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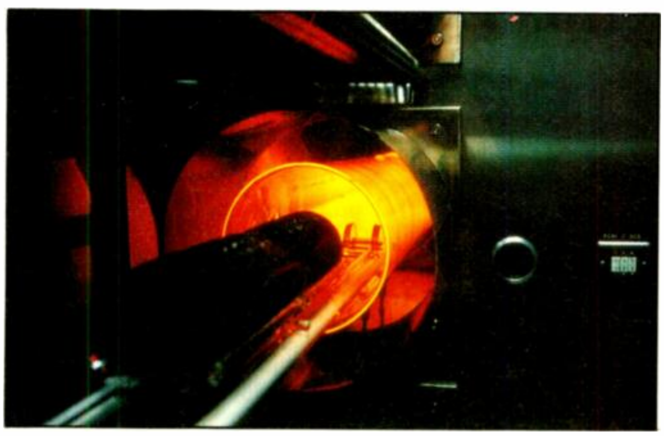

World beating British transistors. Page 660.

In next month's issue. Audio design special. Subjectivist, technologist and golden ears are not part of the feature. Amplifier design by Doug Self, digital design by Stan Curtis and loudspeaker design by Dave Berriman are.

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Cover photo: Trevor Bailey

A real opportunity

This year's Wimbledon, as always, received excessive television coverage. Indeed, armchair players may have noticed even more cameras than usual though they probably won't have seen the pictures from them. That is because the BBC used the event to demonstrate Eureka, Europe's high definition television system and the most significant piece of consumer electronics since the domestic video recorder.

Conservative estimates indicate a European market of some £5 billion by the end of the century.

But the Japanese aren't going to let the opportunity pass without a struggle.

Vast numbers of yen have already disappeared into the 1125-line, 60Hz frame *Muse* system. But it now seems clear that Europeans won't settle for anything less than 1250 lines at a 50Hz frame rate, and the CCIR effectively endorsed the European view of HDTV when it rejected adoption of Japanese proposals a couple of months ago.

On the manufacturing front an unusual co-operation between Europe's remaining consumer electronics companies, led by Philips and Thomson, resulted in an investment pool of more than £2 billion to fight the Eastern challenge. So whatever the Japanese decide to use for themselves, their equipment sold over here will have to support HD-MAC, the system behind Eureka.

There is also opportunity for Europe's hard pressed semiconductor industry. The patents on MAC picture processing have been sewn up by the Europeans, who will be reluctant to release them to predatory competition. Since Philips and SGS-Thomson represent more than half of Europe's indigenous semiconductor manufacturing capacity, Far Eastern set makers will have to do their chip shopping here.

Europeans shouldn't develop qualms of conscience about this proper exploitation of patents; JVC has piled up royalties from the VHS recording system while Philips' V2000, a better way of doing things, withered and perished. But there is a *caveat*. The original Telefunken patents on the PAL system successfully defended large-screen set makers for years. However, when the patents expired, the protected industry was so sick that it couldn't withstand free market competition. The European television manufacturing industry nearly sank without trace. The UK's did.

There is a further caution which must be observed. The CCIR has yet to advocate positively the European system on a worldwide basis and several US institutions have been working on HDTV, mostly from a starting point of downwards compatibility with NTSC.

Universal adoption of anything connected with NTSC looks extremely unlikely. But a spurt from behind – at \$30 million, US investment in HDTV systems is paltry compared with Japanese and European programmes – could queer the pitch for European opportunity. For instance, the US company General Instruments says it has developed a compression system which allows HDTV signals to be transmitted within a standard terrestrial bandwidth with little compromise. GI is to submit its system to CCIR.

But, providing that Europeans can distance themselves from complacency, and remember it is demand rather than technology that drives the consumer market, the euro-electronics industry may now enjoy unprecedented opportunity.

What a shame we don't have a UK set-making and component industry which can take advantage of it.

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Electronics World + Wireless World is published monthly USPS687540. By post, current issue £2.25, back issues (if available) £2.50. Order and payments to 301 *Electronics and Wireless World*. Quadrant House. The Quadrant. Sutton. Surrey SM2 5AS. Cheques should be payable to Reed Business Publishing Ltd. **Editorial & Advertising offices:** *EWW* Quadrant House. The Quadrant. Sutton. Surrey SM2 5AS. **Telephones:** Editorial 081-661 3614. Advertising 081-661 3130 081-661 8469. **Telex:** 892084 REED BP G (EEP) **Facsimile:** 081-661 8939 (Groups II & III). Newstrade – Quadrant Publishing Services No. 081-661 3240. **Subscription rates:** 1 year (normal rate) £30 UK and £35 outside UK. **Subscriptions:** Quadrant Subscription Services. Oakfield House, Perrymount Road. Haywards Heath. Sussex RH15 3DH. Telephone 0444 441212. Please notify a change of address. USA: \$166.00 airmail. Reed Business Publishing (USA). Subscriptions Office. 205 E. 42nd Street. NY 10117. **Overseas advertising agents: France and Belgium:** Pierre Mussard. 18-20 Place de la Madeleine. Paris 75008. **United States of America:** Jay Feinman. Reed Business Publishing Ltd. 205 East 42nd Street. New York. NY 10017. Telephone (212) 867-2080 Telex 23827. USA **mailing agents:** Mercury Airfreight International Ltd. Inc., 10(b) Englehard Ave. Avenel N.J. 07001. 2nd class postage paid at Rahway NJ. Postmaster – send address to the above.

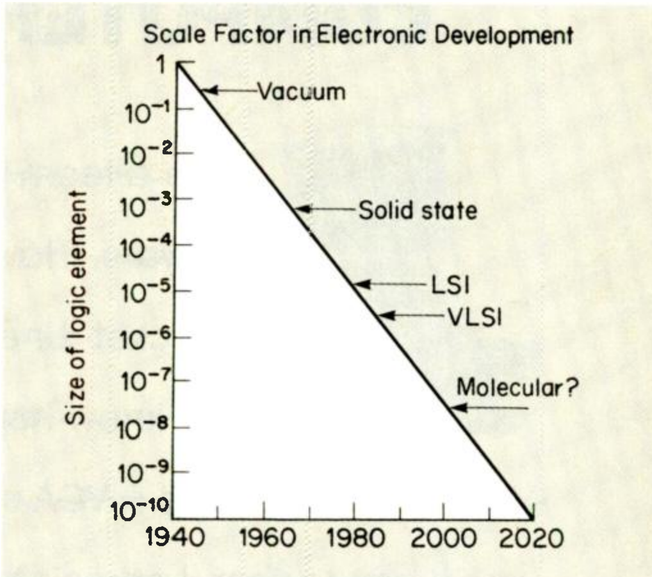
 ISSN 0959-8332

Memory in a molecule?

Fabricating an electronic device as small as a few atoms or molecules across is an appealing notion since it would clearly represent the limits of miniaturisation. February's *Research Notes* described an intriguing step in this direction with the production (or rather discovery!) of a tunnel diode about 6nm square. Tiny though that is it's still about two orders of magnitude bigger than a typical atom.

Fabrication may be one practical limit to existing silicon technology but it's not the only one. Even at the dimensions of today's most densely packed chips, it's difficult to avoid production defects and an increasing sensitivity to radiation. Heat dissipation is another bogey that will force limits on how many switching operations can occur in a given volume of silicon or other semiconductors. Finally there are quantum effects that cause ultra-small devices to behave in strange and sometimes unpredictable ways.

Shrinking electronics. VLSI is already five orders of magnitude smaller than valve technology and ME two orders smaller still. The average atomic diameter is about 3×10^{-10}***m.***



The very fact that biological systems, like the human brain, seem to circumvent these problems is now prompting scientists in many different disciplines to consider the future of what's now been dubbed molecular electronics (ME). Officially it's defined as the use of molecular materials performing an active function in the transmission, storage and processing of information. Molecular materials in this context usually means complex organic chemicals. The potential advantages of such substances is enormous. In theory a bit of data could be stored by nothing bigger than a single molecule that undergoes some conformational change. Molecular materials also have the advantage that such changes of state would dissipate much less energy than the switching of silicon gates — one reason, I suppose, why we don't have heat-sinks on our heads! Finally it would seem that molecular processors will be much easier to create in three-dimensional form than their silicon counterparts.

Back in 1986 the Science and Engineering Research Council (SERC) established an ME Committee to encourage high quality research across a broad range of disciplines. Now it is giving top priority to programmes for getting molecules or molecular clusters to perform useful electronic operations. At a recent meeting at the Royal Society, the SERC ME Committee made even clearer its specific objectives. These include the synthesis of such active molecules, together with their integration and electrical or optical interfacing.

Beyond that point ME begins to diverge markedly from the sort of concepts that are familiar in silicon technology. No-one working in the field, for example, expects molecular devices to be fabricated by processes like vapour deposition or etching. Such engineering methodology is far too crude and imprecise for use at the Ångstrom level. Practical ME devices, it's generally thought, will either self-assemble at molecular thickness (like an oil film) or else be grown under the control of some chemical software. Growing ME devices could well have many parallels with the way human neurons are fabricated and link up under control of the gene codes.

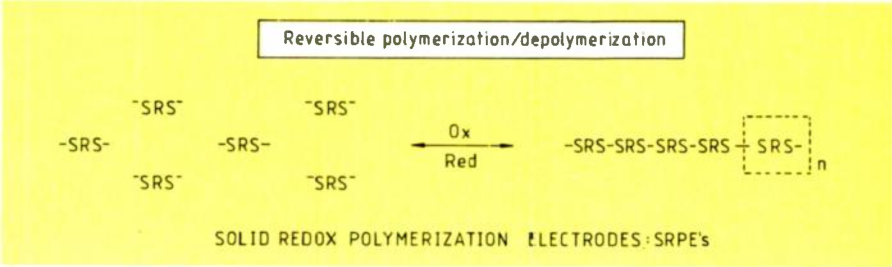
One obvious problem with artificial molecular arrays would be reliability. So far, most candidate molecules tend to be unstable or difficult to interface. Then there's the question of how rugged a biochemical chip would be, especially if it were filled with material like the human brain. Professor Sir George Porter, President of the Royal Society, is pessimistic about ever copying the architecture and performance of the brain unless, that is, we adopt a biological rather than a traditional engineering approach. Human memory, he reminds us, owes its (relative!) non-volatility to the body's automatic mechanisms for cellular repair and reproduction. Any rugged molecular machine must likewise have the ability — on line — to replace its cells whenever they become defective.

Such visionary thinking, of course, takes us far into the future, possibly a decade or more ahead. But the message behind the growing number of research grants being given for ME is that things are actually beginning to happen. Already we have organic molecules that perform useful electronic functions like conductivity, semiconductivity, superconductivity and photoconductivity. Liquid crystals are examples of what has already been achieved in this field. In fact the SERC does not primarily see ME in terms of some far-distant molecular supercomputer. Now, having encouraged scientists to continue researching molecular electronics phenomena, it fully expects this work to lead to "a new golden age for electronics!" (SERC: *The Challenge of Molecular Scale Electronics.)*

Polymer power gets closer

A report from the Materials and Chemical Sciences Division of the Lawrence Berkeley Laboratory in California indicates the extent to which solid electrolyte batteries are likely to become commercially viable.

Professor Lutgar De Jonghe and co-workers have developed a rechargeable secondary system that stores up to 180W/kg — roughly the same as a sodium/sulphur battery — but without needing to be heated to 350°C. The new battery, using a polymer anode and electrolyte, is about half the weight of comparable rechargeables and also has a much lower rate of self-discharge than most.



Cells using polymer electrodes and electrolytes aren't exactly new, but they have, for the most part, been less efficient in terms of current density than liquid-based systems. Poor ionic conductivity of the electrolyte has also limited the available discharge current, except at elevated temperatures.

De Jonghe and his colleagues have now developed what they call an entirely novel class of solid-state organic positive electrodes which not only operate on a total new principle for energy storage, but which also outperform other anodes used in solid-state sodium or lithium batteries.

Experimental cells, which use lithium cathodes and the now commonplace polyethylene oxide (PEO) electrolyte, store their energy in the disulphide bonds of the polymer anode. When the bonds break, electrical energy is released and, conversely, when the cell is charged the bonds reform. It's a form of reversible polymerisation.

The precise characteristics of the cell can be changed by changing the molecular grouping represented by 'R' in the diagram. Groups containing nitrogen and fluorine, for example, tend to depolymerise rapidly and so enable greater output currents. By means of suitable molecular 'cookery', De Jonghe believes that rechargeable batteries will eventually be tailor-made for virtually any application from wristwatches to electric traction.

At room temperature, output current is still limited compared, say, to NiCd or lead-acid cells, but with a higher total energy capacity and lower self-discharge rate, there would still be no shortage of applications. Increase the temperature to 80°C, however, and the available discharge current becomes comparable to that of a NiCd cell.

The most exciting application for what promises to be a low-cost lightweight system capable of yielding high currents at modest temperatures is obviously the electric vehicle.

Electronic nose for beer

A project funded jointly by the Government, Bass plc and Neotronics Ltd could, within three years, lead to an electronic nose better than your average sniffer dog. That's the hope of Dr. George Dodd of Warwick University who's leading the development work.

As you might gather from the business of at least one of the sponsors, the Warwick team will be concentrating initially not on explosives but on beer. Already they have an advanced prototype capable of distinguishing three different brands of lager by smell alone.

Of all our five senses, smell has always proved the most difficult to transduce into meaningful electrical signals. This is a consequence partly of the huge range of odoriferous substances and partly the difficulty of translating what amounts to a chemical analysis into something quantitatively meaningful. Previous attempts to create an instrument to match the performance of the human hooter have fallen somewhat short of success.

Dr Dodd's prototype electronic sniffer employs 12 tin oxide sensors, each one doped to make it sensitive to a different organic vapour. The outputs of these sensors feed a neural network which, given time, can learn the aroma signature of anything from draught Bass to whatever the Aussies wouldn't give a XXXX for.

Further work, still on the secret list, is aimed at gaining a substantial lead in what promises to be a highly lucrative market. Other than monitoring beer production for consistency, the artificial nose has tremendous potential for quality control work in everything from coffee blending to perfume production.

Similarly, in less pleasant areas it could sniff out explosives or detect bacterial decay products in food.

Solar cells — the Liquid Factor

Most of us, I'm sure, think of solar cells as an expensive way of using semiconductor junctions to generate a few watts on a sunny day — scarcely a way to boost the national economy. But if recent pronouncements on the threat of global warming don't force a rethink on so-called renewable energy sources then recent studies in technology may well do so.

As regular readers of this column will be aware, most of the claims for highly efficient solar cells are made for solid-state devices based on silicon or gallium arsenide. Efficiencies of greater than 25% are now frequently quoted. But figures of this order are only achieved using costly materials or complex manufacturing techniques that don't usually lend themselves to cheap mass production. At least, not cheap when compared to the cost of generating an equivalent amount of electricity using coal or uranium.

One approach to reducing drastically the cost of solar power is to use wet photoelectrochemical cells. Stuart Licht and Dharmasena Peramunage of the Department of Chemistry, Clark University, Worcester, Mass, report (*Nature*, Vol. 345 No 6273) one of the first such cells to combine high conversion efficiency (16.4%) with reasonable freedom from corrosion. These results, not earth-shattering in terms of pure physics, have to be seen in the context of manufacturing and production.

Unlike conventional photovoltaic devices, "wet" solar cells are potentially simple and cheap to construct — all that's necessary is to dunk an appropriate pair of electrodes in a suitable conducting liquid. The only problem so far has been to find a combination that works efficiently without self-destructing at the first whiff of current. Usually there's a marked trade off between efficiency and stability.

Licht and Peramunage took as their starting point a cadmium selenide photoanode known to be capable of efficiencies approaching 17% in aqueous solutions. The only snag is that CdSe usually undergoes a rapid surface modification that effectively insulates the electrode within minutes, or hours at most. When, however, the electrolyte consists of a precise balance between solutions of ferrous and ferric hexacyanide complexes, all appears to work well for several days.

This may still be a long way from being a solution to the greenhouse effect, but it does mark a vast improvement in the performance of wet photovoltaic systems. That makes the prospect of economic large-scale solar power considerably more realistic.

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

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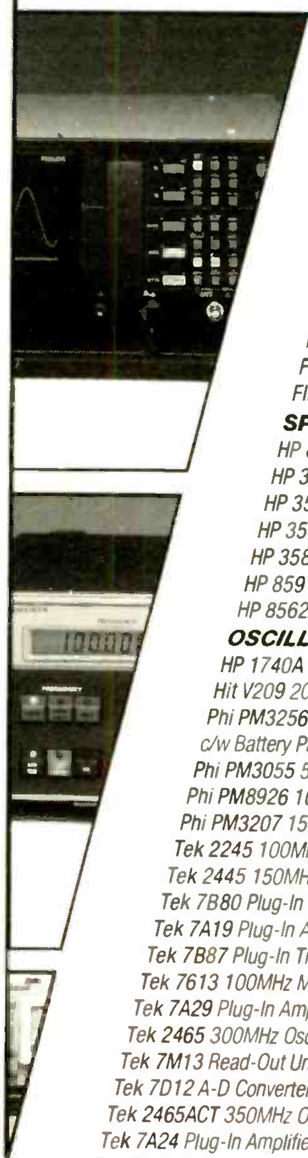

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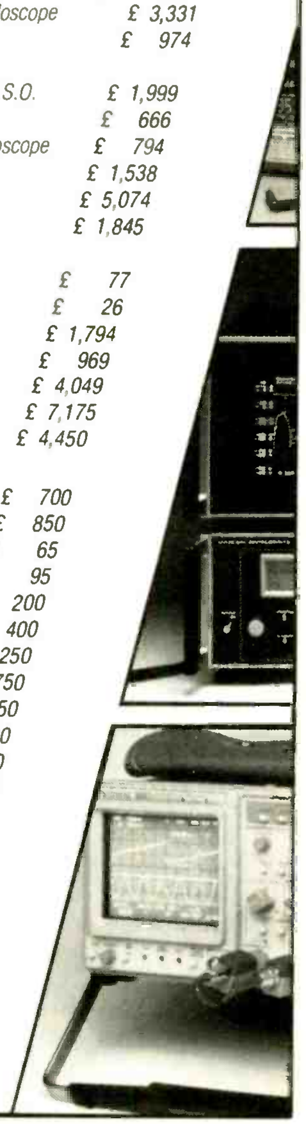

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Prototype for DIY IC design

Plessey Semiconductors' collaboration with Pilkington on electrically reconfigurable arrays (ERAs) has now reached prototype stage, in the form of field programmable logic devices with equivalent gate counts between 3600 and 40 000.

The advantage of ERA technology is that each logic cell (and there are up to 10 000 cells on a chip) contains some static RAM, allowing the user to define the overall interconnection pattern.

The logic itself is made using Plessey Roborough's 1.4 micron low-power c-mos process, and is organised as a sea-of-gates. Plessey's intention is to move to a 1.0 micron process later this year, cutting gate delays to 1.5ns (currently 2.5nsec).

1991 should see availability of devices made using a 0.8 micron process, giving even higher densities, and gate delays at 1.2ns.

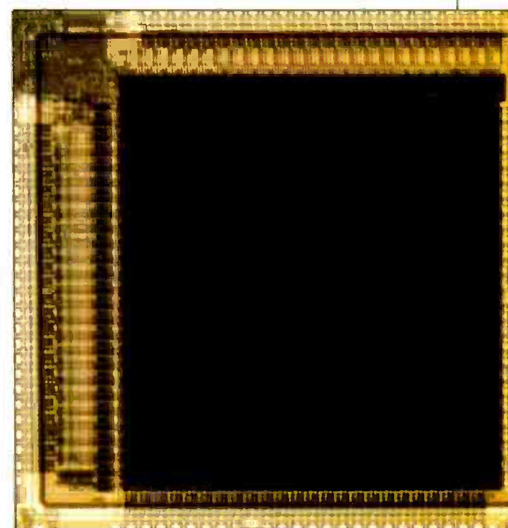
The complete configuration of an ERA device is defined by 3415 bytes of data, fed to the chip in either serial or parallel form. This whole process can take as little as 35μs, so there is plenty of scope for designing bizarre circuits which reconfigure themselves during processing, either under the control of a central processor, or according to the results of previous operations.

It is not even necessary to reconfigure the entire array in one go. The programming process means engineers can modify small parts of a design, when developing and prototyping. Also systems which need to be fault tolerant, like electronics on communications satellites, can be made self-healing – the arrays have built-in diagnostics, which can be used to reconfigure, avoiding damaged cells.

Plessey believes there is mileage in pushing ERA as a reconfigurable development tool, allowing designers to make easily modifiable prototypes, before moving to volume production of standard (Plessey) ASICs using the same design. So it is not coincidence that the ERA architecture has much in common with Plessey's standard gate array products, or that the cell libraries, supplied in conjunction with Viewlogic, form a subset of those for the company's standard ASICs.

Other likely uses are in interface logic; half-duplex modems, or disk drive controllers; where a quick reconfigure operation could switch the equipment between read and write mode.

Pilkington has now signed another technical collaboration agreement covering its semi-custom silicon technology, this time with Japanese chip firm Toshiba. Declining to clarify exactly what developments the deal covers, Pilkington denied it included ERAs.



● GEC's takeover of Plessey may put in doubt the future of the last bastion of UK-owned semiconductor research, Plessey's Caswell Laboratory. Following the departure of Caswell's head, John Bass, and Ray Oakley, who was in charge of silicon research, it looks odds-on that the silicon group, at least, will be broken up.

Engineering Council comes out fighting for nuclear power

The Engineering Council has joined the debate over the future of nuclear power in the UK with the issue of a polemical statement arguing that development of nuclear power is essential to cutting pollution, ensuring cheap electricity and safeguarding engineering jobs.

In the statement setting out to show that environmental pollution poses a greater threat than the nuclear power risk, the Council says that the government was right to remove nuclear power from the electricity privatisation plans. But that it would be wrong to call a halt to Britain's civil nuclear power programme.

A spokesperson for the Council said that government policy had already put thousands of highly trained professional engineers under threat. In addition to job losses recently announced, with nuclear-experienced industrial companies now reviewing their positions, further job losses were inevitable, he said.

The Council also took an attacking stance on health worries, saying that risks and health hazards from nuclear power had been "exaggerated by anti-nuclear groups who have played on the public's imagination".

It said the principle of probabilistic risk assessment applied to other methods of power generation would put nuclear risks in perspective. According to the Council "safe engineering solutions exist to stop a Chernobyl-type accident happening again".

The Council also argued that emerging countries should develop their nuclear power. Addressing the risks this posed in managing nuclear energy safely, the Council said risks could be minimised by careful cross-border siting of plants, international agreement and control.

The last thing the UK should do was to adopt an "ostrich-like attitude hiding our heads in the sands of short term financial gain and political manoeuvring", said the spokesman.

Sounding off about noisy lines

If you live near a railway line and sometimes don't hear the phone because of train noise then you might lend an ear to a new device from ECC Electronics. According to the company its CB14PAC piezo-electric sounder module, suitable for low power space savings applications such as telephone handsets, is actually louder than a train. The sounds can reach levels of 90dB which is about the same as standing 3m from a train climbing a hill. Might not go down too well with the neighbours though.

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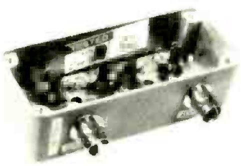

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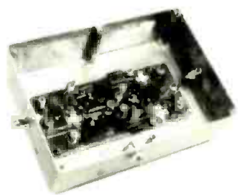

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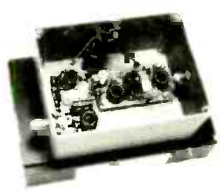

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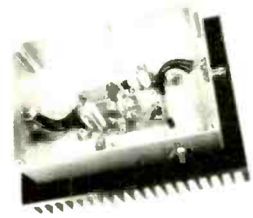
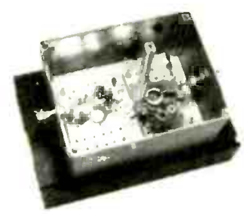


TYPE 9263



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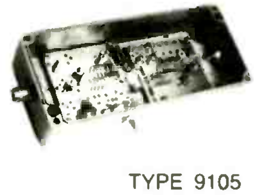
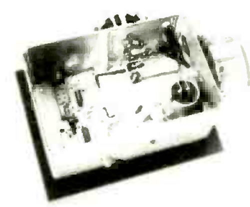


TYPE 9105



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CIRCLE NO. 122 ON REPLY CARD

Zetex nine months on

Set against worldwide competition, the existence of a commercial semiconductor industry in the UK seems unlikely. So perhaps it is not surprising that its youngest entrant, Zetex — the name derived from the famous Ferranti part number prefix ZTX — nearly never happened.

When Plessey took over Ferranti's semiconductor manufacturing interests a couple of years ago, it was left with a diversity of wafer lines and product types which it couldn't order into a sensible marketing strategy.

Ferranti's attraction was its widely acclaimed bipolar asic process and the accompanying software. Plessey's marketing department, long attuned to its own widely diversified products — ranging from consumer ICs through high-density gate arrays and high-speed military products — never really got to grips with the Ferranti portfolio of mature technology discrete transistors.

Generally this sector of the business was regarded as a liability rather than an asset and when the GEC-Siemens consortium bought Plessey in the summer of 1989, it too considered the Ferranti discrete business a corporate burden to be removed.

The result was a £2.5million management buy-out of the Ferranti Gem Mill semiconductor plant led by a former Ferranti engineer and marketing man, Bob Conway.

Conway's team declined venture capital backing raised on the very substantial material assets at the Oldham plant, preferring instead the financial help of a trading partner, the widely diversified computer terminal company Telemetrix.

But with the Plessey links severed, the administrative infrastructure also disappeared, leaving just a production shell and 370 employees. "We didn't buy a business, we bought a manufacturing unit. What we needed and didn't have was management experience," explained Mr Conway.

For instance, the new company couldn't continue in the Plessey pensions scheme and Telemetrix had to step in to provide this.

"It must seem strange how something insignificant like a pension scheme can turn out to be of major importance in making semiconductors," said Mr Conway. But he added that if the management buy-out team had gone the venture capital route for funding, the new Zetex company would have disappeared under the pressure of rising interest rates. It didn't and it hasn't. Though Mr Conway describes the first six months as like "hell on wheels."

The Gem Mill building, Zetex's home, is a massive red brick Victorian workhouse built in several floors, partly lit, partly dark. The vast acreage is scattered with abandoned diffusion lines and empty device assembly rooms; ghosts from an industrial past. Yet it still produces a wide range of discrete bipolar and mos devices on a mix of equipment, old and new.

The old Ferranti business was defence driven, money no object. Zetex has to rely, at least initially, on the reputation for quality associated with the miniature, silicon-based E-line transistor range.

Conway himself admits that his business requires only medium technology; the three and four inch lines run at a fairly coarse pitch by modern standards.

Careful chip design and close control over emitter dopant diffusion count for more in low to medium frequency transistors than fine lines. Tight processing can produce individual bipolar devices with a current gain up to 3000, but without the high saturation voltage associated with the Darlington configuration. The company's multi-point emitter structure enables a 6A peak current switching device to be produced in E-line form, a package about half the size of the standard TO-92.

Zetex technology, rescued in turn from Plessey and GEC, combines many ideal bipolar transistor properties. However, it faces a greater challenge in persuading the world of its excellence.

Equipment designers are conventional people who consider that devices as small as an E-line simply don't pass currents of up to 6A reliably. They tend to reach straight for the TO–220 catalogue.

Bob Conway has the measure of the problem: "We have good products but our marketing is not very good".

He says Zetex is looking at opportunities elsewhere in the world to expand its markets. Business is mainly drawn from the UK and part of Europe plus some in the north US; "but we have struggled rather in the US and have had very little success in the Pacific rim," he says.

Looking at the health of Zetex now Mr Conway says that Plessey's fight with GEC-Siemens sapped the company's available energy and trying to work with Plessey was a bit like "running through treacle." But Zetex had now revived its network in the Far East and expects to pick up an increasing part of its business there. For the future his view is quite simple: "We will stand or fall on the performance of people here," he says.

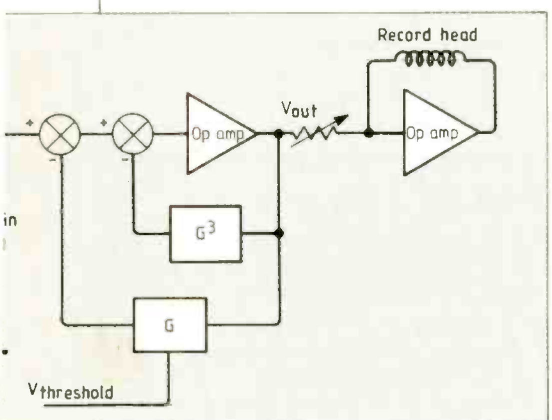
Analogue bias could bury DAT

Work in Scotland on a technique called contour biasing could deal a further blow to digital audio tape's chances of ever being taken up seriously by the music industry. At Paisley College Archie Pettigrew, of Ampsys, has been developing a model of precisely how magnetic tape recording works. The result, according to Pettigrew, is his technique of contour biasing, producing recordings which could rival CD.

The basis of the work is that, as input to the tape rises from zero, the resulting playback output changes as the cube of that input. Then, at a threshold point, the relationship becomes linear, before moving into saturation, where more input produces no more output.

The resulting curve is anhysteritic so that tracing from high input levels to low input levels follows the same path as moving from low to high.

Pettigrew has constructed a circuit **(Fig. 1)** compensating for this non-

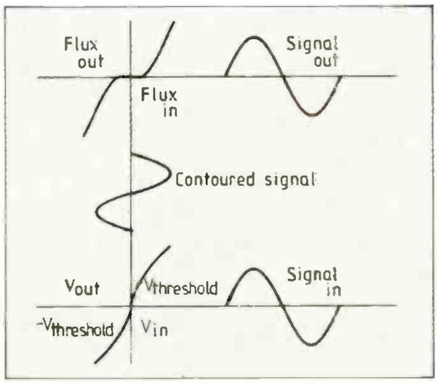


linear relationship, using a diode-pair function generator (G^3) whose conductance increases as the cube of the input voltage. Output is the cube root of the input.

When the input reaches $V_{threshold}$, the network is switched to a linear transfer function (block G) **(Fig. 2)**.

The efficacy of the method obviously depends on knowing $V_{threshold}$, and also on the number of diodes in G^3, which is used to approximate the cube law. Recording at 3¾ips, with standard tape and no precompensation, Pettigrew says that his system can achieve a 43dB improvement in signal to noise ratio over the equivalent standard AC bias recording.

However, at higher frequencies, there are two inconvenient distortion



mechanisms which must be dealt with. The first is caused by the fact that the line of recording sweeps backward and forward across the head gap. This causes the rising edges of a sine wave signal to be expanded, while the falling edges are compressed. The remedy is an anti-Doppler correction – adding harmonic energy on the increasing cycles, and subtracting it on the falling edges.

Pettigrew also found that, at high amplitude and frequency, magnetisation from one half cycle may not be removed from the record head sufficiently quickly, leading to "clipping". But adding a slew-rate limiter effectively solved the problem.

The overall effect is of a brighter, more dynamic recording, and Pettigrew says that several manufacturers are already interested in producing the necessary hardware.

With DAT failing to come to heel, it may yet prove that there is life in the old analogue dog yet.

Richard A Waldron — an obituary

Professor Richard A Waldron, who died suddenly earlier this year, will leave a hard to fill gap in the world of electromagnetic wave propagation in which he was a much respected international authority.

For over 20 years Professor Waldron was active in Britain and the US in the telecommunications industry and up to his death was Professor of Mathematics at the University of Ulster.

Altogether he published over 70 papers and six books including "The Theory of Guided Electromagnetic Waves" and "The Wave Ballistic Theories of Light" which displayed his command of his subject.

At one time he was a former chairman of both the Northern Ireland section of the Institution of Electrical and Radio Engineers and the Irish branch of the Institute of Mathematics and its Applications. He was also an overseas Consulting Professor and a member of the Overseas Advisory Board for the Eurotechnical Research University, Palo Alto US, gaining his professorship at the University of Ulster in 1979.

Professor Waldron, who lived in Carrickfergus and was due to retire this year leaves a wife, a son and a daughter.

A letter by Professor Waldron written just before his death appears in this month's letters column.

1994 is too late for agreeing HDTV detail

CCIR's decision to extend the study programme on definition of parameters for a world production standard for HDTV high definition television has been welcomed by the Eureka joint industry organisation in the sector. But Eureka was critical that agreement on standards was not expected to be reached until 1994.

According to Eureka it should be possible to come to an earlier agreement if discussions with the other parties involved could produce an acceptable compromise. However Eureka said that the CCIR decision means that Europe's proposals can now be considered on an equal footing with those of the Japanese.

Apart from the production standard, transmission standards also need to be specified. In this area a European Community directive is expected for MAC to be used with DBS, forming the technical framework for harmonised broadcasting standards in Europe.

The standards should be applicable to all direct-to-home satellite and cable transmissions, and should include encryption and conditional access.

Eureka says it is continuing to work on the extension of its interim production standard towards a single world standard on the basis of 1250/50/ progressive scanning.

New game in town

It was standing room only at London's Royal Lancaster Hotel last month, when the CD-I show came to town. CD-I stands for compact disc interactive, and it is backed by Philips, Sony and Matsushita, among others.

Philips reckons that the success of the system will depend on the availability of programme material (now called 'software'), and this was the point of the conference — to encourage 'software authors' to invest time and energy in CD-I.

Representatives from Motorola turned up to pledge their support in the form of a chip-set, based on the 68000 family of microprocessors. The chips will form the basis of home CD-I players, promised at a US launch price of $1000 within the next year.

CD-I integrates video pictures, high quality audio and computer programs onto a CD-type disc. The technology mix will be used to create new types of video game which are context sensitive with realistic pictures and sounds.

The warmest welcome, though, was reserved for Nobuyuki Idei of Sony, when he showed delegates one of the company's latest products, a portable CD-I player. DVI (digital video interactive), the nearest rival to CD-I, attacks the problem of selling interactive video from the computing side, rather than the consumer electronics angle.

Full motion interactive video from a CD is now becoming attainable, the biggest problem being how to compress all the necessary data so that it will fit on the disc. Advocates of DVI, including Motorola's chip-making rival Intel, say that their PC approach has the advantage there, because compression algorithms can be implemented in software, making them adaptable and upgradable. It is still not clear (apparently even to some of the hardware developers) what algorithms are used in the CD-I standard.

Sony's Ideo has a less unequivocal view, seeing CD-I as "a bridge between computer and consumer products." This, according to him, is "the new consumer electronics". And with the backing of Philips, Pioneer, Ricoh, Panasonic and Fuji, as well as Polygram, the world's largest record company, one would have to be very brave to disagree.

UK industrial strategy is "counter-productive"

Britain's components industry must have the support of a clear government strategy if it is to compete successfully in Europe in the next decade. But according to David Kynaston, chairman of the ECIF (Electronic Components Industry Federation) government policies were often "counter productive" while showing "an apparent indifference to the long-term harm" being done to industry.

Mr Kynaston made his criticisms to executives at a business seminar held in London. He compared UK government with US and Japanese governments' strategies which he said were coherent, understood and underwritten by the public and private sectors.

He said throughout Europe there was a fragmented approach to business which resulted in considerable resources being wasted in simply trying to gain a consensus. Consensus could only flourish if "there is a government environment committed to Europe", he said.

The seminar was organised by Kynaston International.

Median focus turns DRAM into drama

Memory-makers everywhere are scrabbling to publicise their progress toward the next generation-dram – the 64Mbit device.

Such is the kudos involved in not just having, but being seen to have, a technology lead, that the race for headlines has started well before most people have laid eyes on even a 4Mbit device (the sequence will run from 4Mbit, to 16Mbit, to 64Mbit).

All this development (and media) energy will not impress those who have replaced 1Mbit devices with 4Mbit versions and watched as the new chips flip themselves, apparently at random, into test mode. But, as far as the chip-makers are concerned, that problem is small potatoes – 64M is the place to be.

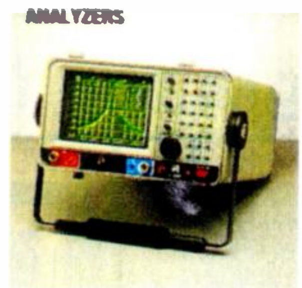
First to move were IBM and Siemens, dram collaborators, who announced a 64Mbit device by 1994. Not to be outdone, Jessi, the European Community's chipmaking consortium, brought its 1995 target forward by a year.

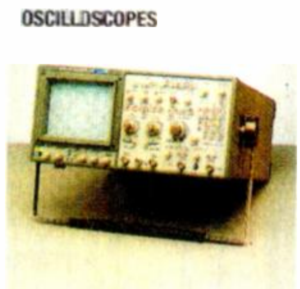
Hitachi has already designed, simulated and fabricated a chip which could form the basis of 64Mbit memories, and NEC has given some details of how it intends to go about fabricating its 64M device.

Meanwhile Siemens has made 16Mbit chips, using 3.3V internal logic levels, and a 3-d memory cell. Access time is 60ns.

Both Jessi and Hitachi will rely on a shrink down to 0.3 micron feature sizes to achieve the extra density, the latter using logic levels as low as 1.5V, for an access time of 50ns. The Japanese company also uses some smart design to ensure that 1.5V data is not hopelessly degraded by noise, but details are still sketchy. The company claims to have fabricated a device, though all the performance figures still come from simulations.

Siemens is now confident enough to predict full production of its 3.3V, 16Mbit device by late 1992. So, the race is very definitely on. But who will win remains to be seen.





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HUNTING

CIRCLE NO. 123 ON REPLY CARD

Single-chip micros – an overview

To control anything from a microwave oven to an industrial robot, a single-chip microcomputer may be the answer. Morteza Safavi looks at available devices and their application

Single-chip microcomputers are leading the thrust of microelectronics into domestic and industrial products, often replacing standard microprocessors in dedicated computing applications because of their low system cost and ease of use when timers and other real-time peripherals are required. A single-chip microcomputer incorporates all the units of a computer into a single device.

It is important to be clear on the distinction between microcomputers, microprocessors, and microcontrollers. A microprocessor is the CPU part of a computer without the memory, I/O and peripherals needed for a complete system. All the other chips in a microcomputer such as the IBM PC are there to add features not within the microprocessor chip itself.

When a microprocessor is combined with external I/O and memory, the combination is called a microcomputer. A device having the I/O and memory peripheral functions on the same substrate as the CPU to make a complete microcomputer is called a single-chip microcomputer (SCM).

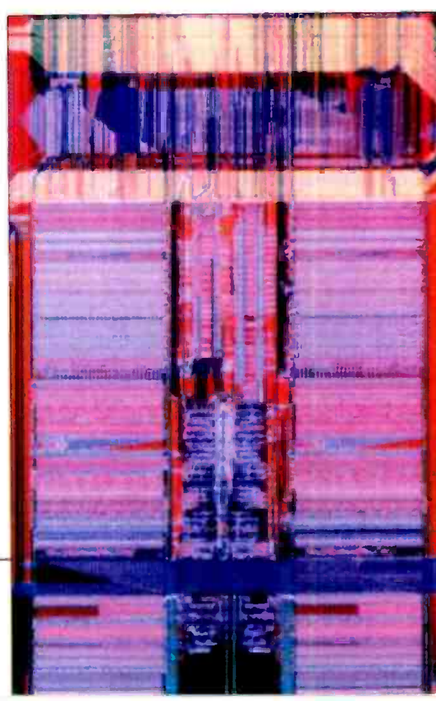
Generally, SCMs are designed for very small computer-based devices that do not require all the functions of a full computer system. In cost-sensitive control applications, even the few chips needed to support a CPU like an 8088 or Z80 may take too much space and power; instead, designers often employ an SCM to handle the control-specific activities. Where single-chip micros are designed or used in industrial control systems, they are often called microcontrollers. Basically, there is no difference between single-chip microcomputers and microcontrollers.

Frequently, microcontrollers are used to replace circuit functions that normally require many low-level chips or need the main CPU's attention each time the circuit is active. The IBM PC keyboard-interface circuit is a prime example of the use of a microcontroller chip.

Sometimes the term "embedded controller" is used instead of microcontroller — Intel, for instance, has adopted the term for its controller chips. However, an embedded controller, according to one definition, is a computer system hidden within some other device. By another definition, it's a computer whose programs cannot be altered by the user. Generally, the term embedded controller suggests a highly compact, although not very powerful, dedicated processor; for example, an SCM controlling a microwave oven.

Morteza Safavi is a senior lecturer at Leicester Polytechnic

Part of Motorola's 96002 "Media Engine" floating-point dual-port processor, which generates colour graphics and stereo sound.



Microcontroller hardware

Microcomputers and computers in general are usually classified in terms of the characteristic width of the internal data paths. This width — 4, 8, 16 or 32 bits — has a great bearing on the performance of the device in specific applications. It is a feature of practically all reasonable general-purpose computer architectures that, regardless of data path width, any computational problem can be solved, in logical sense, by any processor. The crucial issue is the time it takes and, to a lesser extent, the ease of programming it.

Four-bit devices are widely used in calculators and small controllers. This type of device can handle binary-coded decimal (BCD) data one decimal digit at a time, but information involving more than one decimal digit must be processed in a digit serial manner. Individual bits can be manipulated readily for I/O purposes, but address-processing with only four bits is difficult. These devices are therefore suited to low-end applications involving relatively small amounts of data driven by small programs operating within a comparatively relaxed time scale.

Four-bit microcontrollers offer a low-cost solution for timing, counting, and control functions. Some devices, such as National Semiconductor's COP413L, sell for less than $0.50 each in large volumes. They have limited on-chip features, however, such as 0.5Kbyte rom, 32 x 4bit ram, 16 I/O lines, no interrupts, and no timer/event counters.

NEC's μPD7556 microcontroller, still designed for low-performance applications, can cost as much as $2. It has a 1Kbyte rom, 64 x 4bit ram, 20 I/O lines, two testable interrupts, four analogue comparator inputs, and an 8bit timer/event counter.

Eight-bit microcomputers represent, for many more demanding applications, a sensible compromise in terms of performance and on-chip circuit utilisation. With eight bits, two BCD characters can be manipulated simultaneously. Eight bits are necessary for the convenient handling of alphanumeric data in the ASCII code used in terminals, displays and character handling in general.

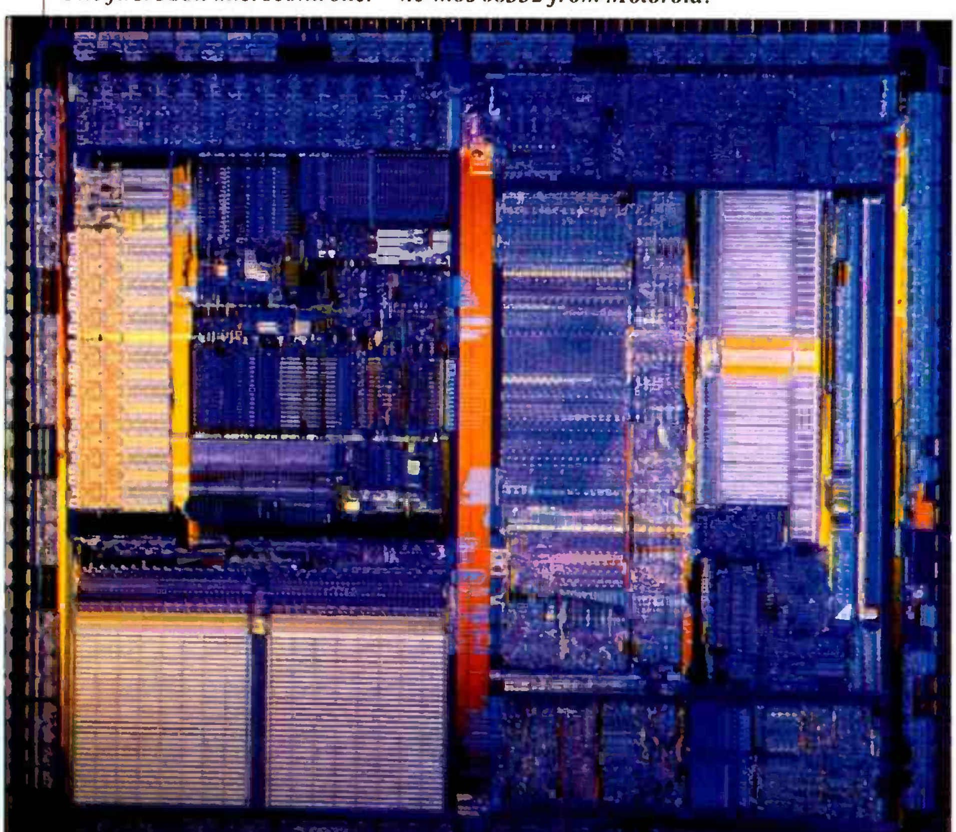
Reasonable precision arithmetic is possible with 16bit data, which is not too onerous with an 8bit processor. This is also a convenient size for instruction op-codes, and addresses can be specified with only one or two 8bit words. However, because of the maturity of some 8bit microcontroller families, some of these devices are now cheap enough to compete in the 4bit marketplace.

Although these devices don't have the on-chip output-drive capabilities of the mature 4bit families, they do combine powerful on-chip computing and data-handling features with extensive instruction sets.

Sixteen-bit devices can offer the general-purpose computing capabilities of a small microcomputer and the regularity of architecture and instruction set found in microprocessors such as the Motorola 68000, the Zilog Z8000 or the National Semiconductor 16032. This size of data path permits alphanumeric data in ASCII, etc., to be packed at two characters per word or BCD-packed at four digits per word.

As is the case with high-end 4bit and low-end 8bit devices, the cost performance/features of high-end 8bit devices overlap. 16bit chips are finding uses in high-speed equipment such as laser printers and disk drives, and in high-performance control applications such as satellite receivers, modems and robotic equipment. Evolution to 16 bits is in the automotive industry and is spreading to other applications[1].

The first 32bit microcontroller – hc-mos 68332 from Motorola.



Thirty-two-bit processors will handle a good-resolution floating-point number as a single datum and possess the addressing and comprehensive processing capabilities normally associated with these microprocessors. The 32bit microprocessor is helping to create and expand the relatively new markets in esoteric areas such as real-time signal processing, where processor arrays will become commonplace[2]. First to become available are the 80376 and 80960, both from Intel.

Some applications demand performance that is not available with a general-purpose architecture, which has given rise to a group of microcomputers with architectures adapted to a particular type of task.

