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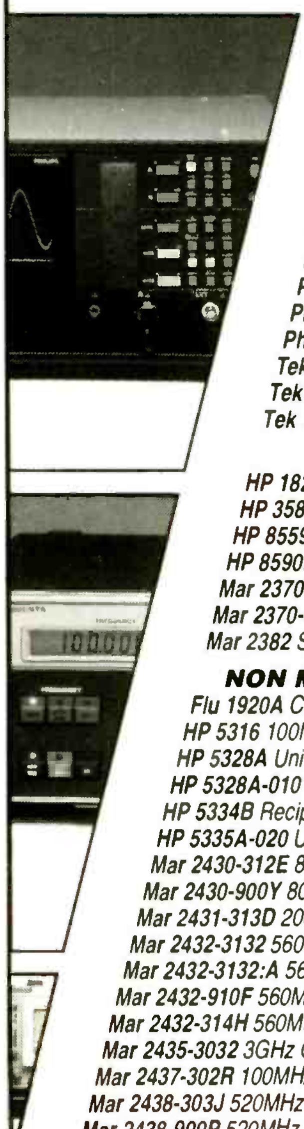

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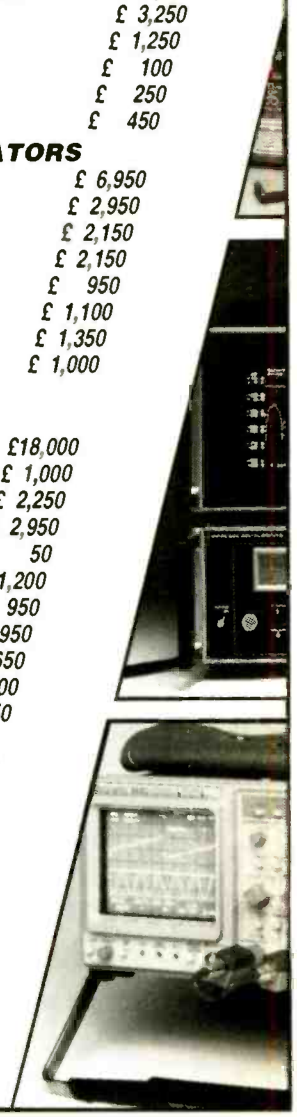

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Electronics World + Wireless World is published monthly USPS687540. By post, current issue £2.25, back issues (if available) £2.50. Order and payments to 301 *Electronics and Wireless World*. Quadrant House. The Quadrant. Sutton. Surrey SM2 5AS. Cheques should be payable to Reed Business Publishing Ltd. **Editorial & Advertising offices:** *EWW* Quadrant House. The Quadrant. Sutton. Surrey SM2 5AS. **Telephones:** Editorial 01-661 3614. Advertising 01-661 3130 01-661 8469. **Telex:** 892084 **REED BP G (EEP) Facsimile:** 01-661 8939 (Groups II & III). Newstrade – Quadrant Publishing Services No. 01-661 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.
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Appropriate technology

New technology should be treated with care. Inappropriate technology creates more problems than it solves. Excessive technology acts similarly.

The paper-less office is a clichéd paradox. Its most impressive feature is the sheer volume of paper required to make it work. Each element of the system demands a substantial manual, software particularly so. Even a lowly laser printer requires an initial set-up procedure which wouldn't be out of place in a computer lab.

Instructions are complicated because equipment and software offer so much. Users, in the main, haven't actually requested the diversity of features. They appear because equipment and software designers can put them there at little cost. This is the principal hallmark of new technology – lots for little.

Features don't come free. They do have to be paid for. Perhaps not at the time of purchase, but as an intellectual investment later on. The latest version of your favourite word processor will offer far more features than the old one. But to use them – if you need them – will require much time spent reading the manual followed by even more time wasted in playing around on the computer. By contrast, you know everything there is to know about the old version of the software and can do 99% of what you want in a single pass.

Neither should one be totally seduced by the argument that it will earn its keep eventually. The old version was doing most of what you want and, while you may want to use some of the new features, the basic things which you were doing easily may well be more difficult to achieve.

There are occasions when advanced technology looks beguiling but may be totally wrong when applied to simple tasks, keeping track of work in progress for instance. A computer in the office will do the job but a ball-point and a duplicate book just might perform the task more effectively. Too much technology wastes time.

