told **Dom Pancucci** how the mission was salvaged after two computer terminals controlling the payload of four massive telescopes went down.*

Failure of space-observatory equipment in recent missions could mean that manned observatories may once again find popularity. Astro-1 astronaut Ron Parise, who was in London recently, recalls how it was only human intervention – and ingenuity - that salvaged his mission and argues that a manned Hubble may have been less of a technical disappointment.

Purpose of the Columbia space shuttle Astro-1 project was to take ultraviolet and X-ray readings from stars, which are impossible to measure under the Earth's atmosphere. But the mission was almost crippled by failure of computer terminals controlling the four massive telescopes.

"Debris built up on the cooler fins of the terminals and they stopped working," explains Parise. "Due to delays and postponements to the flight, the machines suffered 3000 hours of run-time on the ground before we got up."

The terminals were designed by the European Space Agency for the Space Lab's avionics cooling unit. They were intended to have a clean air supply and therefore had no air filters when they were fitted to the Columbia. By comparison to the Space Lab, the shuttle's air was dirty; weightlessness in the cabin gave rise to swirling clouds of food remnants, dust and dead skin coming off the astronauts and ground crews. This all contributed to the computer crash.

While ground control remotely moved the telescopes into general alignment with their targets, Parise and his colleagues had to "do some fine tuning" with joysticks similar to those used with home computer games. This was ironic: the terminals were Mitra 125 machines with only 64Kbyte of memory. Eighty per cent of this capacity was required for the operating system, leaving little room for applications. "The technology was low-end, tried and tested despite our computer problems," says Parise "Laptops would probably be better suited for our purposes and we may use them in the future."

This future extends to 1994 and the follow-up mission to Astro-1, which Parise and others have campaigned hard to keep on the flight schedule. And there are some cogent arguments in favour of sending people on such missions, according to Parise. "Manned flights are flexible, where free-flying vehicles lead to constraints. Astro-1 would not have been a success if we had not been there to adjust the telescopes. This is not the case with projects like the Hubble telescope, where problems can have a catastrophic impact," Parise said. "Our payload also cost only $65m, which is a fraction of the total government budget and less than sending up unmanned vehicles."

*Ron Parise (centre). Equipment failures could put humans back in the space mission picture.*

Parise can see a permanent manned space observatory in the future, possibly set up next to a space station.

Parise is currently working at the Goddard space centre in the US on the material gathered from Astro-1. It will take another two years before results are produced. There is a huge database of known stellar objects held at Goddard and one of the hardest tasks is selecting which ones to observe during those precious hours in space. Parise says the process carried on right up to the much-delayed launch of Astro-1 on December 2 last year.

Seconded to the Nasa space agency, Parise is an employee of Computer Services Corp, which claims to be the world's largest independent computer services company. CSC has 20 years of involvement in the space programme, providing mission concepts and performance analyses. The US government is its biggest customer. Parise himself helped design the hardware, software and system for the Ultraviolet Imaging Telescope used for photographing stars on Astro-1.

Apart from the imaging telescope, other instruments carried on the Columbia included a broadband X-ray telescope and two spectrometers. These last two recorded chemical composition, temperature and polarised light emissions from quasars, star clusters and supernovas, among other phenomena.

Not all Parise's time went on stargazing during last year's trip. He organised amateur radio link-ups with two groups of school children and held random conversations with Earthbound radio enthusiasts. "The educational idea came from the scientists and we ran two space classrooms with kids on Earth, fielding questions about electro-magnetic radiation and the Astro-1 work," Parise says. Trying to hold random conversations with people proved to be difficult when Columbia was travelling over highly populated areas. The resulting logjam led to chaos, with Parise attempting to hold one link with several others interrupting.

Over parts of the globe where people are more scarce, the contacts were more rewarding. As the shuttle passed over Western Australia and South Africa, for instance, Parise could hold conversations in a queue. ■

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**To qualify** you need or hope to obtain a BTEC National Diploma (or HNC/HND) in a Telecommunications, Electronics Engineering or similar dicipline. Special consideration will be given to applicants holding an MRGC Certificate. The C&G 777 (advanced) or other qualification incorporating morse skills would be advantageous but not essential.

You can apply if you have a minimum of 2 years recent radio operating experience and preferably be capable of receiving the morse code.

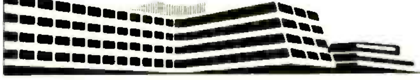
Age limit for experienced Radio Officers 18-45. Age limit for candidates who do not possess the full range of skills 18-40 (depending on background and experience). **Training Period:** Between 29-52 weeks.

**Salary** after training (over 5 years) £13,756-£19,998 with prospects for further promtion. Salaries include an allowance for shift and weekend working.

**GCHQ is an equal opportunity employer**

APPLICANTS MUST BE BRITISH NATIONALS

For further information and application form contact:
Recruitment Office, Room A/1108, GCHQ Priors Road, Cheltenham, Glos. GL52 5AJ or telephone (0242) 232912 or 232913



GCHQ

# APPOINTMENTS

### EMC CONSULTANT
*Midlands* — *c.£25,000*

Two leading consultancies urgently require EMC Consultants to act as the 'in-house' EMC/RFI 'guru' and advise various clients on all areas of EMC from overcoming design shortcomings to setting up test facilities – you must be degree educated and be fully conversant with the relevant commercial (including Automotive) and MoD standard in conjunction with the Namas requirements. In return your package will include an excellent basic salary and relocation where necessary.

### RF DESIGN MANAGER
*Essex* — *Negotiable*

Your chance to be responsible for the complete RF development of a business. You will be working for an organisation who are currently producing products to be used within the radio data field. This role will require considerable 'hands-on' involvement coupled with your abilities to lead a team, which will expand with the success of this company. You will probably be between the ages of 30–35, degree qualified, and have considerable experience in the RF field (500 MHz–1GHz). In return you will receive a first-class package and a chance to prosper with this expanding company.