Intel's 2920 is a radical departure in the development of SCMs. The TMS320 from Texas Instruments is another device with an architecture adapted for real-time signal processing; its main features are a 16bit parallel-hardware multiplier and a 32bit accumulator. A barrel shifter is also provided, with capabilities similar to that in the Intel 2920, for performing multiple place shifts in a single operation. The TMS320 does not incorporate an analogue interface, but does have a flexible and powerful instruction set which makes it suitable for applications such as digital filtering, Fourier analysis, speech analysis and synthesis and image processing[3].

Microcontroller products intended for digital signal processing (DSP) are starting to resemble more conventional microcontrollers. Microchip Technology, for example, has incorporated the core of the TMS320C10 with the I/O normally found in conventional microcontrollers. The addition of such things as an on-board A-to-D converter and eeprom may well put DSP-based controllers in contention for applications in automotive engine control, an area now dominated by such popular microcontrollers as the 68HC11 from Motorola and the 80C51 from Intel[4].

Fast programming algorithms alleviate the problem of eprom programming time, but a more elegant solution has emerged in the form of eeprom technology: Motorola has integrated eeprom cells on its MC68HC11 and MC68HC805B6 single-chip micros. Various forms of these devices are

Continued over page▶

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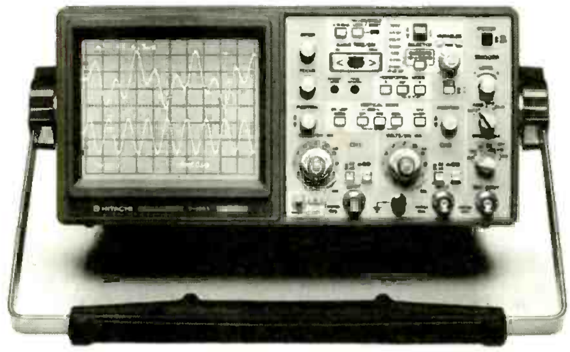

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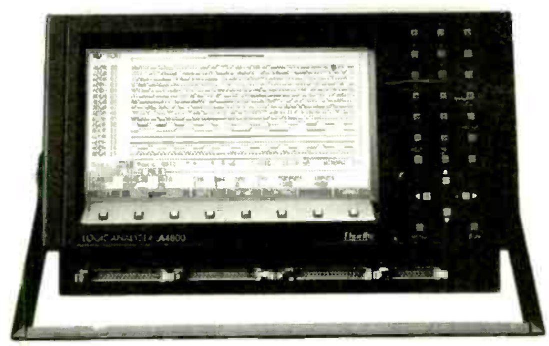

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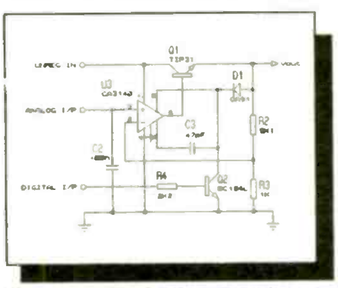

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Model	ram (bytes)	rom	addr.	SI/O	PI/O	C/T	int.	width
ADVANCED MICROSYSTEM								
80C521	256	8K	64K	1	32	2,16bit	2	8
DALLAS SEMICONDUCTOR								
DS5000T	8-64K	4K	128K	1	32	2,16bit	6	8
HITACHI EUROPE LTD								
63L05F1	96	4K	-	-	20	1,8bit	6	8
HD647180	512	16K	1M	3	54	3,16bit	15	8
H8/532	1K	32K	1M	1	57	5,8bit	7	16
					8i/p	3,16bit		
INMOS LTD								
IMST425	4K	-	4G	4,links	-	2,32bit	2	32
IMST222	4K	-	64K	4,links	-	2,16bit	2	1
IMSM212	2K	4K	64K	4	16	2,16bit	2	16
INTEL CORPORATION (UK) LTD								
80C512	256	8K	128K	1,uart	56	2,16bit	2	8
80196KA	232	8K	64K	1,uart	40	4,16bit	16	16
80C51BH	128	4K	64K	uart	32	2,16bit	2	8
87C51	128	4K	64K	uart	2	2,16bit	2	8
8096BH	232	8K	64K	uart	40	6,16bit	8	16
80C196KB	232	8K	64K	uart	40	6,16bit	16	16
MITSUBISHI ELECTRONIC (UK) LTD								
M50747	256	8K	64K	1	56	3,8bit	6	8
M3700M4A	2K	32K	16M	3	68	8,16bit	7	16
MOTOROLA LTD								
68HC05B6	176	6K	8K	1	32	4,16bit	4	8
68HC11E9	512	12K	64K	2	40	8,16bit	17	8
6804P3	124	1.7k		0	20	1,8bit	1	8
146805G2	112	2K	8K	0	32	1,8bit	3	8
68HC05L6	176	6K	8K	1	58	4,16bit	4	8
68HC11	256	8K	64K	2	40	8,16bit	17	8
NATIONAL SEMICONDUCTOR (UK) LTD								
COP420	64 digits	1K	-	1	8	1,10bit	1	4
COP888CG	192	4K	32K	2	40	3,16bit	14	8
HPC16083	256	8K	64K	uart	52	8,16bit	8	16
NEC ELECTRONICS UK								
78214	512	16K	64K	1	60	1,16bit	18	8
78322	640	16K	64K	2	55	1,16bit	19	16
						1,12bit		
ROCKWELL INTERNATIONAL								
R6501	192	-	64K	1	32	2,16bit	10	8
R6500/15	192	4K	16K	1	32	2,16bit	10	8
SGS THOMSON MICROELECTRONICS								
ST6041	64	64	3.8K	-	16	3	1	8
Z86E21	240	8K	-	1	32	2,8bit	48	8
TEXAS INSTRUMENTS LTD								
TMS370	256	4K	112K	2	55	2	2	8
TMS70C48	256	4K	64K	1	54	3	2	8
TMS7000	128	4K	to 64K	0	16	-	2	8
ZILOG UK LTD								
Z86E21	256	8K	120K	1	32	2,14bit	6	8
Z8800	352	8K	128K	1	40	2,16bit	8	8
Z86C11	128	4K	to 120K	uart	32	2,8bit	6	8

available, giving the ability to use the on-chip eeprom either for semi-permanent data storage (such as calibration tables), or for execution of user-written code directly from the eeprom[5].

Microcontroller software

Conventionally, software for 8bit microcontrollers has been written in the assembly language of the CPU, which is much more code-efficient than working with a high-level language compiler. However, with the advent of faster processors, more efficient compilers, increased on-chip memory and more complex designs, assembly language is no longer the only viable solution.

There is a trend towards high-level languages and structured programming techniques, which can provide productivity benefits over assembly-language development. Prime candidates are C and Modula-2, although Ada, Forth and Pascal can also be considered.

C compilers exist for almost every microcontroller; C is portable and is an efficient language that executes quickly. It is also easy to interface with assembly for time-critical routines. Modula-2 is often chosen by those migrating from Pascal-based development systems, because of its similarity to Pascal. It has many of the desired high-level characteristics, together with the necessary support needed for bit operations, interrupt handling and co-processing.

For the general run of commercial systems, however, C may still be the better choice, its main advantage over Modula-2 being the ease of direct low-level access to the processor and memory. In this respect, C is between high-level and low-level languages and offers many of the benefits of both[6].

High-level debuggers have long been available for 16bit processors and are increasingly available for 8bit microcontrollers. Debugging C programs is made faster and easier by such tools, which allow programs to be stepped a statement at a time and are aware of C variable types, names and scopes.

High-level debuggers exist in simulator and emulator versions. Simulator high-level debuggers are designed to validate the general flow of a program and avoid the costly and time-wasting attempts to debug both hardware and software simultaneously.

Motorola single-chip micros

Motorola's first home-grown single-chip microcomputer, the MC6801, appeared in 1978. It is a very versatile device, capable of operating not only as a true single-chip microcomputer under the control of the program fixed in its on-board rom, but also in a number of expanded modes using up to 64Kbyte of external ram or rom. Consequently, it is suited to a wide range of control applications.

This includes the consumer-goods and automotive markets, which need relatively cheap, simple devices tailored for particular applications. The MC6805 family was developed from the MC6801 by removing many of the computer-oriented features and augmenting its control features.

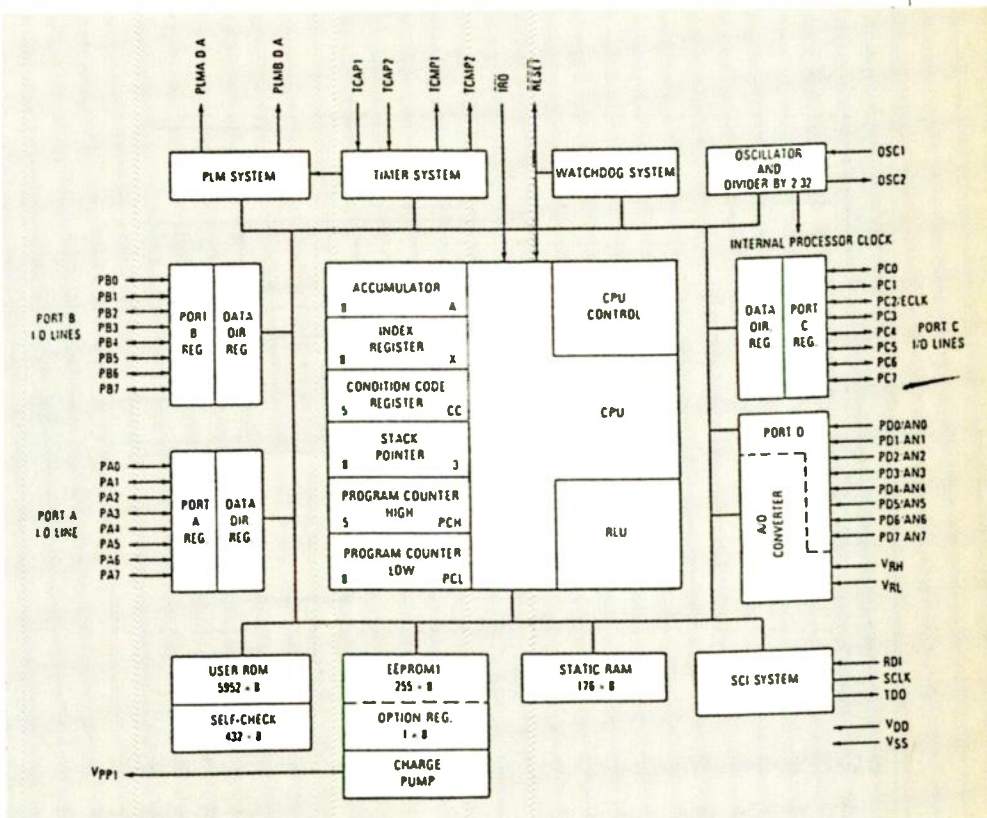
Because simpler applications require simpler programs, one of the accumulators was removed, and the ram and rom, along with a number of internal registers, were reduced in size. A simpler 8bit timer replaced the 16bit type and the serial interface was removed completely. Removal of some of the I/O capability allowed the devices to be produced in a 28-pin package and bit manipulation was added to allow input/output pins to be monitored and controlled individually. Modular design of the MC6805 family was carried through to the MC146805. These silicon-gate c-mos devices exploit the very low power consumption of the technology.

SCMs present a number of problems which do not exist with normal non-customised parts. User's software is programmed into the on-board rom at an early stage of wafer fabrication and cannot be changed once it is completed. Consequently, the user has to be confident that the application software is correct before committing it to rom. To help the user do this, Motorola, in common with other manufacturers, has developed a number of in-circuit emulator systems.

Motorola's SCM families

Motorola currently has three SCM product families and a fourth in development. At the bottom of the ranges in both areas is the 6804/68HC04, which lies on the 4bit/8bit performance border at 4bit prices and is designed for use in high-volume, cost-sensitive applications. These SCMs are true 8bit devices, with 8bit registers and instructions; the CPU also processes 8bit-wide data, but serially one bit at a time. It appears as an 8bit device to the programmer.

Two generations of c-mos micro-



MC68HC05B6 hc-mos device, with 256byte of eeprom, 8-channel AD/DA and two PWM outputs.

computer unit (MCU) technology are included in the 6805 range, making it the broadest product family available. It serves a wide range of applications, possessing numerous blends of memory types and I/O. These MCUs are available in h-mos, c-mos and hc-mos.

This family is a controller-optimised outgrowth of the original MC6800 MPU. Its instruction set and architecture were modified to simplify common controller operations without giving up the regular structure of the 8bit architecture which already existed in the MC6800.

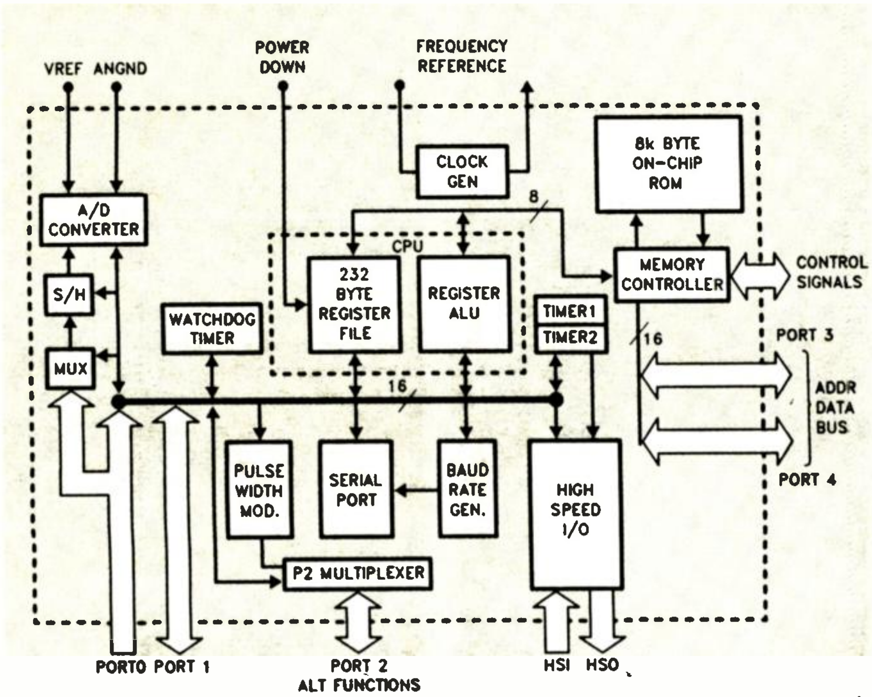
The MC146805 is the only MC6805-family MPU with external address and data buses. It is a 40-pin device and is virtually a complete minimum system in itself, since it contains two 8bit I/O ports similar to the PIAs used in the 6800, a timer and some on-board ram memory and necessary control functions.

A recent addition to the MC6805 hc-mos family is the MC68HC05L6 MCU device (**Fig. 2**). However, the latest introduction is the MC68HC05B6, which includes the core CPU with 256byte of byte-erasable memory (eeprom), an 8-channel 8bit ADC, a serial communications interface and two PWM outputs. For emulation purposes the device can have 6Kbyte of eeprom in place of the 6Kbyte of rom. MC68HC05B6 also has 176byte of on-chip ram, 32 bi-directional I/O lines and an internal 16bit timer.

The hc-mos MC68HC11 is an advanced 8bit microcomputer with sophisticated on-chip peripheral capabilities. It uses a greatly enhanced MC6801 core, loaded with a variety of control and interface features to meet the demands of industrial control. Hc-mos technology combines smaller size and higher speeds with the low power and high noise immunity of c-mos.

On-chip memory systems include 8Kbyte of rom, and 512byte of eeprom; eeprom increases the efficiency with which software can be debugged in the microcontroller application. Apart from the eeprom, the utilities are also capable of programming 2864 8Kbyte external eeproms, which can be connected to the 68HC11's external bus.

Based on an extensive five-port architecture, the 68HC11 microcontroller is equipped for the kind of communications required by a distributed data-processing system. For applications where additional off-chip resources are needed, the device can easily be expanded using a multiplexed



Block diagram of Intel's MCS-96 family, intended for high-speed control.

data address bus. Additional I/O to drive displays, an additional A/D converter and memory may be connected to the MCU via its synchronous serial bus SPI.

Motorola has skipped the 16bit stage in microcontroller development and moved directly to 32bit architecture for control applications beyond the capability of the 68HC11. The result is the 68332, containing a full 32bit hc-mos CPU and a risc-like timeprocessing unit (TPU) based on the 68020 microprocessor. 68332 includes most of the 68010 and 68020 enhancements, such as virtual memory support, an instruction pipeline, loop mode operation and 32bit mathematical operations. Additional addressing modes provide compatibility with existing software programs and increase the efficiency of high-level language compilers. It also includes new commands, such as table look-up/interpolation and low-power stop, to support the requirements of microcontroller applications.

Figure 3 shows the block diagram for the 68332. Its CPU core is 68020-based with the 32bit register set and 32bit ALU. It communicates with other functional units such as the 2Kbyte of static ram by way of the intermodule bus (IMB) which is a fully arbitrated 16bit data, 24bit address bus and provides two-cycle access. On-chip memory is fully addressable and not organised as a cache. The second-largest functional block on the die is the TPU, which processes 16 channels of time-based event functions independently of CPU intervention.

These two processing units are supported by several on-chip peripherals: the queued serial module (QSM) contains the serial peripherals interface (SPI), which links the 68332 to peripherals such as A-to-D converters, LCDs, or DSPs; and the serial communications interface (SCI), which enables duplex asynchronous communications with a CRT, terminal, host microprocessor, printer or other MCUs. Many resources conventionally supplied by external ICs are consolidated in the system integration module (SIM), including an external bus interface, programmable chip selects, system clock, periodic interrupt, test/emulation and system protection features.

This device is intended for automotive, telecommunications, factory automation, industrial controls, office automation, and communications control applications[7].

Intel single-chip micros

Intel microcontrollers come in the form of embedded control processors or embedded controllers; the operation of the computer is not obvious to the user — it is "hidden," or embedded in the system.

Intel introduced its first microcontroller architecture, the 8048, in 1976. It was designed for general-purpose 8bit control, with on-board rom and ram plus 27 I/O lines. Four years later came the 8051, which was up to ten times faster than the 8048 and had a 1μs instruction cycle at 12MHz.

Intel and other companies sell variations of the 8051 family enhanced with more internal memory, more I/O, lower power and so forth. All members of the 8051 family have the same core hardware and therefore use the same core instruction set, but some have one or two additional instructions for features unique to the particular chip. The 8751 is an eprom version of the 8051 whose on-chip program memory can be electrically programmed and can be erased by exposure to UV light.

There are many members of the MCS-96 family of 16bit microcontrollers, shown in **Fig. 4**, all designed for computationally intensive real-time control. Its CPU, as well as the 8bit or 16bit external bus, supports bit, byte and word operations. With a 12MHz clock, instruction execution times average 1-2μs in typical applications. An on-chip A-to-D converter includes sample-and-hold and converts up to eight, multiplexed, analogue input channels to 10bit digital values, each conversion taking 22μs; A-to-D conversions can be performed at programmed times or asynchronously. Also provided on-chip are a full duplex, double-buffered receive serial port with one synchronous and three asynchronous modes, and a 256-state pulse-width-modulated output signal.

The 80196 16-bit microcontroller is a high-performance, hc-mos, low-power member of the 8096 family and executes a true superset of the 8096 instructions. Four high-speed capture inputs are provided to record times at which events occur, and six high-speed outputs are available for pulse or waveform generation. High-speed output can also generate four software timers or start an A-to-D conversion. Events can be based on the timer or up/down counter.

First member of Intel's new 32bit microprocessor family, the 80960, is designed for embedded control applications, using both RISC (reduced instruction set computer) and CISC (complex instruction set) techniques. RISC-based machines are usually two to five times faster than CISC devices with the same number of bits, but RISC machines have one major disadvantage: they can be difficult to program in assembly language.

Continued over page▶

Assembly-language programming usually provides the best machine performance, but pure RISC machines are usually programmed only in a high-level language. A RISC machine depends on the language compiler to detect any program errors and prevent the device from becoming locked; such a compiler is often referred to as optimised. Because the 80960 uses both hardware and software to check for errors and protect the processor, it can be programmed in assembly language as well as a high-level language. The RISC-related features of the 80960 are used only for complex tasks in embedded environments[8].

It is designed for high-speed embedded applications that need real-time control (it can easily control up to six independent axes in robots). Intel claims that the device is powerful enough to serve as a controller for a lan such as Ethernet or Starlan, another chip (the 82586) being the communication manager for individual lan stations.

A 32bit derivative of the 386 microprocessor, the 376, is for embedded use in digital switching networks, laser beam printers and lan controllers. In essence, the 80376 is a stripped-down version of the 80386, with a 33bit CPU and internal architecture, a 16bit external data bus and a 24bit address bus providing a 16Mbyte address space. A second device, the 82370, provides a number of system peripherals, including eight channels of DMA, three 82C59A interrupt controllers, four 16bit interval timers, a d-ram refresh controller, a programmable wait-state generator and system reset logic.

Intel says that the 80376 offers up to 3MIPS performance at 16MHz, zero-wait state operation with 100ns access time d-rams. It is packaged in a 100-lead PQFP or 88-pin PGA. A major advantage of the 80376 is that development tools and compilers for high-level languages are already present in the forms of those developed for the 80386 — any 386-based PC can be used for developing 376 processor embedded applications[9].

Zilog — the Z8 family

Zilog introduced the Z8 SCM in 1978, two years after the introduction of its first microprocessor, the Z80. Z8 family products can be used either as single-chip computers or as processors in a small computer system.

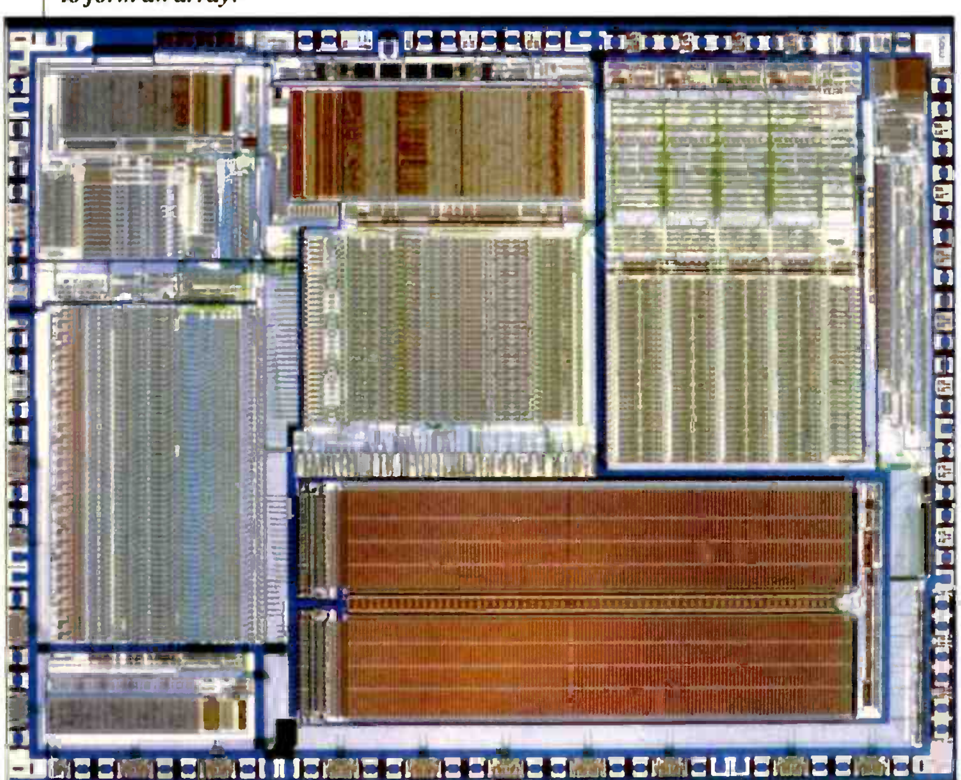
When the Z8 was introduced, the maximum clock speed was 8MHz, but devices are now available which operate at 20MHz (Z8874 Super8 MCU with Forth interpreter). Average instruction execution time (for the Z86C11 microcomputer, at 8MHz) is 2.2μs, with the longest instruction taking 4.25μs.

Super8 (Z8800/8801/8820/8822) MCU architecture has a flexible I/O scheme, an efficient register and address-space structure and a number of ancillary features. It possesses an improved Z8 instruction set, including multiply and divide, Boolean and BCD operations. Additional instructions support threaded-code languages, such as Forth, and enhanced real-time operation. The interrupt structure will handle 27 interrupt sources and eight interrupt levels, and it can provide 1-level serving in 600ns.

It has an on-chip DMA controller that can be used by its uart or a handshake channel to transfer data from a peripheral to either the register file or an external memory. It also has 325 single-byte registers, including 272 general-purpose registers and 53 mode and control registers. Two register pointers allow use of short and fast instructions to access register groups within 1μs. There are two 16bit timer/event counters and the device runs at either 12 or 20MHz. The counter/timers are programmable for capturing a count value at an external event or for generating an interrupt whenever the count reaches zero.

Zilog's new digital TV controller chip (the Z86C27, based on a Z8 core) packs an on-screen display circuit, a pulse-width modulator and all the essential I/O elements into one chip, which handles all the functions of a digital colour TV set, reducing both board space and system cost[10].

T800 floating-point transputer by Inmos, which can stand alone or be interconnected to form an array.



Texas Instruments microcomputers

Texas introduced the TMS1000 family in 1974. Despite its relatively modest performance, it has had an ever-expanding market in areas where previously a microcomputer would never have been considered, mainly for cost considerations.

An increase in performance is offered by the TMS7000 family of 8bit devices, with a comprehensive instruction set that can be customised. It is intended primarily as a single-chip solution, with ram and rom on board, but it may also be used as a normal microprocessor with up to 64Kbyte of external memory space.

TI and Microchip Technology have jointly introduced the 320C14, a 16bit DSP microcontroller that combines the high performance of a DSP with the

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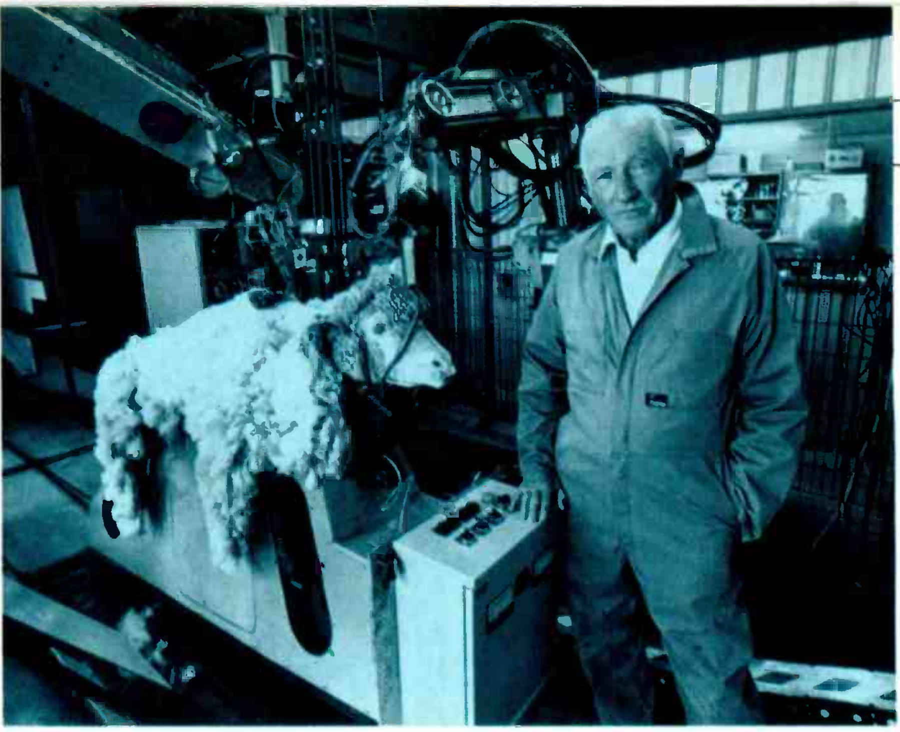
on-chip peripherals of a microcontroller. Operating at 25.6MHz, the 320C14 provides analogue designers with a digital solution without sacrificing the precision and performance of their systems.

Combining speed and integration makes the 320C14 ideal for servo control or any application that needs more performance than traditional 16bit microcontrollers provide[11]. **Figure 5** is the block diagram.



One industrial application of the transputer from Merino Wool Harvesting pty, Australia. The sheep was not available for comment.

Transputers

Inmos transputers, manufactured in Britain, are high-performance single-chip microcomputers with integral processor-to-processor serial links and on-chip memory, the intention being that transputers shall be the building blocks of a whole new range of machines.

They have their own built-in serial communication links, each capable of concurrently inputting and outputting at up to 20Mbit/s (the standard operating speed is 10Mbit/s). A typical transputer has four such links, giving it a communications capacity of 80Mbit/s into and out of the device. Since these links are integral parts of each individual transputer, the greater the number of transputers in a network, the greater the total bandwidth of the system. So transputer architecture **(Fig. 6)** does not define a single device, but a whole family.

Inmos has developed a new programming language, Occam, hand-in-hand with the transputer. Occam is a language which attempts to combine the performance benefits of an assembly language with the readability, programmer productivity and maintainability aspects of a higher-level language. A number of more well established languages such as Pascal, Fortran and C will also be available for use on transputers, but it is Occam which will enable the performance potential to be fully realised.

In October 1985, the T414 was the first 32bit transputer to become freely available. It has four serial links, but only 2Kbyte of on-chip ram, and provides high-performance arithmetic and microcode support for floating-point operations. It can directly access a linear address space of 4Gbyte. Its 32bit-wide memory interface uses multiplexed data and address lines and provides a data rate of up to 4byte every 150ns for a 20MHz device.

Another 32bit microcomputer from Inmos, with graphic support, is the T425. It has 4Kbyte of on-chip ram, a configurable memory interface and four communication links. The device is pin-compatible with the IMS T800 and the 20MHz version of the T414 and runs at 30MHz. The IMS T800 is a 64bit floating-point member of the transputer family.

Inmos has introduced samples of the 25MHz version of the T800 floating-point transputer, the IMS T800-G255, integrating a 64bit IEEE-754 floating-point unit, a 32bit integer processor with microcoded block move instructions and 4Kbyte of s-ram, and four standard Inmos communication links. Internal memory interface to the 4Kbyte of s-ram achieves a 100Mbyte sustained data rate and the transputer can address up to a total of 4Gbyte of external memory directly at a 33Mbyte sustained data rate through the memory interface. It is manufactured in Inmos 1.5μm c-mos technology and will initially be in a 48-pin PGA.

National Semiconductor

National's COPS family includes more than 60 different compatible microcontrollers, designed with the core/modularity concept to make it easy to expand the range. COP400 and COP800 cover the 4bit and 8bit data widths with the HPC range providing 16bit microcontroller performance.

The COP4xx range integrates all facilities necessary to implement control functions in a variety of applications. Features include single-supply operation and several output-configuration options, with an instruction set, internal architecture and I/O scheme designed for keyboard input, display output and BCD data manipulation. Instruction cycles are in the range 4 to 16μs. Stepping up to 8bit data width, the COP8xx offers 1μs instruction cycles and the integration of a 16bit timer function, and PWM outputs. This is being supplemented with additional features such as watchdog timer, uarts, 8bit A-to-D converter and memories of 1Kbyte to 4Kbyte of rom and 64byte to 192byte of ram.

Since its launch in 1978, the COP400 has sold around 40 million units each year, about 50% of which are used in car radios, electronic door openers, alarm systems, and other automotive applications[12]. The same source describes the application of the COP888 to a two-wheel adaptive braking system.

Harris Semiconductor

The RTX (Real-Time Express) 2000 microcontroller chip is the first offshoot of the Force (Forth optimised RISC engine) processor and toolbox Harris unveiled in 1987. At the heart of the controller chip is the RTX processor core, a 16bit CPU that executes Forth language instructions. With a 20MHz external clock, the processor executes 10 to 20MIPS (sustained) and hits peaks of 30MIPS for simple repetitive operations.

The chip features parameters and stack memories of 256 words each, a single-cycle 16×16-bit hardware multiplier, a 14bit-input interrupt controller and three 16bit general-purpose timers. The microcontroller's asic bus allows the attachment of external asic peripherals to the IC and provides a parallel communications interface for system enhancements. RTX2000 is housed in an 84-lead pin-grid-array package and additional package options will be released later.

Harris now has the RTX2001 for real-time control applications which are less arithmetically intensive than those which need the RTX2000. It is a pin-compatible (84-pin PLCC or PGA) subset of the RTX2000, but has dispensed with the 16bit hardware multiplier of the RTX2000, which yielded a single-cycle (100ns) multiplication, and has parameter and return stacks of 64×16 and 64×21 bits respectively. Buses from the RTX2001 include a 16bit memory data bus, a 19bit memory address bus and the 16bit extension bus for connection to off-chip peripherals or for I/O.

Hitachi

Hitachi offers a broad range of 4bit, 8bit and 16bit micro-controllers. The HMCS40 series (HMCS44/5/6/7C/CL) 4bit, single-chip microcomputers are designed to perform controller as well as arithmetic functions for both binary and BCD data. Their general features include 4bit architecture, up to 4K×10bit program and pattern rom, 256×4bit data ram, 44 I/O lines and two external interrupt lines[15].

Hitachi's HD4074408 and HD4074008, designed for the higher-performance 4bit market, each feature 8K×10bit rom, 512×4bit ram, and 58 I/O lines. The instruction cycle time of the HD4074004 is 0.89μs, for the faster HD4074408 0.5μs. Both devices operate from 5V (±10%) and feature two low-power modes. The HD4074008 has 12 15mA outputs, two timer/event counters, an 8bit serial interface and a 16-level subroutine stack. HD4074408 provides eight 12.8Vmax. outputs, 16 100mA outputs, two separate 8bit serial interfaces, four comparator inputs, a 16-level subroutine stack, and four timer/event counters, two of which can provide PWM outputs[16].

Hitachi also produces the 8bit c-mos single-chip 6305 series, an enhanced version of the Motorola MC6805 family and upwardly compatible with the HD6805 family in respect of instruction set.

The H8 family includes devices based on both 8bit and 16bit CPUs, with 200ns cycle times and 2.3μs 16×16 multiplication. There are two series of H8 microcomputers: the high-performance H8/500 series, and the value-for-money H8/300 series. In the H8/300 series the H8/330, with Hitachi architecture and high performance, includes 16Kbyte of rom, 512byte of static ram, three types of timers, a serial I/O interface, a dual-port ram, an 8-channel 8bit A-to-D converter and general-purpose I/O ports[17].

Three further H8/500 standard products are currently under development. The H8/520 will have half the memory of the H8/532, the H8/510 will be a rom-less version with a 16bit external bus and the H8/550 will contain 512byte of eeprom in addition to 32Kbyte of eprom and 1Kbyte of ram.

Mitsubishi

Mitsubishi also offers 4bit, 8bit and 16bit families. The 740 family is built around a core that is compatible with the 6502 instruction set and can use code written for that family. M50740FP-7FP c-mos, 8bit SCMs are designed for office equipment and other consumer applications.

Mitsubishi's 7700 series is a single-chip micro family with 16bit architecture and an instruction set upwardly compatible with its MELPS740. It has 8MHz and 16MHz clock-frequency versions and a minimum instruction cycle time of 250ns. A relocatable assembler allows assembly language code to be developed for time-critical or code-density critical portions of programs[14].

Some other manufacturers

Rockwell International R6500 8-bit SCMs, also based on the 6502 microprocessor, are designed for control. Main features are 1.5Kbyte to 4Kbyte of rom, 64byte to 192byte of ram, 23 to 56 I/O lines, multiple use of counter/timers, serial communication channels, expansion bus, multiple bus interface, and multiple interrupts. They are also available in rom-less versions.

NEC Electronics is another with two families of 8/16bit c-mos microcontrollers — the μCOM87 family and the expanding μCOM78K range. Versions of the μCOM78K are offered for servo control (78112) and motor control applications (78322/78312). The 78K series includes 16bit microcontrollers that support 16bit and 8bit external architectures and maintain 16bit on-chip data paths and 20bit address paths. All the features of the μPD70322 (V25) are in the μPD70332 (V35), but the former's external bus is 16bit wide rather than eight.

These devices use an instruction set that is upwardly compatible with Intel 8086/8088 software, making possible both easy cross-development from a personal computer and easy porting of code that was originally written for 8086/8088-based board-level controllers. The 20bit address bus lets the chip address a 1Mbyte address space. 70332 includes an on-chip dynamic-ram controller and the 70322 has two DMA controllers[16].

NEC's V25 and V35 have now been redesigned with on-chip peripherals, which means increased processing speed, much more efficient I/O transactions and possibly lower cost for external memory. The single-chip controllers offer 256byte of ram, 16Kbyte of masked or erasable rom and a register-banking scheme to speed context switches. On-chip peripherals include comparators, timers, serial and parallel I/O, and DMA and interrupt control logic. An unusual additional feature, called the macro service function, is essentially an additional DMA controller that can handle data transfers between on-chip peripherals and memory with very low overhead. Both chips can attach external memory as well, the V25 via an 8bit, and the V35 via a 16bit external data bus[19].

Siemens, AMD, and Signetics offer enhanced versions of the Intel 80C51 microcontroller. Siemens's SAB80C517 provides 8Kbyte of rom and 256byte of ram on-chip (the SAB80C537 is a rom-less version of the SAB80C517). Nine ports are provided for I/O — these may be arranged as seven 8bit ports, or 56 individual lines and one 4bit input port. The input ports can be multiplexed into an 8bit A-to-D converter.

Although based on an 8bit CPU, the SAB80C517 is intended to bridge the gap between 8bit and 16bit performance and therefore has a dedicated mul/div unit which performs 32bit division, 16bit multiplication and 32bit normalise and shift. At 12MHz, more than half the instructions execute within 1μs and the 16×16bit multiplication is performed within 4μs.

AMD provides rom, rom-less and eprom versions in the range. The 80C521 contains twice the rom (8Kbyte) and ram (256byte) of the 80C51, plus two 16bit timers and an additional watchdog timer programmable from 128μs to 4s at 12MHz clock frequency. The 80C321 is the rom-less version and the 87C521 replaces the rom with eprom. The 80C541/87C541 is a 16Kbyte version of the 80C521 allowing for larger code to be integrated on chips with the same functionality. Eprom 8bit microcontrollers are offered in windowed ceramic packages to allow UV erasure.

Dallas Semiconductors has taken the Intel 8051 microcontroller, piggy-backed a 32Kbyte static ram on top so it can be reprogrammed, added a tiny lithium battery to make the package non-volatile, and called it DS5000 Soft

Microcontroller. Dallas believes the DS5000 is suited to systems that can program themselves whenever operating conditions change.

Once software is created using 8051 development tools, programming of the 5000 is done through a serial or parallel interface. In parallel mode the 5000 emulates the 8751 so that an eprom programmer can be used, and in serial mode it is simply fed with data through an RS232 link. Dallas Semiconductor also provides a DS5000 evaluation kit.

Conclusion

What about the future? Naturally, the microcontroller families will continue growing. The market will be more lively and competitive and costs will fall in line with the general downward trend of the price of computing equipment. We can expect microcontrollers to become commonplace and continue to be the designer's choice for intelligent control applications.

I wish to express my deepest gratitude to Dr Brian Bramer and Dr Martin Lefley for their helpful advice and constructive criticism. Thanks are also due to the microcontroller manufacturers, Motorola, Intel, Zilog, Inmos, Hitachi and Dallas Semiconductor for their co-operation and permission to reproduce various figures.

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It is impossible in an article of this nature to cover the field completely. For full details of the devices mentioned in the article and others, contact the manufacturers at the following addresses.

Advanced Microsystem, AMD House, Goldsworth Road, Woking, Surrey GU21 1JT. 0483 740440.
Dallas Semiconductor, Westminster House, 188-190 Stratford Road, Shirley, Solihull B90 3AQ. 021-782 2959.
Fujitsu Microelectronics, Hargrave House, Belgrave Road, Maidenhead, Berks. 0628 76100.
Harris Semiconductor, Beech House, 373-399 London Road, Camberley, Surrey GU15 3HR. 0276 685911.
Hitachi Europe, 21 Upton Road, Watford, Herts. WD1 7TB. 0923 246488.
Inmos, 1000 Aztec West, Almondsbury, Bristol BS12 4SQ. 0454 616616.
Intel Corporation (UK), Pipers Way, Swindon, Wilts. SN3 1RJ. 0793 696000.
Microchip Technologies, Chiltern House, 17 College Road, Maidenhead, Berks. SL6 6BX. 0628 776433.
Mitsubishi Electronic (UK), Travellers Lane, Hatfield, Herts. AL10 8XB. 07072 76100.
Motorola, Colvilles Road, Kelvin Estate, East Kilbride, Glasgow G75 0TG. 03552 139101.
National Semiconductor (UK), 301 Harpur Centre, Horne Lane, Bedford MK40 1TR. 0234 47147.
NEC Electronics UK, 116 Stevenston Street, New Stevenston, Motherwell ML1 4TL. 0698 732221.
Rockwell International, RCS Microelectronics Ltd, Uxbridge Road, Hampton Hill, TW12 1BL. 081 979 2204.
SGS-Thomson Microelectronics, Planar House, Parkway, Globe Park, Marlow, Bucks. SL7 1YL. 0628 890800.
Siemens Components, Siemens House, Windmill Road, Sunbury-on-Thames, Middx TW16 7HS. 0932 785691.
Signetics, Mullard House, Torrington Place, London WC1E 7HD. 071-580 6633.
Texas Instruments, Manton Lane, Bedford MK41 7PA. 0234 270111.
Zilog UK, Zilog House, 43-53 Moorbridge Road, Maidenhead SL6 8PL. 0628 39200.

Power Electronic Handbook, by F.F. Mazda. One of the professed aims of this very expensive book is to ". . .collect within a single volume all the material relating to power components, circuit design and applications. . .". That might seem to be a tall order indeed, but the book does appear to live up to the author's intention.

It is in three parts: components, circuits and applications. Part 1 considers the full range of power semiconductor devices (including bipolar and field-effect devices as well as thyristors), their thermal characteristics and heat-sinking, control components, electromagnetic compatibility and protection.

Part 2 is to do with circuitry: static switching, AC control, rectification and inversion, frequency conversion and DC to DC conversion. The circuits are generic, rather than specific but enough information for design is provided in the discussion. Mathematics are kept to a relatively unobtrusive level, the tendency being to provide results rather than their derivation.

The final part concerns the application of the circuits described in the earlier chapters in power supplies and machine control. A list of symbols, a glossary and a bibliography complete this very helpful book which, even at the elevated price, will earn a place in many laboratories. Butterworth Scientific Ltd, 417 pages, hard back, £60.00.

Cable Television Technology and Operations, by Eugene R. Bartlett, is a comprehensive work on the design, construction and maintenance of cable systems intended to carry NTSC (the book is American) and HDTV broadcasts.

It appears to be written for technicians, since the discussion starts at an extremely elementary level (Ohm's Law) and goes on to describe cables and cable systems, antennas and head-end circuitry, cable system design and test and measurement.

Mathematical treatment is, in the main, confined to simple algebra, with sections explaining trigonometry, logs and decibels at the relevant places.

A practical approach is adopted, problems and their solutions forming the impetus to the description. McGraw-Hill Publishing Company, 421 pages, hard back, £39.50.

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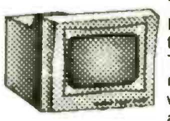

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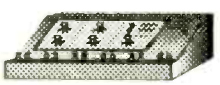

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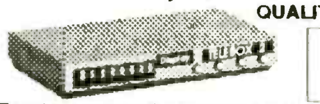

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CIRCLE NO. 129 ON REPLY CARD

Going to the proms

Firmware in programmable devices has become an essential part of most micro-based systems. Brian Frost reviews a cross-section of programming hardware.

A few years ago many users were able to fabricate simple eprom programming equipment with much success, but today devices have increased in density and in their programming requirements to the extent that this task has become much more difficult. At the same time the growth of logic devices has introduced programmable parts that differ from eproms both in their technology and in their method of programming, making it a difficult task to build suitable programming equipment.

With many vendors offering programming equipment, even when the decision has been taken to purchase it can still be difficult to short-list suitable items due to the complexity of some of the more esoteric equipment. This review does not set out to examine items in direct comparison but aims to illustrate the nature of points that should be remembered when defining and purchasing such equipment against any budget.

The most expensive item here is a Stag model 3000 universal device programmer which can program many single-memory, microprocessor and logic devices, and is intended as an all round engineering support tool. The other items are an eprom-only programmer from MQP, an eprom and PAL universal programmer from Sunshine, and an EPLD programmer from MPE. As an indication of how the capability of this equipment can be easily extended, an eprom emulator from Flash Designs has been included. All of these devices are primarily aimed at the engineering user and can work only with single devices.

Planning to purchase

As ever, your budget will define the nature of the equipment, although programming capability can be bought either outright or in instalments. Several vendors market "universal device programmers" aimed at offering a programming solution for most, if not all, of the programmable devices sold by the semiconductor manufacturers. These top-flight machines cover a range of technologies from the early bipolar fuse technology of PALs and proms, through eprom technology to the more recent earom technology used for newer EPLDs and rams.

In general, the more expensive and high-profile the machine, the more rapidly it can be expected to receive device software as new devices become available. Exceptions to this are devices where the manufacturer is selling programming software and hardware as a package and does not support third-party equipment. There may be a good reason for this attitude (found more recently with large, new logic devices which can require highly specialised development software) although it is not unknown for semiconductor manufacturers to desire a share of the programming market too. As a result, if purchasing a universal device programmer with its long device capability list, remember that you may still need to purchase additional equipment later.

This concept of equipment dedicated to limited devices or manufacturers is also used to offer low-cost equipment to those with limited budgets and requirements. For example, eprom programmers are still relatively simple items and can be found at low costs which reflect their construction. Also, many users will already possess eprom programming equipment and simply wish to add, for example, PAL programming capability.

One market that this has opened is for PC users to plug in expansion cards dedicated to specific programming tasks, such as an eprom programmer, a PAL programmer, etc. These are available as separate items and their relative simplicity is reflected in low purchase prices. Other low-cost equipment is designed to remain independent of the specific host computer used and relies on a defined communication link to pass data to and from the device.

In general, the lowest-cost equipment is inserted directly into a host computer such as the PC, and which is often dedicated to one type of programmable device. This makes it possible to use simple programming hardware and to use the large memory and disk capability (and usually the power supply) of the computer to support the hardware and software. Against this, of course, the equipment is not easily moved without the computer.

With increasing cost comes equipment intended to operate over a communications link, usually RS232, and this usually demands that the equipment possess some ram in which to hold the device data, which for eprom programming of large devices can be a costly item. The equipment will also require a power supply and a built-in microprocessor, and all of these increase the cost.