None of this suggests a Luddite philosophy. The correct application of science will deliver proper benefits. Nobody could argue that wet film medical X-rays are better than CT scans, or that mind-numbing, inhuman production lines should be staffed by people rather than robots. Simply, our needs should guide the evolution of technology rather than the other way around.

Frank Ogden

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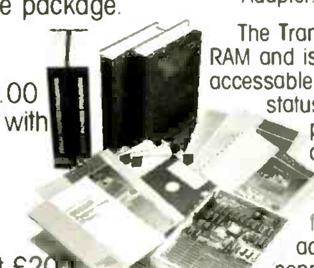

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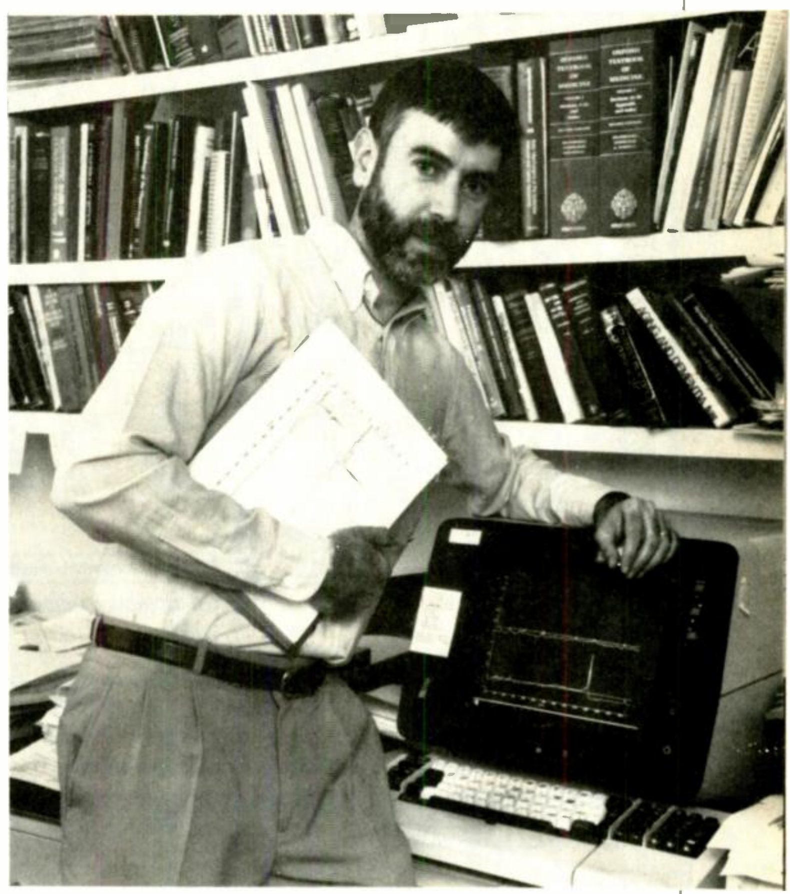
Computer has a brain-wave

A computer model for studying the brain has unexpectedly produced – on its own – electrical waves like those actually found in the brain itself. The supercomputer-based model generated this result in tests conducted recently by its developers, IBM scientist Roger Traub and Columbia University reearchers Richard Miles and Robert Wong.

The computer model was designed to simulate 10 000 cells in the brain's hippocampus, an area essential for the formation of new memories and the origin of many epileptic episodes. Using the model, the scientists can simulate how the hippocampus works and study, in a controlled environment, some of the medical benefits that the increased understanding of epilepsy could bring.

Perhaps the most startling aspect of the waves – technically known as population oscillations – is that no one understands precisely how they are generated either by the supercomputer model or by the brain. The fact that the waves spontaneously arose in the supercomputer model, however, gives the scientists potent evidence that the model is accurate in its simulation of brain activity. The next step is to use the model to discover the waves' cause and function.



Dr Roger Traub of IBM, whose supercomputer-based model spontaneously produced the "brain waves". The screen and printouts display rhythmical activity in two cells chosen from a large population. Picture courtesy of IBM.