### YOUNG DESIGN ENGINEERS
*Berkshire/South* — *to £16,500*

We are currently recruiting for a number of internationally established companies operating within the field of radio communications (GSM, CT2, PCN). They are currently wishing to recruit a number of young RF Engineers to join their design and development departments. For these positions you will be degree qualified Engineers who have one to two years' experience of the RF field within the ranges 500MHz to 2GHz. In return you can expect to receive a first-class package with relocation where applicable.

### RF ENGINEERS
*Midlands* — *Negotiable*

A well-established company involved in the design and development of Mobile Communications equipment has an immediate requirement for an innovative and enthusiastic engineer capable of RF design and the ability to progress projects through the manufacturing cycle. Applicants will be qualified to degree level with at least three years' experience of RF design up to 2GHz. Of equal importance is a strong sense of project responsibility and the desire to see projects from inception to completion.

**Orion ELECTRONICS**

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# IC PROGRAMMING TESTING & ERASING SOLUTIONS

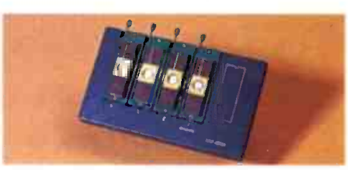
## PC82 UNIVERSAL PROGRAMMER & TESTER £395


Universal programmer. The complete designer's kit. This will program EPROMS, EEROMS, BPROMS, PALS, GALS, EPLD's, Z8 and 87XX microprocessors. A unique feature is the testing of logic parts such as 74LS393 etc. The PC82 can check and identify parts. Already programmed are the TTL & CMOS logic test vectors. Software is supplied to write vectors for most unique chips. One of the most popular programmers in the USA.

**TTL, CMOS, DRAM & SRAM TESTING**
PC82 can test and verify any TTL/CMOS logic chip, DRAM & SRAM. The software will also identify a TTL chip. Do you have a few TTL chips aside not knowing whether they are working?

### DEVICE GUIDE

| 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 | √ | — |
| MPU Z8,8741,42,48,49,50,51,C51,C52,C252,TMS7742,77C82,63701 | √ | — |
| Device testing TTL/CMOS logic, DRAM & SRAM | √ | — |



**ADAPTERS FOR PC82 FROM £95**
A wide range of plug-in adapters to expand the capability of the PC82. Various PLCC convertors & 4 gang 28/32/40 pin Eprom, Gal & Pal. Popular CPU types include PIC 16C54/5/6/7, 8796/7, 68705, 87C751/2, & TMS320E25.

## FEATURES ALL MODELS

For the IBM PC, install the interface card and programming socket, load the menu-driven software and you have a complete design system at your fingertips.

**EASY TO INSTALL**
The programmer comes with an interface card that plugs into any free slot of your PC. There is no DMA channel to worry about and it occupies limited I/O space. The programmer socket box is connected via a ribbon cable to the back of the interface card so that the socket box is external. After the interface card is installed the PC never need be opened again.

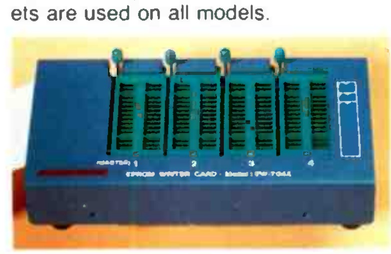
**SUITS ALL PC's**
The programmers will run on any compatible IBM machines such as XT's, AT's, '386 and '486. Whether it be AMSTRAD or COMPAQ the programmers will work. The software is text only monographic so is compatible with any machine.

**SOFTWARE DRIVEN**
All software for the programmers is supplied on 5¼" low-density disks. The software can be copied onto hard disk using the DOS copy command. Programs are supplied for the various features and are menu-driven. All programming is done from the menu, no hardware switches are needed. Just select the type and manufacturer and the programming is done automatically. Free software updates for new types which are continually being added.
The menu-driven software is a full editing, filing and compiling package as well as a programming package. Save to disk and load from disk allows full filing of patterns on disk, to be saved and recalled instantaneously. Device blank check, checksum, program, verify, read and modify are all standard features. Hex to bin file conversions included for popular file formats including Intel Motorola etc. 2 ways/4 ways bin file splitter for 16/32 bit file data. Selection of speed algorithm for FAST, INTELLIGENT, INTEL, etc.

**PC86 HANDY POCKET TESTER £99**
Tests all popular TTL 74/54, CMOS 40/45 & DRAM types, can search and display type number of unknown/house marked types. Simple operation. 9 volt battery operated with LCD display.

**M1 FAST ERASER £99**
NO MORE WAITING FOR EPROMs TO ERASE. New advanced UV source gives under 2 minute erasure time on most types of modern EPROM. Digital down counter & display plus added features for simple operation in use. Large capacity e.g. 13×28 pin devices. Small footprint. Designed for heavy industrial/workshop use. UK design & manufacture.

**PC84 EPROM PROGRAMMERS 1-GANG £139, 4-GANG £199 & 8-GANG £299**
PC84 -1, -4, -8 Eprom programmers only. The variant is only gang size. The -4 and -8 gang will program multiple EPROMs simultaneously. Device sizes are from 2716 to 271000 both C and NMOS. ZIF (zero insertion force) sockets are used on all models.



**ORDER INFORMATION**
Please include £7 for carriage by courier, plus VAT on all UK orders. (£20 for exports.) All pricing for programmers includes software, Interface card, socket box and full instructions. (Prices do not include VAT or carriage). ACCESS, VISA or CWO. Official orders welcome from Government bodies & local authorities.

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