Some eprom programmers get around this by trading off the need for costly ram against a slower programming speed by transmitting device data directly along the communication link for every device operation. In contrast, top-flight items of equipment add more standalone features, with their own ram, often an in-built terminal and keyboard, and extensive software as well as programmable pin drivers that can cope with wide device requirements of voltage, current, timing and slew-rate.

The Stag 3000 Universal Device programmer

As an example of the latter, I examined a universal programmer from Stag, a company that has been dedicated to device programming for many years. This machine is an engineering tool designed to accept as many device types as possible and to offer a complete programming solution.

The machine is used with any communications link, such as RS232, and is otherwise self-contained. A large base unit contains a small screen and keyboard, and accepts plug-in modules that define its exact capability. The module that I used offered a range of individual soft-sockets of various sizes for the devices to be programmed.

The review machine came with a comprehensive manual, but after only a cursory glance I decided to try to install the supplied module then switch on and see what happened. The result was aloud tone, no screen display, and within a few seconds the familiar smell of a burnt component. A call to Stag revealed that the loan machine was a demonstration model which had "seen the world" so it was arranged that a replacement would be shipped by return.

Data-edit screen on the Stag 3000 universal programmer.

When the replacement arrived I powered it up with no initial attempt to connect it to a host device. The small CRT and keyboard were surprisingly easy to use for the purposes of selecting device types and other menu options, but I would not wish to use it for longer periods of entering or modifying any device data. The presentations of simple menus and of device data were very clear although I had to pause and eliminate some other options before confirming that the LOAD key meant "to read from" a device. The software was very well behaved and both prompted and allowed me to quit from processes without any quirks.

One moment of panic occurred when I was about to plug a serial cable into the rear of the machine and suddenly the screen went blank. Pressing a key restored the screen and confirmed that this was simply good design — a safeguard to prevent CRT burn over long idle periods. Going on to examine the connectors at the rear of the machine revealed interfaces for serial, parallel and IEEE connections.

Entering a menu option, SET HARDWARE, I discovered a clearly presented menu with all of the existing serial port settings against which I was able to set up the host PC. Since there was no cable supplied I had to use one of my own. I chose my simplest RS232 cable, with all the control lines wired to default levels (i.e. always clear-to-send, always request-to-send) and only the two signal lines and ground connected (2, 3 and 7). I have found that the best tip for success with RS232 is to keep it simple — this cable is ideal since any mains cable will do.

With the cable installed, my first attempt at sending a PAL Jedec file to the programmer failed when I used the popular communications program PROCOMM to set the baud rate, etc., and to send the file in its ASCII UPLOAD mode. The programmer screen confirmed that the data was being received but finally "checksum error" indicated that the file contents were being altered by PROCOMM. For quick confirmation I went back into MS-DOS and attempted to send the file again using the COPY command. To my amazement this worked immediately.

Basic cost: £6325

Other items: Yearly hardware maintenance and calibration, about £400. Yearly software updates of new devices (at least four per year), £300. PC-specific control software, £295. PC cable, £20.

This illustrates an important point. Equipment that relies upon a connection to a host computer should always be obtained with the appropriate leads and, where necessary, software. Do not be put off by a salesman's assurances that, "The equipment is so versatile that it will work with anything." Even if that is true, the designers will know much more about connecting it to your system than you do and you are likely to get much better results if you point this out before purchase rather than after. RS232 problems can be frustrating even to those with a drawer full of variously connected cables, gender-changers and pin-connection diagrams.

With the Jedec file loaded into the programmer, I inserted a 16V8 PAL and pressed PROG. This electrically eraseable device was erased, blank-checked, programmed and verified in just over 1 sec. Following this I selected the TEST option that instructed the programmer to apply the logic test vectors contained within the Jedec file to the now-programmed device. The device passed, but to investigate what would happen on a failing part I inserted a blank device and repeated the test. Two test vectors appeared on the screen in the format seen within the Jedec file and showing the stimulus vector and the vector read from the device.

Selecting eprom devices I inserted a 27C256 (32k) eeprom and loaded a hex-format file of 32k data bytes (file size about 70k) — this took some 2 min. A complete programming operation took about 90 sec. This did seem rather slow, but it was not possible to inspect the programming algorithm being used (for example, 50ms, Intel quick-pulse, etc.) to calculate the theoretical time.

For both the eprom and the PLD programmed, the equipment was easily operated and largely hid the details of the programming task from the menu options presented. Assuming regular software updates this machine would be ideal for shared use within an engineering department.

I understand that the programming

Part of list of eprom manufacturers on Stag 3000.

and verification of each device also include some parametric testing to verify, for example, that the device supply current is within limits, and that its outputs can drive bus loads. This raises the quality of the programming and verification to a very high level indeed.

Supplier:
Stag Electronic Designs Ltd,
Stag House,
Tewin Court,
Welwyn Garden City,
Herts AL7 1AU.
Tel: 0707 332148

The MQP 200-series eprom programmer

This programmer is connected to a host computer, in this case the PC, by a serial lead and PC-specific software. It was supplied with a manual, connecting lead, software disk, and the device list. This range of programmers covers single eproms up to 32 pins with one single device socket. Eprom microprocessor programming is possible using adaptors plugged into the upper two models from the range.

Unpacking the programmer revealed a satisfyingly heavy case with mains cable and 25-way D-type connector. The supplied serial lead, with 25-way connectors at both ends, was thoughtfully marked to the effect that it would be replaced with an IBM AT-style lead (with 9-pin D connector) by simply returning to MQP.

This programmer operates using the standard serial link at up to 19,200baud and with no programmer data ram. This has the advantage of not requiring large amounts of costly memory in the programmer, but does mean that any programming write or read operation with large devices is limited in speed by the bottleneck of the serial link. When using the device as an engineering development tool this is unlikely to be a serious limitation, although I was surprised not to see higher PC-specific serial rates available — for example, speeds of over 100kbaud are possible by direct software control of the PC serial port and are now used regularly.

With the serial cable connected and power applied, I loaded the supplied program, PromDriver (PD.EXE). Installing this is quite simple, with easy-to-follow step-by-step instructions at the start of the manual. A device list appeared with an opening menu of programming and data manipulation options. The screen writing was slow, indicating (ironically) that the software is using MS-DOS to access the screen instead of the more usual, but technically improper, direct writing to the PC video ram. While less pleasant to use, it does not affect any programming facilities.

Selecting the data file format shows a creditable list of the common data formats, with Intel, Motorola and Texas formats supported as well as the common object file formats and simple binary files.

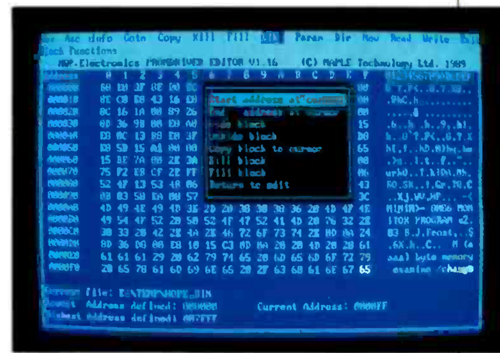
With a programmed 32k x 8bits 27256 eprom inserted, I selected the device type and picked the option "READ Prom". After I had entered the destination file name the software "went away" with only the flashing of the socket-active lamp on the programmer to reassure me that all was well. It was, and some 55 secs later the read operation was complete with data in the file on the PC.

Due to the lengthy nature of these read and write operations I would have liked to see at least a reassuring message, and ideally some guide to time-to-completion — for example, the programming address or a percentage value. As devices get larger this will become more of a problem.

Programming my 32k x 8bytes eeprom with a 32kbyte file took about a minute — 10 secs to blank-check the device, 38 secs to program it and another 10 secs to verify it. This was measured with the system set to 19,200baud (its fastest speed) and was performed on an AT-compatible with the quick-pulse algorithm selected.

Basic cost: £295

Other items: Additional adapters typically £75. Users notified of software and firmware upgrades typically four times yearly, cost £35. Refund within one week if it does not meet expectations.



PromDriver edit screen on MQP eprom programmer.

The other necessary eprom support facilities were present, including the ability to split and shuffle data, where byte file data can be split and shuffled to program odd and even eproms for use with 16-bit bus applications. Lacking, however, was the more recent, although infrequent, requirement for four-way splits allowing byte-wide eproms to be programmed for 32-bit applications.

The supplied programming software has a separate editor package that allows direct editing of file data. It can be called from within PD and is supplied free with the model 200. This can be used to patch existing code or to quickly inspect eprom contents for data without having to invoke an external file editing utility. This is comprehensive but I did not discover any search option (often useful when locating data strings in large data blocks).

Opening menu on MQP 200, with 27256 eprom READ selected.

This package has a better window-based environment than the programming software PD, and is more in keeping with other third-generation software. It is easy to use although still somewhat slow in screen operations, but otherwise all of the software is well designed with previously selected options being retained following an exit to DOS and subsequent reload.

MQP can also supply active adapters for the common microprocessors to enable them to be programmed. Adapters are also available for earom devices, including one for the serially loaded types.

Supplier:
MQP Electronics,
Park Road Centre,
Malmesbury,
Wilts SN16 0BX.
Tel: 0666 825146

The Sunshine Expro-40 PC-based programmer

Using a host computer for as much of the hardware and software support as possible can allow the manufacturer of a programmer to reduce the cost significantly, and the Expro-40 does just this.

This device is capable of programming both eproms and PALs, using a close-coupled technique to connect a PC to the device to be programmed. A special card is inserted into the user's PC and provides a small address window in which the device pins are available to the PC as I/O addresses. With suitable software dedicated to the PC, the programming algorithms are applied directly to the device pins without the potential speed limitation of a serial communication link. No power supplies or other support are needed since the programmer power is obtained from the PC via this card.

Installation was no great problem although I would have appreciated a slightly longer lead between the PC plug-in card and the device socket. This would allow the PC to go under a desk yet keep the programmer pod in an accessible position.

Due to the great variation in the devices that can be programmed, the software for this programmer is supplied on four 360kbyte disks in the form of individual programs for different device families — in some cases there are even individual programs for certain devices. Despite this, it is quite easy to identify the software required for any particular device — even easier once a batch file is created to translate the device name into an automatic load of the appropriate software. Once into the software it is easy to see that this company has concentrated on achieving a high number of device types available, which do indeed cover a very wide cross-section of eproms, micros, PALs, proms and EPLDs. Unfortunately this is at the expense of the screen presentation. In mitigation all the options seem to work, and throughout an extensive period of use I have had no operational problems at all despite the number of misspelt messages and the primitive (by today's standards) screen layout.

I configured the system to program a 27C256 eprom with a 32kbyte binary file. Since the system is functionally part of the PC, there is no need to consider serial parameters and file formats since the system accepts binary files directly. It was easy to select the eprom device and an impressive set of five programming algorithms was offered. File data is loaded into a memory buffer allocated within PC memory space and provision is made to load multiple files into this buffer at any required address offset. As long as you can keep track of this loading of your data, this is a useful feature for combining separate data into one eprom device. The system took 7 secs to blank-check the eprom, 25 secs to program it and another 7 secs to verify it — a total of about 40 secs to program the complete device.

To test its ability to handle PLDs, I configured it to program a 16V8. The software has an almost identical feel to that used in eprom programming, with a memory buffer into which Jedec data files are loaded prior to programming the device. I loaded my Jedec file into the buffer and first erased the device, an operation that took 2 secs. Blank-checking the device took another 1.5 secs and programming a further 3 secs. I looked for an option to apply the test vectors from within my Jedec file to the programmed device, but all I could find was a general logic test program that claims to test most of the 74 series and 4000 series logic families but which offers an option for loading user-defined test vectors.

Basic cost: £484.50

Other items: Software supported on request with new devices added at least four times a year.

Interestingly the format of these vectors is almost identical to that used in the Jedec file, so using a word-processor to extract the vectors from my Jedec file I imported them into the test program and persuaded the programmer to apply them to the programmed 16V8. Although the test program accepted the vectors I found that during the test run it applies a current limitation of around 50mA to its V_{CC} pin — adequate of course for the logic families but insufficient for many PLDs. This inability to test-vector check PLDs is not a serious limitation but is made all the more frustrating by the obvious capability of the hardware if suitable software were available.

This device will be particularly attractive to PC owners since it provides a low-cost method of programming a wide range of devices of all types.

Supplier:
Mutek Limited,
Farleigh House,
Frome Road,
Bradford-on-Avon,
Wilts BA15 1LE.
Tel: 02216 6501

Sunshine Expro 40 handles eproms and pals, using a PC as host computer to reduce hardware cost.

The MPE PowerLogic development system

Another example of a PC-specific programmer is the PowerLogic development system from MPE. This device is designed specifically for programming third-generation logic devices. These are PALs (or, more properly, PLDs) which use mos technology instead of the bipolar fuse technology used for first-generation PALs and proms. The advantage of this is that programmer hardware for these devices can be manufactured with much simpler pin-drive electronics since mos PLDs require similar programming principles to those of eproms, with little actual current necessary for each pin. Bipolar devices that use fuse technology require quite high current pulses applied to specific pins to blow the fuses, and this complicates the programmer electronics significantly.

The PowerLogic Development System exploits this to offer a simple PC plug-in card to which is attached a ribbon cable and a 24-pin 0.6in ZIF device socket. The programmer was supplied with device algorithms that covered devices from the common 16V8 family up to devices such as the Altera EP600 and the Cypress C22V10. Only logic devices are supported.

Installing the card proved straightforward, although I would have liked to see a D-type connector used for the programmer cable instead of the ribbon-cable header supplied. The card and bracket are rather flimsy and liable to damage unless care is taken.

The supplied software, PLDS, was well written and fast. I found the menus to be intuitive and where any difficulties occurred the standard "F1 for help" displayed an excellent context-sensitive help window. Mouse control of the menu cursor worked well and I noted the addition of useful screen information such as the manner in which to insert a device that is smaller than the ZIF socket.

With this system the user needs no additional software to proceed from a source text file through to a programmed device. As well as the usual programmer options of device selection, blank-checking, programming and verification, the software includes an assembler which accepts a text file containing the user's logic device equations and generates a fuse-map immediately prior to programming. Alternatively, it is possible to read industry-standard Jedec files generated by other logic development software.

Main menu of MPE PowerLogic EPLD development system, with 16V8 device selected.

I chose to use a Jedec file that I had used regularly for a 16V8 that I use often. Choosing the device "Lattice 16V8" I loaded the Jedec file and returned to the main menu to erase this electrically eraseable device.

At this point I began having problems — the system kept informing me that the 16V8 device was not recognised. A call to MPE established that this was probably a hardware fault since I had been loaned an early model brought up to present requirements with some simple modifications. Unfortunately, although I received a replacement model very quickly, it too gave the same problems, illustrating the need to be able to consult with the supplier easily and quickly.

As with the Expro-40, there appeared to be no test vector facilities within the software. This is a significant omission since it prevents the function of the programmed PLD from being checked. Although a correctly verified device should operate as programmed, there are some situations, particularly when programming flip-flops, that only show state transition problems when a test-vector check is applied after programming and verification.

This device would appeal to PC users interested in the more recent logic devices and who would benefit from the complete solution of the logic assembler within the supplied software.

Basic cost: £350

Other items: Additional device pods where necessary, £145. Free upgrade facility as individually necessary. Loan of replacement while any upgrades are being performed on user's hardware.

Supplier:
Microprocessor Engineering Ltd,
133 Hill Lane,
Southampton SO1 5AF.
Tel: 0703 631441

The Flash Designs Ram-Blow 1Mbit emulator

This unit provides a neat link between a conventional eprom programmer and expensive eprom emulators used for debugging dedicated micro systems without in-built monitors or program load software.

The unit is a small case containing 1Mbit of ram configured with two short 32-way ribbon cables and DIL plugs and with interfacing hardware that allows it to plug into any standard eprom programmer at one end and into the eprom socket of your target system at the other. In use, you load your eprom software into the unit by using your eprom programmer exactly as if you were programming the eprom itself. This writes the program data into the ram contained in the Ram-Blow unit. Provision is made for this programming operation to hold the target system RESET line active to prevent any execution of unstable code until complete.

When loaded, the code can be run by the target system as if it contained an eprom with identical data. This provides a convenient method of shortening the design cycle by removing the need to erase eproms ready for a minor modification. Also, the patching facilities offered by most eprom programmers, whereby small blocks of eprom data can be edited and reprogrammed, can be used to achieve immediate replacement of faulty data without any erase operation.

The unit is quite easy to use, although in order to cover the wide variety of eprom types and sizes available it has a number of configuration links that need to be set correctly. It appeared to be no problem to insert the target connector into the socket of a 2764-type eprom and to "program" the unit via its programmer connector as if it were a 2764 device. An advantage here is that the user can easily select the fastest programming algorithm available on the programmer, since the data is only being loaded into ram and thus does not need to wait for each eprom byte.

The target connector has an addi-

Basic cost: £299

Other items: Free support for one month from date of purchase. A 4K trace breakpoint card should be available now.

tional write line which can be connected when emulating ram devices, or left unconnected for eproms. This allows the device to be used for investigating target-system ram devices where a satisfactory program may already exist in eprom but where it is necessary to examine the data contained within a ram device on the target micro processor. Using this mode it is easy to alter this data and observe the target effects.

This device is definitely an engineering tool since it is quite delicate, with its twin ribbon cables and DIP plugs, but handled carefully it should provide a very worthwhile reduction in the design cycle of a microprocessor target system.

Supplier:
Flash Designs,
St Andrews House,
PO Box 167,
Crawley,
W. Sussex RH11 9YE.
Tel: 0293 551229

Is a conclusion possible?

Probably only in very general terms. This review illustrates that there are at least several ways to approach the problem of programming devices. To some extent the problems do diminish as one spends more money, although this would appear to be at best logarithmic. Remember that many companies are sufficiently convinced of the qualities of their products to be prepared to offer equipment on a trial basis, or to offer a thorough demonstration to enable any incompatibilities to be discovered quickly. This is often a good indication of how popular the equipment is, too.

To make this work it is also wise to remember to tell a prospective supplier everything about the work situation and the devices with which the equipment will be used. In the end much will depend on your exact situation, but remember also that both logic and memory devices are evolving very rapidly and that the next piece of programming equipment that you purchase to program them will most certainly not be the last.

Speed summary

A summary of the complete erase (where necessary), blank-check, programming and verify times for an eprom and a PLD device on each item of reviewed equipment.

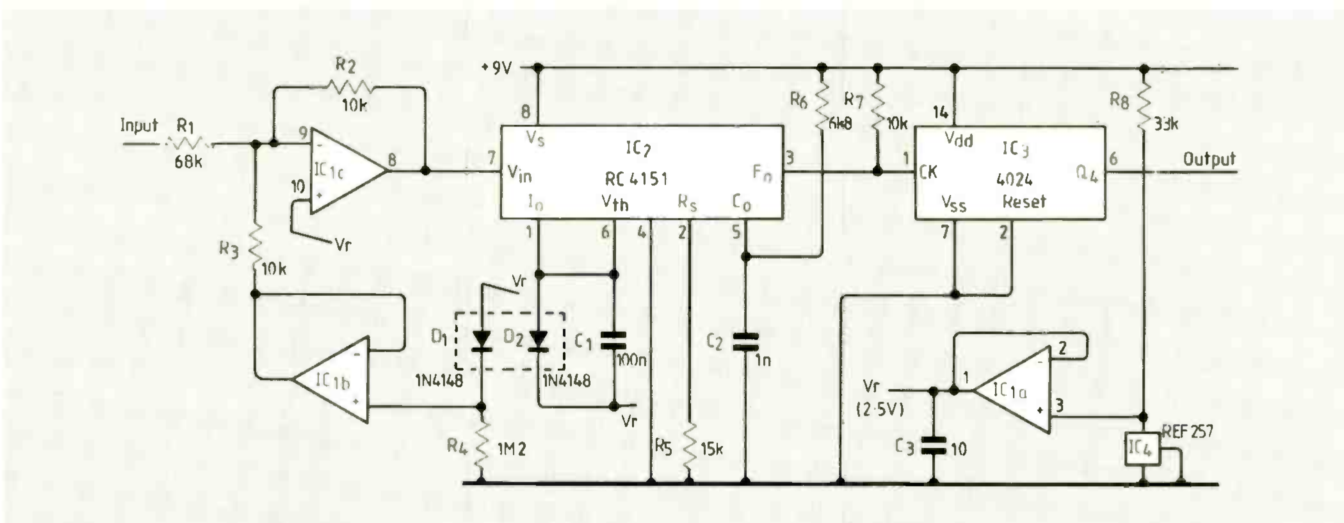
PLD	27C256 eprom	16V8
Stag Universal Programmer	90s	1s
Sunshine Expro-40	40s	6.5s
MQP 200 eprom programmer	60s	—
MPE PowerLogic Development System	—	—

Logarithmic tone generator

This circuit produces an audio tone which varies roughly logarithmically with input voltage. With the values shown, an input change of 0–1V negative with respect to the 2.5V reference V_r increases frequency from 120Hz to 3.2kHz.

Voltage-to-frequency converter IC_2 tries to keep the voltage at pin 6 equal to that on pin 7 by delivering current pulses, at pin 1; pulse length is set by R_6, C_2 and amplitude by R_5. Capacitor C_1 integrates the pulses, the resulting current flowing through D_2 to give the logarithmic characteristic. Low-level pulses at the open-collector output pin 3, at the same frequency as the current pulses are converted to a square wave and reduced in frequency by IC_3. Diode D_1, R_4 and IC_{1b} determine the frequency output for zero input. The two diodes should be in close thermal contact.

Andrew Chadwick
Hull
North Humberside



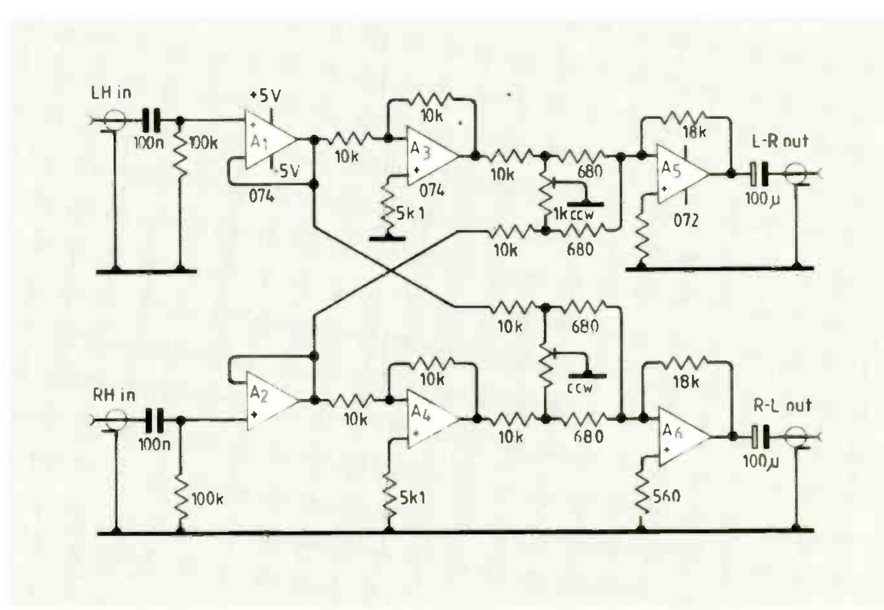
Stereo expander

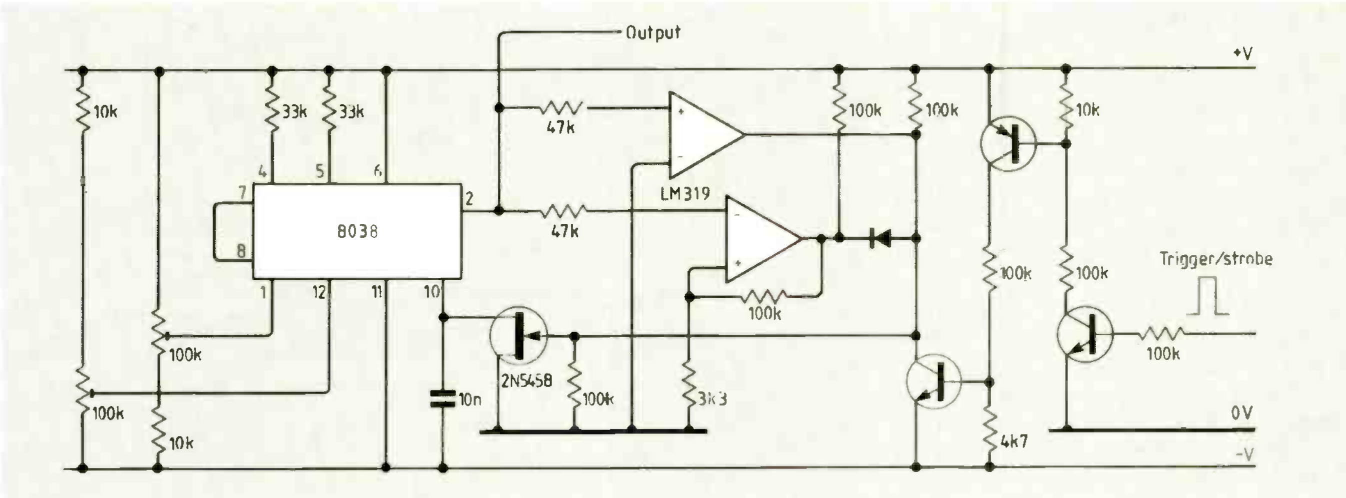
This produces a sum-and-difference output: the original signal and an anti-phase one.

Op-amps A_1 and A_2 buffer the right and left channel inputs, while A_3 and A_4 invert the two signals. Constant-amplitude summing networks mix in-phase and anti-phase channels prior to the gain stages A_5 and A_6, which compensate for signal loss in mixing. The two potentiometers are ganged to give a mono-nulling point at mid-travel. Overall gain of the circuit is unity.

Good results are obtained with a standard audio system and the circuit is useful as a driver for an extra amplifier to produce a four-speaker arrangement.

John Paul
Hyson Green
Nottingham





Single-cycle sinewave/burst generator

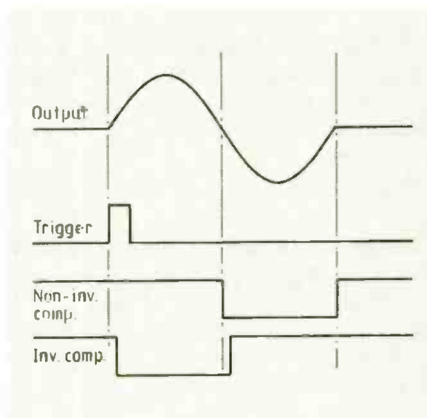
An alternative to the single-cycle sine generator by Barnett (September. 1989 Circuit ideas) is based on an Intersil Application Note and is more economical.

Comparators at the output of the 8038 function generator provide inverted and non-inverted square waves which change state at the zero crossing points; hysteresis in the inverting one provides a small delay.

At rest, both comparators are high and the fet clamps pin 10 of the 8038, and therefore its output, at 0V. A short trigger pulse cuts the fet off and the capacitor begins to charge. The output starts a positive-going excursion, the inverting comparator keeping the fet off. At the first zero crossing, the non-inverting comparator goes low, still keeping the fet off, until at the end of the cycle both comparators go high, the fet coming into conduction again and ending the sequence.

A trigger pulse longer than a number of periods of the sinusoid produces a burst of pulses.

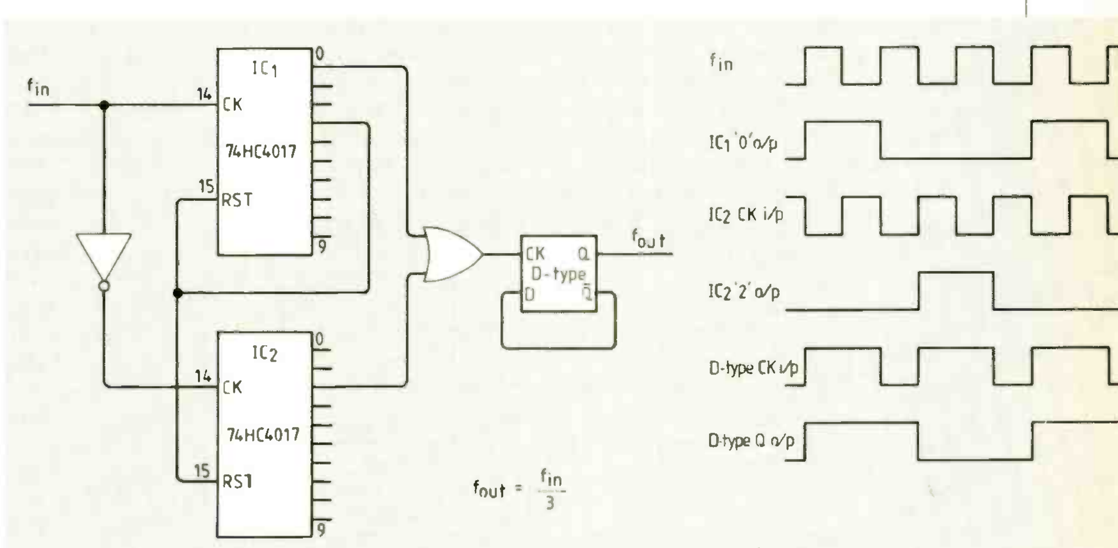
D. M. Bridgen
Racal-Tacticom
Reading
Berkshire



Divide-by three with 1:1 M/S ratio

Two decade counters are used in divide-by-three configuration, their outputs being in anti-phase. Their outputs are Or-ed and divided by two in a D-type latch, whose output $f_in/3$ and is a square wave.

Mark Watson
Roath
Cardiff



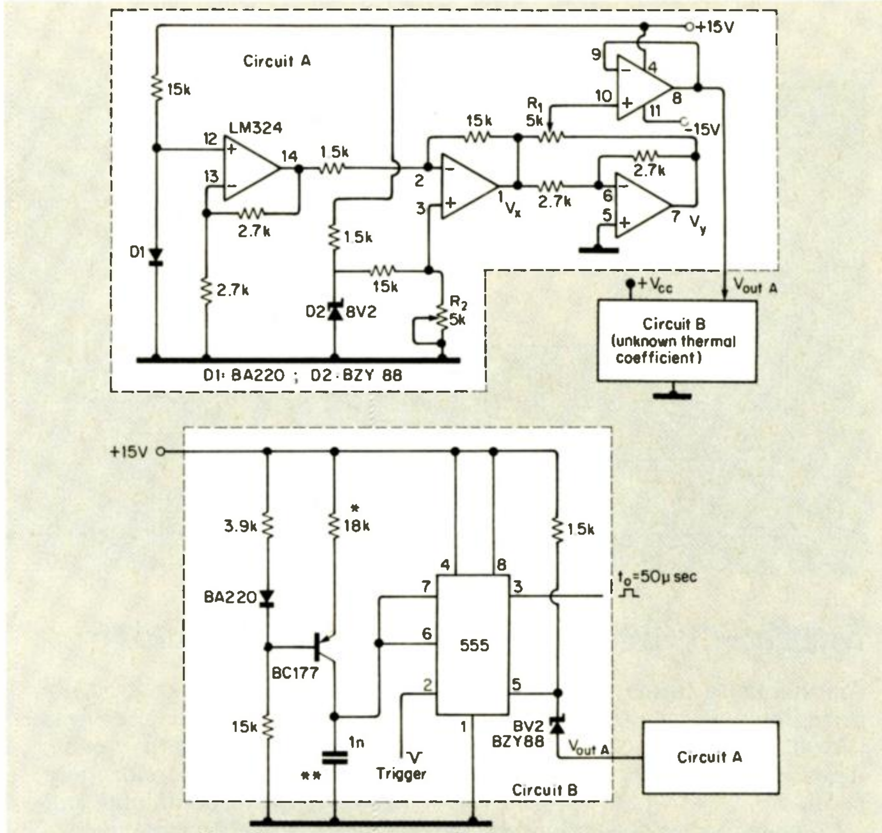
Versatile thermal compensation

This circuit (**Fig. 1**) provides accurate thermal compensation regardless of the temperature coefficients of the components, which must have a constant variation with temperature of less than a known value. Diode D_1 is the sensing element and must be mounted near the circuit to be controlled (B).

Adjustment is as follows. At room temperature, trim R_1 until $V_x = V_y \approx 0$; measure the parameter of interest in circuit B; warm up the whole circuit to a temperature, of 70° to 80° and trim R_2 until the previous value in B is obtained. In this way, compensation obtains over a wide temperature range.

With R_2 at full scale, sensitivity is at least 30mV/°C, of either polarity. Setting R_2 at mid-range zeros sensitivity. $|V_{outA}|$ is less than 14mV at room temperature. **Figure 2** shows a monostable under control, the value of interest being the pulse duration.

Alexandru Ciubotaru
Galati
Romania.

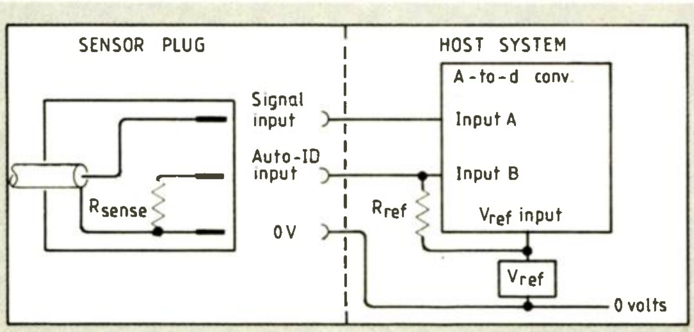


* Metal film type ; ** Polystyrene film type

Self-ID for plugs and sensors

When different sensors, leads or accessories are to be plugged into a measurement or control system it can be desirable for the system to know precisely what type of device has been connected. This is particularly the case with computer interfaces or data loggers, for example, because if the system knows exactly what type of device has been connected it can automatically adjust its input or output parameters accordingly and even load the relevant program for processing, displaying or controlling that particular device or accessory. Previous self identifying systems have used multi-way connectors with pins held high or low to produce a unique code for the device being connected and others have used serial data streams for more complex identification.

The system described here, like many ideas, is the novel adaptation of a simple principle applied to solving a problem. The principle is that a resistor (R_{sense}) is connected between 0V and a single terminal of the connector of the device or accessory being used to form one half of a potential divider, the other half being a fixed value reference resistor (R_{ref}) inside the host equipment which is connected to the ADC's voltage reference (V_{ref}). The junction of these two resistors is the auto-ID terminal, and this is applied to the input of an analogue to digital converter in the host. The voltage measured by the ADC at the auto-ID terminal is proportional to the ratio of the fixed internal reference and resistor and the resistor in the auto-ID connector.



Therefore a very simple and inexpensive identification system can be achieved using just a cheap resistor and one terminal of the connector, so in the simplest system the device's connector could simply be a three-pin connector for 0V, signal and auto-ID.

The number of different identities possible is limited only by the resolution and accuracy of the ADC and the tolerance of the resistors being used. In practice other considerations, such as noise, should be taken into account but it is quite easy to achieve over 100 different IDs if a 10-bit ADC and 1% resistors are used. If an A-D converter is already being employed in the project then it is a simple matter to utilise unused channel(s) or use an analogue multiplexer to obtain the required number of auto-ID inputs.

David Palmer
DCP Microdevelopments
Cambridge

The George Washington University
WASHINGTON DC

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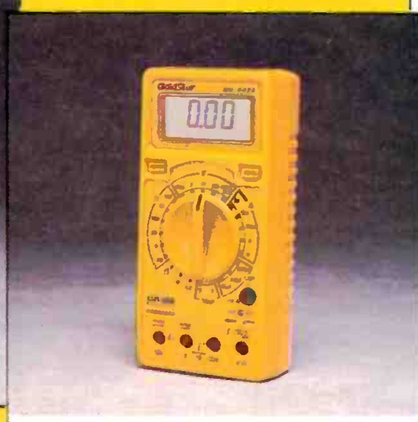

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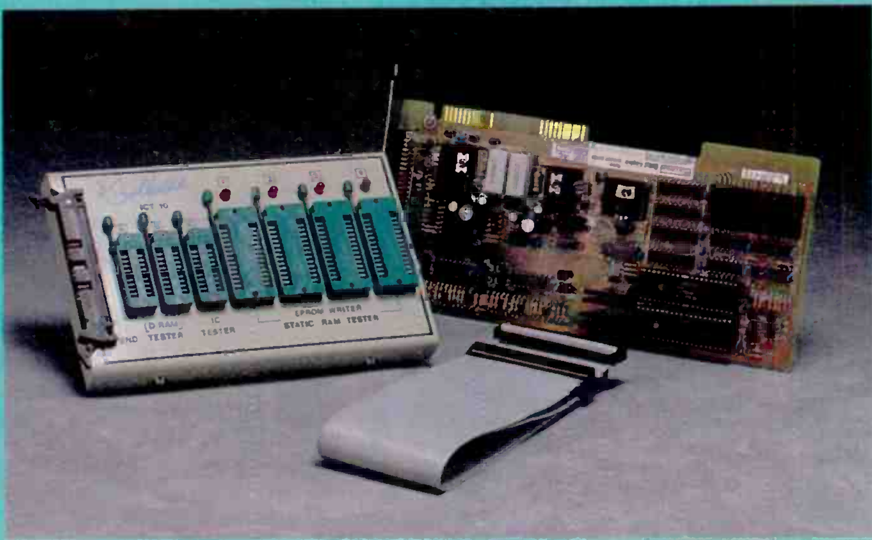

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AUDIO PREAMPLIFIER DESIGN

In the concluding article in his short series on preamplifier design, John Linsley Hood examines gain control techniques, input switching arrangements and power supplies.

In the first part of this article, I observed that the main functions of a preamplifier were to select a required input signal; to amplify it and lower the source impedance, if necessary; to adjust it to the level needed; and to modify its gain/frequency characteristics as required by the characteristics or shortcomings of the input signal.

Gain controls

Unfortunately, even the simplest of these functions, that of adjusting the signal level to the value desired by the listener — a task which might seem to need only a simple potentiometer circuit of the kind shown in **Fig. 1(a)** — conceals a whole range of problems, of which the most obvious are those indicated in **Fig. 1(b)**.

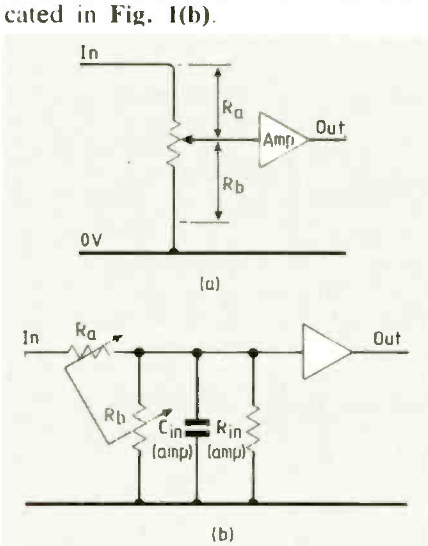


Fig. 1. Simple volume control at (a) carries the problems of stray capacitance and varying input impedance.

These are that, if the succeeding stages present any significant load capacitance, which may quite often be added deliberately because of circuit requirements, the combined effect of this capacitance and the resistances from the top and bottom of the track of the potentiometer to the slider (R_a and R_b) cause a loss of high-frequency signal components which vary according to the slider position. Similarly, unless the amplifier input impedance is very high, the impedance presented by the gain-control circuit to its input signal will also vary as a function of the gain-control setting.

These problems can be substantially reduced if the value of the potentiometer is low enough, but this conflicts with the frequent requirement that the system should offer a very high input impedance to its signal source, so as not to alter the output characteristics of this source.

Inevitably, this has meant that the resistance values chosen for the gain control potentiometer must involve some measure of compromise between a high value, which will suffer from some frequency-response and input-impedance variation as a function of its setting, and a low value which may impose an inconveniently high load on the signal source.

With the improvement in performance and the reduction in cost of IC op-amps, it is now becoming more common for manufacturers to interpose an IC buffer stage between the signal source and the gain control, as shown in **Fig. 2**, so that it can have a low value, typically 1kΩ to 10kΩ, without input-circuit loading.

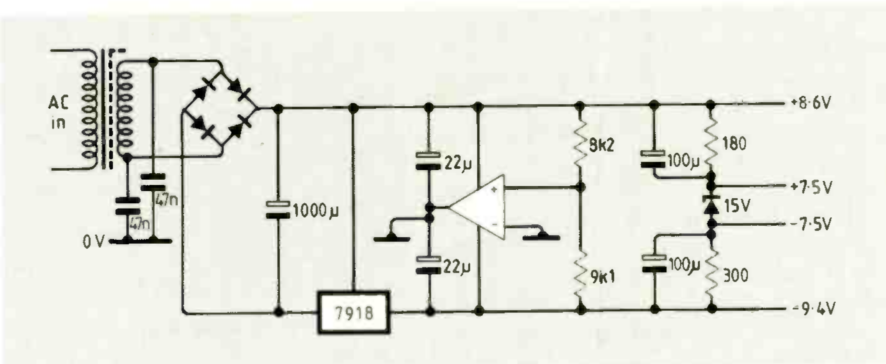


Fig 14. Stabilised power supply for Quad preamplifier.

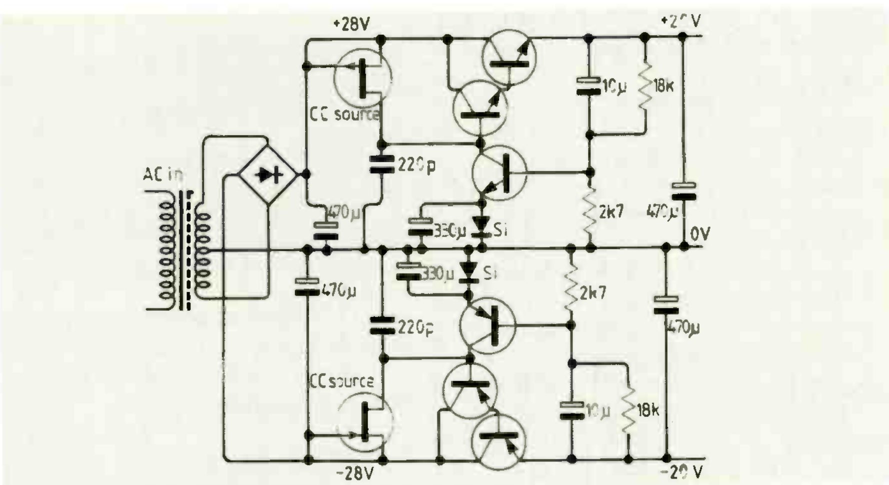


Fig. 15. Discrete-component stabilised PSU for Pioneer preamplifier (similar type used by Marantz).

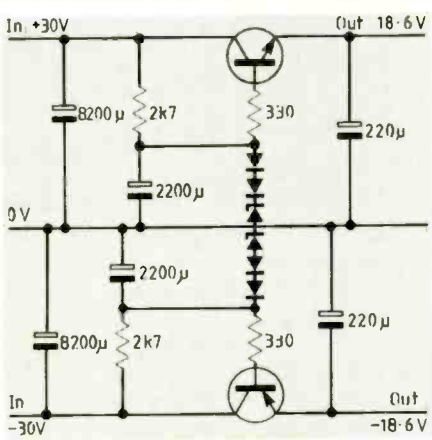


Fig. 16. Zener-referenced PSU by Rotel.

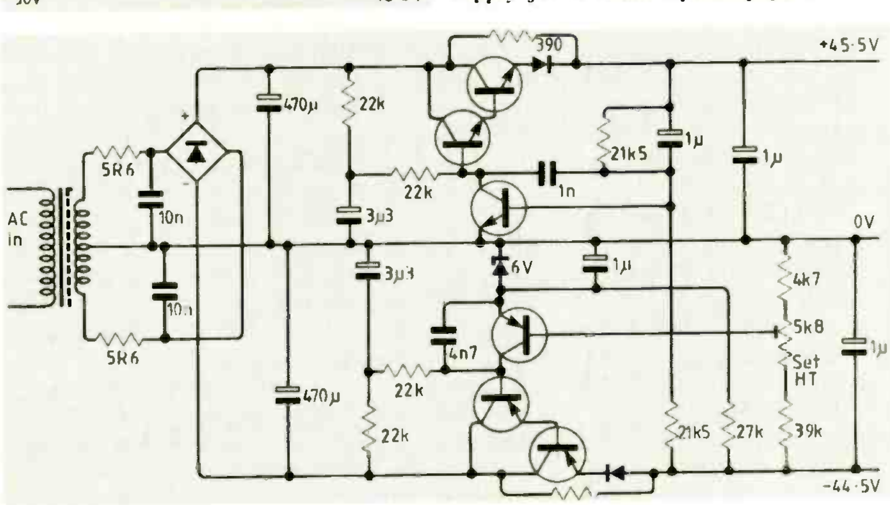


Fig. 17. High-voltage stabilised DC supply for Technics preamplifier.

OP27/37, the NE5534, or the LM833 are of the order of 100dB or more and many of the advanced designs for discrete-component gain blocks are similar in this respect.

However, either because of the wish to operate from higher input voltages than the 35V of the typical three-terminal IC voltage regulator, or for a wish to retain in-house circuit technology, several manufacturers still use discrete-component regulator arrangements, those by Quad, Pioneer, Rotel and Technics being illustrated in **Figs 14-17.**

The claimed advantages of large output reservoir capacitors, coupled with the simple transformer-diode DC supply systems so favoured by the "subjective sound" fraternity in power amplifier application, have made little headway in preamplifier design, in the face of the demonstrably better performance of circuitry operated from smooth, stable, regulated DC supply lines.

Miscellaneous

The last major area in which preamplifier design has evolved since the early days of transistor circuitry concerns the provision of extensive ancillary facilities, such as the visual display of the control options selected: e.g, input channel, tape input or output, subsonic filter, loudness compensation, signal-line muting, tone controls, or mono/stereo blending. Separate input/output channels are provided to allow, for example, one progamme to be recorded while listening to another. Some of these additional facilities can be genuinely useful, but many of them, one suspects, are present merely as part of the "specmanship" deployed to influence the undecided buyer.

Facilities for enhancing stereo image width, though technically feasible, are seldom offered commercially; the various four-channel or surround-sound techniques are now entirely ignored in commercial equipment. This is, presumably, a commentary on the reluctance of the man in the street (or, more likely, his wife) to give house room to more than two loudspeakers.

There has been a slow growth of input and output digital conversion facilities, intended particularly to accommodate direct digital inputs from CD players, on which digitally encoded (RF) outputs are becoming increasingly common. There have also been some promises, though relatively little hardware, of optical-fibre links for these signals, which offer the possibility a long, noise-free life expectancy and a degree of accuracy and channel balance as high as the maker chooses to provide.