The research began 10 years ago as an attempt to understand epilepsy and has already yielded valuable and unexpected insights into the disease. For example, the study provided a surprising answer to the long-standing puzzle over what starts an 'interictal spike', an abnormal burst of activity in a group of neurons. It indicates a tendency for that group of neurons to initiate an epileptic seizure. Traub's computer model revealed that an impulse from a single neuron may under certain conditions start a chain reaction that can quickly excite an entire population of brain cells into the synchronised firing that constitutes an interictal spike.

In future, Traub and his collaborators believe, the model could provide insight into certain aspects of how the brain works and help solve some of the mysteries of how people think, learn and remember. For example, the scientists have recently discovered that the way neurons respond when stimulated can change if the stimulus is applied repeatedly. These changes may be at the heart of how memory works.

Built into the computer model of the very complex mammalian brain are descriptions of both the anatomy of single neurons and the way any pair of connected neurons is likely to interact. This approach differs from studies that concentrate on the whole organ or on details of the activity of single, randomly selected neurons. By examining the interconnections between neurons, Traub is trying to work out how large collections of brain cells must work in concert.

A mammal's brain contains billions of neurons, and each neuron may be linked to hundreds or even thousands of others. The apparently random arrangement has long baffled scientists – a mammal has too few genes, in fact, to specify every connection in its brain.

Even for a small part of a mammal's brain, a precise wiring diagram showing the exact, cell-by-cell workings is impossible to work out. There are simply too many cells, too many connections, and too many impulses racing from cell to cell in a seemingly chaotic interplay.

It is a relatively simple matter, however, to record measurements of any or all of a few electronically-simulated neurons. And although Traub's first computer model contained only 100 neurons arranged in a grid, even this small-scale simulation was able to reproduce certain real-life brain functions.

One was a phenomenon called a double burst. In the brain, after an impulse triggers a group of neurons to fire, a short lull follows. Then a second flurry occurs as a new group of neurons responds to the initial burst of activity.

When Traub discovered his 100-neuron simulation doing this same thing as living brains, he felt he was on the right track. Since then the model has been improved considerably, one refinement being the addition of "field effects" – the electrical fields that arise when large numbers of neurons begin firing in unison.

Now Traub and his team plan to use the improved model to explore what regulates the complex rhythms that are part of the regular activity of the healthy human brain.

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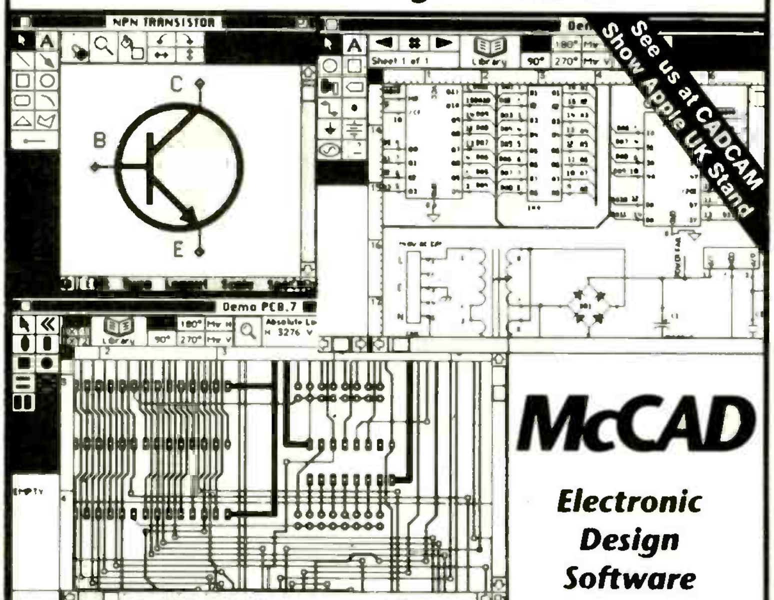

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Danger — animal magnetism!

Scanning the February and March issues of *EW&WW*, it's difficult to remain unaware of the growing concern that's being expressed over the safety of electromagnetic and electric fields. As with the latest research linking nuclear radiation to leukaemia, a point is reached when, despite the weak statistical correlation, common sense dictates that *something* must be afoot.

Conversely, I believe, it's necessary to apply that same faculty of commonsense to avoid unnecessary public panic. Most ordinary people do not understand statistics and are apt to assume that there's no smoke without fire. Scientists and engineers, trained not to speculate, add fuel to that fire by sticking firmly to the line that nothing is proven until a direct causal link is established.