As an alternative to the use of a logarithmically graded switched resistor, a resistive transmission line can be used, as adopted by the author for the input circuit of a test instrument[4], shown in **Fig. 6(b).**

Inevitably, the existence of this need for high-quality and high-accuracy ganged log.-law potentiometers has led to the appearance of Japanese components at a price which makes the other alternatives less than cost-effective.

Input switching

There is a growing, and welcome, tendency for audio power amplifiers to give their full output at an input level of 0.774V RMS (0VU), equivalent to 1mW in a 600Ω load. Similarly, there is an increasing consensus among the suppliers of ancillary units, with the notable exception of CD players where a 2V RMS nominal output has been adopted as the standard, that the output signal level from these units should also be of the order of 0.77V RMS.

The practical advantages of handling signals at this level are that the signal-noise ratio of the signal is unlikely to be degraded by the power amplifier, and that mains hum and breakthrough from one input signal source to another through stray capacitance coupling are unlikely to be significant at source impedances of less than 10kΩ.

For this reason, it has now become almost universal practice to separate the moving-magnet or moving-coil pick-up inputs from the other, higher-level signals and to amplify them separately before the input switching stage, as shown in **Fig. 7(a).** In the classic Dinsdale[5] and Bailey[6] preamplifier designs, all the inputs were handled at their own level, with the input stage gain adjusted by the selector switch, as in **Fig. 7(b)**.

However, the need to be able to select inputs connected to the rear of the chassis by means of switching at the front panel can still mean inconveniently long lengths of screened lead between most of the input sockets and the amplifier boards, which can lead to major layout problems in integrated amplifiers with both power and preamplifier stages in the same housing.

An additional problem with simple sliding-contact rotary or push-button switches of the conventional type is that the mating contact pairs can become mechanically distorted with use, or corroded with time and cause intermittent or noisy operation.

These problems have led to much exploration of the possibilities of remote switching, in which only the control signals would be handled by the front-panel selector switch. Such switching could be by means of junction transistors, fets or mosfets, electromechanical relays or, increasingly in modern designs, by special-purpose channel-switching ICs.

Mechanically, the simplest of these remote control options is the relay type, as shown in **Fig. 8.** This is likely to be entirely satisfactory, provided that the quality of the contacts is good and that hum and switching clicks are not introduced by the coil energising voltages — a requirement which would normally restrict this option to fairly high-level signals.

Provided that the input signal is derived from a moderately low-impedance 0V referenced source, the simple small-signal bipolar switching arrangement shown in **Fig. 9** is capable of surprisingly good performance, with off-state attenuation ratios of 80dB or better, and an on-state THD of less than 0.005% at 1V RMS. Design constraints are that the turn-off voltage applied to Tr_1 base cannot exceed some 5VDC without causing the base-emitter junction to conduct as a zener diode, which will inject carriers into the normally open-circuit base-collector junction and cause partial turn-on in a very noisy manner!

This limit on negative base voltage implies, in turn, that the maximum permissible input signal voltage swing must not be so large that the collector potential ever becomes lower than that on the base. Nevertheless, within these constraints, this system is effective and straightforward, and better in performance than the shunt-connected fet switch shown in **Fig.10.**

This has the same kind of constraints that apply to its bipolar transistor equivalent, complicated by the fact that the on resistance of the fet is higher than that of the bipolar device, so that

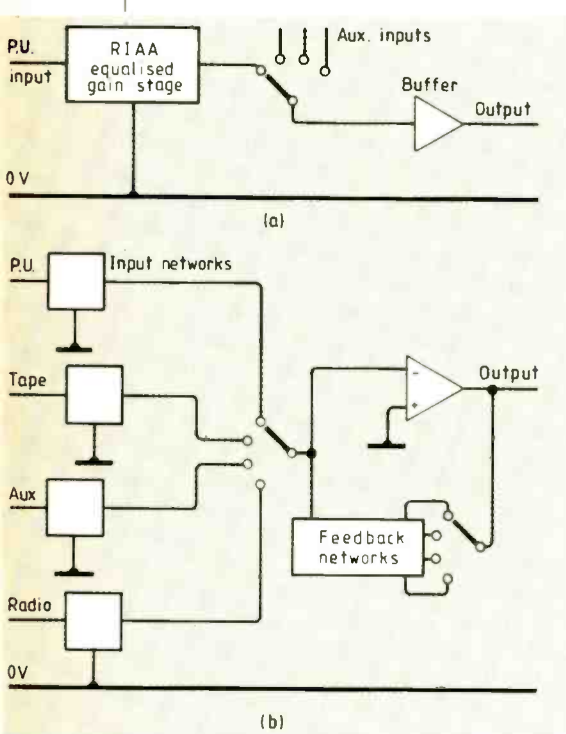


Fig 7. Contemporary practice is to separate low-level from high-level inputs to preamplifier, as at (a). Earlier method was to provide a separate input arrangement for each input (b).

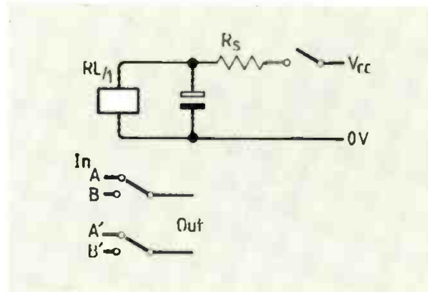


Fig. 8. Simple relay input selector, most suitable for high-level inputs which are not affected by switching transients and hum.

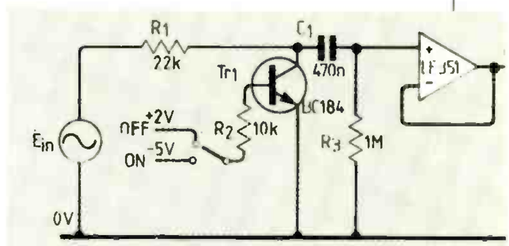


Fig. 9. Small-signal bipolar transistor switch, shunt connected, for low-impedance sources, which can offer THD of less than 0.005%.

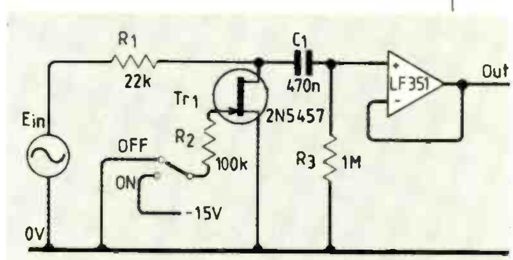


Fig. 10. Shunt connected fet switch, which exhibits higher on resistance and provides less attenuation. Distortion occurs at lower input levels.

attenuation ratios of only around 60dB are typical. Also, the negative gate voltage cut-off of the fet is less abrupt, so that the onset of distortion will occur at rather lower input-signal levels.

Both of these shunt-connected switches will operate with very little disturbance of the zero-signal DC level and should therefore be unobtrusive and click-free in operation.

The series-connected junction fet switch shown in **Fig. 11** is usable. For low distortion, however, it needs a series resistor R_1 to lessen the effects of the change in conducting resistance as a function of instantaneous signal voltage level. This resistor also ensures that the succeeding stage operates in a low-impedance input (virtual earth) configuration, so that there is some fixed potential for the source as a reference for the applied gate voltage. An example of this type of application is the "noise blanker" circuit of my modular preamplifier[7].

Mosfets are also fully usable in both the shunt and series connection and the latter has been exploited commercially to provide a wide range of IC multi-pole mosfet switches intended for remote switching applications such as the CD4051, the LF13509, and the LF13508.

While these devices can also be used for audio, provided that the signal levels are not too large and that the signal DC level is kept well within the span of the IC supply rails, there are now some very low-distortion c-mos analogue switches, such as the National Semiconductors LM1037 and LM1038 and similar devices from other manufacturers. These are designed for audio use, offering very high inter-channel isolation and very little switching or other noise intrusions. They have become very widely used for signal channel selection in current designs from most of the major manufacturers, particularly where on-board microprocessors are used to control the switching functions and where the low input power to the switching devices is particularly advantageous.

Power supplies

In early audio designs, great care was taken progressively to decouple the DC supply line from which the various parts of the preamplifier circuitry were powered, using one or other of the layouts shown in **Fig. 12.** It was common practice to feed the amplifying devices, for both stereo signal channels, from the same point on the decoupled supply – mainly to avoid possible LF instability (motorboating) rather than to optimise LF channel separation.

With the advent of low-cost IC voltage-stabiliser devices, the provision of low-voltage DC supplies to preamplifier modules has been greatly simplified, and most amateur designs rely on IC regulator devices of this kind.

A typical "no-compromise" amateur power supply layout is shown in **Fig. 13,** in which an additional RC decoupling circuit of the kind shown in Fig. 12(b) is sometimes used on the output of each individual regulator IC. This use of a multiplicity of regulator ICs or additional output decoupling indicates little faith either in the claimed 0.2Ω output impedance of the regulator IC over the 10Hz-10kHz frequency range (above this frequency, a 100μF parallel capacitor can take over) or in the supply-line signal rejection of the amplifier itself.

The rejection ratios of typical high-quality op-amp gain blocks, such as the

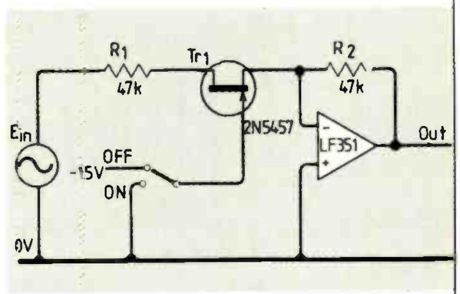


Fig. 11. Series-connected fet switch, which needs virtual-earth succeeding stage.

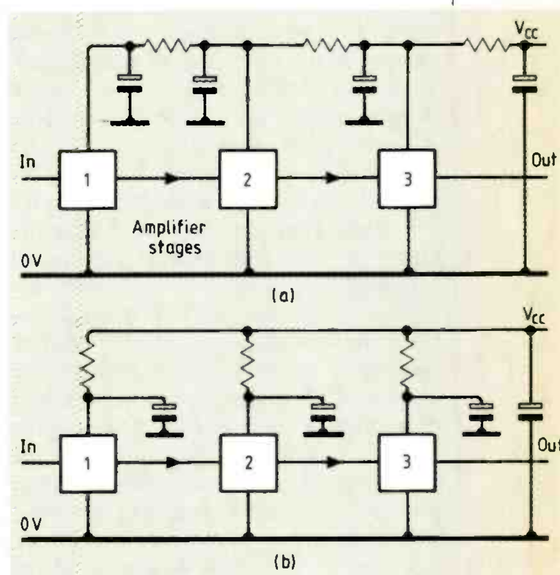
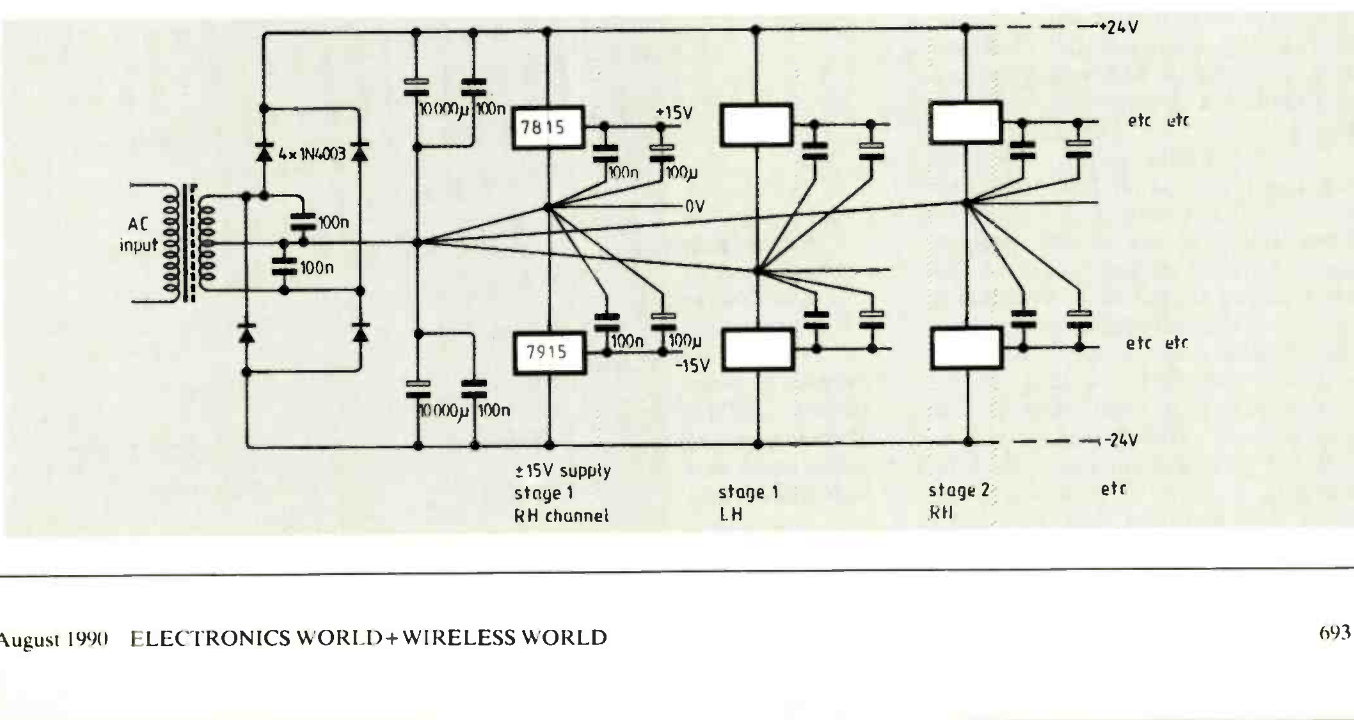


Fig. 12. Earlier methods of supply-line decoupling to avoid LF instability.

Fig. 13. Typical amateur power supply, the use of separate regulators and decoupling taking advantage of capabilities of either ICs or amplifier itself.



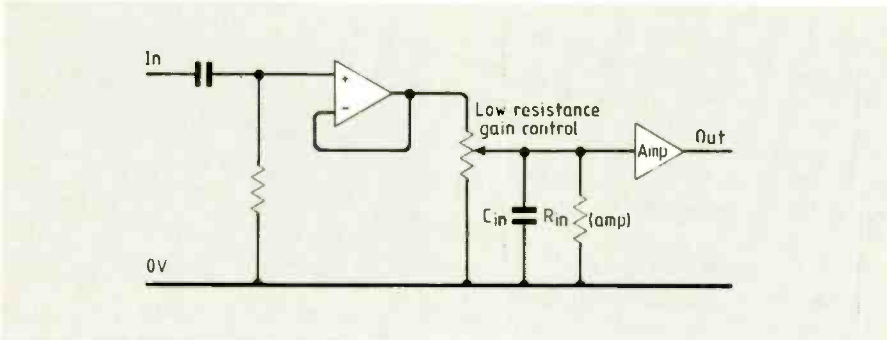


Fig. 2. Buffer stage eliminates effect of variable impedance and allows use of low-value control.

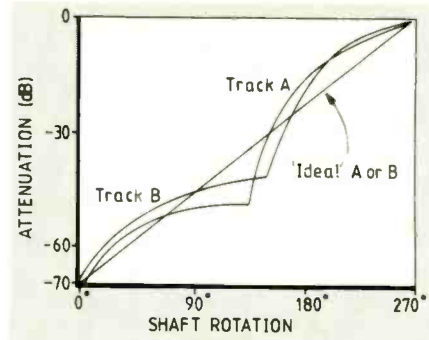


Fig. 3. Ideal logarithmic gain-control response and that given by ganged controls in a stereo system, which may not be well matched.

There are many other practical problems in the adjustment of signal level, such as the non-ideal signal:background-noise ratio and overload characteristics, inherent in a simple input potentiometer gain control. Various alternatives were examined by Baxandall[1], but the most noticeable effect to the lay user is the tendency for the image position in stereo systems to shift as the gain-control setting is adjusted.

This arises because of the relative difficulty of making accurately graded, non-linear potentiometer tracks. In gain controls, these are generally of a "logarithmic" characteristic, having the ideal form shown in **Fig. 3** to avoid the shortcoming, in a gain potentiometer with a linear track resistance, that most of the effective gain adjustment would take place during the first part of the rotation. However, when two such log. potentiometers are ganged on a common control spindle, any errors in matching the track resistances will cause the output signal level to vary between channels.

Baxandall[2] has shown some of the alternatives, based on linear-law potentiometers, which give better track-to-track matching. One of the alternatives proposed by Baxandall and adopted by Self[3] in his 1983 preamplifier design is to use a combination of input attenuation and adjustable negative feedback, as shown in **Fig. 4,** which gives the type of attenuation characteristic shown in **Fig. 5.**

Of the simple passive systems examined by Baxandall, the best though still not perfect characteristics were offered by the use of potentiometers having a tapped track. Unfortunately, these are not easily obtainable, so some of the more perfectionist audio manufacturers use ganged multi-pole switches, with up to 24 ways. In the current series of Quad designs, the mechanical multi-pole switch is replaced by c-mos analogue switching wired to a string of resistors in the manner shown in **Fig. 6(a).** This offers

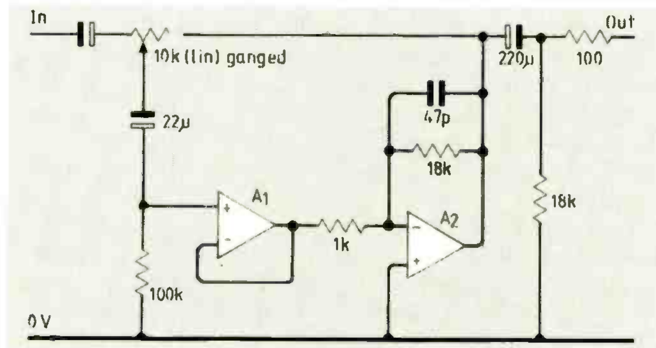


Fig. 4. Active gain control by Baxandall, which uses a combination of input attenuation and feedback.

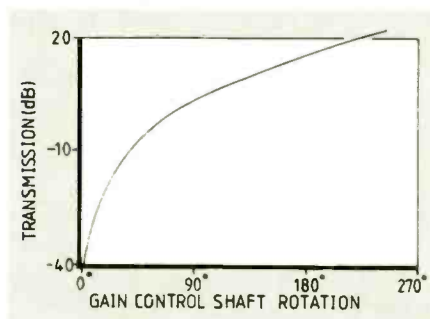


Fig. 5. Characteristic of circuit of Fig. 5, using linear potentiometers.

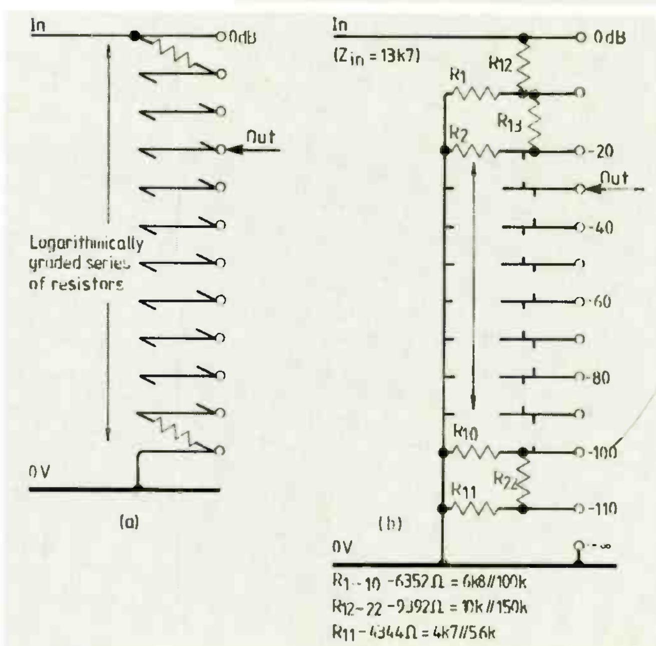


Fig. 6. Log.-law switched gain control used by Quad (a), in which graded resistors are switched by c-mos elements. At (b) is alternative type by author which uses non-graded resistor values.

of interconnections that are free of degradation and hum over substantial distances, both between CD inputs and the preamplifier and between the preamplifier and remotely positioned power amplifiers.

There seems also to be very little progress in equipping preamplifiers with infrared remote-control facilities, though these are now commonplace in television sets, video recorders, and CD players.

Acknowledgements

I would like to thank the importers and distributors of Marantz, Pioneer, Technics, Rotel, and Hitachi audio equipment for their kindness in supplying me with technical information on their recent models, which have been of great assistance in the preparation of both this and the preceding series of articles on audio power amplifiers. I would also particularly like to record my gratitude to the Acoustical Manufacturing Company (Quad), who have been very generous with their technical literature and circuit details. ■

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BOOK REVIEW

Power Control Circuits Manual by R.M. Marston, is a practical book in the Newnes Circuits Manual series. The first chapter on basaic principles of electronic power control is followed by a further seven which present an enormous range of circuits (with component values) for AC and DC power and motor control using switch and relay circuits or semiconductors. For the purpose of this book, audio amplifiers are considered as power control circuits and are therefore included, as are power supplies.

No mathematics are used, the strength of the book residing in its practicality. It is intended more for the experimenter and early student than the designer and forms a useful collection of ready-made and tested circuits for instant use or modification. Heinemann Newnes, 198 pages, card back, £12.95.

INTERFACING WITH C

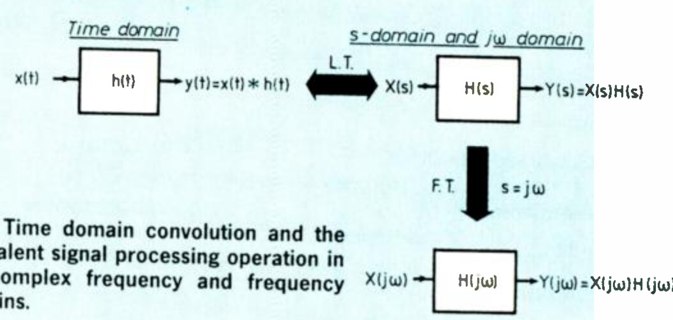
PART 5

Convolution is not an easy concept to visualise, but it does provide an insight into the dynamic behaviour of linear systems. For a large number of terms, a computer program is needed and Howard Hutchings presents a numerical listing

Historically, signal processing in the time domain has been avoided and the equivalent operation carried out in the complex frequency domain. As electronics becomes increasingly digital, modern signal-processing methods compel engineers to revise traditional techniques and concentrate on discrete-time models of sampled-data systems and signals. This approach is particularly rewarding because it unifies the signal-processing operations in the time and frequency domains, in addition to providing extraordinary insight into the operation of computers as real-time control components.

Don't be discouraged or intimidated by the concept of a time or frequency domain model: these are simply alternative descriptions of a signal or linear processor viewed from a different perspective. A down-to-earth analogy may help you to develop a feel for the subject. Suppose you wish to retain for posterity your favourite recording of Captain Biro and the Fantastics playing "Heatwave". One way would be to record it on a tape deck and let the electronics capture the amplitudes and frequencies before modulating the signal into magnetic fields for storage on tape. But there is a completely different way.

Draw a musical scale and write down the notes of the complete score on paper. Admittedly, this doesn't tell you the amplitude but it does tell you something about the frequencies. A recording method that stores data as a function of time, such as the trace of an oscilloscope, is said to work in the time domain. Decomposing a signal into its



Time domain convolution and the equivalent signal processing operation in the complex frequency and frequency domains.

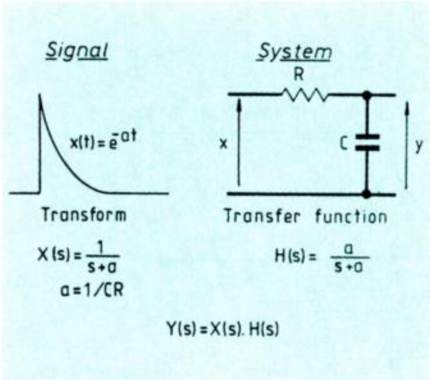


Fig. 4.2. Signal and system are matched in the sense that the system impulse response is identical to the characteristics of the signal.

constituent frequencies and recording the amount of energy present at each frequency produces a frequency domain model. If you had a spectrum analyser and oscilloscope you could routinely confirm the reality of each model. Despite the difference in domains, each is a valid representation of the system or signal. This chapter describes the operation of convolution and explains how it provides a time-domain description of the dynamic behaviour of both analogue and sampled data systems.

Consider, for example, the dynamic behaviour of a linear system described by a differential equation in the time domain. The Laplace transform converts the linear relationships described by the differential equation into algebraic expressions from which the transfer function may be derived. Regarding the Fourier transform as a degenerate form of the Laplace transform we may commute between domains and establish the frequency response of the system. Digitally, the dynamic behaviour of a sampled-data system is modelled by a train of weighted impulses in the time domain. The z-transform converts the delays into an algebraic equation from which the transfer function or difference equation can be derived. **Figure 4.1** shows time-domain convolution and the equivalent operations in frequency and complex-frequency domains.

Matching analogue signals and systems

There is no distinction between the Laplace transform of signals and systems. This is immediately apparent when you examine the effect of applying a decaying exponential signal to the first-order low-pass filter shown in **Fig. 4.2**. Initially, the signal processing will be completed in the complex-frequency domain.

Clearly, the processed output is simply the product of the transform of the signal and the transfer function of the system. This is the fundamental attraction of complex frequency-domain signal processing. It is important to realise that no such simple relationship exists in the time domain, where the equivalent operation is that of convolution, as the following contrasting examples illustrate. Initially consider signal processing in the complex-frequency domain:

$$Y(s)=X(s).H(s)$$

$$Y(s)=\frac{1/CR}{(s+1/CR)(s+1/CR)},$$

which can be written as

$$Y(s)=\frac{1/CR}{(s+1/CR)^2}.$$

To obtain the form of the time-domain response it is advantageous to use the frequency-shifting rule, together with a table of Laplace transform pairs, as shown in **Fig. 4.3**.

Frequency shifting rule

The previous part of this series demonstrated how a shift or delay of T seconds in the time domain gives rise to a multiplication by e^{-sT} in the complex-frequency domain. A similar pattern exists from the frequency-shifting rule. If s is replaced by (s+a) in each term of the transform, the effect corresponds to multiplication of the original time-domain signal by e^{-at}. **Figure 4.4** shows the effect of multiplying the ramp function f(t)=t, by the decaying exponential e^{-at}.

It may help to visualize the effect of the frequency-shifting rule in terms of the s-plane diagram in **Fig. 4.5**. The Laplace transform of the ramp function $f(t)=t \rightarrow 1/s^2$ results in a double pole at the origin. The frequency shifting rule has the effect of moving the poles to the left by 1/CR units.

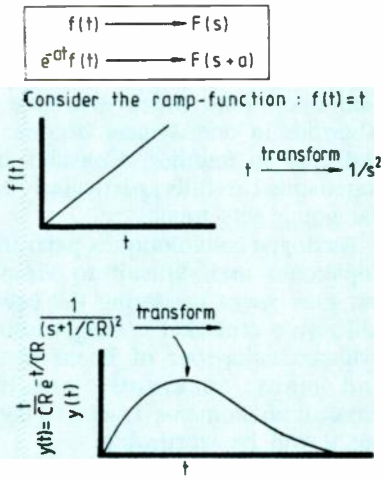


Fig. 4.4 To obtain the time-domain response, use the frequency shifting rule with a table of transform pairs.

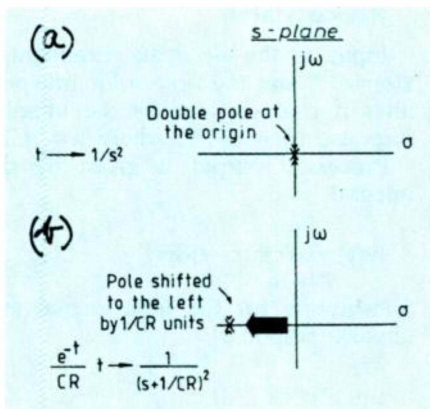


Fig. 4.5. The effect of the frequency shifting rule on the pole-zero diagrams corresponding to the signals (a) f(t)=t and (b) $f(t)=te^{-t/CR}$.

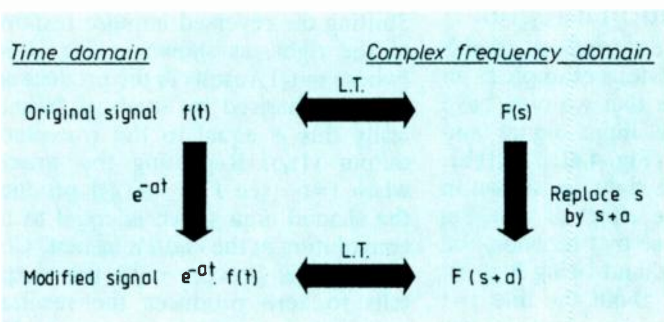


Fig. 4.3. Frequency shifting rule.

Convolution

Re-examine Fig. 4.1 – what does it represent? Obviously, the relationship between the input and output of a linear system – but from two different points of view. Certain facts which aren't apparent in one domain become obvious when viewed differently. Critical operations which are slow and laborious in one domain become fast and easy in another. Consider these statements carefully, particularly when the going gets tough.

Analogue convolution is particularly unpleasant and difficult to visualize, but time spent mastering the concept will give a remarkable insight into the dynamic behaviour of linear systems and many apparently unrelated physical phenomena. It won't be easy, but it will be worthwhile.

The convolution integral of two continuous functions x(t) and h(t) is defined by the integral relationship

$$x(t)*h(t)=\int_{-\infty}^{\infty}x(\tau)h(t-\tau)d\tau$$

$$=\int_{-\infty}^{\infty}h(\tau)x(t-\tau)d\tau$$

Despite the unappealing appearance of these expressions, they do represent the facts behind the figures. The operation of convolution is symbolised by an asterisk. Dummy variable τ symbolises excitation time and the real variable t response time. The mathematical scaffolding states: multiply the input signal $x(\tau)$ by the time-reversed impulse response $h(t-\tau)$ before integrating the product over all time. Applying the convolution integral to the signal and circuit shown in **Fig. 4.2** yields

$$y(t)=x(t)*h(\tau).$$

Input is the decaying exponential $x(t)=e^{-at}$ and the first-order low-pass filter is characterized by the impulse response $h(t)=ae^{-at}$, where $a=1/CR$.

Processed output is given by the integral

$$y(t)=\int_{-\infty}^{\infty}x(\tau)h(t-\tau)d\tau$$

Substituting for the input signal and impulse response,

$$a\int_{0}^{t}e^{-at}e^{-a(t-\tau)}d\tau$$

When simplifying, notice that $\exp(-t/CR)$ is a constant:

$$ae^{-at}\int_{0}^{t}e^{-a\tau}e^{a\tau}d\tau$$

Integrating between the limits 0 and t:

$$ae^{-at}[\tau]_{0}^{t}$$

Finally, the processed output is

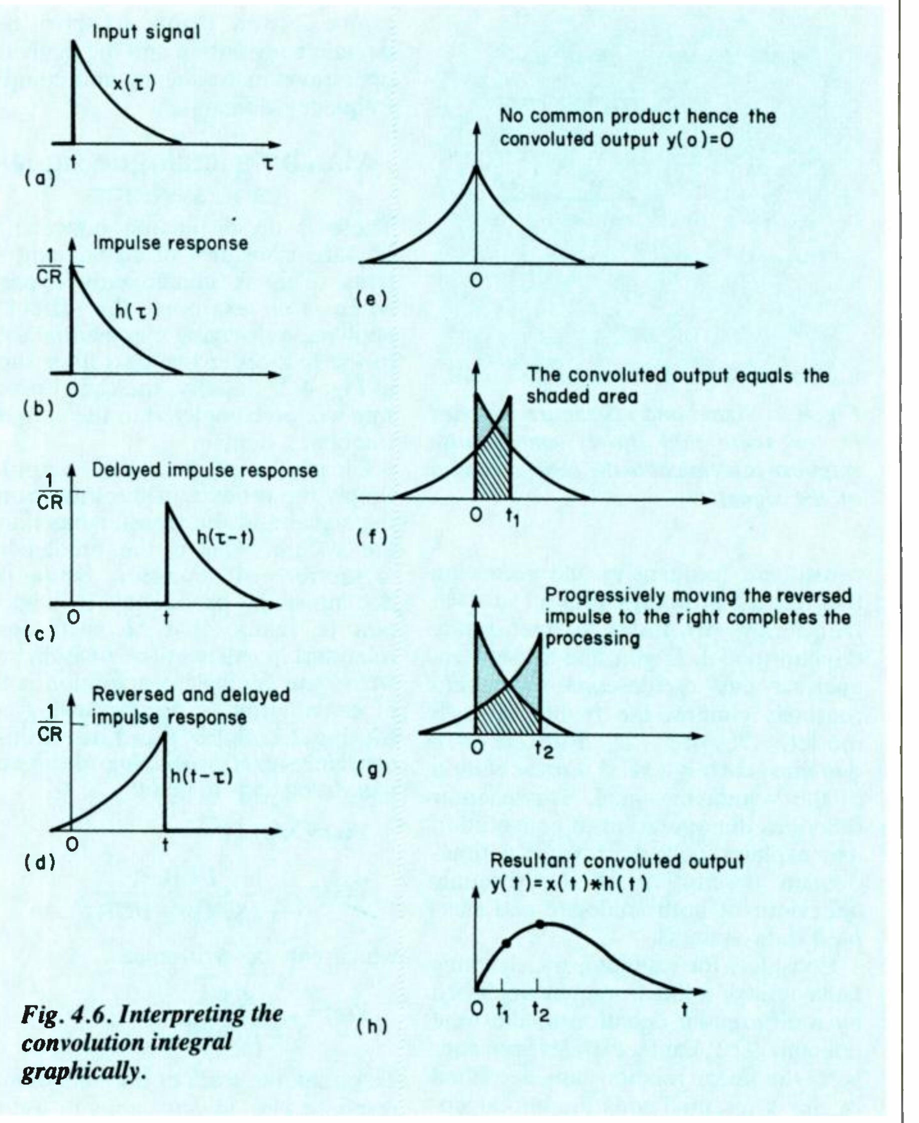


Fig. 4.6. Interpreting the convolution integral graphically.

$$y(t)=1(1-e^{-t/CR}).$$

Compare this result obtained by time-domain convolution with the equivalent operation carried out in the complex-frequency domain. Time-domain analysis makes Laplace transformation unnecessary, but the compromise replaces multiplication by integration.

Graphical interpretation of the convolution integral

Convolution may be carried out graphically. Using the previous example as an illustration, assume that we only have the graphs of the input signal and impulse response in **Fig. 4.6**(a) and (b). Shifting $h(\tau)$ to the right, as shown in Fig. 4.6(c), has the effect of delaying the impulse response by t seconds, the mathematical shorthand being $h(\tau-t)$. Folding this graph about the line $\tau=t$ will give the reversed impulse response $h(t-\tau)$, as indicated in Fig. 4.6(d).

The convolution integral commits us to integrating the product of $x(\tau)$ and $h(t-\tau)$ over the range of interest. Frequently, the signal is applied at $t=0$, making the lower limit zero. Geometrically, we may interpret this as meaning evaluate the area by multiplying and integrating the functions $x(\tau)$ and $h(t-\tau)$ for each value of t between the limits 0 and ∞. As illustrated in Fig. 4.6(e), where t equals zero, the two graphs do not overlap, so the product and convoluted output y(0) is zero. Shifting the reversed impulse response to the right, as shown in Fig. 4.6(f) (where $t=t_1$), results in the product and area emphasised by shading. Numerically this is equal to the convoluted output $y(t_1)$. Repeating this process when $t=t_2$ (see Fig. 4.6(g)) produces the shaded area which is equal to the convolution at the chosen instant. Continuing this process until the output falls to zero produces the resultant convoluted output as shown in Fig.

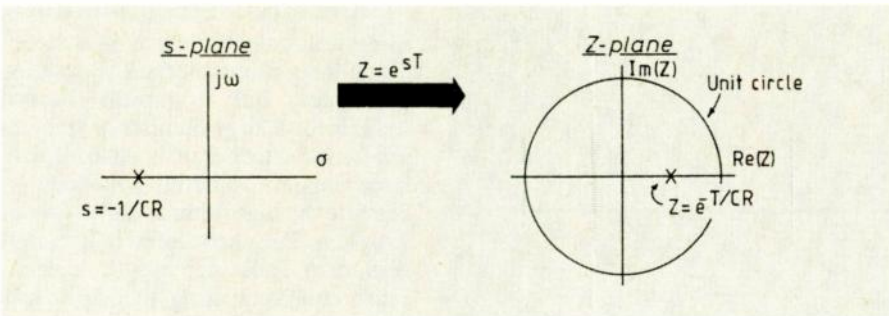


Fig. 4.7. A digital equivalent of the first-order low-pass filter can be derived from the pole position of the system impulse response.

4.6(h). To make the picture clearer it was convenient to draw the graphs with a change of scale; multiplying the area by 1/CR gives the precise output.

Obtaining the digital output recursively

Having reviewed convolution in terms of analogue signals, we will now turn our attention to the digital system equivalent of the first-order low-pass filter and sampled-data signal. Under the z-mapping, the system pole given by $s=-1/CR$ has been transformed from the left-hand stable region of the s-plane to a point on the positive real axis of the z-plane located inside the unit-circle, as shown in **Fig. 4.7**.

The transfer function of the digital system, derived from the z-plane pole, is

$$H(z)=\frac{1/CR}{z-\alpha}$$

where $\alpha=e^{-T/CR}$. To obtain the recurrence relationship from the transfer function, we must convert from transforms to sequences:

$$\frac{Y(z)}{X(z)}=\frac{1/CR}{z-\alpha}.$$

Cross-multiplying:

$$Y(z)(z-\alpha)=1/CR\ X(z).$$

As usual, interpret z as a unit advance, so the recurrence formula is given by:

$$y(n+1)=\alpha y(n)+1/CR\ x(n).$$

Expressed in terms of the current output:

$$y(n)=\alpha y(n-1)+1/CR\ x(n-1).$$

Digital feedback

Differential equations described the dynamic behaviour of continuous systems. Similarly, difference equations characterised digital systems. Because this system is realised recursively, the current output y(n) is the sum of weighted versions of the previous output y(n−1) and the previous input x(n−1). This is an example of a system with digital feedback; as with all feedback systems, care must be taken to ensure that it is stable and well-behaved.

A system that calculates the current output, using one or more previous outputs, is called recursive. Such systems occur when the transfer function has poles situated other than at the origin of the z-plane, as in **Fig. 4.7**. In an attempt to simplify the arithmetic, let the time-constant CR be 2.0 seconds and the sampling period T be 1.38 seconds. This gives the recurrence relationship in a neater form and ensures a DC gain of unity:

$$y(n)=0.5\ y(n-1)+0.5\ x(n-1),$$

the equivalent digital filter being shown in **Fig. 4.8**.

Employing the recurrence relationship in the advertised form, it is instructive to examine the shape of the processed output when the input signal is the decaying exponential $x(t)=e^{-0.5t}$ sampled every T seconds.

Table 4.1 shows a convenient method of representing the history of the input signal as it is processed by the filter. It is easy to keep track of the recurrence relationship by adopting a "backward arrow" notation, so that any carried-over results can be monitored as they ripple through the system.

sample number n	previous input x(n−1)	current input x(n)	previous output y(n−1)	current output y(n)
0	0	1.000	0	0
1	1.000	0.501	0	0.500
2	0.501	0.251	0.500	0.501
3	0.251	0.126	0.501	0.376
4	0.126	0.063	0.376	0.251
5	0.063	0.032	0.251	0.157
6	0.032	0.016	0.157	0.094
7	0.016	0.007	0.094	0.055
8	0.007	0.004	0.055	0.031
9	0.004	0	0.031	0.018
10	0	0	0.018	0.009

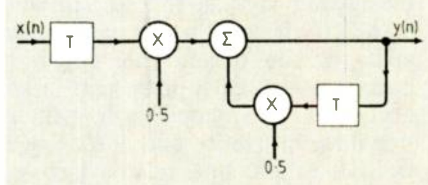


Fig. 4.8. System block diagram of the digital filter described by the recursive relationship y(n)=0.5y(n−1)+0.5x(n−1).

Obtaining the digital output by convolution

The sampled-data version of convolution only needs elementary arithmetic; an adequate toolkit is the ability to draw and understand a graph, to multiply in an ordered manner and finally to add the products.

This particular system can also be realised non-recursively by expressing the transfer function as a power series:

$$H(z)=\frac{1}{CR}(z^{-1}+\alpha z^{-2}+\alpha^2 z^{-3}+\alpha^3 z^{-4}\ldots.)$$

Using the discrete form of convolution confirms the results shown in Table 4.1. To evaluate y(n), the output of the filter after n conversions, a systematic approach is required.

Table 4.2. Convolution is the name given to the ordered combination of multiplication followed by summation.

t=0	t=T	t=2T	t=3T	t=4T	Response due to
x_0h_0	x_0h_1	x_0h_2	x_0h_3	x_0h_4	x_0
	x_1h_0	x_1h_1	x_1h_2	x_1h_3	x_1
		x_2h_0	x_2h_1	x_2h_2	x_2
			x_3h_0	x_3h_1	x_3
				x_4h_0	x_4

Column	Sum
1	$y_0=x_0h_0$
2	$y_1=x_0h_1+x_1h_0$
3	$y_2=x_0h_2+x_1h_1+x_2h_0$
4	$y_3=x_0h_3+x_1h_2+x_2h_1+x_3h_0$
5	$y_4=x_0h_4+x_1h_3+x_2h_2+x_3h_1+x_4h_0$

In **Table 4.2** the rows represent the responses to the input sequence x(0), x(1), x(2), x(3), x(4) respectively. The columns show the terms present at times t=0, t=T, t=2T, etc. and the response y(n) is simply the sum of the

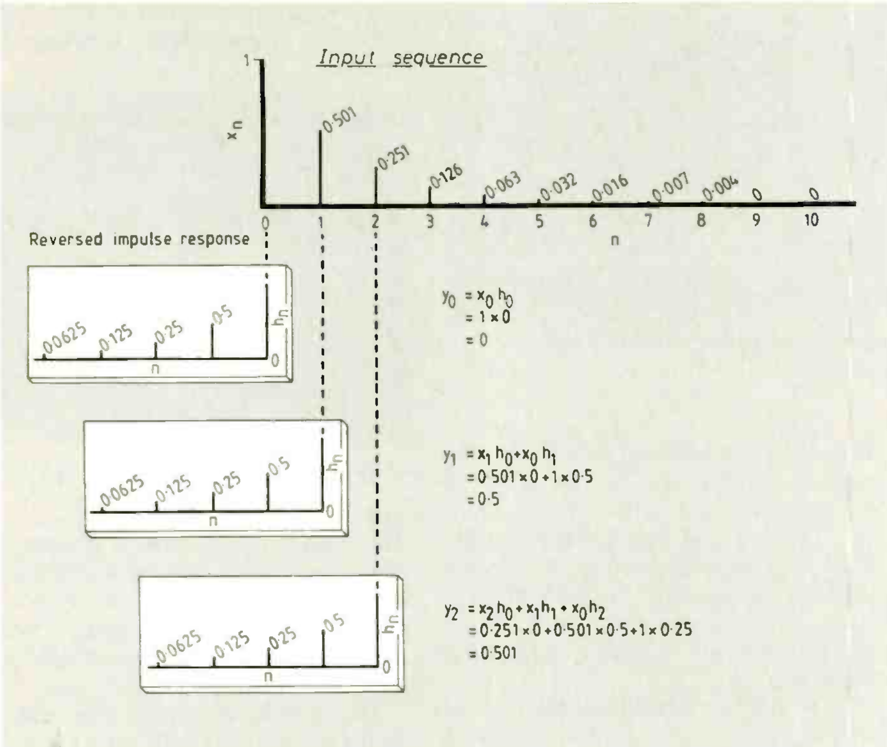


Fig. 4.9. Graphical convolution of the input signal x(n) and the impulse response h(n) is achieved by reversing the impulse response under the sample of current interest.

terms in the nth column.

Within this algebraic jungle exists a very simple pattern: to find the convoluted output, simply reverse the impulse response, aligning it so the h_0 and the sample of current interest x_n are coincident, the ordered weighted products then following automatically. The sum of the coincident cross products is the convolution of that sample and the impulse response of the system. This procedure should be repeated at each sampling instant by moving the impulse response to the right until none of the samples overlap, in the manner shown in **Fig. 4.9**. My results are

```
y(0)  =0
y(1)  =0·5
y(2)  =0.501
y(3)  =0.376
y(4)  =0.251
y(5)  =0.157
y(6)  =0.094
y(7)  =0.055
y(8)  =0.031
y(9)  =0.018
y(10)=0.009
```

Sophisticated applications

Time-domain convolution is a fundamental operation which provides a basis for more advanced signal-processing applications. For example, the analogue form of the convolution integral,

$$x(t)*h(t)=\int_{-\infty}^{\infty}x(\tau)h(t-\tau)d\tau$$

bears a remarkable resemblance to the finite form of the auto-correlation function,

$$r_{xx}(\tau)=\int_{-\infty}^{\infty}x(t)x(t+\tau)dt$$

To obtain the auto-correlation function by signal-processing methods, the signal x(t) must be multiplied by a time-shifted version of itself, $x(t+\tau)$, and the product then averaged. The result, an even function of τ, gives a measure of similarity between the original and time-shifted pulse.

A less esoteric description of the auto-correlation function is obtained by making τ equal to zero, in which case $r_{xx}(0)$ is equal to the mean-square value of the pulse. This apparently unconnected signal-processing operation is, in fact, related to the convolution integral. Notice that, if the characteristics of the time-reversed impulse response $h(t-\tau)$ are made identical to the characteristics of the time-shifted pulse $x(t+\tau)$, then the operation of convolution is identical to that of auto-correlation.

Computerised convolution

Graphical convolution as illustrated in Fig. 4.9 is a useful method of describing principles, but it rapidly becomes tedious for a large number of terms and if attention to detail is relaxed errors soon appear. A better approach is to execute the algorithm using a computer program. The convoluted output represented in Table 4.2 can be expressed more concisely using the sigma notation, which symbolises the summation of all terms from k=0 to i:

$$y_i=\sum_{k=0}^{i}x_k h_{i-k}.$$

In an effort to make the algorithm a little more attractive, I will use the following notation:

$$y_i=\sum_{k=0}^{i}x(k)h(i-k),$$

where y(i) represents the convoluted output, x(k) describes the sample of interest and h(i−k) denotes the coefficient of the reversed impulse response.

```
/************************
* CONVOLUTION *
* DIGITAL OUTPUT *
************************/
#include<stdio.h>
#include<graph.h>
main()
{
int i,j,k,m,n;
float x,h;
float input[40];
float impulse[40];
float output;
/* --------------------
CLEAR ARRAY
--------------------*/
for(i=0;1<=20;i++)
{
input[i]=0;
}
/* ----------------------------
READ IMPULSE DATA AND
  IMPULSE RESPONSE
----------------------------*/
printf("Enter No. of i/p samples: 20 max");
scanf("%d",&n);
printf("Enter i/p data");
for(i=20; i<=20+n-1; i++)
{
scanf("%f",&x);
input[i]=x;
}
printf ("Enter No. of samples in impulse
     response: 20 max");
scanf("%d",&m);
printf("Enter impulse data");
for(j=1; j<=m; j++)
{
scanf("%f",&h);
impulse[j]=h;
}
/* ------------
CONVOLUTION
------------ */
for(i=20; i<=20+n-1; i++)
}
output=0;
/* --------------------
RESET SUM TO ZERO
--------------------*/
```

```
for(j=1; j<=m; j++)
{
output+=input[i-j+1]*impulse[j];
}
printf("Output:%f n",output);
/* -------------------------
PRINT CONVOLUTED O/P
------------------------- */
}
}
```

Obtaining the processed output by software convolution, listing 4.1.

The interactive program listing 4.1 performs the ordered multiplication, followed by summation, before printing the convoluted output digitally on the monitor. Initially, the program requests the number of input samples, up to a maximum of 20, to be entered from the keyboard, followed by the individual data values which are stored in the array input [i]. Prompted by the program, enter the number of terms in the impulse response (20 maximum) before finally entering the individual coefficients, term-by-term from the keyboard, to be stored in the array impulse [j].

Essentially, the convolution construction is made up of a pair of nested loops, to provide the necessary multiply-summate and shift structure.

```
/* ---------------
 CONVOLUTION
--------------- */
for(i=20; i<=20+n-1; i++)
{
output=0;
/* -------------------------
 RESET SUM TO ZERO
--------------------------- */
for(j=1; j<=m; j++)
{
output+=input[i-j+1]*impulse[j];
printf("Ouput; %f/n",output);
/* ---------------------------
 PRINT CONVOLUTED O/P
---------------------------- */
}
}
```

Input data and impulse response coefficients are stored in a pair of arrays, identified by the square brackets. Shifted and multiplied data is summated by the addition assignment operator +=. Contrast the elegant C construction with the equivalent Basic structure.

output=input (i−j+1)*impulse (j)+ output

System response testing

This chapter is rather theoretical, emphasising the underlying principles of convolution, together with the acquisition of some computational skills. Although the examples are based on practical filters, it is assumed that the transfer function can be derived analytically; in certain instances, the system parameters can only be obtained by dynamic measurement. Unit-step and unit-impulse test signals are widely used to investigate the dynamic properties of analogue filters and continuous systems. For our purposes it is sufficient to define the unit-impulse as the derivative of the unit step. Remembering that differentiation in the time domain is equivalent to multiplication by s in the complex-frequency domain, we deduce that the Laplace transform of the unit impulse is unity, as **Fig. 4.10** shows.

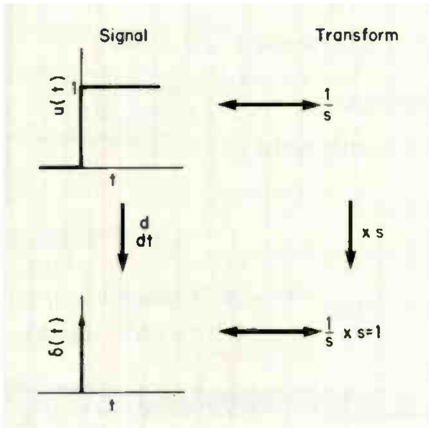


Fig. 4.10. Laplace transform of the unit impulse.

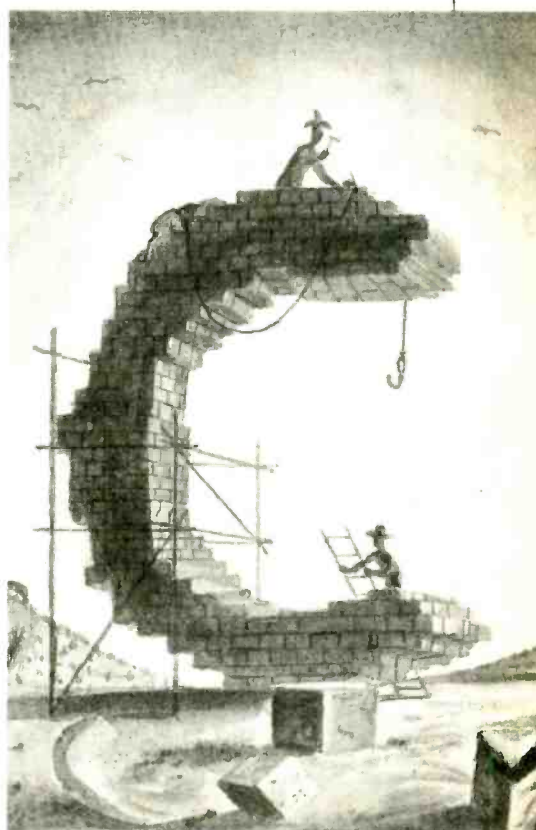
In sampled data systems the equivalent test signals are the unit-step, 1, 1, 1, . . . and the unit-sample 1, 0, 0, . . . conveniently expressed at n=0. To confirm these results and verify that listing 4.1 is operating correctly, enter the input sequence 1, 1, 1, . . . , followed by the truncated impulse response 0, 0.5, 0.25, 0.125, 0.0625, ... The convoluted output y(n) will be the familiar exponential response 0, 0.5, 0.75, 0.875, 0.9375 . . . . You may recognise this more readily in the analogue form:

$$y(t)=1(t-e^{-t/CR}).$$

Now enter the unit-sample 1, 0, 0, . . . , followed by the impulse response; the convoluted output will be identical to the impulse response of the system. Expressed in analogue form:

$$h(t)=1/CR\ e^{-t/CR}.$$

Clearly, this is equal to the differential of the step response and serves as a useful reminder of the principle of linearity. Recognise the significance of these results; convolution is seen to be a powerful and incisive method of solving linear differential equations of the form indicated in **Fig. 4.11**. Traditional methods either rely on classical analysis together with solution by Laplace transform, or avoid the facts behind the figures, preferring to present solutions. Convolution provides an alternative time-domain procedure which gets close to the physical reality behind the abstraction. ■



The next part of the series provides a practical programming example of convolution in graphical form, and a family of filters implemented in C.

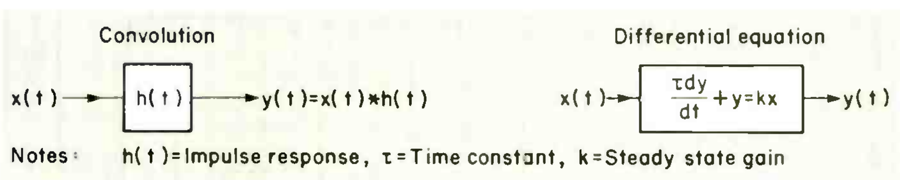


Fig. 4.11. Two perspectives of the same system.

DESIGNING FRACTALS TO ORDER

Early fractals seemed to come about by sheer luck but, since more fractals have been uncovered, the field now has a theoretical basis. Keith Wood describes how to tailor them to order

There is no formal definition of a fractal; so long as the field is expanding, any definition would soon be out of date. I am assuming here that, if a pattern or map can be generated by the repeated application of a simple process, and the result occupies a fairly restricted shape with a tortuous and essentially interesting boundary, then it can be regarded as a fractal.

In this article I shall look at the quite remarkable displays which can be generated with a first-order linear equation — you can't get simpler than that. A single equation would work in one dimension; two equations work in two dimensions, and so on. Consider first the equation

$$f(x)=0.5x+0.5.$$

Substitute any value of x in this equation and the result will be f(x) as defined. Use this value of f(x) as the new x and find another f(x). Repeat this process indefinitely and the result will be x=1. Iterating the equation produces a sequence of values of x which tend to 1, from any initial value whatsoever. At this level there is a short cut, since ultimately applying the equation produces no change in the value of x. This value of x arises immediately if we write

$$x=0.5x+0.5,$$

whence x=1. This will always happen if the equation is "contractive", which in this case means that the coefficient of x must be <1 or >−1.

Before we leave the one-dimensional case, it is illuminating to consider a second equation, which tends to 0:

$$f(x)=0.5x.$$

What happens if we use both of these at the same time? We can take a value of x and use two equations to calculate two new values. Next we can take both these with both equations to calculate four new values, and so on. Each set of values is discarded after calculating the subsequent set. Thus any values of x outside the range between 0 and 1 which may be present at the start are discarded; we can start with a set as well as a point. After iterating, the result is a complete fill of the interval. We will call this method A.

There is another way of using both equations at once. We can use one or the other equation at random, starting with an arbitrary x and using each result as input to the next equation. This leads to a value for x which dances about. After an initial sequence bringing it between the two limit values of 0 and 1, thereafter x remains entirely within that range. If each x value is plotted, the interval between 0 and 1 will become entirely filled as before. We will call this method B.

Both these methods produce, in the limit, a line between 0 and 1 which is the attractor of the procedure; a simple fractal. The pair of equations is called an iterated function system, or IFS: the values 0 and 1 to which the individual equations converge are fixed points, which are not in general at the edges of the attractor. In all cases, the resulting pattern or map is quite independent of the starting value, although there must *be* a starting value. All these concepts apply in two dimensions, and are our principal interest.

Fractals in two dimensions

Two equations are needed: one for x and one for y, as a pair. Any group of such pairs forms an IFS with an attractor, provided they are all contractive. Not all attractors are attractive in appearance, but that is for the operator!

A pair of equations is called a transformation. Any point (x,y) will yield a new point (f(x),f(y)). It is easy to see that if the pair of equations

$f(x)=0.5x$
$f(y)=0.5y$

is applied to all points in a map, the result would be a half-size map. Since only first-order linear equations are

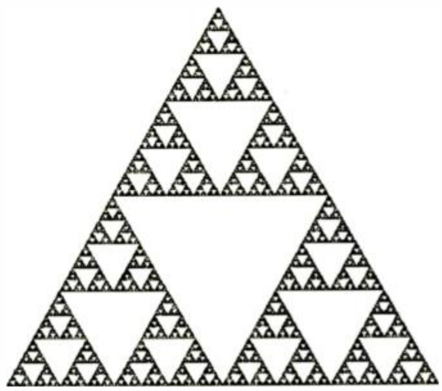


Fig. 1. Sierpinski triangle, formed from three half-size images, shifted horizontally and vertically

involved, the map resulting from a transformation is directly and recognisably related to the map transformed. If the equations were

$f(x)=0.5y$
$f(y)=-0.5x$

the result would be the same shape, reduced by half, and rotated 90° clockwise. This provides the clue to the amazing attractors which can be generated by such simple arithmetic.

Once again there is a fixed point to each transformation. This time it is the pair of simultaneous equations which has to be solved. In both the above cases, the fixed point will be the origin.

Whether or not the transformation is contractive is defined by the distance between two different points (x_1,y_1) and (x_2,y_2), before and after the transformation. If

$$d[(x_1,y_1),(x_2,y_2)]>d[(f(x_1),f(y_1)),(f(x_2),f(y_2))]$$

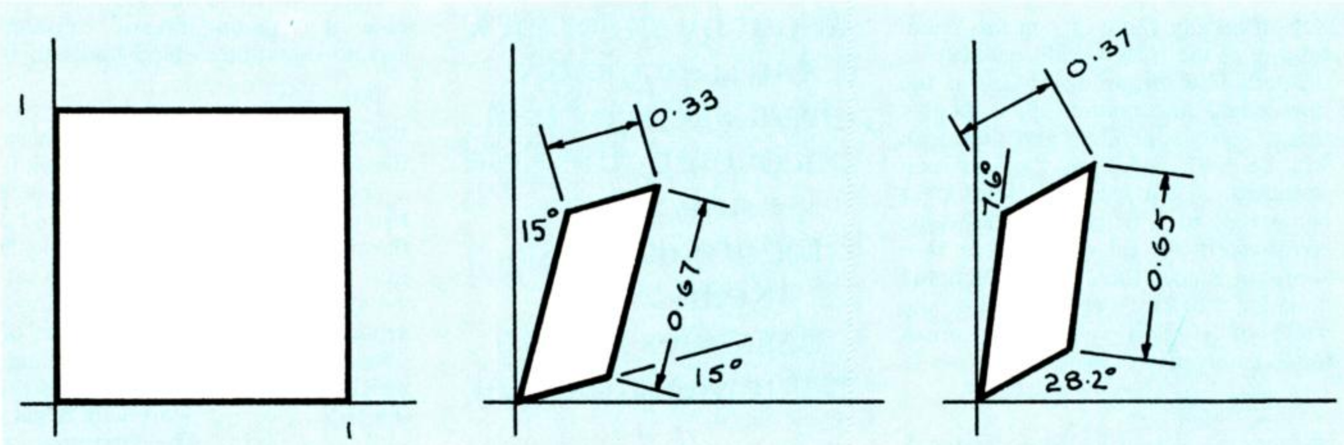


Fig. 2. Starting set: conveniently ordered transform (b) and inconveniently ordered transform (c). Both use 15° rotations and ⅓ and ⅔ contractions

for all pairs of points (x,y) where d defines the Euclidean distance in the plane, then the transformation is contractive.

A single point for an attractor is pretty uninteresting; we require further equations to flesh out a display. One such set generates a figure known as the Sierpinski triangle shown in **Fig. 1**:

$f_1(x)=0.5x$
$f_1(y)=0.5y$

$f_2(x)=0.5x+0.5$
$f_2(y)=0.5y$

$f_3(x)=0.5x+0.25$
$f_3(y)=0.5y+0.433.$

The first transformation generates a half-size image, the second generates a half-size image shifted 0.5 to the right and the third produces a half-size image up in the air over the other two. These three together make a triangle, and the starting data can be anything at all. Either of the two procedures applies; the result is the same.

It is cumbersome to have to write out all the equations in full to define an IFS; a table of coefficients is about the irreducible minimum[1]. Defining the general transformation as

$f_i(x)=ax+by+e$
$f_i(y)=cx+dy+f,$

then the coefficients can be listed as

i	a	b	c	d	e	f	p
1	0.5	0	0	0.5	0	0	0.33
2	0.5	0	0	0.5	0.5	0	0.33
3	0.5	0	0	0.5	0.25	0.433	0.34

for the Sierpinski triangle. The quantity p is a probability which is used to decide the random choice of transformation when method B is used; method A does not require it. The p values must add up exactly to 1 — more about p later.

The general transformation can be written in a variety of ways. Three useful ways are

$$\begin{bmatrix} f(x) \\ f(y) \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix}$$

where p, q, z are complex and the plot is an Argand diagram.

$$\begin{bmatrix} f(x) \\ f(y) \end{bmatrix} = \begin{bmatrix} r_1\cos\theta_1 & -r_2\sin\theta_2 \\ r_1\sin\theta_1 & r_2\cos\theta_2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix}$$

In the last case, r_1 and r_2 contract the x and y range respectively, θ_1 and θ_2 rotating the x and y directions anticlockwise from their respective axes. The proportion of the map changes if $r_1 \neq r_2$ while the angles in a map change if $\theta_1 \neq \theta_2$. **Figures 2(a)** and **2(b)** show "before" and "after" using $r_1=0.333$, $r_2=0.667$, $\theta_1=15°$, $\theta_2=-15°$.

Writing the general form of a transformation in matrix notation permits a further extension of the process. If one wants a transformation to carry out a complex change, one can break that change down into a number of simple changes, write down the matrix for each, and multiply them together to get the desired result. There is one snag: a matrix product is, in general, different according to which of a pair is taken first. The sequence of products must match the sequence of simple changes to work.

The transformation of Fig. 2 is clearly of more practical use if the contractions and rotations required are the coefficients in the matrix. A rotation does not alter the contractions, although it may alter the angle between them. Changing the proportion of a map will alter the angle of off-axis directions, so the proportion matrix must be applied before the rotation matrix to achieve the desired result. The breakdown of the above transformation is

rotation.(proportion.(x,y))

If the order of the matrices is reversed, the resulting matrix is

$$\begin{bmatrix} f(x) \\ f(y) \end{bmatrix} = \begin{bmatrix} r_1 & 0 \\ 0 & r_2 \end{bmatrix} \begin{bmatrix} \cos\theta_1 & -\sin\theta_2 \\ \sin\theta_1 & \cos\theta_2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} r_1\cos\theta_1 & -r_1\sin\theta_2 \\ r_2\sin\theta_1 & r_2\cos\theta_2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

and the result of that transformation can be seen in Fig. 2(c). When there are more than two matrices, the right-most pair are multiplied as usual; rows of the left matrix with columns of the right matrix. Then the resulting matrix is multiplied by the next matrix to the left and so on.

In every case, the transformation is applied relative to the origin. If we require to work about some other point, then we substitute (x−m) for x and (y−n) for y in the right-hand side of the equation. This has the effect of moving the array to the origin, where (m,n) is the point in the display which we want to move to the origin. In this and any other case, the constant (e,f) defines where the map origin goes after the transformation.

Here are a couple of examples to illustrate the utility of the approach. A simple spiral consists of placing a map a little way from the origin, and applying a rotation of a few degrees while reducing both its size and distance from the origin. Repeating this process produces a converging spiral. In the example, the start is a small-scale image of the whole spiral, reduced by a factor of 0.15 and placed by moving its centre to (−1,0) and rotating it 180° at the same time. The spiral as a whole is generated by reducing by a factor of 0.95 and rotating by 30° anticlockwise. The first transformation will be

$$\begin{bmatrix} f(x) \\ f(y) \end{bmatrix} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} 0.15 & 0 \\ 0 & 0.15 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} -1 \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} -0.15 & 0 \\ 0 & -0.15 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} -1 \\ 0 \end{bmatrix}$$

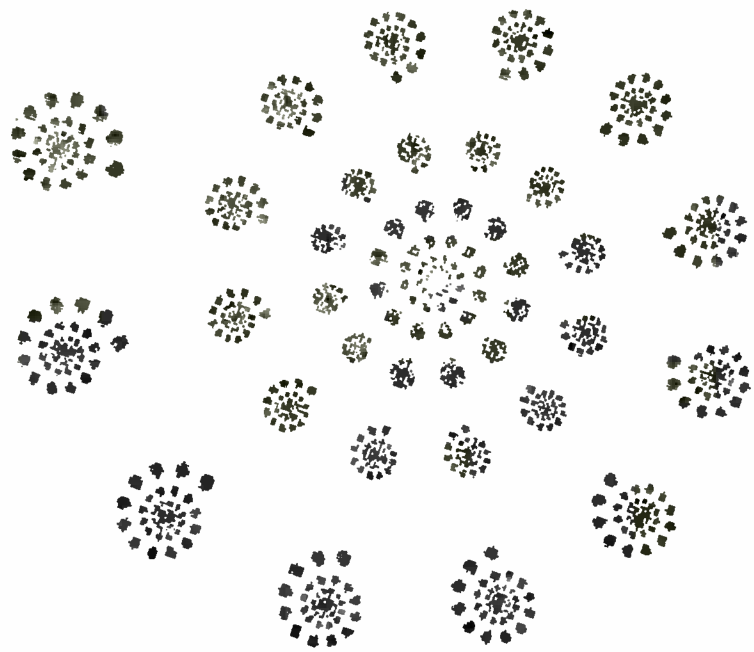


Fig. 3. Simple spiral made by rotation and reduction of distance from map to origin

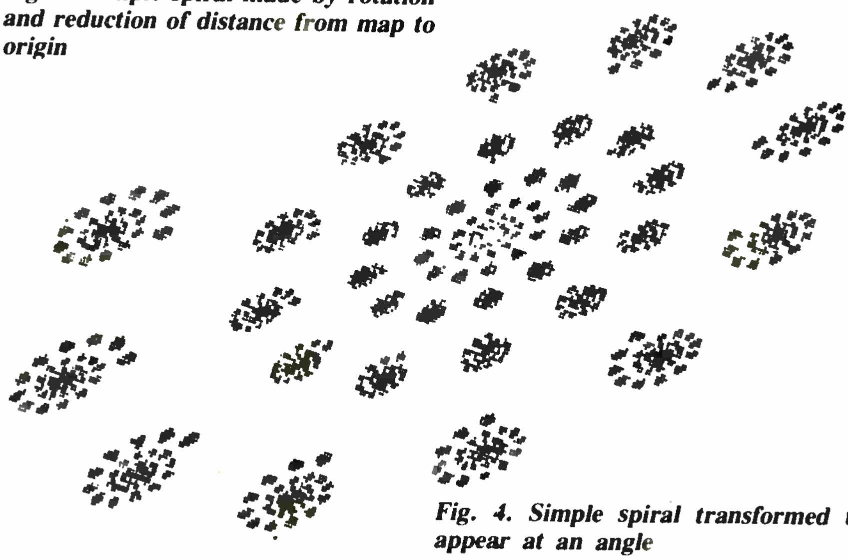


Fig. 4. Simple spiral transformed to appear at an angle

and the second

$$\begin{bmatrix} f(x) \\ f(y) \end{bmatrix} = \begin{bmatrix} 0.95\cos30 & -0.95\sin30 \\ 0.95\sin30 & 0.95\cos30 \end{bmatrix}$$

Written in condensed form, the IFS is

i	a	b	c	d	e	f	p
1	−0.15	0	0	−0.15	−1	0	0.1
2	0.823	−0.475	0.475	0.823	0	0	0.9

and the corresponding attractor is shown in **Fig. 4**.

Now, suppose we would like to see this spiral from an angle to its plane, such as is often seen in photographs of spiral galaxies. The difference is that the spiral, as plotted, does not smoothly approach the origin — the reverse, in fact; being elliptical it moves away from the origin for a few steps as it approaches the long axis. To design a suitable transformation we have to change our viewpoint to get a circular spiral, transform it, and change the viewpoint back. All this can be accomplished with a single transformation. If the long axis of the spiral lies along the line x=y (ψ=45) and the normal to plane of the spiral is at 60° to the line of sight (ϕ=60), transformation 2 in the above IFS becomes

$$\begin{bmatrix} f(x) \\ f(y) \end{bmatrix} = \begin{bmatrix} 0.75 & 0.25 \\ 0.25 & 0.75 \end{bmatrix} \begin{bmatrix} 0.823 & -0.475 \\ 0.475 & 0.823 \end{bmatrix} \begin{bmatrix} 1.5 & -0.5 \\ -0.5 & 1.5 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$= \begin{bmatrix} 1.179 & -0.594 \\ 0.594 & 0.467 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

The general case using ψ and ϕ is given in the appendix. The IFS of the spiral galaxy becomes

i	a	b	c	d	e	f	p
1	−0.15	0	0	−0.15	−0.75	−0.25	0.1
2	1.179	−0.594	0.594	0.467	0	0	0.9

Figure 4 reveals all. The constant in the first transformation is changed from (−1,0) by the angle of view, using the leftmost of the three matrices in transformation 2. This ensures exact comparability with Fig. 3.

The probability p is chosen to be broadly in proportion to the area of the attractor filled by the transformation and must be greater than zero.

Condensation sets

The spiral just described consists of a repetition of itself. Suppose we want to make a spiral which repeats something else? If it can be placed at the beginning of the spiral, then the rest would follow as before. Using method A we can use the desired shape as the starting set of points, and ensure that it isn't discarded by adding an extra transformation f(x)=x, f(y)=y. This will replicate the entire map of course, but if the starting set is always present as we intend, the subsequent transformations of it would be generated anyway. It is simply a duplication, making for easy programming. Alternatively, the starting set can be kept on one side and added in each time, which is quicker; the set used in this way is known as a condensation set.

Using method B requires a different approach. The transformation f(x)=x, f(y)=y won't work, since method B doesn't use a starting set. Instead, the condensation set has to be kept on hand, and whenever the random choice falls on the transformation representing this set, a point from it is chosen at random and plotted. This transformation isn't really a transformation at all, in the sense we have used up to now. The condensation transformation is really a place keeper having a probability attached and an independent process for generating the next point. Note that we can't just copy in the whole set, since a randomly generated point from the set is necessary to provide the seed for the next transformation.

There is a great variety of shapes which can be produced; the spiral used in the above examples is probably the simplest, requiring only two transformations. **Figure 5** is an example of the use of a condensation set; it is a solid rectangle in the centre of an attractor. Method A was used with the following IFS

i	a	b	c	d	e	f	p
1	0.5	0	0	0.5	0	0	0.25
2	0.5	0	0	0.5	0.5	0	0.25
3	0.5	0	0	0.5	0.5	0	0.25
4	1	0	0	1	0	0	0.25

The first three transformations on their own would produce a Sierpinski triangle again; the superimposed larger rectangles are derived from the condensation set which, on this occasion, does not go away.

Making a collage

The collage theorem[1] provides a way of generating an attractor of almost any shape. Given a desired shape, the more closely we can tile it with transformations of itself, the more likely it is that the IFS composed of those transformations will produce the desired shape when iterated. Tiling means what it seems to mean: covering the shape with pieces as when tiling a floor or making a mosaic — the Sierpinski triangle in Fig. 1 is tiled exactly with three half-size reproductions of itself. The spiral of Fig. 3 is tiled with a 0.95 reduction of itself and a 0.15 reduction, again exactly. The calculated attractor will always tile exactly with its transformations; if the target attractor is not well tiled, the result will differ from the target.

Fig. 5. Collage. Letters formed from strokes, each of which is transformation of whole. Figure is "tiled" exactly

Figure 6 illustrates the use of the collage theorem. The desired shape is rectangular, formed from the two letters ME, each letter comprising four straight strokes and each stroke being a transformation of the whole rectangle. There are eight transforms in all, and the degree of rotation and compression of each is easily identified from the orientation of the letters. The IFS is

i	a	b	c	d	e	f	p
1	0	−0.15	0.425	0	0.075	0	0.1
2	0.17	0.3	−0.5	0	0	0.5	0.2
3	0.129	−0.15	0.382	0	0.336	0.05	0.1
4	0	0.25	−0.5	0	0.414	0.5	0.2
5	0	−0.3	0.5	0	0.75	0	0.2
6	0.25	0	0	0.15	0.75	0.425	0.06
7	0.25	0	0	0.2	0.75	0.2	0.08
8	0.25	0	0	0.15	0.75	0	0.06

Fig. 6. Use of a condensation set in the Sierpinski triangle

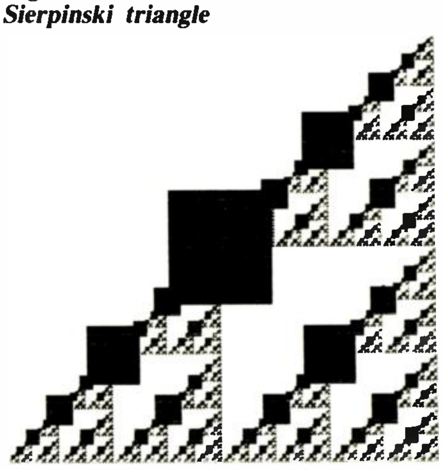


Fig. 7. Selection of collages

Other examples of collages, seen in **Fig. 7**, are produced by following IFSs. See if you can find their tilings.

(a)

i	a	b	c	d	e	f	p
1	0.498	−0.448	0.448	0.498	0.468	−0.181	0.5
2	0.498	−0.448	0.448	0.498	0.381	0.233	0.5

(b)

i	a	b	c	d	e	f	p
1	0.504	−0.121	0.089	0.685	0.248	0.25	0.5
2	0.214	−0.378	0.214	0.378	0.393	0.044	0.2
3	0.2	0.354	−0.2	0.354	0.4	0.367	0.2
4	0.025	0	0	0.35	0.495	0	0.1

(c)

i	a	b	c	d	e	f	p
1	0.382	0	0	0.382	0.138	0.074	0.2
2	0.382	0	0	0.382	0.48	0.074	0.2
3	0.382	0	0	0.382	0.585	0.399	0.2
4	0.382	0	0	0.382	0.309	0.6	0.2
5	0.382	0	0	0.382	0.033	0.339	0.2

Because the whole process is linear and first-order, curves cannot be generated explicitly. The usual tricks work, though; a circle can be formed by two transformations, one to collapse the whole figure into a short line and the other to replicate the line round by the necessary number of degrees each time. This is often done in computer-generated curves. To ensure that the circle closes, greater accuracy is required when deciding the coefficients. The following IFS gives a good circle

i	a	b	c	d	e	f	p
1	0.995	−0.0998	0.0998	0.995	0.0524	−0.0474	0.97
2	0	0	0	0.05	0.9	0.475	0.03

Parameters

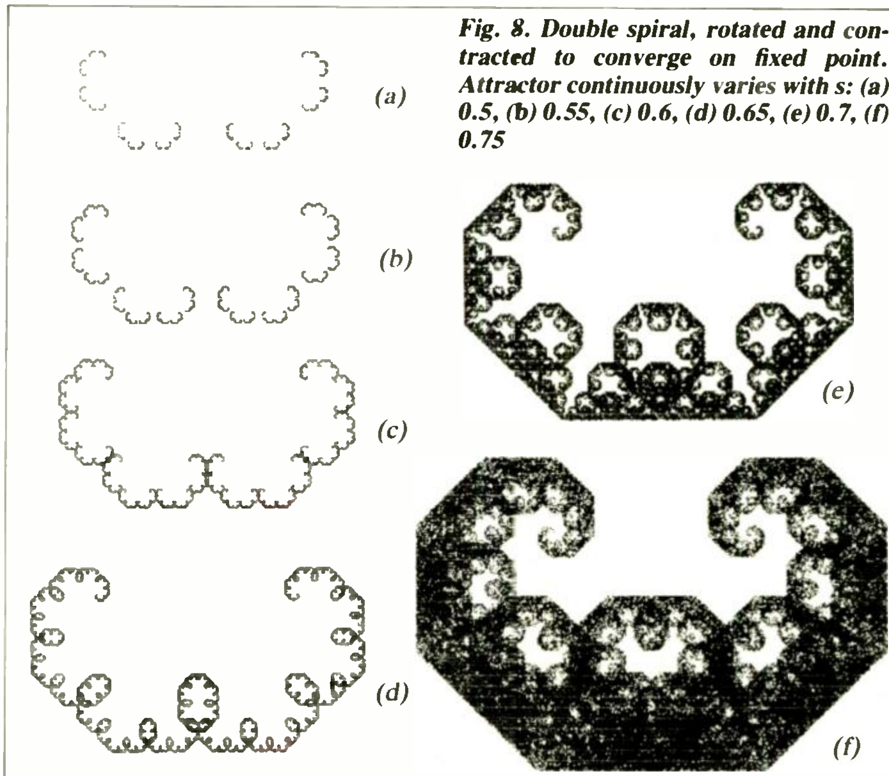
Although these shapes are fractals, they are not chaotic. In other words, a small change in a parameter makes a small change in the attractor, which is why we can design them to order. If an attractor is not quite what we want, we can adjust the parameters to get closer. The images in **Fig. 8** are produced by the IFS

i	a	b	c	d
1	0.707s	−0.707s	0.707s	0.707s
2	0.707s	0.707s	−0.707s	0.707s

i	e	f	p
1	0.708+0.03s	0.75−1.031s	0.5
2	0.292−0.737s	0.75−0.324s	0.5

Figure 8 gives values of s. This attractor is a double spiral; each transformation takes the whole map and

Fig. 8. Double spiral, rotated and contracted to converge on fixed point. Attractor continuously varies with s: (a) 0.5, (b) 0.55, (c) 0.6, (d) 0.65, (e) 0.7, (f) 0.75



rotates and contracts it to converge on its fixed point. The right-hand side is anticlockwise and converges to (0.708,0.75), while the left-hand side is clockwise and converges to (0.292,0.75). Rotation is 45° and s is the contraction factor for the equations. Expressions for e and f are derived from the equation for the fixed point for each transformation.

Calculating the IFS

Figure 9 is a listing of a routine written in GWBasic, which will accommodate an IFS with up to nine transformations without alteration. It has a twist in that a tenth possibility is included if the probabilities add up to less than 1. The twist is a pair of equations written out in the listing, and which can therefore be anything at all, not necessarily linear or first-order.

This listing uses method B; a Basic listing for method A would require two very large arrays and extra code to manage them and so is not suitable for reproduction here. All the IFSs given in the article except the spirals are arranged for a plotting window of x=[0,1] and y=[0,1].

Another advantage of method B over method A is that method B will generate a blow-up of a small area of an attractor.

The careful reader will have noticed that I specified contractive transformations in the IFS. I then proceeded to include transformations which are not contractive in the rose algorithm, the circle and when describing a way of including a condensation set in method A. There are always cases which fall outside algorithms and yet work.

Fig. 9. Listing to produce a drawing of a rose

```
10   REM The listing for iterating a set of affine transformations
20   REM which may include one polynomial pair.
30   REM Up to 9 pairs of equations can be handled here.
40     DIM A(9),B(9),C(9),D(9),E(9),F(9),P(9)
50   REM M is the number of transformations excluding the polynomial.
60     M=5
70   REM Each line of data is a,b,c,d,e,f,p for one transformation.
80     DATA .5,.866,-.866,.5,0,0,.4
90     DATA .5,.289,-.289,.5,0,0,.11
100    DATA -1,0,0,1,0,0,.12
110    DATA -1,0,0,-1,0,0,.12
120    DATA 1,0,0,-1,0,0,.12
130    PT=0
140    FOR J=1 TO M
150    READ A(J),B(J),C(J),D(J),E(J),F(J)
160    READ PK
170    PT=PT+PK
180    P(J)=PT
190    NEXT J
200    FOR J=M+1 TO 9
210    P(J)=PT
220    NEXT J
230  REM Set up plotting environment
240  REM The next line sets 200 line EGA display.
250    SCREEN 8,,1,1: WINDOW (-2,-1.3846)-(2,1.3846):PALETTE 0,2
260    CLS
270    SEED=INT(TIMER/4)
280    RANDOMIZE SEED
290    X=0
300    Y=0
310  REM do 10000 iterations
320    FOR N=1 TO 10000
330    PK=RND
340  REM Type the next line without using return.
350    IF PK<=P(1) THEN K=1 ELSE IF PK<=P(2) THEN K=2 ELSE IF PK<=P(3) THEN K=3 E
LSE IF PK<=P(4) THEN K=4 ELSE IF PK<=P(5) THEN K=5 ELSE IF PK<=P(6) THEN K=6 ELS
E IF PK<=P(7) THEN K=7 ELSE IF PK<=P(8) THEN K=8 ELSE IF PK<=P(9) THEN K=9 ELSE
460
360    XNXT=A(K)*X+B(K)*Y+E(K)
370    YNXT=C(K)*X+D(K)*Y+F(K)
380    X=XNXT
390    Y=YNXT
400    IF N>10 THEN PSET (X,Y),12
410    NEXT N
420    A$=INKEY$
430    IF LEN (A$)=0 THEN 420
440    SCREEN 0
450    END
460    XNXT=.125*(7-X*X-X-X)
470    YNXT=.217*X*X-.144*X-.361
480    GOTO 380
```


Reference

1. Barnsley, Michael. Fractals Everywhere. Academic Press, 1988.

Appendix

Clock attractor, Fig. 10

Parameter t in the following IFS is the decimal equivalent of 24-hour time; that is, t=14.75 means 14:45 hours. The attractor is the hour and minute hand showing that time. If the IFS is placed in a loop and t is increased regularly by an amount equal to the time it takes to calculate and display the attractor, then the VDU will display the time for as long as it runs.

Fig. 10. Hour and minute hands which will tell time

i	a	b	c
1	$0.618(\cos\theta)^2$	$0.618\sin\theta\cos\theta$	$0.618\sin\theta\cos\theta$
2	$0.618\cos\phi$	$0.618\sin\phi$	$0.618\sin\phi$

i	d	e	f	p
1	$0.618(\sin\theta)^2$	$0.382\cos\theta$	$0.382\sin\theta$	0.6
2	$-0.618\cos\phi$	0	0	0.4

where $\theta=((90-360t)\ \mathrm{MOD}\ 360)/57.3$ radians and $\phi=((180-360t)\ \mathrm{MOD}\ 360)/57.3$ radians.

Some more matrices

To reverse (not rotate) an image about the x axis:

$$\begin{bmatrix}1 & 0\\ 0 & -1\end{bmatrix}$$

and the y axis:

$$\begin{bmatrix}-1 & 0\\ 0 & 1\end{bmatrix}$$

To tilt the plane of the map until the direction of view is at an angle ϕ with the normal to the plane, the tilting being about an axis at an angle ϕ to the x axis and the plane of the map being normal to the direction of view before the tilt

$$\begin{bmatrix}1-(1-\cos\phi)(\sin\psi)^2 & (1-\cos\phi)\sin\psi\cos\psi\\ (1-\cos\phi)\sin\psi\cos\psi & 1-(1-\cos\phi)(\cos\psi)^2\end{bmatrix}$$

If the plane of the map is tilted by 90°, the result is a line or part of a line at an angle ψ to the x axis.

The reverse of this takes a map whose normal is assumed to be at an angle ψ to the direction of view, tilted about an axis at an angle ψ to the x axis, and rotates the plane of the map about that axis until it is normal to the direction of view ■

$$\begin{bmatrix}1+((1/\cos\phi)-1)(\sin\psi)^2 & ((1/\cos\phi)-1)\sin\psi\cos\psi\\ -((1/\cos\phi)-1)\sin\psi\cos\psi & 1+((1/\cos\phi)-1(\cos\psi)^2\end{bmatrix}$$

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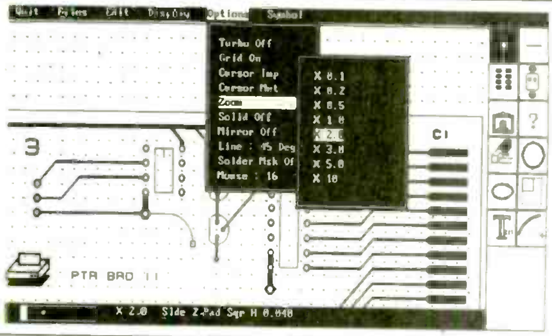

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PIONEERS

John Ambrose Fleming (1849-1945) The Birth of Electronics

W A ATHERTON

You probably would not think of building a radio detector from a light bulb, but that is what Ambrose Fleming did in 1904. The result was what he called the "oscillation valve", now better known as the thermionic diode. It was only two years later when Lee de Forest added a third electrode to make the first primitive triode. These two classic inventions led to a fight between the two inventors, but they also led to the now-vast, worldwide industry we call electronics.

The story begins with that great American inventor, Thomas Edison. In 1883, he probed inside an incandescent light bulb, first with a wire and then with a metal plate. He found that if this electrode was connected to the positive end of the filament via a galvanometer then a current was detected. If it was connected to the negative end, no current flowed. A little later, using a separate battery in the plate or anode circuit, J. Elster and H. Geitel showed the unidirectional nature of the current flow.

This "Edison effect" was studied by many people over the following 20 years, particularly to examine thermionic emission. Fleming studied it "carefully" in 1883 and again in 1896, and he may have discussed it with Edison when he met "the Wizard" during his trip to the USA in 1884. Certainly, for 20 years it was a well known phenomenon before anyone thought of an important application for it.

Fleming's real invention was the use he found for the established Edison effect as a rectifier of high-frequency oscillations. Edison kicked himself when he realised the opportunity he had missed, even though he held what is now seen as the first patent in electronics — the effect used as a voltage indicator (1884).

Fleming's career, meanwhile, had progressed over those 20 years. In 1896 he experimented with methods of focusing cathode rays and three years later he was appointed scientific adviser to the Marconi's Wireless Telegraph Company. In this role he specified equipment for the famous transatlantic signal transmission of 1901. He had also gained extensive experience of consultancy, to the National Telephone Company and the Ediswan Electric Light Company. With all this highly relevant experience he was in an ideal position from which to make his famous contribution to electronics.

Very happy thought

It was in October 1904 that Fleming had what he described as "a sudden, very happy thought." Telephones and meters were too slow to register the positive-negative cycling of a high-frequency radio signal and therefore only indicated the average value, which was zero. Knowing that a light bulb with a hot filament and an insulated plate sealed within it would only pass current in one direction, he speculated that this might act as a rectifier for the high-frequency currents. He asked his assistant, G.B. Dyke, to test the idea — and it worked. The next month he wrote to Marconi, "I have been receiving signals on an aerial with nothing but a mirror galvanometer and my device."

It would be nice to think that Fleming made his fortune from this pivotal invention, but it brought him relatively little joy. Marconi's held the patent, and manufactured and used some diodes. But in this early form they were no panacea for all radio detection problems and they played only a small part in the early years of radio.

A couple of years later H. H. Dunwoody, of the De Forest Wireless Co., produced an important rival — the crystal detector. This was part of De Forest's determined effort to challenge Marconi's dominance of the radio scene. In 1905 De Forest patented the two-electrode valve with the double-battery Elster-Geitel connection instead of the single battery circuit used by Fleming[1]. He called his diode an "audion". Fleming felt that his invention had been hijacked and he accused De Forest of plagiary. A bitter row ensued.

In October 1906, De Forest added the third electrode to make the first triode. Unfortunately he still called it an "audion", the name he used for his diode, and confusion reigned. The dispute with Fleming was prolonged. However, at no time did Fleming ever claim to have invented the triode. Though he experimented with zigzag wires as alternatives to metal plates for the anode he never used the two together. As he himself wrote, "Sad to say, it did not occur to me to place the metal plate and the zigzag wire in the same bulb and use an electric charge of positive or negative on the wire to control the electron current to the plate."[1]

Nonagenarian

John Ambrose Fleming lived to the ripe old age of 95, and late in life became very deaf — this was seemingly a family trait, for his sister suffered similarly. One story from his time as Professor of Electrical Engineering at University College, London, recalled a loud conversation between the two of them in which his sister told him not to be so cantankerous — at times his colleagues thought his deafness varied at will to suite his purposes, becoming "impenetrable" when he so wished.

Fleming was born at Lancaster on 29 November, 1849, the oldest of the seven children of a Congregational minister. His father, he said, was descended from "a long line of Scotch ancestors of Flemish origin." His mother's family came from Swanscombe in Kent and were pioneers of the manufacture of Portland cement.

In 1854 his parents moved to London where Fleming was to spend almost 70 years of his life. When he finally retired at 77, after an action-packed working life, he moved to the seaside, to Sidmouth, where he enjoyed nearly another 20 years before his death on 18 April, 1945. He married twice but had no children. His first wife, Clara Ripley, died in 1917 but his second, Olive Franks, whom he married in 1933, survived him.

Fleming started school at about the age of ten, attending a private school where he particularly enjoyed geometry. Prior to that his mother tutored him and he had learned, virtually by heart, a book called the "Child's Guide to Knowledge," a popular book of the day — even as an adult he could quote from it. His schooling continued at the University College School where, although accomplished at maths, he habitually came bottom of the class at Latin.

Even as a boy he wanted to become an engineer. At 11 he had his own workshop where he built model boats and engines. He even built his own camera, the start of a lifelong interest in photography. Training to become an engineer was beyond the family's financial resources but he reached his goal via a route which alternated education with work.

He enrolled for a BSc degree at University College, London, in the mid-1860s and studied under the mathematician A. de Morgan and the physicist G. Carey Foster. After two years he left because of a shortage of money and took a job with a shipbuilder in Dublin. The work was so dull that he quit after a few months and found work with a stock jobbing firm on the London Stock Exchange.

For two years he earned his living in the financial world. Later, as a teacher, he preached that every boy and girl should have some practical training in "the bulls, the bears and the stags of The Stock Exchange" and "their efforts to make money out of the trustful and optimistic public."

At the Stock Exchange his work finished at the early hour of 4 o'clock. So it was not only about the bulls and bears that he learned, for he completed his degree through evening study, graduating in 1870 with a first class degree.

For 18 months, from January 1871, he replenished his funds as a science teacher at Rossall School before resigning to return to his studies, this time as a student of chemistry at the Royal College of Science in South Kensington (now Imperial College). It was while there that he first studied the voltaic battery which become the subject of his first scientific paper. This turned out to be a unique honour, for it was the first paper to be read to the new Physical Society of London (now the Institute of Physics) and appears on page one of volume one of their *Proceedings*.

Financial problems again forced him to work for his living and in the summer of 1874 he became science master at Cheltenham College, a public School, earning £400 a year. His own scientific research continued and he corresponded with James Clerk Maxwell at Cambridge University. After saving £400, and securing a grant of £50 a year, in October 1877 he once again enrolled as a student, this time at Cambridge. He was now 28 years old.

Fleming's Banjo.

At Cambridge, Maxwell asked Fleming to compare the values of various resistance standards. To do this Fleming improved the Carey-Foster bridge so as to give fast and accurate measurements. His measuring wire was formed into a nearly complete circle while other parts were arranged along an arm. The appearance led to Maxwell dubbing it "Fleming's banjo".

One of Fleming's early experimental diodes. Courtesy of the Marconi Co. Ltd.

Maxwell's lectures, he admitted, were difficult to follow. Maxwell, he said, often appeared obscure and had "a paradoxical and allusive way of speaking." We are told that on occasions Fleming was the only student at those lectures.[1]

In due course Fleming again graduated, this time with a first in chemistry and physics, He then got a DSc from London and served one year at Cambridge as a demonstrator of mechanical engineering before being appointed as the first Professor of Physics and Mathematics at the University of Nottingham. But after less than a year he left.

Up to this stage in his career Fleming had proved himself as a brilliant scholar and a gifted teacher, but with a stronger aptitude for learning than for being an employee. While he might have appeared as a perpetual student he was now about to find his forte in life.

Consultant

Cousins can be useful — Fleming's was a Mr Arnold White who happened to be secretary to the Edison Telephone Company in London, and through him Fleming was offered the post of consultant. The telephone business went through a period of great change, including mergers and the extension of the Post Office monopoly from telegraphs to telephones, and Fleming took an active part in the ensuing litigation.[1]

White was also the secretary of the new Edison Electric Light Company and Fleming duly became scientific adviser there too. He appears to have obtained a number of orders for the company including one for the first Admiralty Ship to have electric lighting. It was on behalf of this company (by that time merged with the Swan Electric Light Company) that he visited America in 1884, during which visit he met Edison.

By that time Fleming's reputation was such that in 1885 he was invited to become the first Professor of Electrical Engineering at University College, London. At last he had a position which really suited his many and varied talents. London always appealed to him and his light teaching duties (one hour a week during the first few years) allowed plenty of time for consultancy.