Journalists (*mea culpa*) undoubtedly highlight this communication problem by selective amplification of dangers which, in engineering terms, are right down in the noise. Yet, selective that amplification must be unless our newspapers and journals are to become infinitely large (or infinitely boring!).

Such ethical dilemmas are highlighted

even further when reporting effects that are still in the realms of supposition. AC fields are probably (un)safely in the arena of legitimate concern, but what about steady fields, especially of the magnetic variety?

Investigations at the Jülich Nuclear Research Centre in West Germany, have drawn attention to mechanisms by which strong magnets can disrupt biological systems. The details are wrapped in complex biochemistry and have been worked out only in mice. Nevertheless it seems that strong steady magnetic fields can alter the alignment of certain diamagnetic molecules that exist in all animal cell membranes, including our own.

Using enzyme probes to analyse cells taken from the bone marrow of anaesthetised mice exposed to strong magnetic fields, the Jülich researchers found a significant temperature-dependent effect. In everyday terms, they say that the effects of fields up to 1.4T at 37°C (human body temperature) for around 30 minutes are comparable to the effects of minor radiation doses or lack of Vitamin E.

Lest this discovery be reproduced in the tabloids as 'Magnets can harm your health', it's worth pointing out that fields as high as 1.4T are not usually encountered in everyday life. Nor do these laboratory tests point to any life-threatening disease. Nevertheless, in the same way that DC theory is helpful in understanding AC theory, a study of the biological effects of steady-state magnetism may well help elucidate some of the controversial effects now being attributed to sinusoidally varying magnetic fields.

Why is the universe so lumpy?

Evidence emerging from a satellite called COBE (Cosmic Background Explorer), launched last November, seems to confirm the now well-established view that the Universe was created in a Big Bang about 15,000 million years ago. But COBE's instruments, which have been measuring the so-called microwave background – radiation left over from that primaeval fireball – have, if anything, heightened another great cosmological mystery; why the Universe is so lumpy.

Scientists at the Goddard Spaceflight Center, who've been collecting data from COBE, say that all the measurements indicate that the cosmic microwave background is absolutely uniform in all directions, both in intensity and frequency.

In one sense this is gratifying because it confirms all the measurements made from the ground and from space using less sophisticated equipment. On the other hand it's hard to understand in the light of what we now observe when we study the heavens.

The problem is that a uniform microwave background implies that the Universe expanded smoothly and evenly in the time following the Big Bang. Had the Universe expanded in fits and starts, then the background radiation would be similarly uneven in its characteristics. Of course there's no reason why the initial expansion of the Universe should have been irregular; in fact the observed regularity is much more consistent with the Big Bang theory than any other. The only problem is that something must have changed subsequently to make the Universe the lumpy affair that it is today.

Recent astronomical surveys, covering more than 30,000 galaxies measured in three dimension seems to indicate that matter is spread very unevenly indeed. The latest, by Geller and Huchra of the Harvard Smithsonian Center for Astrophysics, shows galaxies arranged in a sort of tightly-packed sheet which has been dubbed the 'Great Wall' in space. Either side of this sheet, there are huge regions almost devoid of matter.

So what was it that changed the Universe from being uniformly smooth? Or as someone graphically asked: what put the lumps in the cosmic porridge?

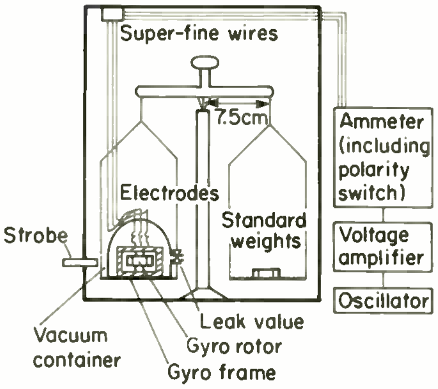
At the moment, there don't appear to be any convincing answers. It could be that, in spite of COBE's observations, there are still tiny irregularities in the cosmic background that could, over a period of 15,000 million years, have grown to become the large irregularities we see today. Or it could be that what was once a smooth expansion of the Universe suddenly became lumpy because of some subsequent catacylsmic event of which we have no knowledge at present.