When he took up his new position, which he retained until his retirement, the only equipment he received was "a blackboard and a piece of chalk!" However he persuaded the authorities to give him a small room and a £150 grant. Largely due to his efforts £5000 was received in 1896 to establish an electrical laboratory.

His interests ranged widely over the years. At various times he specialised in transformer tests (acting as consultant to Ferranti), standards and measurements, incandescent lamps and photometry, the effects of low temperatures on the electrical resistance of metals (with Sir James Dewar), and (of course) thermionics. In his retirement he was for 15 years president of the Television Society of London. He received many honours, including the Followship of the Royal Society in 1892, medals from scientific and engineering institutions and, in 1929, a knighthood.

He has been described as a born teacher and gave meticulously prepared public lectures. Showmanship however, was not allowed into his student lectures. As we have seen he was also an accomplished photographer. In addition, he painted watercolours and enjoyed climbing in the Alps. His interests were not those which entailed much socialising and he disliked organised games.

He was also a devout Christian and preached on one occasion at St Martin-in-the-Fields in London. Having no children, he bequeathed much of his estate to Christian charities, especially those that helped the poor. But of his many achievements his enduring fame rests on turning a light bulb into the first electronic valve. ■

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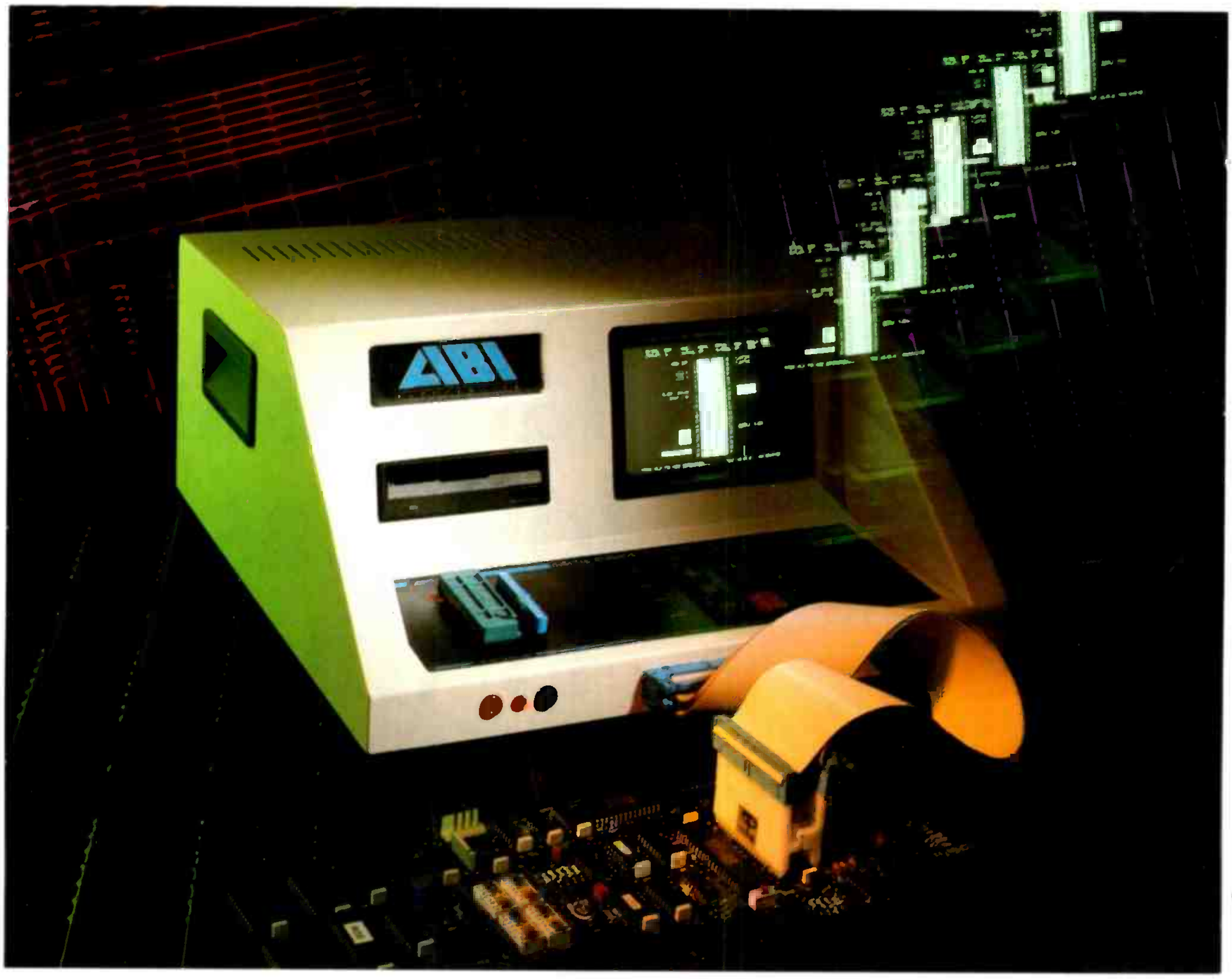

ABI

Variable-slope, low-pass LF filter

Tone controls in audio preamplifiers are regarded by the cognoscenti as outmoded. Reg Williamson disagrees and presents a design for a steep-cut, variable slope filter to remedy deficiencies in some programme sources

Some of the more fascinating aspects of commercial hi-fi are the effects of contrived fashion. Each new fashion, be it oxygen-free copper cables or gold-plated plugs, seems to be dreamed up by a company's promotions department and then aided and abetted by a sycophantic review industry. None of this has anything to do with the aims of high quality sound reproduction and real engineers have little time for such commercially motivated goings-on; happily, there is a remaining handful of companies that eschews such practices.

It is a paradox that, in so-called "high end" amplifiers and preamplifiers, the facilities offered appear to be in inverse proportion to the price; the more inflated the cost, the more minimalist the functions. One might expect the volume control to disappear as soon as some self-appointed guru prescribes it as yet another cause of subjective aberration of minuscule magnitude.

Despite the considerable improvement in the quality of programme sources in the home, there is still the need for "tone controls", although they may now take a somewhat different form. Since 78s and LPs are still popular, and since the transfer of old analogue tapes to CD is sometimes not especially careful, the desirability of access to a steep-cut low-pass filter still remains.

This design arose from a feeling of irritation with the current, irrational, minimalist trend and, while it may form part of a complete preamplifier, it was felt that the steep-cut filter as an independent unit might prove of interest. I make no secret of the fact that it emulates the well-tried and trusted Quad control with its selection of three frequencies and a variable slope; although, as will be seen later, the design approach is somewhat different.

A variable-slope low-pass filter was a feature of a design of mine some 21 years ago[1], but this had only one fixed frequency and was based on a conventional m-derived full π-section filter (**Fig. 1**) with a potentiometer progressively shorting the inductor and shunt capacitor to provide the variable slope. A novel function was that, at the minimum setting of the potentiometer, an integral switch could take the filter out of circuit altogether.

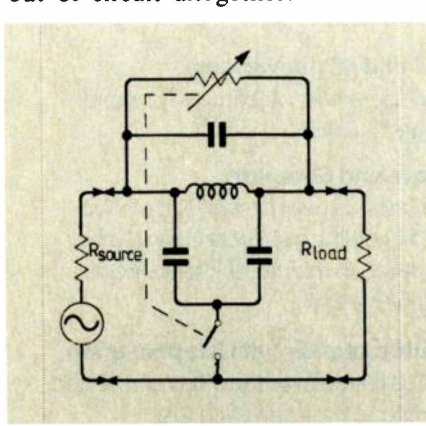


Fig. 1. Variable-slope filter based on an m-derived π-section with the capacitor shorted by a potentiometer.

Gyrators

The new version uses the same approach, but this time a pot-core inductor is not used. Fortunately, modern linear design methods now include an alternative to real inductors, a circuit technique that had just been introduced at the time of my first design. I refer to the gyrator.

It is outside the province of this article to deal in any depth with how a gyrator functions — there are many excellent references[2] — but a little historical background is not without interest. The concept was first mooted by Tellegen in 1948 and I believe he coined the generic noun. In simple terms, it can be shown that, by the use of active devices, one can in a linear circuit interchange the relationship between current and voltage; so in theory, for example, it is possible to make a capacitor behave like an inductor and vice versa.

Figure 2 shows the simplest version I know, and in this series tuned circuit,

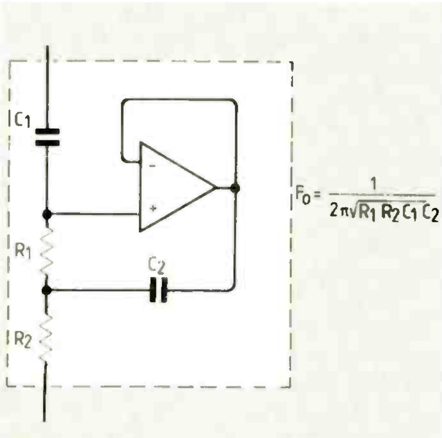
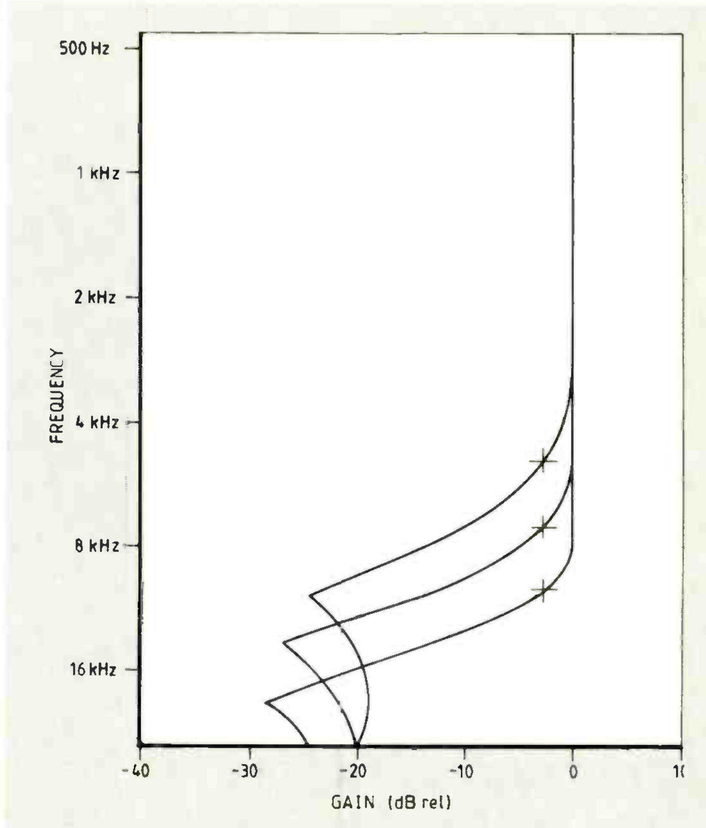


Fig. 2. Elemental gyrator circuit, which emulates an inductor in series with a resistor.

C_2, R_1 and R_2 behave like an inductance in series with resistance; acceptable where a modest Q is required. Riordan proposed a rather more sophisticated version using two op-amps in 1967[3] and two years later Antoniou[4] realised a number of variants, all bearing superficial similarity to the Riordan original with one in particular proving of special interest — the one adopted for this design (**Fig. 3**).

Fig. 5. Manually plotted curve of filter characteristic. Roll-off may be varied from −25dB/octave down to −6dB/ octave at half-way setting.



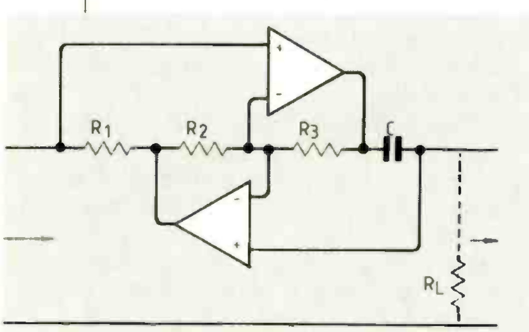


Fig. 3. Gyrator due to Riordan, after Antoniou, which forms the basis for the present design.

Fig. 4. Practical filter with switchable cut-off control. R_1 and R_2 in buffer amplifier control gain.

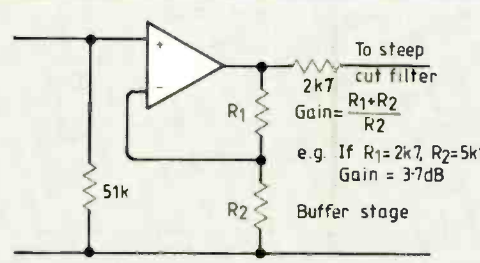
This circuit is a generalised impedance converter and if a resistor is connected from the output to ground, it appears to the input as an inductor

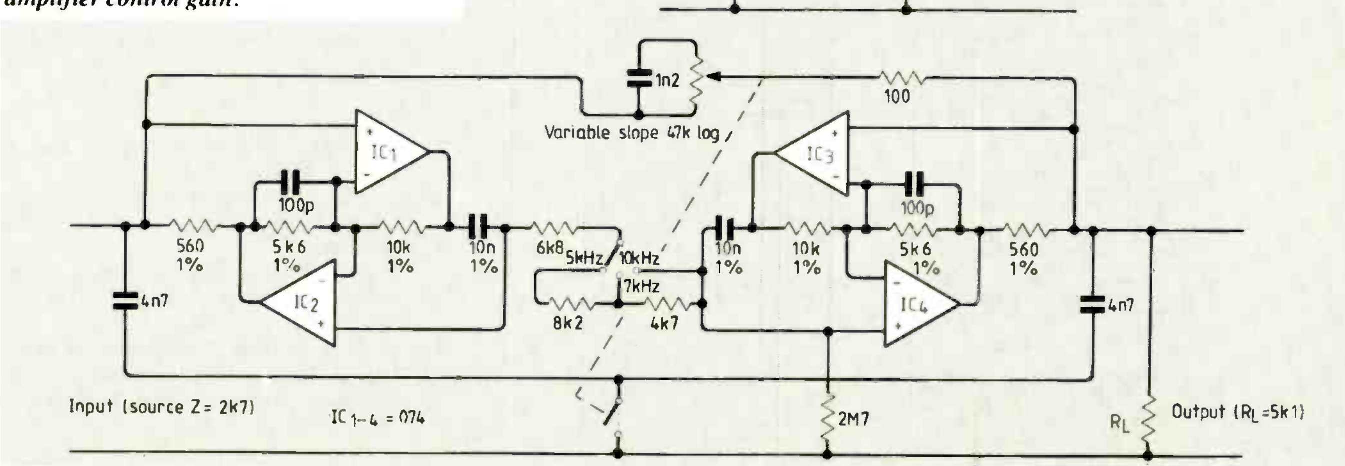
$$L_{eff} = KR_L$$

where $K = CR_1R_3/R_2$. So it can also be seen that if one chooses appropriate values for the capacitive and resistive elements, the scaling factor K can be a comfortable round integer. In the practical design of **Fig. 4** this is equal to

$$L_{eff}(\text{henries}) = R_L(k\Omega)/100$$

A special feature of the Antoniou circuit is that, where the "inductor" is floating above ground, as in the case of a low-pass full-section π configuration, then two can be connected tail-to-tail with resistor (inductor) between them.





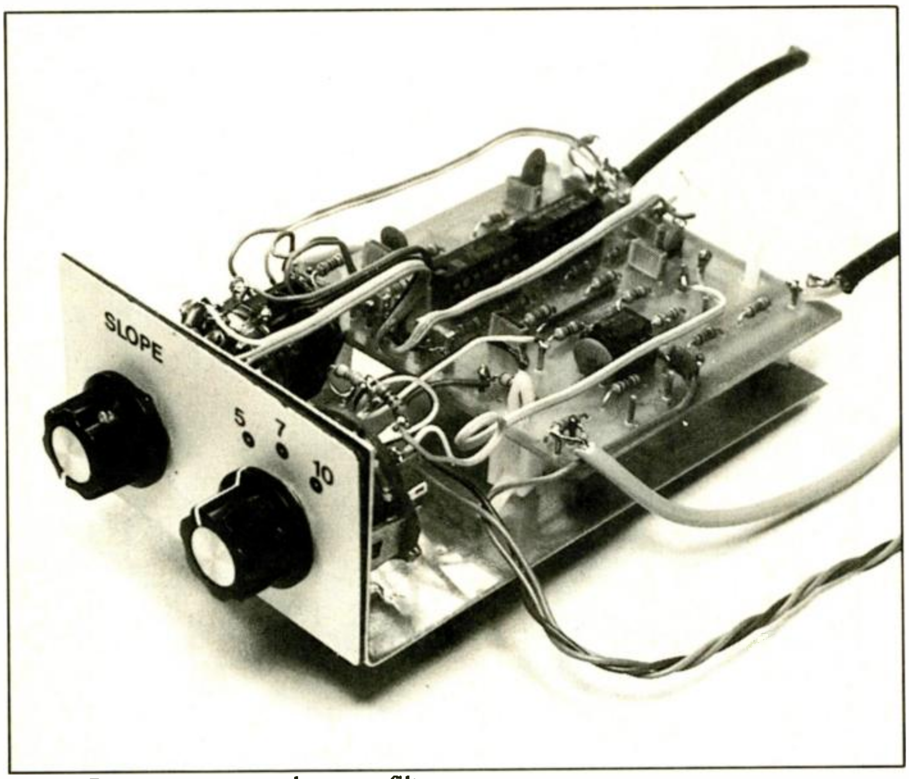


Fig. 6. Prototype steep-cut low-pass filter.

Fast Basic listing for the design of m-derived, half-section high or low-pass filter.

```
\These programs are to facilitate the design of a m-derived half section
\parallel·high or low pass L-C filter.Designed sections may be cascaded
\in T or π configuration. Written in Fast Basic by R Williamson 20/1/87.
CLS:TXTSIZE 13
start:INPUTTAB(12,10)"Do you want High pass or Low Pass? Type HP or LP..:"A$
CLS
IF A$="HP" OR A$="hp" THEN GOTO hp
PRINTTAB(8,0)"This Program will design a low pass half section filter,"
PRINTTAB(8)"m-derived and which may be cascaded in π configuration."
PRINTTAB(8)"It is of the parallel type (see associated diagrams)":PRINT
lps:INPUTTAB(8)"Select the frequency of cutoff (Fc in KHz)";Fc
PRINTTAB(8)"Enter the null frequency (Fn in KHz and which"
INPUTTAB(8)"should not be <1.25Fc)................     ";Fn
IF Fn/Fc<1.25 THEN PRINTTAB(8)"Fn is too low. Re-start!":PRINT:GOTO lps
PRINTTAB(8)"Enter source and load resistances in KΩ"
INPUTTAB(8)"(which are initially assumed to be equal)..";R
M=DSQR(1-(Fc/Fn)^2)
L = M*R/(2*PI*Fc)
C = M/(2*PI*Fc*R):C=C*1000000
Cp = (1-M^2)/(M*2*PI*Fc*R):Cp = Cp*1000000 :PRINT
PRINTTAB(8)"Inductance L is.......                ";L" Henrys"
PRINTTAB(8)"(if standard gyrator module used"
PRINTTAB(8)"                        ...then Rz = ";L*100" KΩ)"
PRINTTAB(8)"Shunt Capacitance C is........       ";C" pF"
PRINTTAB(8)"Series Capacitance Cp is.......      ";Cp" pF"
PRINTTAB(8)"Note: m = ";M
PRINT: PRINTTAB(8)"Assuming cascaded sections in preferred"
PRINTTAB(8)"π configuration, then....      L = ";2*L" Henrys"
PRINTTAB(8)"(if standard gyrator module used"
PRINTTAB(8)"                        ...then Rz = ";L*200" KΩ)"
PRINTTAB(37)"Cp = ";Cp/2" pF"
GOTO end
hp:CLS:TXTSIZE 13:PRINT
PRINTTAB(8,0)"This Program will design a high pass half section filter."
PRINTTAB(8)"m-derived and which may be cascaded in T configuration."
PRINTTAB(8)"It is a series type (see associated diagrams)":PRINT
hps:INPUTTAB(8)"Select the frequency of cutoff (Fc in Hz)";Fc
PRINTTAB(8)"Enter the null frequency (Fn in Hz and which"
INFUTTAB(8)"should not be >0.8Fc)................     ";Fn
IF Fc/Fn<1.25 THEN PRINTTAB(8)"Fn is too high. Re-start!"::GOTO hps
PRINTTAB(8)"Enter source and load resistance in KΩ"
INPUTTAB(8)"(which are initially assumed to be equal)..";R:PRINT
M=DSQR(1-(Fn/Fc)^2)
L =R*1000/(M*2*PI*Fc)
C =1000/(M*2*PI*Fc*R)
Cs=M*1000/((1-M^2)*2*PI*Fc*R)
PRINTTAB(8)"Inductance L is......                ";L" Henrys"
PRINTTAB(8)"(if standard gyrator module used"
PRINTTAB(8)"                       ...then Rz = ";L*100" KΩ)"
PRINTTAB(8)"Shunt Capacitance C is......       ";C" µF"
PRINTTAB(8)"Series Capacitance Cs is....       ";Cs" µF"
PRINTTAB(8)"Note: m = ";M
PRINT:PRINTTAB(8)"Assuming cascaded sections in preferred"
PRINTTAB(8)"T configuration, then....    L = ";L/2" Henrys"
PRINTTAB(8)"(if standard gyrator module used"
PRINTTAB(8)"                       ...then Rz = ";L*50" KΩ)"
PRINTTAB(35)"Cs = ";Cs*2" µF"
end:PRINT
INPUTTAB(8,19)"Type Y for repeat or N to end..."E$
IF E$="Y" OR E$="y" THEN CLS: GOTO start
END
```

Filter design

The final step is to decide on the parameters for a conventional m-derived low-pass filter, determine the value of the inductor and, from that, the equivalent resistor. The mathematical procedures are freely available and will not be repeated here. In the design of Fig. 4 there are three resistors, giving three switched frequencies. The null frequency above the nominal turnover point is a little lower than one octave, giving an m factor of ≈0.8.

The circuit was first simulated by a cad program and a few empirical changes were needed in the prototype, not only because only the inductive component is varied, but also because some adjustments were necessary to allow standard values of R and C outside the gyrators. This departure resulted in some shifts to the turnover frequencies which are insignificant.

Attention to DC and AC stability was also needed. To meet the matching needs of the filter and to compensate for its insertion loss of 3.7dB, there is an input buffer, giving an overall gain of 0dB. The gain may be modified by a simple adjustment to the two resistors in the buffer amplifier feedback path. **Figure 5** shows that the asymptotic rate reaches about 25dB/octave and can be infinitely varied down to a first-order rate of 6dB/octave at about the half-way setting.

Interfacing the unit with existng equipment is simple, since the input impedance is high at around 50kΩ and output impedance is low (this must always "see" 5kΩ, so a fixed resistor might be needed across the output when the load is determined). To preserve an adequate s:n ratio, the signal level should be greater than 100mV. The maximum signal level before clipping is 5.3V RMS and THD<0.002%. ■

My thanks to the University of Keele for the use of facilities and to Alan Watling for constructing and initially testing the prototype.

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Garbage in, garbage out

EW+WW has recently discussed at length the currently fashionable topic of dangers to health associated with low frequency and radio frequency fields. Readers might be led to believe that there is a clearly established causal relationship between exposure to various forms of non-ionising radiation and a variety of diseases. In fact, the correlations are generally very weak, some are statistically flawed, and some result from "data dredging". Any review of the entire series would require a tedious and lengthy paper: to show the problems of this kind of study I will comment only on two of the papers discussed by Simon Best in the March issue.

The study of 2495 radio amateurs is interesting. From the raw data it might be inferred that: first, hams are remarkably healthy — only 70% of the expected deaths occurred. This is a very reliable figure, the C.I. being 69-74. Second, deaths due to acute myeloid leukemia were higher than expected (expected deaths 8.5, observed 13). This is a very weak statistic due to the small number of cases and to the low overall mortality. The C.I. was 103–285. And third, amateurs are largely immune to cancer of the pancreas — observed deaths 27, expected 42, with a C.I. of 42–94. It would be a gross misuse of statistics to assert this.

More significantly, Mr. Best writes, "a sample of 2495 radio amateurs." This is a misleading use of the word "sample". In the original study, the population was roughly 69,000, of whom 2495 died. Thus the chance of dying from any leukemia was 0.5%, not 1.4%, which might be inferred from Mr Best's data. Moreover, the study was not corrected for age nor for the lower than anticipated overall death rate.

The data on electrosurgical machines strongly supports the hypothesis that radiation from these devices is harmless. ESUs have been around for over 50 years and since WWII have become ubiquitous. Virtually all surgeons use these machines in one form or another; they are all of normal vision at certification and I can find no evidence that they suffer more visual deficiencies at retirement than the normal population. ESUs are well known as devices that can cause fires and burns, although the modern units are designed to reduce these hazards. In any case, they have so improved the practice of surgery that the risk/benefit ratio is very near to zero. By the way, the study that Mr Best quotes does not assert that damage occurs.

EW+WW has a reputation for well considered, accurate and well written editorial material. In this series, the editor's laudable social concerns may have led to bias. There is extensive use of "outquotes" (trade jargon for repeating, prominently and in bold type, selected portions of the text). All these emphasise the supposed risks, none are drawn from opposing viewpoints. These, combined with an excessive number of pictures of CEGB pylons, may tempt readers to consider as fact what is, at present, a very loose and ill-assorted body of data.

Harold W. Shipton
St. Louis
USA

Random creep and noise down under

Your article in *EW+WW* of March, "Riding the solar storm," has stimulated my interest in seismoelectromagnetics. The observation of "long secondary waves from distant earthquakes" certainly deserves comment.

I would like to refer to *EW+WW*, February 1987, p230: here the observed effect was in the VHF range. The author invokes the ether as an FM modulator of VHF transmission in an earthquake region of north-east Italy.

In 1986 Tom Barrett, the manager of a communications manufacturing company in Perth, Western Australia, told me of a "noisy" area near Cunderdin, between Perth and Kalgoorlie. A client had installed an SSB network in Cunderdin and was having interference problems. This led to a field survey in a mobile test vehicle fitted with an S-meter. The receiver had a short whip aerial, and the town was very noisy. Even 10km out of town, in the middle of a huge, empty paddock (empty of habitation and power poles), he measured over 35μV of wideband HF noise.

Many months later he was flying a light plane from Kalgoorlie to Perth, and the HF radio on board was set with the mute on — this was a simple level-sensitive mute system. Near Cunderdin, at 6610MHz and 10,000ft altitude, the mute was broken by white noise. The radio had recently been manufactured by his workmen. The plane flew another five to ten miles before the mute operated normally again.

The area is known to be seismologically active, and his story immediately made me think about long, leaky, quartzitic, piezoelectric antenna elements. Random creep along a fault could possibly produce voltages if metal oxides of barium, titanium and other heavy metals were in the quartzite. Random creep could produce wideband noise. The lowest frequency components, say 1 cycle per decade, could be of earth-shaking consequences.

I don't need to invoke the ether to see this possibility. A geopiezoelectric phenomenon is much more likely to be all that is necessary for Occam and his razor.

Russell Job
Forest Range
South Australia

Amplifier tolerances

In reference to Ben Duncan's article regarding CD player mods (*EW+WW*, May), why is it that manufacturers insist on using practices which would never be tolerated in high-quality amplifiers (the use of low-grade op amps being just one example)?

Also, we have found that CD players are surprisingly sensitive to mains- and power supply-related problems — why not use switched-mode power supplies in CD players?

I would like to say to Barry Fox that high-quality cables do improve sound quality, but why pay silly money when you can make your own for a few pounds? Although Barry's article was written tongue-in-cheek, I would like to add that several different types of solder are used in electronics applications, so why not build with solder formulated specifically for audio applications?

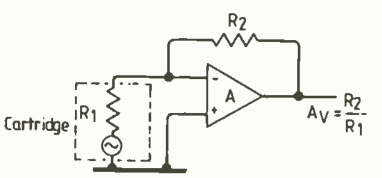
David Carr, editor
Audio Conversions
Rotherham

Economy equalisers and hi-fi subjectivity

I was quite flattered to read in John Linsley Hood's article on pre-amplifier design (*EW+WW*, June 1990) that my phono stage circuit used in recent Rotel amplifiers is "the only other major innovation." As he correctly surmises, the use of a flat response linear gain stage followed by a shunt feedback equalisation stage does follow on from my use of the configuration at Cambridge Audio.

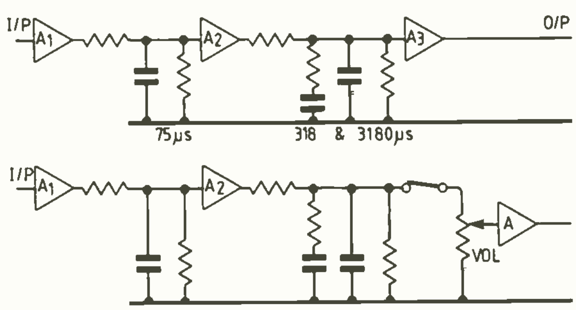
The primary benefit of this configuration is to isolate the critical equalisation stage from the "variable" component — in this case the cartridge. It also enables the phono stage to have switched gain settings (by varying the first stage gain) without changing the frequency response. In most practical amplifiers using feedback equalisation and with moderate open-loop gains, the lowering of the closed-loop gain by, say, 20dB will result in a change in the equalised frequency response.

One interesting variation on the shunt-feedback input stage was used by me in the mid '70s as a moving-coil cartridge amplifier. Here the input resistor is formed by the resistance of the cartridge itself to give an amplifier whose gain shifts to suit the cartridge. Thus a low-output cartridge will typically have few turns, hence a low resistance, and so the amplifier will have a high gain. Conversely a high output cartridge will have more turns, a higher resistance, and the amplifier a lower gain to suit. In addition the virtual earth connection gives good damping of the cartridge. This circuit works well and was to be found in the MYST amplifier, among others.



Another circuit not picked up by the author is a passive system I started to use at Cambridge Audio many years ago and which was used in some of their products (including the current models) and an Acoustic Research amplifier. I termed the configuration "segmented passive equalisation" and it uses three amplifier stages with passive networks between them. This circuit has the advantages of a passive system without the usual sacrifice of either headroom or signal-to-noise ratio. Readers can prove for themselves that with an optimal choice of gains for the three stages there will be no significant loss of performance compared to that of the more conventional feedback equalisers.

An "economy" model is possible without the third stage, the only disadvantage being a possible change in the low-frequency response resulting from any change in the loading



impedance (e.g. the volume control and the following stage).

Turning now to Peter Baxandall's letter in the same issue, we are again seeing the same correspondence that has appeared at regular intervals since the mid-70s. Yet the void between the Walker/Baxandall/Hafler/Self camp and that of Colloms/most successful hi-fi designers seems to be as wide as ever. Having designed well over 200 commercial audio products — a worthwhile proportion of which have earned "Best Buy" or equivalent status in the hi-fi magazines — I feel entitled to throw a couple of comments into the ring.

First, I think we all agree that there is no unexplained "magic" in good amplifier design. Every audible effect has an explanation, but all too often we have been unable to measure the effect with sufficient exactitude. Furthermore if we can measure an "error" what level is acceptable? All too often there is an absence of valid work in correlation between what is measured and what is heard. Precious little published work in this area has been successfully repeated in recent years.

It would seem rational to assume that two amplifiers that measure identically will sound the same and be indistinguishable from each other. And this is normally the case when I've selected two units from a production batch of the same product by a reputable manufacturer. But in testing many, many hundreds of different, commercially available amplifiers over the past 25 years I have *never* ever found two different products which measure identically in every respect. Thus, applying the same logic, there is no reason to assume they should sound the same.

We are left only with two unknowns. How great must the measured difference be before someone can hear a difference; or from the alternative viewpoint, how great an audible difference can there be to a particular listener before we can measure a difference in performance?

I've no doubt that some of your readers can point to a variety of now-dusty research papers which detail investigations into the audibility of minor changes in a measurable parameter. Unfortunately they have by definition been limited to a change in one parameter at a time, yet that is not the situation we find in real life. The differences in the measured performance between two different amplifier designs are rarely differences in just one single parameter. Little, if any, work seems to have been done on the audibility of a number of simultaneous changes of several parameters and the resulting complex interactions.

If a listener can repeatedly hear an effect then we cannot claim he is talking rubbish or that he is an untrained idiot. Instead we have to accept that our previous standards were not rigorous enough and need to be improved. He may be the only listener in one thousand to hear the effect and he may only hear it under his own chosen conditions, yet ultimately he will be the one who sets the standard.

In this context it is worth noting that a listener's perception does improve with practice and reviewers such as Colloms spend almost all their days listening to music systems. Some years ago Bang and Olufsen found difficulties in getting consistent results from randomly chosen listeners and they put together a team of employees who were trained to listen intelligently and who are now, by all accounts, very perceptive. The same practice has been adopted by the Technical University of Denmark to help them fulfil their part in a "Eureka" project.

There has been a great deal of discussion of the nulling technique but, if we are to put to one side any arguments about its relevance, its purpose is to show the degree of input/output error on a music programme when an amplifier is operated within its design envelope. What error is acceptable? What do we do if someone can hear a difference yet the measured error is below the inherent error of the practical test? Whatever, it is up to the amplifier designer to make his own decisions.

Another technique which in some ways is less contentious is that of bridging an amplifier's outputs with a pair of high-quality high-impedance headphones while it is loaded alternately by a 4/8Ω resistor and a real loudspeaker located out of hearing range. This technique has been used by myself, B&W Loudspeakers and others, and has recently been proposed for consideration as a valid tool for magazine reviews by John Crabbe (*HiFi News*, June 1990). Of course, all the usual *caveats* apply but, in my experience, the great majority of amplifiers fail this test.

Let us move on to the real world where real lovers of music listen through real hi-fi systems. They don't check that the programme never drives the amplifier into clip; that their loudspeakers draw "excessive" currents under some circumstances; that their grounding arrangements result in the presence of a high-frequency residual; that the matching of their equipment is less than optimal; and that their record player or CD pumps out significant levels of high frequencies above the nominal audio band.

These people, our customers, will pick up a pair of £200 40W amplifiers, connect them up one at a time, turn up the volume and play their music. Invariably the amplifiers will sound different and it matters not if we jump up and down and say they are being used outside their design envelopes and that their tests are not being conducted in a proper manner.

The fact is that some amplifiers are designed to be more tolerant under such conditions and, when they are in trouble, for the resulting distress not to be audibly unpleasant. In this context readers may remember that the original Quad 405 had very limited output current capability because of its limiters, and that in the real world this was audible. Quad designed their hybrid protection circuit which made more current available, and most everyone agreed they then had a better product.

Returning briefly to the differential/nulling test, I have to say that when I've applied the test to a number of reasonably priced amplifiers and kept the amplifier operating within its design envelope the audible results have rarely been satisfactory for my listeners. One thing this test has shown me is that to satisfy the requirements of today's consumer you either design inevitably expensive amplifiers with a wide operating envelope or you design inexpensive amplifiers whose excursions outside of their envelope are not too apparent to the listener.

If there is a "black art" to amplifier design it is in producing a balanced design which incorporates all the relevant theoretical knowledge and a degree of empirical experience, in understanding the real world of the consumer and in making an amplifier whose performance may fall well short of perfection but whose problems and imperfections are not too obvious to the listener. Since few designers have an unlimited budget the final mix has plenty of room for individual judgment and so it is hardly surprising that we can create products which have quite clear differences, both measured and audible.

I would suggest that it still remains the case that some designers may have better judgment than others.

Stan Curtis
St Ives
Cambridgeshire

Ancient wisdoms

R. V. Harrowell's idea of forming an unofficial, impartial body of "time-expired" scientists and engineers to examine heterodox claims (Letters, *EW+WW*, May) is timely. Anyone thinking of doing so is welcome to write to me for information on a system of committees which, in certain respects, is being formed for such a purpose.

B. E. P. Clement
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Soviet safety standards

There is a difference of a factor of 1000 between Soviet safety standards for electromagnetic radiation and those used in Britain, the USA and the West. In the USA the maximum dose rate is 10mW/cm^2; in the USSR it is 10μW/cm^2. This contradiction is associated with the very crude method used in the West that sets the safety level as one tenth of the level that causes thermal tissue damage (*EW+WW*, March 1990, "Killing Fields"). In the USSR a more technical approach is used ("Occupational Health and Safety in Manufacturing Industries," M. K. Poltev, MIR Moscow, 1985).

In the same issue of *EW+WW* is an article on short range radar (by Lab-Volt) which claims that a power density at 10GHz of 80μW/cm^2 is less than the most stringent safety limits.

The levels of radiation to which a personal computer operator is exposed can be assessed by moving a shortwave radio round the computer. Crude computations regarding the very high signal levels detected by the radio at a wide range of frequencies can be done, which show that the Soviet standard limit of 10μW/cm^2 is likely to be exceeded for an operator seated close to the machine. The fact that computer equipment, particularly that using CRT-type displays, emits significant levels of electromagnetic radiation has long been known and forms the basis of methods of spying on computer installations.

Apart from the dangers of electromagnetic radiation, concern has been expressed over the emission of very low levels of ionising radiation by CRT-type VDU devices. The very long exposure of users, often approaching 2000 hours per year, means that very low levels of ionising or non-ionising radiation constitute a health hazard. The following safety measures are thus suggested:

First, VDU users should use very wide tables to avoid having the equipment too close to them. A size of 1.2m wide (4ft) by 2m long by 750mm high has been found suitable. This is in contrast to the accepted practice of using small stands for computers and having the operator close to the screen.

Second, there is a need for electromagnetic shielding in the form of steel or mu metal screening, conductive coatings on glass screens, etc.

Third, pregnant women, or women likely to become pregnant, must not operate VDU display devices, and the use of such equipment in schools should be discouraged or, better, discontinued. Practically every educational journal in the country now carries photographs of children seated close to computer VDU screens.

It is essential that action is taken now to limit future damage to health from computer equipment. There is ample evidence of the long-term danger of present practices but no action — even to the limited extent indicated above.

J. A. Corbyn
Penhalonga
Zimbabwe

Interested parties should contact Mr Clement, not the EW+WW editorial office. — Ed.

Riddle rewrites

My pleasure in seeing that you published both my letters (*EW+WW*, May) was shattered when I read through that under the heading "The Riddle of Inertia" and saw the extent to which you have fallen short of your usually excellent standards.

Paragraph 2: ". . . and arrived at by Galileo only after much experimentation on bodies moving under gravity on inclined *planes. In fact, the equality* of rates of fall must be so, . . ."

Paragraph 3: "So 201 balls released simultaneously must strike the ground simultaneously. *If 200 of the balls are then lightly welded together, they will still fall as if separate, and strike the ground simultaneously* with the one free ball,"

Paragraph 6: "So are the square root of -1, conformal mapping, matrices, etc., but a matrix or $\sqrt{-1}$ are not physical objects, . . ."

Paragraph 7: "We must go back to *basics* and build up physics again, . . ."

I shouldn't like readers to think that I talk gibberish habitually.

R. A. Waldron
Dept of Mathematics
University of Ulster

I have just received my copy of the May edition in which I notice that my letter has an omission which makes the physics of the argument incorrect. The fifth paragraph should read as follows:

"The three most commonly used classical methods are Newton's Laws, Lagrange's Equations and Hamilton's Principle. These are mutually compatible approaches where the definition of force is that given by Newton's first two laws in the form that force is proportional to the time rate change of momentum. Here the two laws are seen as definitions. It also follows that the moment of external forces is proportional to the time rate of change of the moment of momentum."

H. R. Harrison
The City University
London EC1

ACTIVE

A-to-D and D-to-A converters

Programmable gain A/D. A programmable gain version of the PCL-718, the PCL-818, allows the gain of each of 16 analogue inputs to be stored in an on-board ram sequencer which automatically selects the gain of each channel for high-speed multi-channel/multi-range data acquisition applications. Maximum throughput is 100kHz using the built-in pacer and DMA function. The card also includes two D/A channels and 32 digital I/O lines, plus a 16 bit counter/timer. Fairchild Ltd, 042121 6527.

Multiplying D/A converters. The MX7537 and MX7547, 12-bit current output D/A converters have two precisely matched DACs per package, and are guaranteed monotonic over temperature, with relative accuracy of 1/2 LSB. Resistance mismatch between the two is a mere 0.5% over temperature, making many dual DAC applications possible that were not feasible using discrete DACs. The reduction in board space with two DACs in one package makes them suitable for size-critical applications. Maxim Integrated Products, 0734 845255.

Discrete active devices

Surface-mount d-mos fets. All small signal vertical d-mos transistors from Philips are now available in the SOT-223 surface-mount package, the first surface-mount type capable of dissipating 1W on a standard PCB. This combines the advantages of fast switching speed with the benefits provided by surface mounting. The SOT-223 packaged d-mos range consists of both n-channel and p-channel types. There are 15 types in the range with voltage ratings from 35V through to 450V; on-resistances go down to 1.8Ω. Maximum drain-source currents range from 100mA through to 2A. Philips Components, 071-580 6633.

Eye response photodetector by Centronic.

P-channel mosfet. Despite a threshold voltage no higher than −2V, the new BSS84 surface-mount mosfet features thermal properties said to be unmatched by any of its competitors. Optimised for fast switching combined with low on resistance, the device has a rise time of just 10ns when carrying 270mA. The construction of the SOT-23 package allows the device to meet its full 360mW power rating on a ceramic substrate only 10 x 8 x 0.6mm. This 50V-breakdown device is capable of handling 130mA continuously and peaks of up to 520mA. It has on resistance of no more than 10Ω, input capacitance of 40pF and typical forward transconductance figure of 100mA/V. Zetex plc, 061-627 5105.

Space-saving PNP Darlington. The new ZTX712 PNP Darlington can replace TO126 and TO220-packaged devices in many medium-power applications, saving space and cost, and often offering an increase in performance. The 712's E-line package measures just 2.45 x 4 x 5mm. Capable of handling −800mA continuously, the ZTX712 features a gain of at least 10 000 when carrying −500mA. At maximum current, its saturation voltage is a maximum of 1.25V while its base-emitter voltage at the same current is 1.8V. In audio amplifiers the device is suitable as a driver or output transistor. For symmetrical stages, there is an NPN complementary version of the ZTX712 — the BCX38. Zetex plc, 061-627 5105.

Digital signal processor

C-mos voice processor. The UMC UM5100 is a single chip c-mos LSI for high quality voice recording and reproduction applications in voice storage, intelligent security and voice response equipment, and telecommunication designs. It includes an RC oscillator, address bus generator, serial-to-parallel converter, mode control and delta modulation functions. The delta modulation circuit is based on a continuously variable slope waveform technique. Additional circuits compensate for low frequency distortion, and include an amplifier to translate voice loudness. For recording and reproduction, it is interfaced to a static ram, and for voice-only reproduction, to eprom or rom up to a maximum addressable memory size of 256K. Operating from 3 to 6V, a standby current of only 1 typical is needed. METL, 0844 278781.

Linear integrated circuits

Stepped voltage detectors. The RX5VA range of voltage detectors includes comparators, output driver devices and a hysteresis circuit. Manufactured using low-power c-mos technology, the Ricoh family can be ordered with the voltage specified between 2.0V and 6.0V in 0.1V steps. Three types of output can also be specified: n-channel open drain, p-channel open drain and c-mos output. Suitable applications include reset circuits, battery checkers, level discriminators, battery back-up switching circuits and power failure detectors. Micro Call Solutions, 0844 261500.

Logic building blocks

C-mos real-time clock. The single-chip MSM 62X42BRS c-mos high-speed, bus-oriented, real-time clock is fully bus-compatible with any CPU or MCU and has an access time of 120ns. Each 4-bit address and bi-directional 4-bit data bus is thus enabled to access registers for seconds, minutes, day of the week, date, month and year, with automatic leap-year timing in both 12 and 24 hour. Implemented in low-power Si-gate c-mos the device dissipates 150μW at +5V and 20μW at +2V back-up, which permits continuity of timekeeping even when powered down. Operational temperature range is −40 to +80°C. Norbain Technology, 0734 864411.

Optical devices

Eye response photodetectors. A new range of eye response photodetectors comes in both silicon and GaAsP variants. The latter feature a spectral response with sharp I.R. cut-off at 700nm. Since the response is approximately photopic, the detectors will measure light accurately without the need for expensive filters. Their low dark current compared to silicon detectors, and good linearity and responsivity in the visible range, make them suitable for a wide range of applications. The 'E' range silicon detectors have been designed to closely mimic the human eye, making them suitable for photometric applications. Centronic Ltd, 0689 42121.

Laser diode drivers. A new series of pulse generators features high current outputs to 200A without duty cycle restrictions. The Avtech AVO-8 Series pulse generators are designed for pulsing laser diode and other loads with rectangular pulses as high as 200A or 40V, pulse widths from 2μs to DC, and duty cycles to 100%, with rise and fall times less than 1μs. These units can provide average output power levels as high as 5000W. Output pulse amplitude is controlled by a user-supplied high current laboratory power supply which provides the prime power to the output stage. Output pulse width is controlled by front panel controls, and an electronic pulse width control option is available. A delay control and sync output are provided. Applications should include use as drivers for laser diode arrays and other similar low impedance loads. Lyons Instruments Ltd, 0992 467161.

Oscillators

Crystal oscillators. Euroquartz's family of surface-mountable crystal oscillators is now available for frequencies ranging from 1Hz to 32MHz. Supplied in standard 24-pin ceramic leadless chip carrier packages, they are designed for surface-mounting applications using either vapour-phase solder reflow or wave-solder techniques. TTL and c-mos compatible, they comprise a hybrid circuit and a miniature quartz crystal, and are characterised by low power consumption and high shock resistance. Euroquartz, 0460 76477.

Programmable logic arrays

Fast TTL PLD. What is claimed to be the world's fastest TTL programmable logic device (PLD) is scheduled for volume production this year. The PAL16R8-4 family includes the PAL16L8-4, PAL16R8-4, PAL16R6-4 and PAL16R4-4. These devices are packaged in a proprietary pinout 28-pin PLCC with multiple distributed ground and power pins to eliminate ground bounce and crosstalk. Maximum combinatorial propagation delay for the PAL16R8-4 family is 4.5ns. In registered mode, the worst case maximum frequency is 125MHz. AMD (UK) Ltd, 0483 740440.

24-macrocell EPL. The 5AC324-25 is a 25ns version of the advanced architecture, 24-macrocell, ch-mos EPLD. It doubles the density of the first advanced family member, the 5AC312, while maintaining a fast 25ns propagation delay. Using the "programmable-AND/allocatable-OR" architecture, the chip allows the user to define macrocells allocated with zero to 16 product terms (P-terms), and increases device use by allowing designers to implement complex logic functions requiring more than today's standard eight P-terms, while keeping up with advanced CPU clock frequencies. Intel, 0793 696204.

30,000 gate GaAs array. A 30,000 gate GaAs array targeted at high-speed computer, telecommunication and defence applications does not require liquid cooling. This marks the first time that air-cooled systems are able to make use of high-speed gate arrays in excess of 15,000 gates. The VSC30K features 30,528 2-input NOR gates with 100% gate utilisation. Typical power dissipation is 8-12W. Packaged in a 344-pin leaded chip carrier, the VSC30K offers 256 signal pins configurable to ECL, TTL, and GaAs I/O levels. Kudos Thame Ltd, 0734 351010.

ECL gate array. The ECL-4A gate array family features a gate delay time (unloaded 2-input NAND) of only 90ps, claimed to be the fastest gate array delay commercially available. Five masters, with gate counts from 8,462 up to 35,656, and the classical architecture with dedicated routing channels, allow usage rates in excess of 90%. ECL-4A provides ECL-10KH/100K and TTL I/O options, which with 1.7GHz min logic make the family suitable for applications such as mainframe CPUs. They are available in ceramic flat packages and pin grid arrays with integral heat sinks and pin counts of 132, 208 or 280. NEC Electronics (UK) Ltd, 0908 691133.

PASSIVE

Passive components

RF power resistors and terminations. The new RFP series of power resistors and terminations, available in either surface-mount or flange-mounted styles, provides a high standard of match at frequencies up to 4GHz. The match achieved depends upon the application but a V.S.W.R. of better than 1.10:1 is typical for most microstrip circuit uses. Resistance values from 0.8 to 20kΩ can be supplied in either preferred scales or to custom requirements, and the terminations are available in a choice of 50, 75 or 100Ω. Power ratings range from 5 to 250W. Atlantic Microwave Ltd. 0376 550220.

Displays

Multiline LED display. The Apel multiline LED message module is designed to display from 2 to 64 lines with either 16 or 32 characters. Character heights range from 5.4 to 13.5cm. Suitable for text displays in hotels, conference centres, sports stadia and similar venues, these new modules offer considerable cost and reliability benefits over conventional white-lamp displays. Contained in black anodised cases, they can be specified in four levels of brightness, from standard to "laser"-bright, all suitable for daylight viewing. Each comes with a software programming package which will run on any IBM-compatible PC and allows the user to create a wide range of effects. 750pp of six-line text can be stored at any one time. Elcomponent Ltd, 0279 503173.

Dot matrix LCD driver. The SED 1520 single-chip dot matrix LCD driver connects directly to an 8/16 microprocessor, and is the first of a new generation of display drivers that contain 68/80 series MPU interface, display ram, and LCD driver for a 16 x 61 seg dot-matrix LCD. Supporting up to 1/32 multiplexing allows displays as large as 32 x 200 dots to be realised with just three devices. It is suitable for battery-powered instruments, car phones or pagers and operates over 2.4 to 7V and −30°C to +85°C. Hero Electronics, 0525 405015.

Instrumentation

Panel printers. Model 144 and 144E microprocessor-controlled intelligent panel printers accept serial RS232C, RS422 or RS485 inputs. Menu options include: data rate and format; address; one of eight language character sets; and automatic print interval timing. Other features are a line numerator and a choice of 32 engineering unit captions. Both can print 20 or 40 characters per line at 36 lines/min. Applications include: data logging with a DPM; diagnostic or failure reports; test or QC print-outs; on-site hard copy and remote print-out. Amplicon Liveline, 0273 570220.

40kV digital meter. The 139D direct reading meter is designed for accurate measurement of DC line voltages of up to 40kV. Its very high input impedance limits current to less than 2μA at 40kV. Reliability in a wide range of environmental conditions is assured through use of modern solid-state techniques and circuitry is fully protected against transients and flashover. Fast logging of voltage readings comes through the attachable pen recorder, with an accuracy of 0.3% at 20kV. The meter also has a 3½ digit LCD readout, with auto polarity indication. Two measurement ranges of 0-20kV and 0-40kV are available, and the meter comes with a high voltage probe for testing up to 40V DC and an interchangeable beryllium copper tip suitable for measurements required under CRT anode caps. Astec High Voltage, 0483 756066.

Magnetic field monitor. Recent publicity of the adverse effects of strong magnetic fields from power lines, etc, has revealed a need for a portable field monitor. The MFM 10 Combinova Magnetic Field Monitor is a rugged, self-powered, digital reading meter well-suited to this purpose. In order to cover the 50Hz power lines and its harmonics, field strengths in the frequency range 5Hz to 1kHz are measured down to a sensitivity of 10nT. Measurements are indicated on an LCD display and orthogonal sensing coils provide recording of fields in all three planes. The device comes complete with tripod, battery charger, communication cables, transportation case and operating manual. Eaton Ltd, 0734 730900.

Portable digital recorder. The WindoGraf combines the ease of use of a traditional chart recorder with the power and versatility of a data-acquisition system, and offers a choice of output formats: a built-in 7in real-time display monitor, a 4in thermal array recorder for hard-copy output, and a 3.5in disk drive. The hard-copy recorder and disk drive can be engaged or disengaged independently, so that the user can select one, two or all three outputs. Stored data can be recalled and continuously hard-copied by the built-in thermal array recorder. Signal conditioning is provided by up to four plug-in modules that provide input/output isolation, full-scale selection, AC and DC coupling, zero suppression, and an on/off filter selection. Special-purpose modules are being introduced for medical, strain-gauge, thermocouple, true RMS and frequency/voltage applications. Gould Electronics, 081-500 1000.

Data loggers. The DDL-4000 Series of portable data loggers is a family of full-featured, rugged data-gathering products that tie directly to thermocouples or voltage or current output devices. A wide variety of available hardware and software accessories allow the user to custom-configure a system to meet specific application requirements. The sealed membrane keyboard surrounding the LCD display controls functions such as data-logging interval, HI/LO alarm limits, channel select/skip, time/date settings, etc. The LCD display shows channel data, alarm limits and status, time and date. Each data logger requires a TCV-16 I/O panel. Keithley Instruments Ltd, 0734 575666.

PC-based data acquisition. Greater programming flexibility and memory capacity has been added to the Model 556 GPIB measurement and control system. This IEEE-488 data acquisition unit allows users to conduct analysis, acquisition and control through any computer with an IEEE port. The Model 556 accepts up to 10 plug-in data acquisition cards. Firmware enhancements include: programming the unit to control sample rates in units of Hz from one to 1000, support for nesting conditional triggers and loops to eight levels, without the need for intervention from an outside controller, and the conditional triggering function gains "If . . . Then . . . Else" capabilities. Keithley Instruments Ltd, 0734 575666.

High-precision oscilloscopes. Four new models of digital oscilloscopes are aimed at engineers who need the highest precision available. Models 410, 410E, 420 and 420E claim to offer the highest resolution of any digital oscilloscope and feature 12-bit digitisers operating at 1 megasample per second. Other features include: two or four channel 64k or 256k memory per channel, built-in ms-dos disk drive, optional hard disk and 44Mbyte removable cartridge, built-in waveform processing which includes FFT and averaging, IEEE-488.2, RS-232, plotter and printer interface. Nicolet Instruments Ltd, 0926 494111.

Precision data converter. The multifunction Oasis MADC12R has the versatility to acquire reliable measurement data from a broad range of applications. With programmable ranges from 10mV to 10V (in 1, 2, 5 increments) and built-in cold junction compensation, low-level signals direct from thermocouples are accommodated (with 2.4μV resolution) together with high-level signals to 20V (peak-to-peak). 16, 32, and 64 analogue input channel versions have 30kHz throughput as standard and a high-speed option yields 80kHz (to 12 bit resolution). Software emulates conventional instruments and provides extensive process monitoring facilities. The Design Consultancy, 0603 747887.

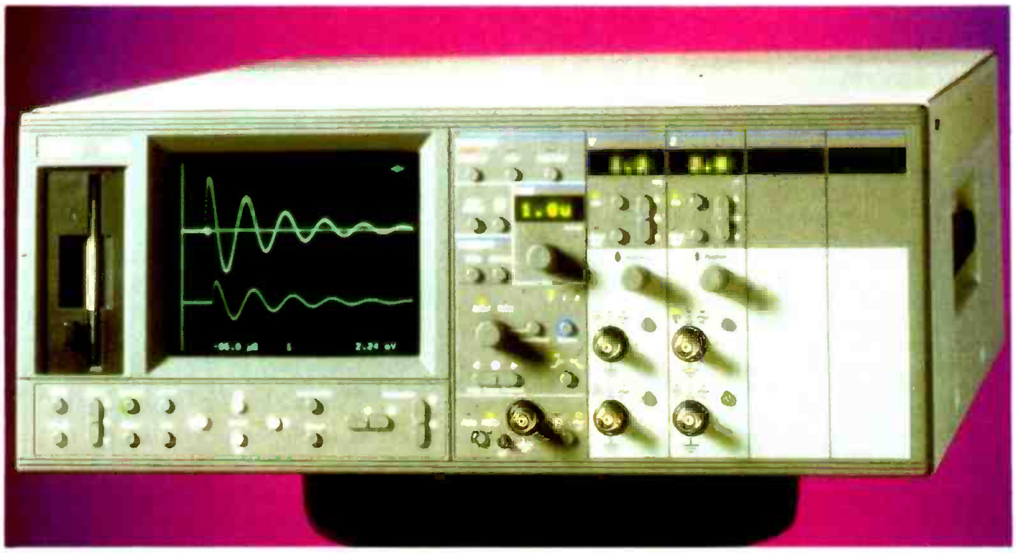
Combined television vector and waveform monitor from Thurlby-Thandar.

Vector/waveform monitor. The Leader 5871 is a TV signal test instrument that integrates waveform-monitor and vectorscope functions. Waveform and vector signals can be displayed independently or simultaneously on the instrument's high-intensity, high-resolution 150mm rectangular CRT. The 5871 has a built-in subcarrier horizontal phase-measuring function for video editing, and a nine-point memory to allow the presetting and recall of field and line numbers. The subcarrier horizontal phase can be numerically read from the CRT, as can phase variations or jitter. Thurlby Thandar, 0480 412451.

Interfaces

Digital I/O card. The PC-DIO48, a 48-channel digital I/O card with interrupts, is a low-cost PC plug-in card using two programmable peripheral interface ICs to provide 48 I/O lines arranged as six 8-bit ports, each configurable as an input or an output. Four of the I/O lines can be user-selected to drive interrupt signals on the PC bus, allowing interrupt requests to be generated in response to I/O port data transfers. The card occupies eight I/O address locations and its base address is DIL switch selectable. To simplify interfacing, space is provided for optional pull up/down resistor networks on all 48 channels. Bede Technology, 091-428 0353.

Digital input interface. Added to the range of boards which operate on IBM PC/XT/AT or compatible machines is the PI-32T, a digital input board which is said to enable the personal computer to be converted into a powerful tool for data acquisition and control applications. It offers 32 channels for acquiring data from TTL/5VDC digital signals, configured in four blocks of eight channels each, facilitating operation with 8-bit parallel data. Two input channels can be connected to



High-res digital oscilloscope from Nicolet. FFT and averaging is built in.

interrupt lines, IRQ2 to IRQ7, to achieve event-driven applications. Interrupt level selection as well as base address selection is via on-board jumpers. Instrumatic UK Ltd, 0628 476741.

Power supplies

Hybrid DC/DC converters. Operating at 15W, the new NFC15 series of high efficiency hybrid DC/DC converters is purpose-designed in a compact housing to suit space-critical telecommunication applications. They will accept input voltages from 20V DC to 72V DC with near constant 80% efficiency over the entire input voltage range, and perform to an extra wide 7:2 input range, ensuring full output power without derating up to 60°C, or needing additional heatsinking. The range features current limited outputs, overvoltage protection and c-mos/TTL compatible remote inhibit/synchronous input. The isolated floating output can be referenced as either positive or negative, or stacked in series for higher output voltage situations. Computer Products Power Conv., 0234 273838.

100W DC/DC converters. Distributed power systems are now viable for companies outside the telecomms industry with the introduction of a range of 25 to 100W DC/DC converters, measuring 61 x 59mm with a power density of 36W per cubic inch, making on-card power conversion for rails up to 100W a reality. Each 'Mini-Mod' module can convert, regulate and output 20 to 100W of DC power at 2 to 95V. Output currents can range from 20A at 2V to 1A at 95V. Standard output voltages are available and line and load regulation is better than ±0.2%. Output set point accuracy for all models is within ±1.0% and outputs may also be trimmed from near zero to 110% of rated output. Output sense voltage lines and overcurrent protection are also provided. Pertech Ltd, 0344 890360.

Switches and relays

Interface relay. The G2R-E interface relay is a single pole system, where the user fits as many relays as are needed. The slim 15.5mm socket is compact, suitable for multiple-banking, and available with one of three configurations: an EMR offering 5kV isolation between coil and contacts and 10A switching, a DC control AC output SSR, or a DC control DC output SSR, both rated at 2A. All relay styles have LED indication of coil energisation and UL and CSA approval as standard. The new P2RF-05-E socket for this relay has coil and contact terminals at opposite ends. An integral clip also provides an elegant means of relay removal, important where relays are mounted closely together. A labelling facility is provided, for indent numbering. Terminals are able to accept up to two 1.5mm cables, and a dual terminal numbering system is used, incorporating both traditional and IEC numbering systems. IMO Precision Controls, 081-452 6444.

Miniature switch. A very small, single-pole, three-position, 2.54mm throw, slide-action switch has surface-mounted terminals moulded into a PBT body. For use within the body of a new generation of lightweight oscilloscope test probes, it had to measure 11 x 0.8 x 4.5mm. Another limiting factor in the design was the small working current requirement of 0.5mA at 500V DC which necessitated gold contacts. Now in production, the switch has a life in excess of 20,000 cycles. ITW Switches, 0705 694971.

Transducers and sensors

Piezo-resistive accelerometer. Claimed to be the first commercially available low-cost piezo-resistive accelerometer to use a surface-mount package, the model 3031 is suited for high-volume production where small size, light weight (4oz), low cost and compatibility with other SMDs is required. These silicon-chip based devices consist of a micro-machined mass suspended by multiple beams to a silicon frame and measure just 3.43 x 3.43mm allowing the use of a surface-mount package with 7.6 x 7.6mm outline. The devices require only a single 5V supply for operation and feature FS acceleration ranges of ±2 to ±500g. Silicon caps provide over-range stops, while built-in damping results in a wide DC to 2.5kHz bandwidth; 0.707 damping factor, ±0.2% of span linearity, including hysteresis and a −40 to +125°C temperature range. Eurosensor, 071-405 6060.

Infra-red sensor. From technology-leading Dewit of the Netherlands, the Quadro-Lux infra-red proximity sensor is small, rugged and reliable. Because it has no lenses, the device can see through condensation, dirt, cloudy atmospheres and even fingers. In such unfriendly environments, the units have the ability to sense target objects up to 15m. The operational integrity of each pair of sensors is enhanced by incorporating phase-locked electronics in the switching circuitry, eliminating problems associated with signal confusion from other sensors or ambient lighting irregularities. Operating temperature range is −25°C to +65°C. Quiller, 0202 417744.

Vision systems

C-mos image filter. A 40MHz c-mos image filter features eight multiplier inputs which are all accessible to the user and can be updated every clock cycle. The new device handles pixel interpolation in real time. The TMC2246 contains four 11 x 10 bit registered multipliers, a summer and an accumulator. A fully registered pipelined architecture guarantees 40MHz data/coefficient input and computation rates. In operation the TMC2246 forms the sum of four separate 21-bit products and then accumulates the sum-of-product. The data or coefficient inputs may also be held constant over multiple cycles providing storage of mixing and filtering coefficients. Ambar Cascom Ltd, 0296 434141.

Time-saving pip board. A new picture-in-picture (pip) board, said to be able to save months of hardware development time, provides a development aid in applications such as video conferencing systems, video telephones, and multi-screen monitoring. Connected to a TV or monitor by means of a scart cable, the board is used in conjunction with 5V and 12V supply rails and appropriate video sources, and generates a stable noise-free picture at one of four predetermined positions on the screen. NEC Electronics (UK) Ltd, 0908 691133.

COMPUTER

Computer board level products

Multimeter card. The new PCL-860 is a complete 4½ digit multimeter subsystem on an IBM-PC/AT card. It is said to provide equivalent features and performance to IEEE benchtop DMMs while offering significant cost savings. An integrating A/D gives basic system accuracy of 0.03% on all DC voltage and resistance ranges. The isolated input enhances noise rejection and gives protection to 400V. Connections are made via 4mm sockets with standard ¾in spacing and up to 256 channels may be scanned by using external relay multiplexors controlled by the onboard 16 digital output lines. Programming is via a device driver and is language independent. Fairchild Ltd, 042121 6527.

Data communications products

Comms controller. The latest addition to the Zilog Datacom family, the Z16C35, is an integrated serial communications controller (ISCC) which, with its streamlined programmable bus architecture, is said to be able to operate with any CPU. In addition, four DMA controllers have been added on-chip (2 per channel) which increases the data transfer rate to at least 3.125Mb/s and is claimed to decrease the typical industry standard CPU bus overhead by some 50%. Celdis, 0734 585171.

Single-chip transceivers. A family of single-chip 10BASE-T products is claimed to meet the emerging IEEE 802.3 standard for Ethernet over twisted pair wiring. The family includes transceivers for hub connections, PC connections and a semi-standard version. The ML4651 and ML4652 are single-chip 10BASE-T transceivers with an AUI interface used for adapter cards which plug into PCs and external transceivers. The ML4654 is a single chip 10BASE-T transceiver used in a multi-port repeater (or hub), the central connection point of a network. The FB3651 is a lan transceiver tile array that allows semi-standard versions of the ML4651, ML4652 and ML4654 to be produced. Micro Linear Corp, 0101 408 433 5200.

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2 A	4	7.01	2.20
3 M	6	12.08	2.36
4 P	8	12.87	2.42
6 S	12	15.62	2.64
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2000	60.41	5.11
3000	102.72	6.32
4000	133.35	O/A
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1	2	6.19	1.98
2 A	4	10.01	2.20
3 M	6	11.60	2.42
4 P	8	13.84	2.53
5 S	10	16.62	2.74
6	12	19.41	2.91
8	16	25.74	3.02
10	20	29.94	3.24
12	24	33.42	3.45
15	30	37.43	4.01
20	40	51 10	6.54

50/25V or 25-0-25V 2×25V
Tapped Secs to give: 5, 7, 8, 10, 13, 17, 20, 25, 33, 40, 50V or 20-0-20V or 25-0-25V

50V	25V	£	P&P
0.5	1	5.91	2.09
1 A	2	7.19	2.20
2 M	4	12.81	2.75
3 P	6	14.82	2.92
4 S	8	20.30	3.24
6	12	25.81	3.45
8	16	36.52	4.12
10	20	43.34	4.41
12	24	51.87	5.22

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1 A	2	10.25	2.20
2 M	4	13.17	2.53
3 P	6	19.05	2.64
4 S	8	21.72	2.75
5	10	27.46	3.19
6	12	31.32	3.41
8	16	44.04	4.12
10	20	51.28	4.40
12	24	59.09	5.22

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96V	36V-48V	£	P&P
0.5	1	7.16	1.76
1	2	12.80	2.31
2 A	4	21.05	2.91
3 M	6	25.49	3.02
4 P	8	32.54	3.32
5 S	10	46.21	4.18
6	12	57.87	4.40
8	16	63.12	5.28

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Inverting regulator

LM2579 is a pulse-width modulated switching regulator which is usable in several DC-to-DC converters, including the buck, boost and inverting types, and also in other applications which need variable pulse-width voltage drive. A control signal, normally taken from the output voltage, is compared with an internally generated reference, the resulting error signal being fed to logic circuitry which turns the output transistor on or off.

It is more flexible in use than most, having separate pins for inverting and non-inverting inputs to the comparator which are provided with their own 1V references. A 1V reference is taken to a modified voltage follower. When both inputs to the chip are open, both inputs to the comparator are at 1V (V_A). An input to, say, the non-inverting comparator input will cause a current of $\Delta V/R_1$ to flow in R_1 and R_2, the comparator inputs now seeing $2\Delta V$ between its inputs, which the high gain of the system, together with feedback, returns to zero.

The output will switch up to 3A, both collector and emitter being accessible, the emitter being happy below ground, so long as total V_{CE} does not exceed 50V. This allows the device to be used in an inverting configuration without an extra output transistor. There is an oscillator on-chip, whose frequency is controlled between <1Hz and 100kHz by one external capacitor:

$$f_{osc}=8\times10^{-5}/C_1.$$

Current limit is referable to either V_{IN} or ground. Two comparators are provided with references of 115mV above or below ground or V_{IN} and the current limit circuit is activated when its terminal exceeds this voltage away from ground or V_{IN}.

Since, during its recovery time, a diode is effectively a short circuit, and since the LM2579 will switch current at 30A/μs and 1in of 20g wire possesses about 30nH of inductance, an inch of wire will give a 1V transient. Schottky diodes are recommended.

LM2579 can be shut down remotely by sinking a larger current from pin 2 than from pin 1. Current to ground through the remote switch or transistor should go through a resistor of about half the parallel value of R_1 and R_2.

The inverting regulator shown in the diagram converts a 15V input to −15V at 1A, with a load regulation of 30mV/A at currents of 100mA to 1A.

Calculate the inductor value from

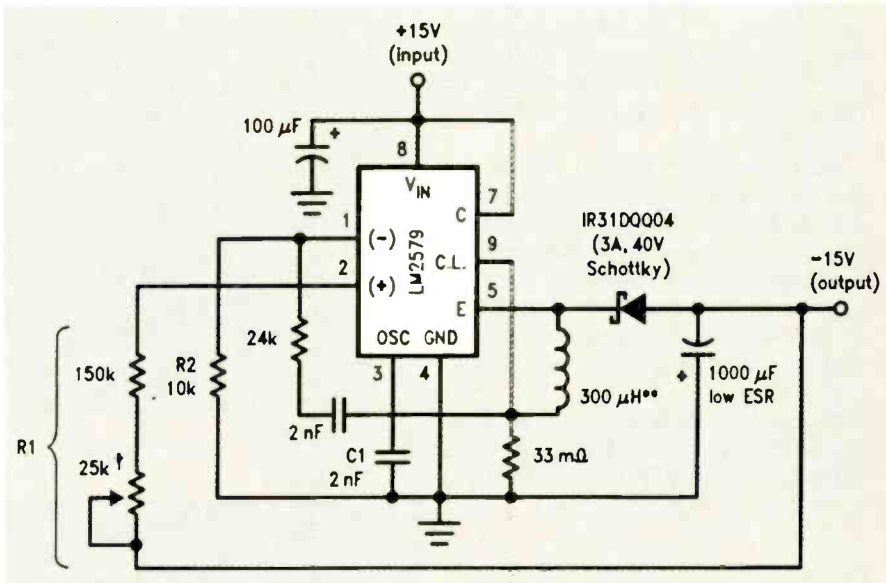
$$L=V_{IN}^2|V_o|/[\Delta I_L(V_{IN}+|V_o|)^2\ f_{osc}],$$

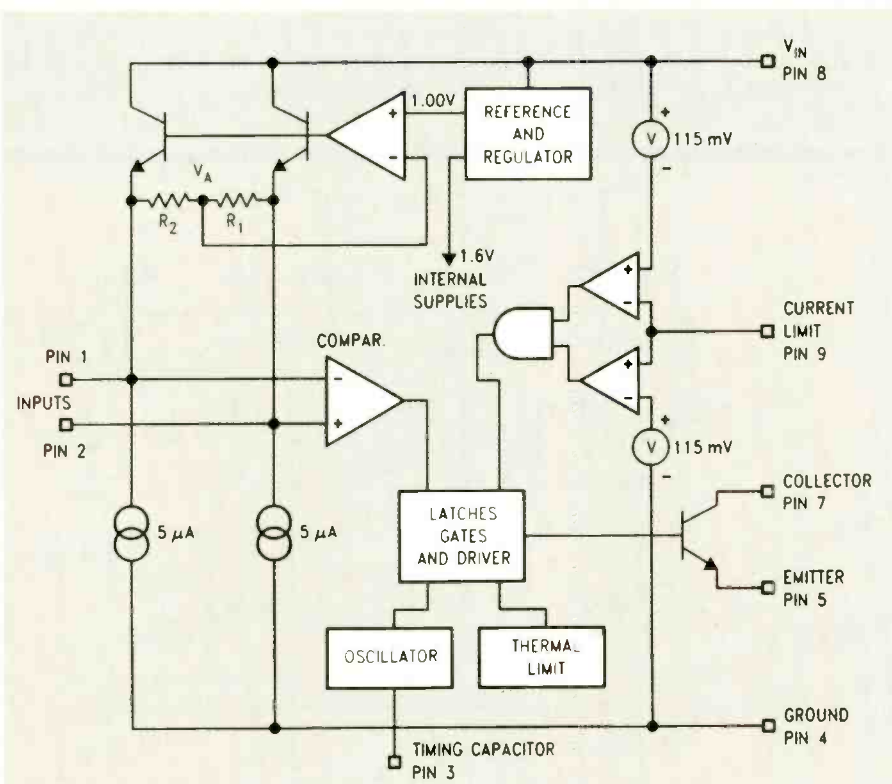
or by means of the chart given in the marker's application information. The quantity ΔI_L is

$$\Delta I_L=2I_{LOAD(min)}\ (V_{IN}+|V_o|)/V_{IN}$$

Full-load ripple voltage is 120mV when C_2 is a standard 1000μF electrolytic or 60mV if a 1500μF low-ESR type is used:

$$C_2\geq V_o(V_{IN}-V_o)/(8\times V_{IN}.V_{ripple}.L.f_{osc}^2).$$

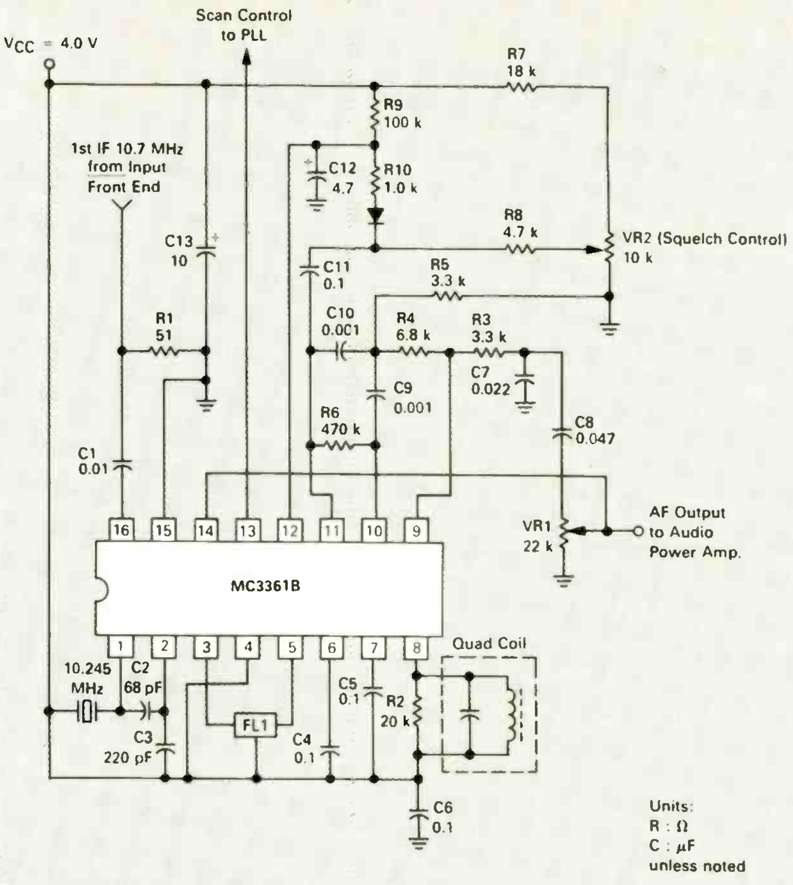




Efficiency is 76%, but can be increased to 86% by adding a secondary winding to the inductor to provide a flyback voltage of 3V and reduce the output transistor saturation voltage to 0.55V from 1.7V.

National Semiconductor points out that the comparators are sensitive to noise and that their inputs must be kept clear of high-energy switching signals. Feedback resistors should be near the input terminals and a single-point ground should be provided for the oscillator capacitor, device ground and feedback.

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



Low-power, narrow- band FM IF

Motorola's MC3361B is designed for use in FM dual-conversion communications equipment and comprises an oscillator, mixer, limiting amplifier, quadrature discriminator, active filter, squelch, scan control and mute. It works from a 2V to 8V supply at a current of, typically, 3.9mA at 4V (squelch off) and has an input limiting voltage at −3dB of 2.6μV.

Audio frequency output is 160mV RMS at a THD of 0.86%.

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

Voltage-controlled attenuator

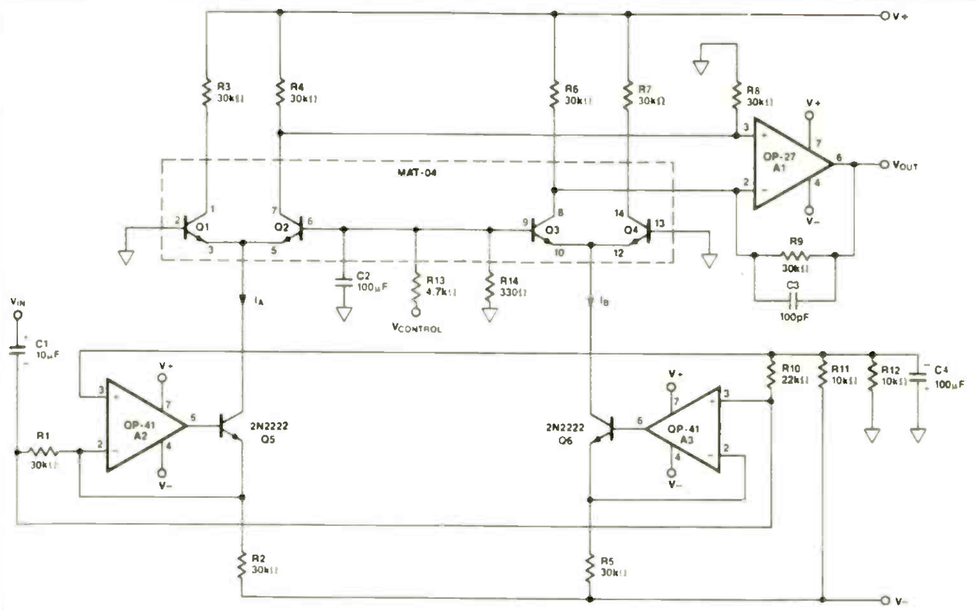
The MAT-04 from Precision Monolithics is a quad n-p-n transistor package which combines good matching of device parameters with a gain of 400 minimum, a noise figure of 2.5nV/√Hz maximum at 100Hz and good conformity to a logarithmic characteristic. Current gains of the devices are matched to within 2%.

As an example of its application, the circuit shown is a voltage-controlled attenuator which varies attenuation to a log.law between −10dB and −50dB for a control voltage range of 2V. It handles the audio band of frequencies from 20Hz to 20kHz at a distortion level of less than 0.03% and noise level of better than 100dB below maximum output.

The two op-amps and their output transistors form a differential amplifier for the input signal to be attenuated. The output transistors vary the current in the MAT-04 long-tailed pair amplifiers, which provide a differential input to the OP-27 output op-amp. A control voltage applied to the "free" bases of the pairs shifts the emitter current between each half of each pair.

It is recommended that the tails and collector loads of the long-tailed pairs should be 1% metal-film resistors and that C_2 should be a non-polarised tantalum type.

Bourns Electronics Ltd, 90 Park Street, Camberley, Surrey GU15 3NY. Telephone: 0276 692392. ■



REVIEW: ACQUISITION-PC

John Martin investigates an add-on for the PC which turns it into a two-channel digital storage oscilloscope and spectrum analyser

There's a lot more than meets the eye to the outwardly simple-looking Strobes Acquisition APC add-on. Because not only does it turn your PC into a dual-beam storage oscilloscope, but a spectrum analyser too, all usable up to about 40kHz.

In general there are two ways that PCs are turned into oscilloscopes: package together everything a real storage 'scope would contain, except the CRT, and use the PC as a semi-intelligent display, such as the £600 Thurlby DSA 524.

Or the approach used here by APC, keep the hardware simple and get the PC to do all the clever stuff. You might expect that to be cheaper too. In fact the APC sells for around £960, but that also buys a spectrum analyser using fast Fourier transforms (FFTs) so making the APC a very attractive package.

Hardware

The acquisition unit is a mains-powered box which communicates with the host PC via a standard RS422/423 serial data link. The front panel has BNC sockets for the two channels, an external trigger input and a programmable output for triggering external equipment.

APC hardware communicates with PC via RS422/423 serial link.

Each input channel can be prescaled from the computer to accept ±8V or ±80V and the input impedances are 1MΩ and 10MΩ respectively. The inputs are DC coupled but sadly there is no internal provision for AC coupling — this has to be done by the addition of an external DC-blocking capacitor.

After prescaling, each channel is passed through an anti-aliasing filter to independent 14-bit analogue-to-digital converters. Data are then multiplexed before being presented to the serial interface. The anti-aliasing filters fitted as standard are fifth-order Butterworth types with a corner frequency of 40kHz. Other filters, down to 400Hz, are available as plug-in options. The sampling rate (selectable from the PC) is a maximum of 100kHz.

Software

Having acquired and digitised the signals on the input channels, the APC hardware transmits the data to the PC via the serial link. This can take several seconds even at the maximum selectable transfer rate of 57.6k baud, during which time the system appears to be dead — a prominent comforting message would have been a helpful addition.

The PC screen consists largely of a graticuled and calibrated 'scope screen on which the user has the ability to select all the colours. Across the top of the display is a menu bar, familiar to users of most popular desktop applications. Typing the first character of the various options causes a full menu to drop down, from which the items are then selected using the cursor keys. This approach takes a little getting used to for those more familiar with the layout of a conventional storage oscilloscope, but, as almost everything is self-explanatory, selection soon becomes easy.

All settings — like "volts per div", "secs per div", etc — can be stored on disk for future use, which is useful.

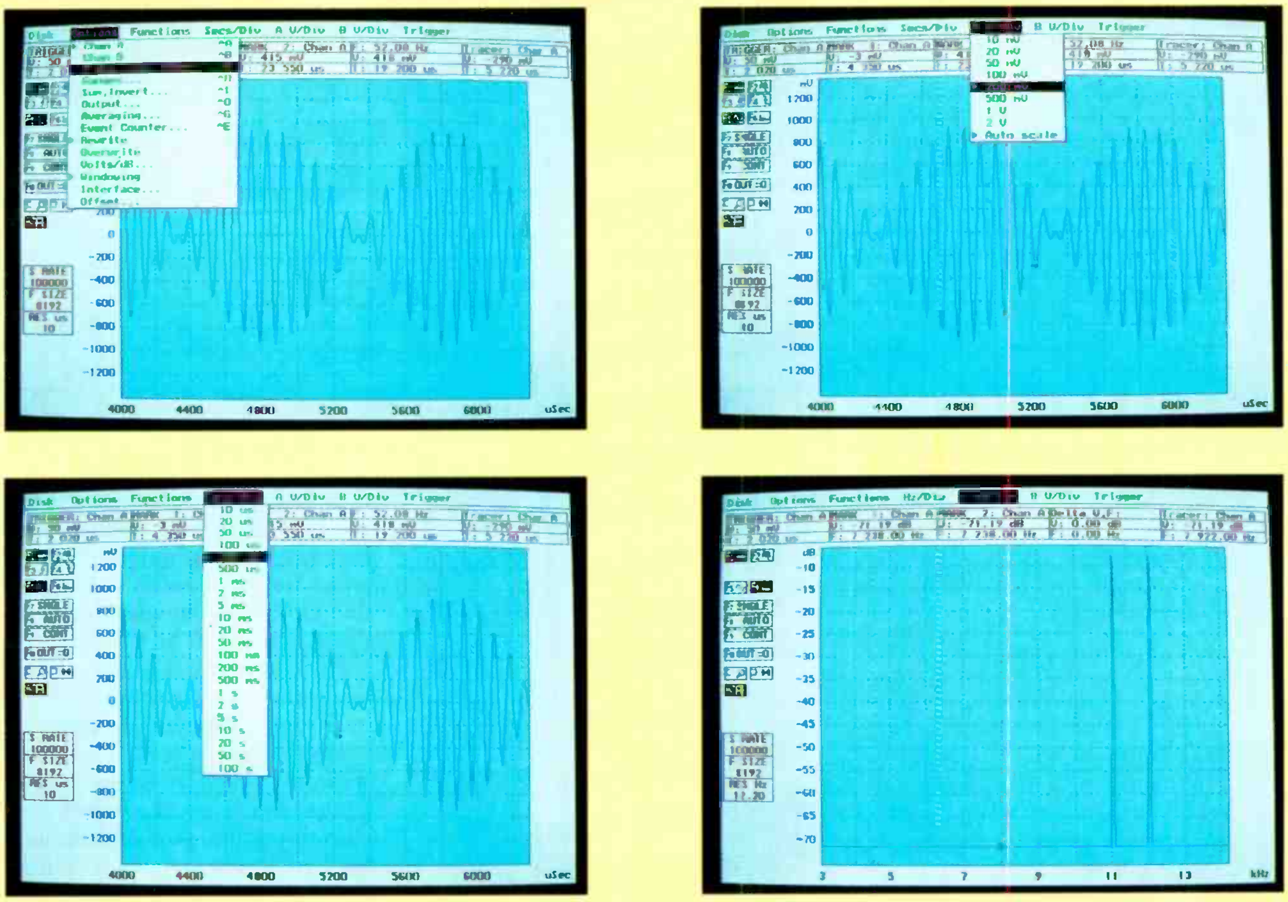
Below the menu bar is an information grid which provides analytical information about the signal being displayed — for example, voltage and time co-ordinates at points along the waveform indicated by movable cursors. Down the left side of the screen are icons defining the operation of the computer's function keys. Here, the operation is much more akin to that of a "real" machine.

For example, function key F5, with a sine-wave icon, brings up an oscilloscope display; key F6, a comb-like icon, starts the FFT of the acquired signal, as well as converting the display into that of a spectrum analyser. Other function keys select positive or negative edge triggering, single-shot or free-running operation, etc.

As well as moving the measurement cursors, the computer's arrow keys allow the waveform to be panned through the display area vertically or horizontally, the axis calibrations being automatically updated. Hard copy of the display can be menu-selected and printed out on most popular dot-matrix printers.

As a storage oscilloscope, one of the most useful features is that the sampled input signals can be stored on disk for later analysis. The usual facilities are present, such as the ability to view a waveform before the trigger point and the stability of vision for very low frequency signals. But one major missing function is the equivalent of the "roll" mode found on conventional digital storage oscilloscopes — the ability to view a signal continuously in quasi real-time, the signal appearing to roll slowly through the display area.

The APC captures its signal in discrete frames and transfers blocks of data, making this mode impossible. As if to remind the user, screen refreshment is vertical, rather than horizontal.



Oscilloscope display of 11kHz and 12kHz sine waves added (top left). Options menu shown pulled down. Sample rate 100kHz. Display at top right shows volts/div menu pulled down and 200mV selected, that at bottom left showing 200µs/div time range selected from time menu. Bottom right is spectrum analyser display, with vertical scale in dB. This is spectrum of 11+12kHz signal.

The range of timebase settings is from 10µs to 100s per division, and the voltage scales go down to 10mV per division with auto range available.

As a spectrum analyser the most limiting factor is the upper frequency limit of about 40kHz. So, given that this makes it an audio spectrum analyser, it would have been useful to have a logarithmic frequency scale, or the option of one. In fairness, for an extra £140 it is possible to have a third-octave analysis add-on, giving the usual format for acoustic and audiometric measurements (see "Review details"). Spectra can be averaged over a number of sweeps if required, making this a more serious tool for the audio engineer.

Fourier transforms are very maths intensive. But the APC makes no use of any maths co-processor which may be resident in the host PC. Apparently the maths have been arranged to be performed as integer arithmetic. For this reason, the time required to perform the FFTs can take a frustrating half a minute or so, but this process also includes conversion of the voltage axis to a dB scale.

Another optional extra (available at £300) is transfer function analysis, which provides gain and phase versus frequency measurements (see "Review details").

Overall, the APC system is impressive and certainly cheap if the limitations are not a problem.

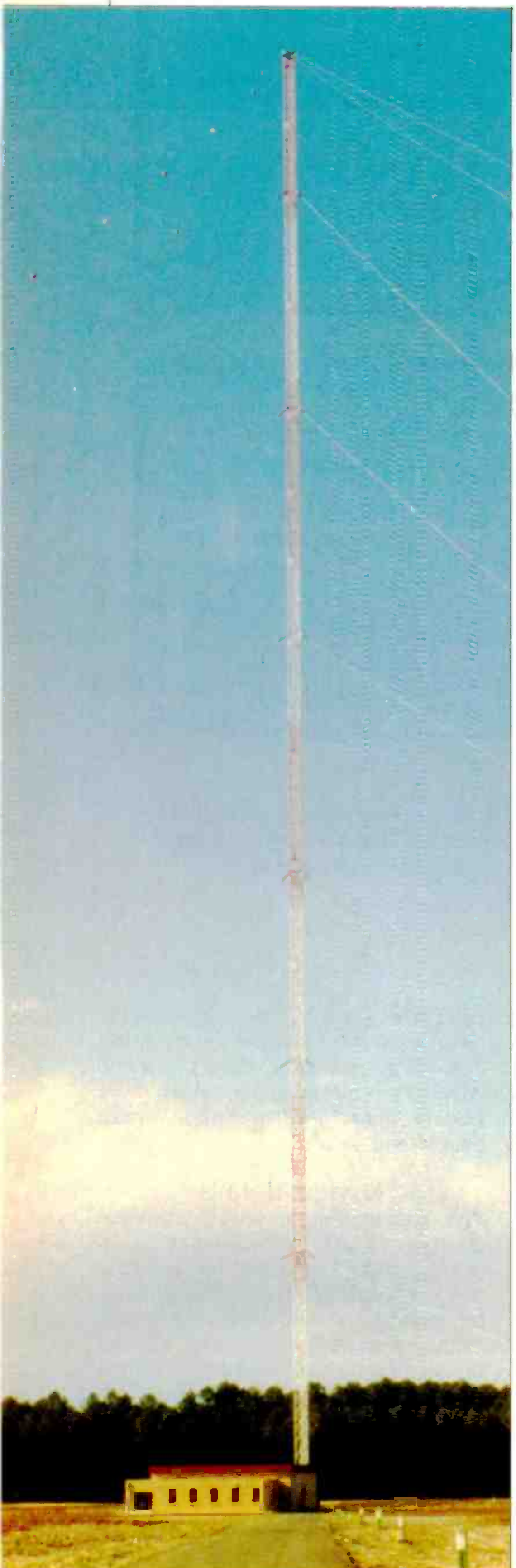
The major criticism is a lack of tactile interaction with the system due to the time delays of data transfer and conversion, when the keyboard appears dead. Some extra on-screen comforters would have been appreciated.

Computer enthusiasts will be pleased to know that the program source code (in Turbo Pascal) is available and the company seems to encourage modifications! The manual is well written and comprehensive and there is also a "Five Minute Manual" which is all that most people will need.

Review details

The system was reviewed using an Amstrad PC1640 with Enhanced Colour Display (EGA) and the software was version 1.3. Version 1.4 is due to be released at any time and it will include the third-octave and transfer function options as standard, as well as some general upgrading.

The Strobes Acquisition-PC (and Macquisition for the Apple Macintosh) are available from Laplace Instruments Ltd, Masters House, Bexton Road, Knutsford, Cheshire WA16 0BU. Tel: 0565-50268. The price of APC is £960 + VAT. ■



Loran or Decca?

There is little to choose between Loran and Decca radio navigation on a technical basis, so why is the Government intent on imposing Loran despite the expense and trouble it will cause? Michael Payne charts a path through stormy waters

As nearly everyone expected, the Department of Transport has decided that Loran C will become the official marine radio navigation aid in British waters from February 1997, replacing Decca Navigator which has done the job for 40 years.

It may well be possible to count on the fingers of one hand the number of Decca users who want this change. In none of its deliberations has the DoT shown more than a cursory regard for the views of the users. Its overwhelming motive in opting for Loran appears to be to get Britain into something that it hopes will be pan-European. There is an inclination by some European governments to develop a Loran network.

Loran C transmitter masts are typically over 700ft tall. This one at Soustons in southern France is 720ft. The station was designed for the French navy by Megapulse Inc of Boston.

and DoT wants to be on the bandwagon.

It is true, though, that the DoT will not switch support unless a sufficient number of other nations commit themselves to developing Loran. Further, the DoT says an acceptable international agreement on the costs of installing and running a Loran system must be ratified by all countries by mid-1991, or Britain will not go ahead.

However is is clear from the DoT's statements that it wants to switch to Loran and is going to pull out every stop to get into place something it can tell Parliament is an acceptable international agreement before the time limit expires. Decca system users — commercial fishermen, merchant ship crews in coastal waters, and pleasure boat owners — who largely, probably almost entirely, want to stay with Decca, will have to stomach a *fait accompli*.

The future of the UK's marine radio navaid system is a problem for the DoT for two reasons. First, the existing Decca transmitting stations in the British Isles mostly use equipment of dated technology which has high running costs. Four out of 24 transmitters have been modernised and the DoT has to decide soon whether or not to come to an arrangement with Racal, which runs the Decca system for the DoT, to modernise the rest.

The second reason concerns the future of Loran in European waters. Several transmitters already exist, most of them owned and operated by the US Navy. However the USN has said it will effectively abandon them when the GPS Navstar satnav network has demonstrated operational reliability. This will be at the end of 1994, if GPS is operational on time at the end of 1992, which looks likely.

The transmitters serve areas where there is generally no other radio navaid coverage, and there are good arguments for keeping them going. However the European governments will have to take on the cost and this raises the question of how to get the most out of the running expenditure, a matter which didn't bother the Europeans when the US Navy was paying. There is a view, which the DoT supports, that the USN transmitters should be integrated with others bought and run by European governments and some new ones in a comprehensive network extending from Greenland, Iceland and northern Norway to south-western France.

Tens of thousands of vessels will be affected if Loran C replaces Decca. Using the DoT's own figures, about 90,000 Decca receivers are installed in vessels using British coastal waters, picking up transmissions from the British Decca chains.

Perhaps 40,000 of these are fitted to British owned vessels and possibly 27,000 of the 40,000 are in pleasure craft, which so far are not obliged to pay a levy to the DoT to help with Decca system running costs, though that may change. Nevertheless, for the foreseeable future the burden will fall at least mainly on the commercial vessels, operating an estimated 13,000 Decca receivers. The vast majority of these vessels are fishing boats.

All these receivers will have to be replaced by or supplemented with Loran receivers, at a typical price of several hundred pounds but up to £2,000 or £3,000 for navigation-critical applications. That may not be a lot to have to spend, but for the fishermen it is the smaller part of the changeover problem.

Fishermen have to be able to return time and time again to the same position, precise to within 50 yards, where experience has shown fish to congregate. Skippers build up private data banks, recorded in Decca co-ordinates, of the rewarding fishing sites. If Loran replaces Decca, the record must also change to Loran co-ordinates.

However, so far there is no way a position fix generated on a Decca receiver can be transformed into a sufficiently exact Loran equivalent for the same real position without actually going to the same spot with both systems working and noting the read-outs. The same applies to the positions of wrecks, oil wellheads and all natural hazards.

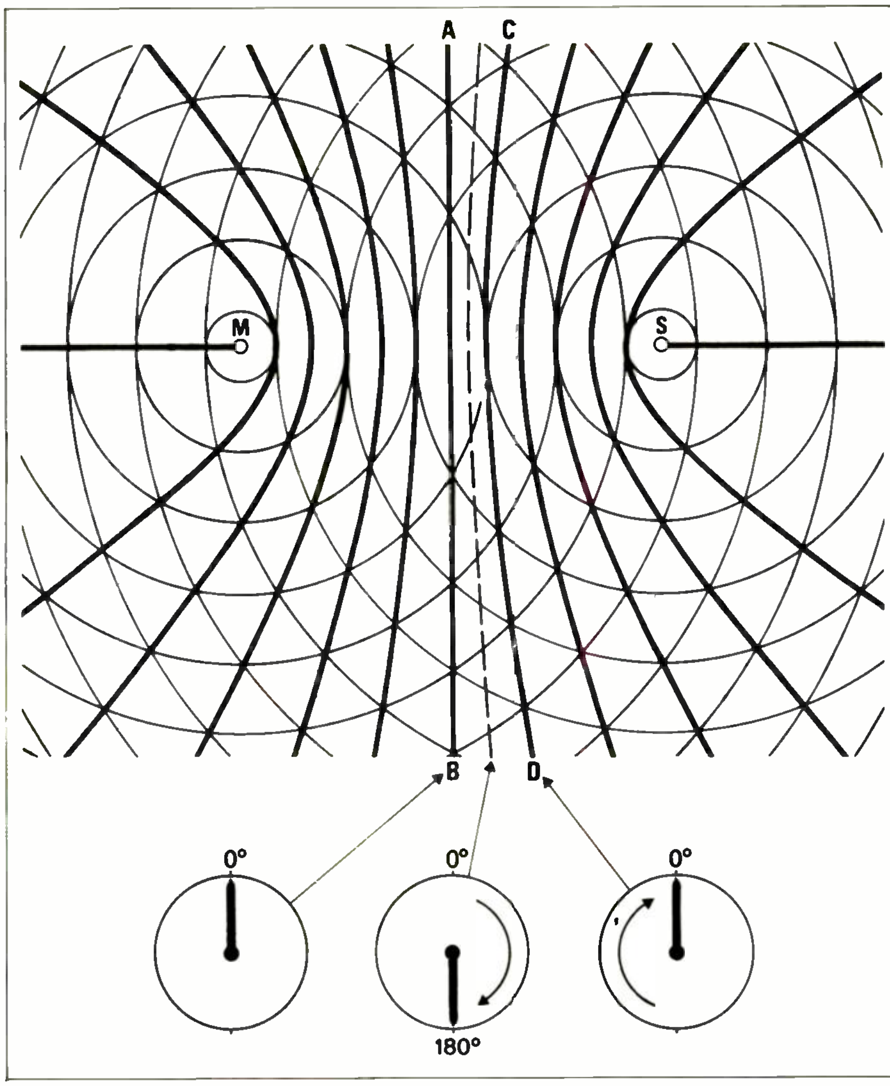


Fig.1.1. Hyperbolic pattern generated by phase-locked c.w. signals. The concentric circles represent successive wavelengths. The space bounded by two adjacent hyperbolae on which the signals are in phase (e.g. AB, CD) is termed a lane. By convention, the Decometer turns clockwise for movement from master to slave.

Skippers will have to re-map from scratch and they say it will take years. This is partly because there are many sites which are visited only every several years because fish swarm there infrequently, and partly because most skippers will have to visit a large number of sites.

Re-charting has to be done the hard way because neither Decca nor Loran transmissions propagate in practice strictly according to theory. Both transmissions distort in transit — for instance, the wave travels more slowly over land — so that position fixes indicated solely by the raw radio signals have to be corrected.

Decca and Loran work at similar frequencies, so that propagation distortion is similar and in principle a computer program could do the conversion. However, the transmitter maps are not the same and in practice there are so many differences nobody knows whether computer conversion to sufficient accuracy is possible.

Even if it is, success will depend on the original Decca fixes being accurate in absolute terms. Because fishermen are interested in repeatability, not accuracy, this is most doubtful.

Decca is well mapped for errors through years of experience. However, the proposed Loran network will have to be re-mapped from scratch for errors, because the two new transmitters will change the interactive working of at least that part of the network covering British waters, and the existing Loran maps will be useless.

This will take years, and in practice users dependent on high precision will have to build up their own maps and correction factors. With Loran there is the added complication that the errors are likely to be greater in many areas which will be further from the transmitters than they are with Decca.

The DoT proposed at first that Decca and Loran work side-by-side for two years so that fishermen could re-map. The fishermen said this was nothing like long enough, and through their associations asked for at least five years.

The DoT has rejigged its offer to make it look like three years, but only by being wildly optimistic as to how quickly a new Loran network can be got working, so that the DoT can bring forward the predicted start date for the overlap. In fact, the DoT is hamstrung because its contract with Racal to run the Decca system runs out in February 1997, and no amount of fiddling with projections can hide the fact that there is just not enough time for proper overlap unless the DoT spends money extending the Decca system's lifetime.

The DoT's timescale for the switch assumes the new transmitter in north-east England will be working by the end of 1992. This has to assume fast and successful international negotiations, and a planning authority only too keen to grant permission for a 700 ft mast on a site yet to be found. And that the Irish, of course, can be depended upon to move just as quickly.

The DoT further assumes that the three existing transmitters with which the two new ones will work — in France, Germany and the Faroe Islands — will then do double duty, functioning as part of both old and new networks until the US Navy says goodbye at the end of 1994. Nobody can be sure that this will work; the Faroes' transmitter already serves two networks and the DoT appears to assume it can serve three. If it can't, Scottish fishermen will have no Loran during 1994 when the DoT says they will have the system.

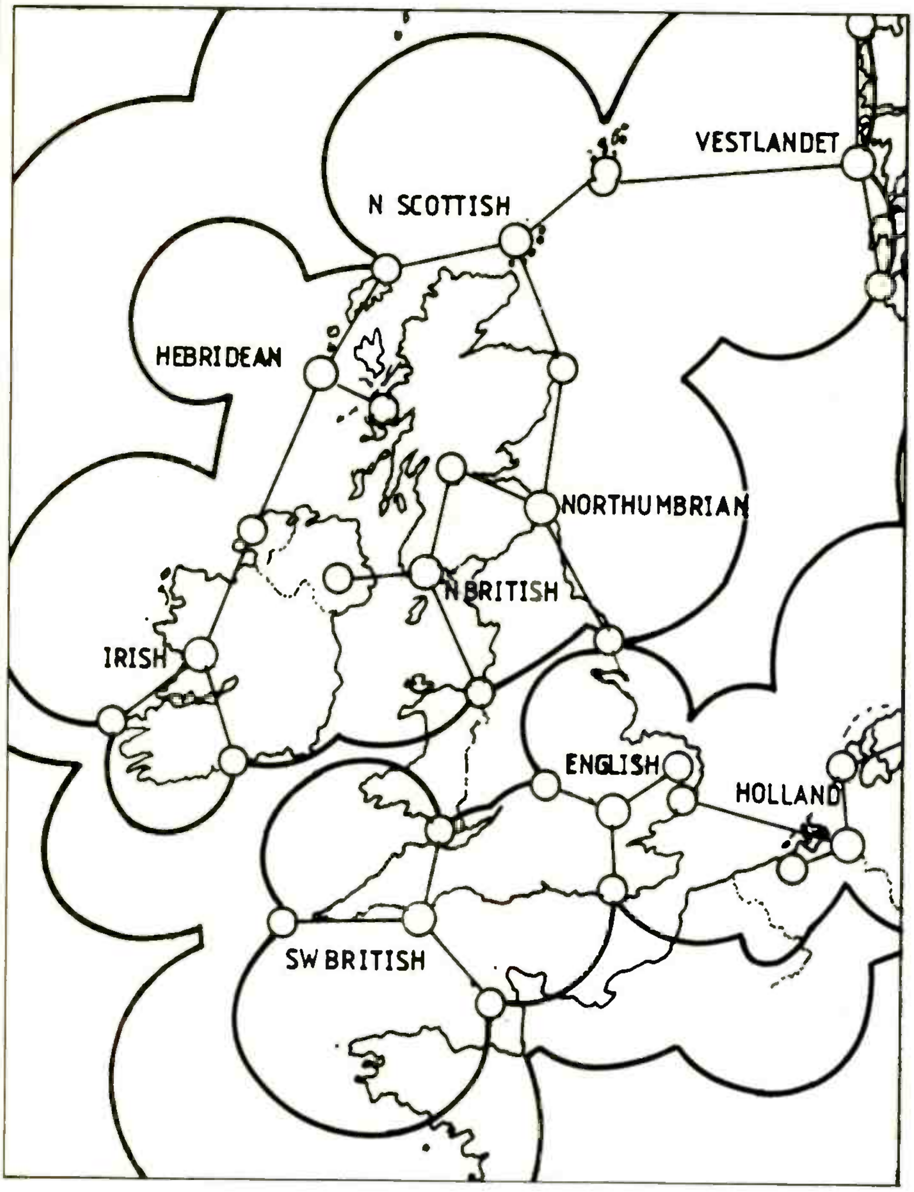
Decca and Loran C are both hyperbolic position fixing systems — that is, a shipborne receiver detects signals transmitted from (usually) three widely spaced transmitters, determines the distance from each transmitter, and finds the only geographic position consistent with all three measurements.

A Decca chain has four transmitters, one a master which controls the others. The master and any two slaves are used for a position fix. The transmissions are omnidirectional and continuous wave, and are discriminated by being narrowband at different frequencies, which are 70, 85, 113 and 127kHz.

Each transmission can be visualised notionally as a series of concentric circles around the transmitter, representing the successive peaks of the waveform. The four transmissions are locked in phase and wholly overlap so that the patterns of circles superimpose as a criss-cross.

Hypothetical lines can be drawn to join the peaks of the overlapping transmissions from any two transmitters (see diagram). These lines are hyperbolae with the transmitters at the foci. At any point on these lines, the two transmissions will be in phase and of equal amplitude.

A shipborne receiver capable of phase comparison can detect when it is located on one of these hyperbolae, and if it is between hyperbolae, it can work out its proportionate distance from the two adjacent hyperbolae. By including a counter which trips every time a peak hyperbolic line is crossed, it can count its



There are six Navigator chains in Britain including N. Ireland. Each chain has one master station and three slaves, so that there are 24 stations altogether. However, there are only 21 transmitter sites, because three sites host transmitters for two chains. Further, one slave in the Hebridean chain is on Eire soil (all Eire sites were refurbished in 1984), leaving 20 sites on British soil. Of these, three single-transmitter sites have been refurbished. A Dutch chain has a slave on a site in Suffolk but this is not a UK responsibility.
The two sets of lines indicate daytime and night time coverage.

progress in terms of hyperbolic lines provided it knows its start position.

However, its instantaneous position could be anywhere on the hyperbolic or intra-hyperbolic line. To turn a line into a point, the receiver carries out the same process using the transmissions from one of the original transmitters and a third transmitter in the chain. This produces a second line of position. The ship will be at the point where the two lines cross.

Decca has the disadvantage that skywave reflections of the transmission, that arrive fractionally after the groundwave and mix with it and distort it, are impossible to eliminate because the transmission is continuous wave. The effects are more serious at night and in winter and at longer ranges, and users have to learn to allow for them.

Decca signals may be received 500 miles from the master transmitter but a more usual summer day maximum is 300 miles. Accuracy may decrease beyond 100 miles. British coastal coverage is provided by 24 transmitters in six chains of four. The resultant overlap provides some redundancy should a transmitter fail, and the masts are small enough to allow prompt replacement.

Loran (LOng RANge) was devised to provide the US Navy with accurate position fixes up to 1,000 miles from a transmitter. Skywave distortion would make continuous wave transmissions useless at this range, so Loran uses pulse transmissions because a good receiver can detect the leading edge of a groundwave direct-path pulse before any skywave reflection arrives.

Loran measures the time of arrival of pulses at the receiver and translates time into distance. However this is not done directly, since the receiver cannot know the absolute instant of transmission of a pulse even if it could measure its absolute time of arrival.

Instead, the local master transmitter broadcasts a pulse train — this is received by users and also by a secondary transmitter which broadcasts a follow-up pulse train a precise time after the master's transmission. This cues a further slave which reacts similarly, and there may be another. The pulse trains contain information to identify the respective transmitters.

A receiver measures the difference in the time of arrival of the pulses from the two most conveniently placed transmitters. The difference places the receiver on a hyperbolic position line as in the Decca system. A second measurement using the input from one of the original transmitters and one alternative produces an intersecting hyperbolic line to indicate a position fix.

Loran C (the current version) uses the whole band between 90 and 110kHz for its high-power pulses. Ranges between 800 and 1,200 miles are claimed but accuracy falls beyond perhaps 500 miles through accumulating propagation variations. Further, its wide-open bandwidth makes it more susceptible than Decca to man-made interference, which can degrade performance.

Far fewer transmitters are necessary than with Decca for equivalent coverage, and oceanic coverage can be far greater. However the installations are much bigger and more expensive, backup is more difficult to arrange, and, most important, because of the triangulation requirement a European system must involve several nations. Britain cannot go it alone, as it can with Decca.

Both use well-proven, reliable technology and have similar performance, but Loran's accuracy is maintained to a greater distance from the transmitter.

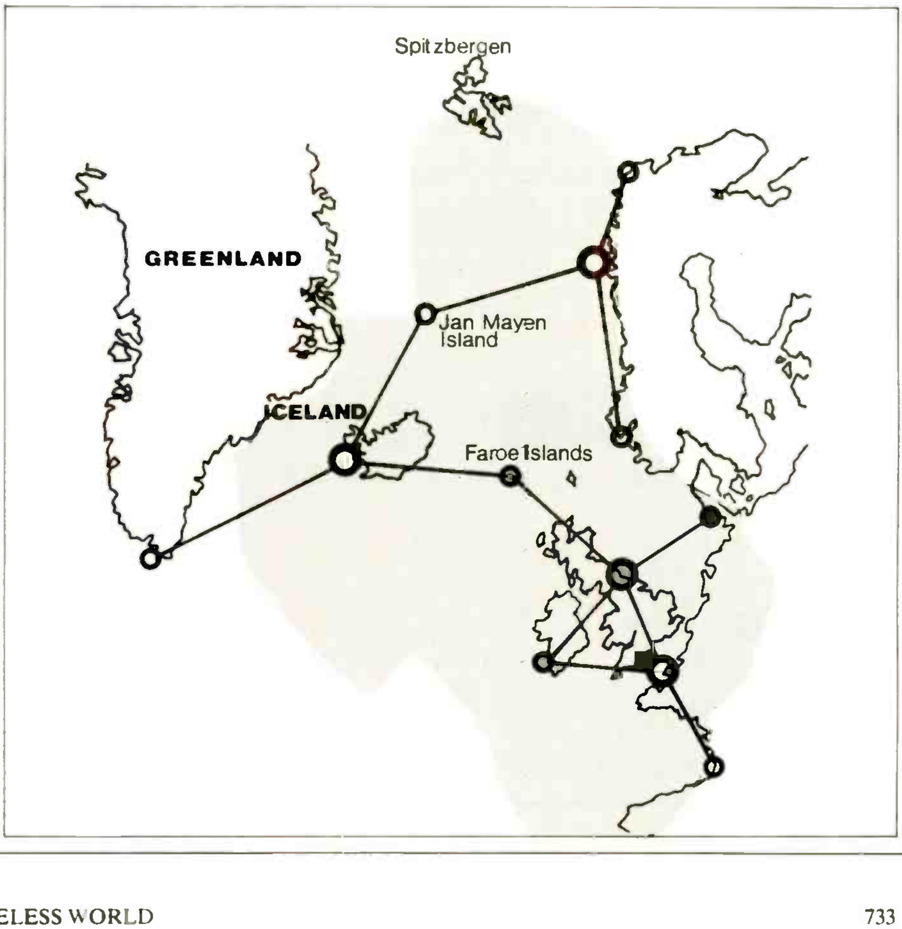
If Britain opts to stay with Decca arrangements will be made to modernise the transmitter stations, including unattended operation and control of all six chains from one location. Running costs will be lower and users will not have to adapt in any way.

If Britain opts for Loran, sites will have to be found for additional transmitters in north-east England and south-west Ireland to provide coastal coverage but this would of course, extend much further out to sea than is possible with Decca. Deep-sea vessels, currently without radio navaid coverage beyond Decca range, would benefit.

Solid state Loran transmitters would be bought from the only maker, Megapulse Inc. of Boston.

Decca and Loran each have advantages and disadvantages, but the balance is fine and overall it is impossible to say categorically that one is the better system.

If there are problems, bang will go 1993, scheduled by the DoT for check-out of the new local network and rudimentary error mapping, and 1994, scheduled by the DoT as the first of the fishermen's three years of confident error conversion. With the US Navy out of the way the complete network can switch to the new configuration (assuming it has all been prepared), triple duty can stop and the fishermen



Layout of the transmitters in the Loran C network proposed by Britain and some other countries. The transmitters in north-east England and south-west Ireland would be new ones; the others already exist but would interrelate differently in the proposed network. The larger circles indicate master transmitters controlling the slaves at the other ends of the linking lines. Some transmitters would serve two networks.

can embark on the first of the two conversion years the DoT originally offered them.

The DoT could also be seriously underestimating — or more likely, is just not interested in — the problems Loran users are likely to have due to man-made interference affecting the performance of receivers. Unlike Decca, Loran is a wideband system, open from 90 to 110kHz, and unlike North America, where Loran is widely used and successful, in northwest Europe there is no general prohibition on other transmissions in that band.

The DoT points out that noise effects can be eliminated with filters, but before that can happen the noise has to be characterised and mapped, and the filters have to be designed into the receivers. This does not bode well for early Loran users trying to build up position-error maps with filter-less receivers.

If early experience shows the noise problems to be significant, potential Loran users are likely to opt instead for GPS. Polytechnic Electronics' Navstar subsidiary, which makes receivers for Decca, Loran and GPS and has no obvious reason for favouring one above another, thinks it quite likely that, partly because of the filter problem, demand for Loran receivers will not reach the quantities necessary to bring the price down to the post-1995 level of GPS receivers. Most users could go straight from Decca to GPS.

Current inexpensive GPS receivers can't be guaranteed to achieve 50 yards repeatability, but Navstar is sure that they will be before too long.

The DoT believes, and it may be the only point on which it is at one with the user community, that marine navigation in British waters should not be wholly dependent on a foreign military navaid such as GPS or the Soviet equivalent, the Glonass system. We ought to have a specifically civil, land-based system over which we have some control as well.

However, the case it makes for switching to Loran, set out in a study document last year and confirmed in a statement to Parliament in April, does not convince. It is extraordinary in appearing to consider the establishment of a transmitter network an end in itself.

The users get unbelievably short shrift: the statement to Parliament answers none of the main objections lodged by the most important group of users, the fishermen, after the study was issued; no serious advantage to them of moving to Loran is mentioned except the possibility of lower dues through cost reductions (although the data cited in the study is far too uncertain to allow any serious prediction of the effects on costs); the practical difficulties of switching are hardly considered; and if there are no serious and certain advantages of switching, the DoT makes no case as to why users should not resent the prospect of expense and trouble.

A betting man has to put his money on Loran displacing Decca solely because the Civil Service is behind it. The real choice ought to be with the users and the crunch is put by the Scottish Fishermen's Federation: "We view Loran as a high risk option yielding no real improvement as far as fishermen are concerned and comparatively little cost saving, while generating in the process severe upheaval and substantial costs." ■

Remote analogue sensing for microprocessors

Robert Townsend describes a low-cost method of transmitting analogue data over long distances

This system compares favourably, in many respects, with the standard, two-wire, analogue current transmitters used for industrial process control. Two obvious advantages are superior noise immunity and easier voltage isolation.

Isolation of analogue signals at high linearity requires the use of a costly isolation amplifier, whereas one can isolate this circuit by means of a single opto-isolator, which need not be excessively linear, being biased into its linear region.

An analogue input in the range 0-2.5V is converted to a digital word by the Plessey ZN 509 eight-bit serial output A-to-D converter. This device features an on-chip voltage reference, an on-chip clock and single-supply operation, and costs approximately half as much as a conventional, parallel-output A-to-D converter offering equivalent performance.

Data, together with a synchronising signal, is transmitted to the microprocessor via a single twisted-pair current loop, the maximum distance between transmitter and receiver being largely dependent upon the data rate.

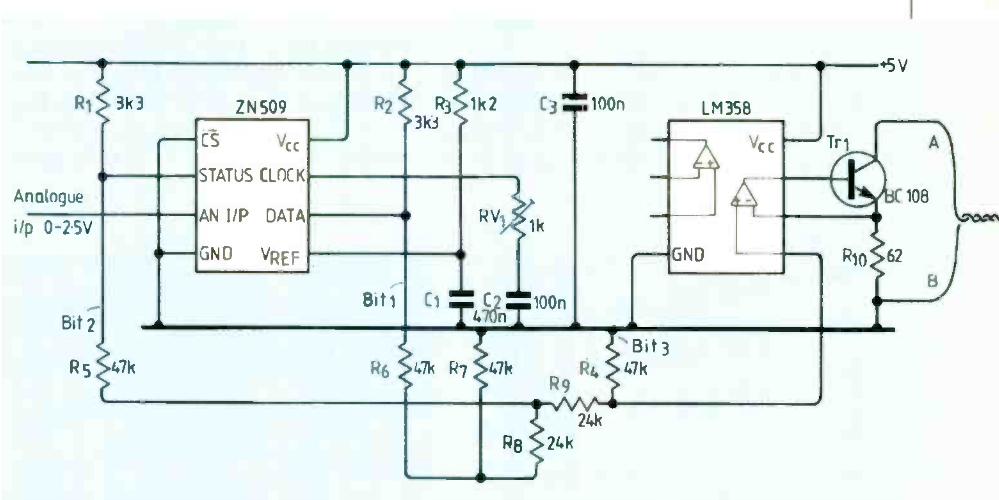


Fig. 1. Transmitter circuit diagram. Signal is sent over a twisted-pair current loop.

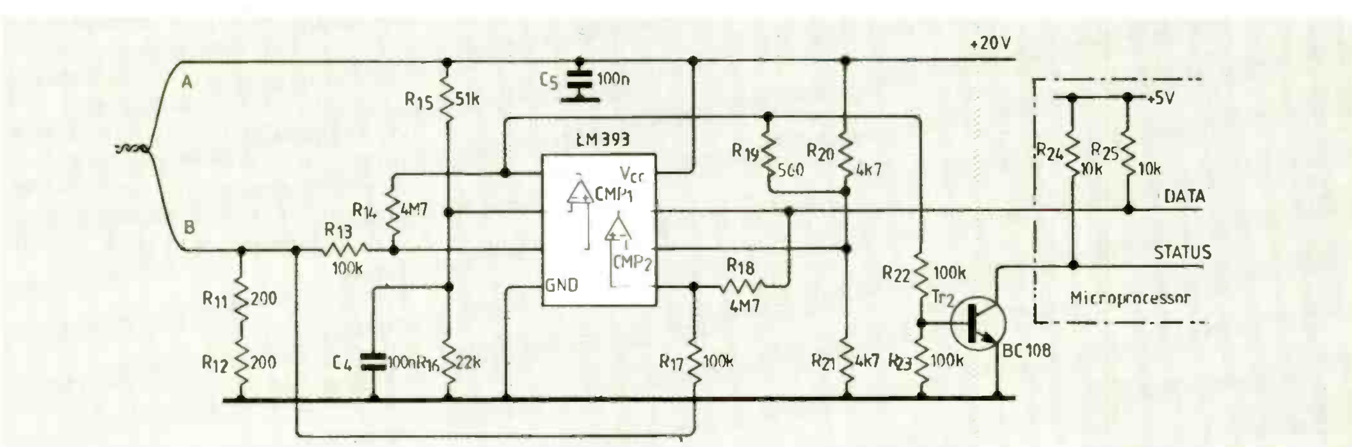


Fig. 2. Circuit diagram of receiver. LM393 is a dual voltage comparator.

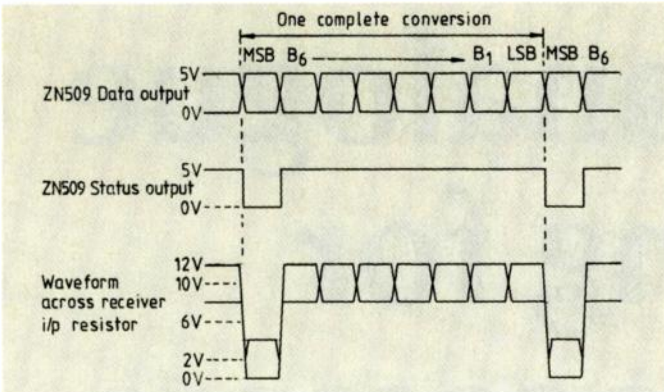


Fig. 3. Receiver input waveforms. Clock period is 196μs.

The prototype has been designed to operate at a distance of a few hundred feet with a clock frequency of just over 5kHz to give a conversion time of 1.6ms. Analogue input bandwidth is not limited by the A-to-D converter, since the ZN 509 is capable of performing a conversion in 8μs.

Circuit description

Grounding the CHIP SELECT input in the transmitter circuit of **Fig. 1** fixes the ZN509 in continuous conversion mode. A status output provides synchronisation, which goes low for the duration of one clock cycle (coincident with the MSB output) to indicate the beginning of a conversion.

Resistors R_4-R_9 can be thought of as the R-2R ladder of a simple 3bit D-to-A converter, where V_{ref} is V_{cc}. This DAC, in conjunction with current source A1, produces a binary-weighted current of 0-30mA from the DATA and STATUS outputs of the ZN509. Bit 3 of the DAC is tied to ground to ensure that the input voltage of A1 is not greater than 2.5V and therefore within its common-mode range.

A voltage developed across R_{11} and R_{12} in the receiver, shown in **Fig. 2**, produces the waveform of **Fig. 3**. Comparator 1 threshold is set to 6V by R_{15} and R_{16} and is used to ascertain whether STATUS is high or low. The open-collector output of comparator 1 switches the threshold of comparator 2 between 2V and 10V at the appropriate time to allow comparator 2 to capture all eight bits of data. A small amount of hysteresis is provided in comparator 1 by $R_{13,14}$ and to comparator 2 by $R_{17,18}$. Transistor Tr_2 serves to buffer the output of comparator 1 and to provide a TTL-compatible status signal.

Transmitter and receiver do not share the same ground potential; if, in a particular application, there is a common ground, then the circuit could easily be modified.

Software considerations

Recovery of parallel data is achieved by detecting the leading edge of the status signal and subsequently sampling the data at mid bit-time. This technique requires precise timing of the software – which is easy – and precise definition of the converter clock frequency – which is not.

On the prototype, clock frequency is trimmed by RV_1, which is perfectly acceptable for one-off equipment, although not desirable for mass production. An alternative would be an external crystal oscillator or, for slowly changing analogue inputs, the clock frequency could be mains derived.

In ultra low-cost applications, a different technique could be used whereby the microprocessor measures the period between status pulses and calculates the converter clock period, then modifies a time constant in the sampling routine before collecting data from the *next* conversion. Advantages here are that the converter clock frequency can be (reasonably) unknown and poor long-term stability can be tolerated. The disadvantage is that it will be relatively slow.

An example program is given, written for the 68705 P3 single-chip computer, which is the simplest (28-pin) version in the popular 6805 microcontroller range. A full explanation of the program is not within the scope of this article, but the source code is supplied with comments so that anyone interested can decipher it. The program is of the first type described above and timing has been calculated precisely.

Data is read in from bit 0, port A and the status signal is applied to the interrupt line (but polled rather than allowed to generate an interrupt). The program repeats, continuously updating the parallel data output at port B. First data sample is taken after 98±2μs, successive samples being taken at 196μs intervals, corresponding to a converter ideal clock period of 196μs. ■

Example program

Address	Object code	Source code	Comments
0100	A6 FF	LDAA #$FF	
02	B7 05	STAA DDRB	Initialise portB as output
04	3F 04	CLR DDRA	Initialise portA as input
06	A6 0B	LDAA #$0B	=Decimal 11
08	B7 10	STAA $10	Store constant for later
0A	A6 15	LDAA #$15	=Decimal 21
0C	B7 11	STAA $11	Store constant for later
0E	A6 08	LDAA #$08	Set loop counter
10	2F FE	BIH	Look for STATUS low (receiver inverts status signal)
12	2E FE	BIL	Proceed on positive edge of STATUS
14	BE 10	LDX $10	Get time constant for first sample
16	5A	DEX	
17	26 FD	BNE	
19	BE 00	LDX PORTA	Sample the level on the DATA line
1B	56	RORX	Shift data bit into carry flag
1C	39 12	ROL $12	Transfer data from carry to memory
1E	BE 11	LDX $11	Get time constant for next sample
20	5A	DEX	
21	26 FD	BNE	
23	9D	NOP	Timing adjustment – wait for 2 cycles
24	4A	DECA	
25	26 F2	BNE	Repeat routine for next data bit
27	B6 12	LDAA $12	Get complete conversion result
29	B7 01	STAA PORTB	Output data in parallel form
2B	CC 01 0E	JMP	Repeat whole process
07FE	01 00		Reset vector

#=Immediate addressing mode
$=Hexadecimal
One machine cycle=1.0us.

Further reading

Plessey Semiconductors Data Converter Handbook.

"Linear Applications of Optocouplers", Hewlett-Packard Application Note 951-2.

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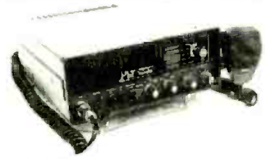

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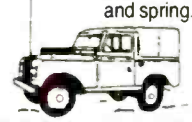

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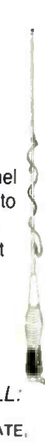

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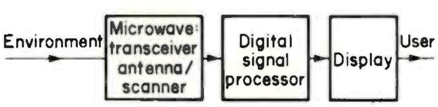
CIRCLE NO. 147 ON REPLY CARD

Another look at car obstacle-detection radars

The current efforts of firms traditionally working in the defence electronics field to turn their swords into ploughshares were in evidence at a May 1990 IEE colloquium on "Millimetre-wave radar". One of the more promising areas for high-volume sales, always provided that device and technology costs can be reduced to meet consumer budgets, is for civil obstacle-detection and avoidance.

Among systems currently under development at Philips Research Laboratories is an 80GHz car obstacle-detection radar. This is an area where a ready market has long been envisaged but for which no satisfactory system has yet appeared. The reason is failure in the past to cope adequately with the quite complex requirements of a system that will reliably help, advise and warn a driver in poor visibility without exerting direct control over the brakes.

Dr Andy Stove of Philips Research Laboratories believes that a successful solution may be found based on the sensors developed for "smart" ammunition, an application that similarly requires a system that is compact, very sophisticated and cheap. During the 1980s, while the emphasis was on military systems, a 94GHz FMCW radar transceiver for smart munitions was developed, and was described in 1987. It was based on components located at the E-plane of standard rectangular waveguides, with a housing mass-produced from metallised plastic by injection moulding.

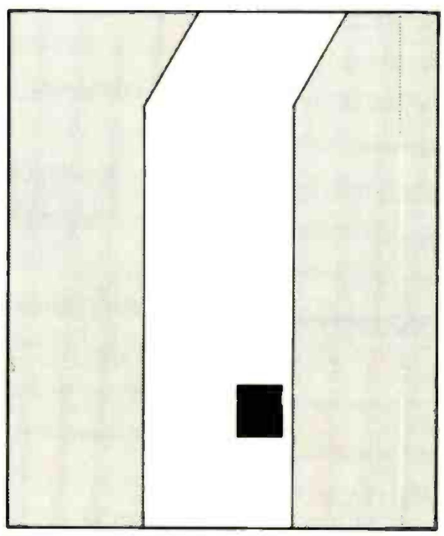


Such ammunition "seekers" are expected to be produced at a price and production level similar to those of upmarket in-car entertainment systems. If adapted for obstacle detectors the very high volumes could further reduce the price and they could become a major application of millimetre-wave technology.

The complete car radar system would comprise a sensor to generate a detailed image of the scene in front of the car; a signal processor to classify the objects and distinguish between hazards, selecting useful information and discarding what is irrelevant; and a display that must present the information to the driver in an easily understood form.

The radar should have resolution in both range and azimuth with a detection range of about 300m. To distinguish between vehicles in different traffic lanes the angular resolution needs to be of the order of 1°. An ideal frequency would be about 90GHz (W-band) and a suitable civil allocation is likely to be made at 80GHz. Measurements have shown that the cross section of a man is about $1m^2$ and a small car about $10m^2$, calling for a transmitter power of about 10mW.

Dr Stove said that it has been shown that a processor based on current devices can identify potential hazards by taking account of curves in the road and distinguish between the different lanes of a multi-lane road. He continued, "Our work is also concentrating on improving this processing and on examining options for an ergonomically effective, simple, low-cost display.



"In an actual display a hazard might be shown in red, with the area off the sides of the road perhaps being green to give a symbolic indication of the line of the road. The display device would probably be a small liquid crystal display up beside the rear view mirror. It is clear that such a radar will be a useful driver aid, and will make a significant contribution to safer driving."

Novice licences

By early 1991, the Radiocommunications Agency of the DTI should begin issuing Amateur Radio Class A and Class B Novice licences, claimed by the RSGB as recognition of the value of the hobby as a training ground for careers in electronics and radio engineering. There will be no minimum age and the entry qualification will be completion of a training course to be provided by the RSGB, followed by a multi-choice test significantly easier than the present Radio Amateur's Examination. For HF operation a 5 words per minute Morse test will have to be passed (compared with the 12wpm of the present Class A licence).

The Class B Novice licence will permit operation within segments of the present 50, 430, 1215 and 10,000MHz bands (but not on the crowded 144MHz band) with modes including Morse, telephony and data (additional modes on 1240-1325MHz and throughout the 10GHz band). The Class A Novice licence will in addition cover operation over 1950-2000kHz, 3565-3585kHz (Morse only), 10,130-10,140kHz (Morse only), 21,100-21,149kHz (Morse only) and three segments (totalling 365kHz) in the 28MHz band. On all bands, maximum DC input power (pip) for Novices will be limited to 5W (maximum RF peak envelope power to the antenna 3W (pep)).

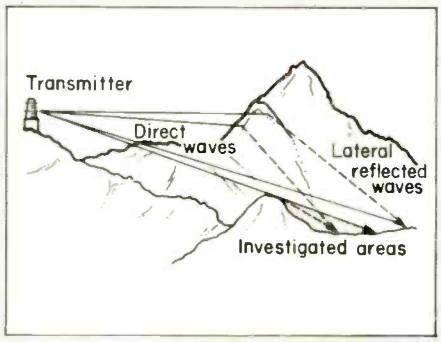
Many of the other conditions of the draft licence are basically similar to those in the current Class A and Class B licences. Holders of existing Class B licences for over 12 months will be granted the HF novice licence facilities on completion of the 5wpm Morse test. For all new amateur licences (Class A, B or Novice) the DTI Radiocommunications Agency is expected shortly to begin using prefixes beginning with the letters MA, etc, rather than G, with the UK country indicated by the number rather than the letter prefix. Existing licensees will continue to use their G, GI, GM, etc, prefixes.

The idea of a UK beginners or Novice licence was first mooted by a Postmaster General in the early 1960s. Its final appearance reflects in part the current difficulty, virtually worldwide, of attracting young people into the hobby and into RF analogue engineering in an era when digital electronics seems to rule the roost.

Polarisation affects VHF/FM sound radio

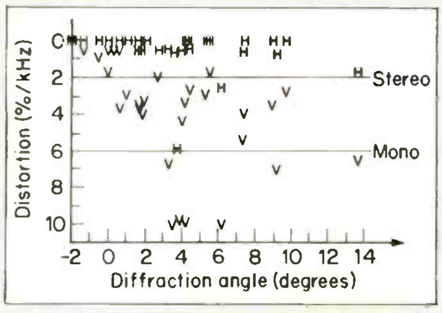
The protracted debate about the value of mixed (circular) polarisation for VHF/FM stereo broadcasting has re-emerged with the publication in *EBU Review — Technical* (No. 236, August 1989) of a detailed study by Theodor Bossert (IRT, West Germany) and Leopold Gregorac (Radiotelevizija Ljubljana) of measurements made on signals from a high-power broadcasting station in a hilly area of Yugoslavia. The results confirm earlier measurements (published in 1980) made by Bossert in West Germany that threw serious doubts on the increasing use (for example, by the BBC) of circular polarisation, as noted in my *Wireless World* article of April 1981, "Multipath distortion — does polarisation matter?" and subsequently rebutted by the BBC.

The new series of measurements with both stationary and mobile reception was made on transmissions from the Nanos station in Slovenia which has its antenna 1262m above sea level, some 600m higher than most of its service area. Two sectors of the service area were investigated, one at distances between 5km and 19km from the transmitter in an area varying between 400m and 700m above sea level but mostly within line-of-sight of the transmitter.



A second test sector took the form of a trench 100m to 200m a.s.l. flanked by mountains but nearly parallel to the direction of propagation, with a few places not line-of-sight.

The results show marked differences in performance, particularly in respect of multipath distortion, between horizontally and vertically polarised signals. In particular, vertically polarised



signals were found to suffer much greater diffraction loss at most locations while also producing much more diffuse reflections.

The authors consider that on Band II in hilly or mountainous terrain, horizontal polarisation performs better than vertical polarisation, with lower diffraction loss and higher loss for diffusely reflected waves. "In home reception, even mixed polarisation may cause problems since the polarisation of diffusely reflected waves is often rotated. With mobile reception, the additional antenna gain and more nearly omnidirectional antenna pattern achieved with the conventional whip antenna when receiving vertically polarised signals is measurable in clear line-of-sight conditions, but in such conditions there are no problems with horizontal polarisation. On critical road sections noisy drop-outs occur more often with vertical polarisation."

They conclude that vertical or mixed polarisation is not to be recommended for high-power stations having hilly service areas, although mixed polarisation could be a good choice for low-power stations in flat terrain in view of its benefits with conventional car antennae. Further studies are being undertaken comparing circular with horizontal polarisation in a hilly area.

Automating presentation

Thames Television, in re-equipping its Euston complex, has brought into service the first installation in Europe to implement two-channel (stereo) digital-audio processing based on the AES/EBU digital-interface specification. The only analogue sound within the new complex is within the talkback system.

Following the completion of the News and Current Affairs Presentation and Master Control rooms, Thames is currently bringing into use a battery of Panasonic "Marc" megacarts, each with a capacity of 1196 90-minute M.II cassettes with analogue-component video and digital sound, and each fitted with five internal and two external transports. By next year the system will be welded into a computerised presentation management system using customised Panasonic software that provides a high-degree of automation but maintains last-minute on-air flexibility with the aid of human intervention. The system, with Pro-Bel routeing switchers, has been designed with the possibility of later upgrading to composite-digital video based on the Panasonic D-3 proposals.

Currently, the major new TV project in the UK is the equipping of the new, purpose-built ITN building in Gray's Inn Road on the site of the former *The Times* building. The entire ITN operation is due to be using the new centre by January 1, 1991, with all equipment installed by the end of October this year. Again, a high degree of automation is planned, based on the resource management system (RMS) being developed by Basys (a subsidiary of ITN) with five Odetics TCS2000 megacarts. The system will extend well beyond the computer-assisted newsrooms as originally pioneered by Basys and which focussed on controlling information.

RMS is designed to control resources, whether people, equipment, input-feeds, library material or costs. The operational functions are divided into a series of interlinked sub-systems sharing common databases with three RMS modules to be used by ITN. The first module will be for booking incoming and outgoing satellite and line feeds; the second will drive the megacarts, tracking changes to the running orders of the newscast items; the third module will track all the bar-coded Betacam-SP tape cassettes in any machine, including those in edit suites and dubbing theatres as well as in the megacarts, storing information in the Basys computers.

Four of the TCS2000 carts will have six Betacam-SP transports, with software permitting four transports to record while the other two play-out simultaneously. The fifth cart will have an additional tower and act as a library management machine. Pro-Bel is supplying the routeing system involving a series of composite- and analogue-video and analogue-audio switchers.

RF Connections is by Pat Hawker

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Printed in Great Britain by Carlisle Web Offset, Caxton Road, Newtown Trading Estate, Carlisle, Cumbria CA2 7NR. and typeset by Marlin Graphics, Sidcup, Kent DA14 5DT, for the proprietors, Reed Business Publishing Ltd, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. © Reed Publishing Ltd 1990. *Electronics and Wireless World* can be obtained from the following: AUSTRALIA and NEW ZEALAND: Gordon & Gotch Ltd, INDIA: A.H. Wheeler & Co, CANADA: The Wm Dawson Subscription Service Ltd., Gordon & Gotch Ltd., SOUTH AFRICA: Central News Agency Ltd.; William Dawson & Sons (S.A.) Ltd.; UNITED STATES: Worldwide Media Services Inc., 115 East 23rd Street, NEW YORK, N.Y. 10010. USA. *Electronics & Wireless World* $5.95 (74513).

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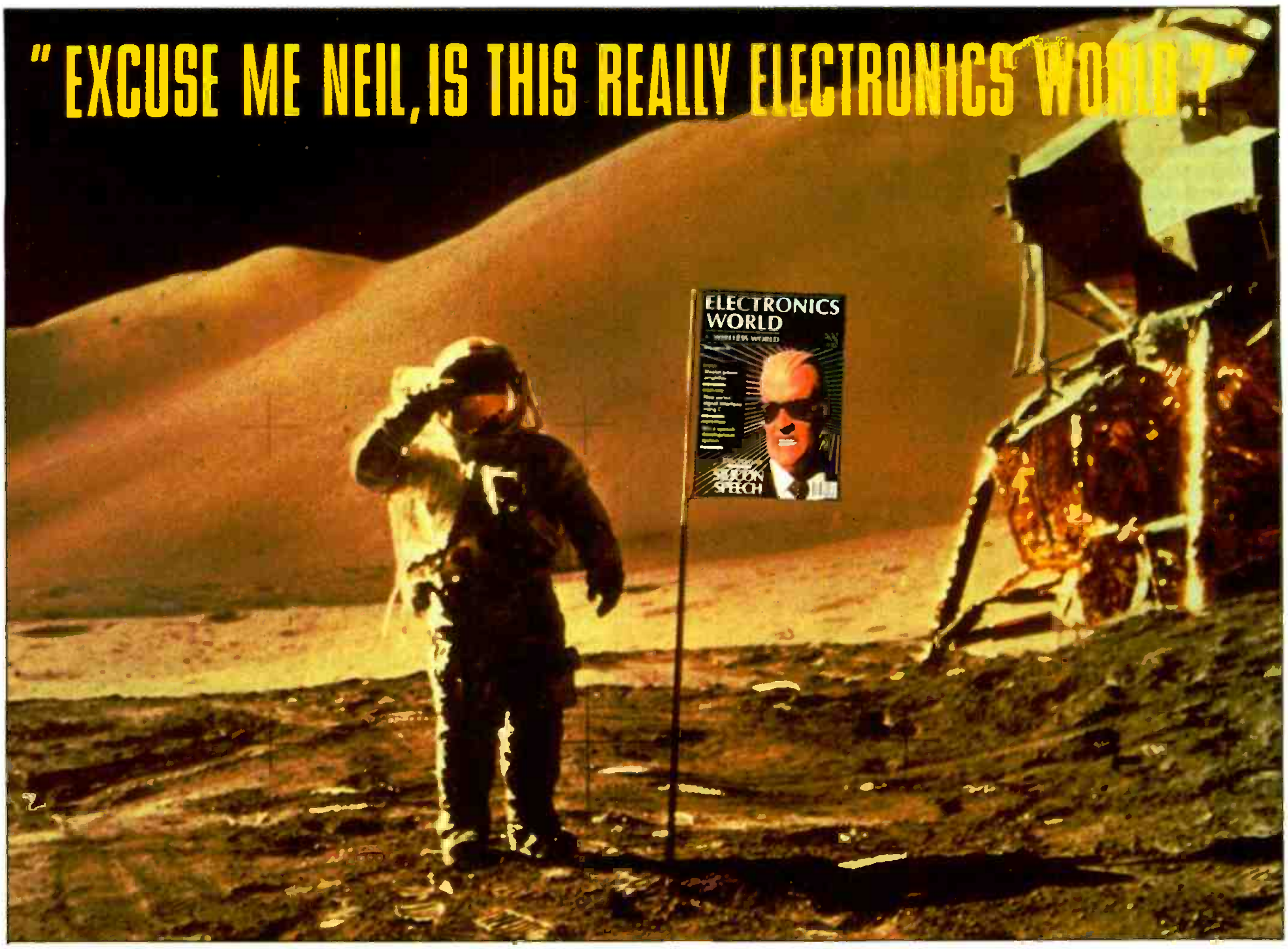

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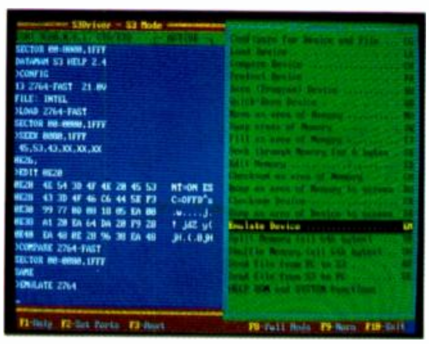

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Specifications and Price List

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