Gyroscopes in a spin

A controversial experiment undertaken by two Japanese physicists suggests that a spinning gyroscope can weigh less than a stationary one. According to their report *(Physics Review Letters* vol 63, no 25) Sakae Takeuchi and Hideo Hayasaka of Tohoku University set up three gyroscopes in evacuated electromagnetically-screened boxes on accurate laboratory balances. These gyroscopes were set spinning electrically and then disconnected from the source of power.

According to all recognised laws of physics the gyroscopes should have weighed exactly the same as they did while stationary – approximately 175 grams. Yet the Japanese claim that the gyroscopes became progressively lighter by up to 10 milligrams as they were spun to a maximum 13,000 rpm. Even more curious was the subsequent discovery that this reduction of weight occurred only when the direction of rotation was clockwise as seen from above. Anticlockwise rotation produced, not the opposite effect, but no effect whatsoever.

So odd is this finding – and especially the lack of reversibility – that *Physical Review Letters*, not surprisingly, spent a year and a half deciding whether or not to publish the paper. Eventually, and with no ceremony, they did publish, much to the puzzlement of the scientific community.



A comment published soon afterwards in *Nature* (vol 343 no 6254) spelt out the dilemma of an editor when faced with a seemingly crazy conclusion. Should he publish uncritically, which may do science a disservice; should he suppress what may turn out to be something new and exciting or should he do what *Nature* itself did some time ago: conduct a detailed on-site investigation?

The Japanese research undoubtedly raises more questions than it answers. Why, for example, is the effect non-reversible when every other force in physics is symmetrical? And what could cause an effect which even the authors say cannot be explained by any of the normal theories?

John Maddox, the Editor of *Nature*, suggests that the best bet would be some sort of coupling between the spin of the gyroscopes and the spin of the Earth, as might be allowed by some versions of Einstein's theory of General Relativity. Maddox admits, however, that a weight loss of 10 milligrams would be uncomfortably large to fit into the mathematics of Einsteinian gravitation.

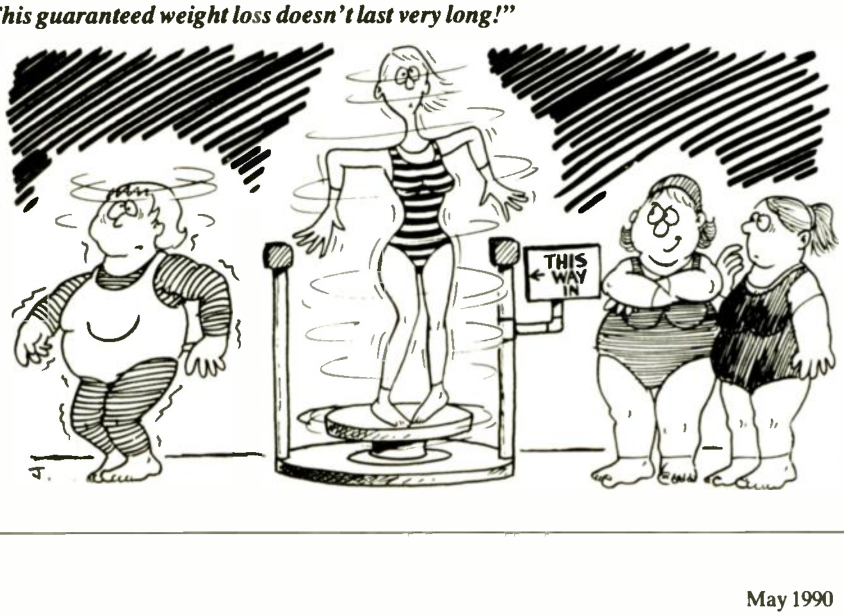
There this controversy might rest but for the views of veteran gyro experimenter, Eric Laithwaite, former professor of electrical engineering at London's Imperial College.

Laithwaite scorns any suggestion that the weight loss in the Japanese experiments is due to mysterious outworkings of Einsteinian relativity theory. He believes that the effect is a consequence of the gyroscopes being essentially fixed to the Earth. As the Earth rotates on its axis, the axis of the gyroscope is forced to move, albeit a tiny amount. Laithwaite explains that any gyroscope when pushed in one direction will respond by moving in another. The weight loss in the Japanese experiments could therefore be nothing more than an upward translation of the rotational force imparted to it by the Earth's movement. On that basis, says Laithwaite, there's no need to invoke mysterious forces or any necessity to tinker with the laws of physics.

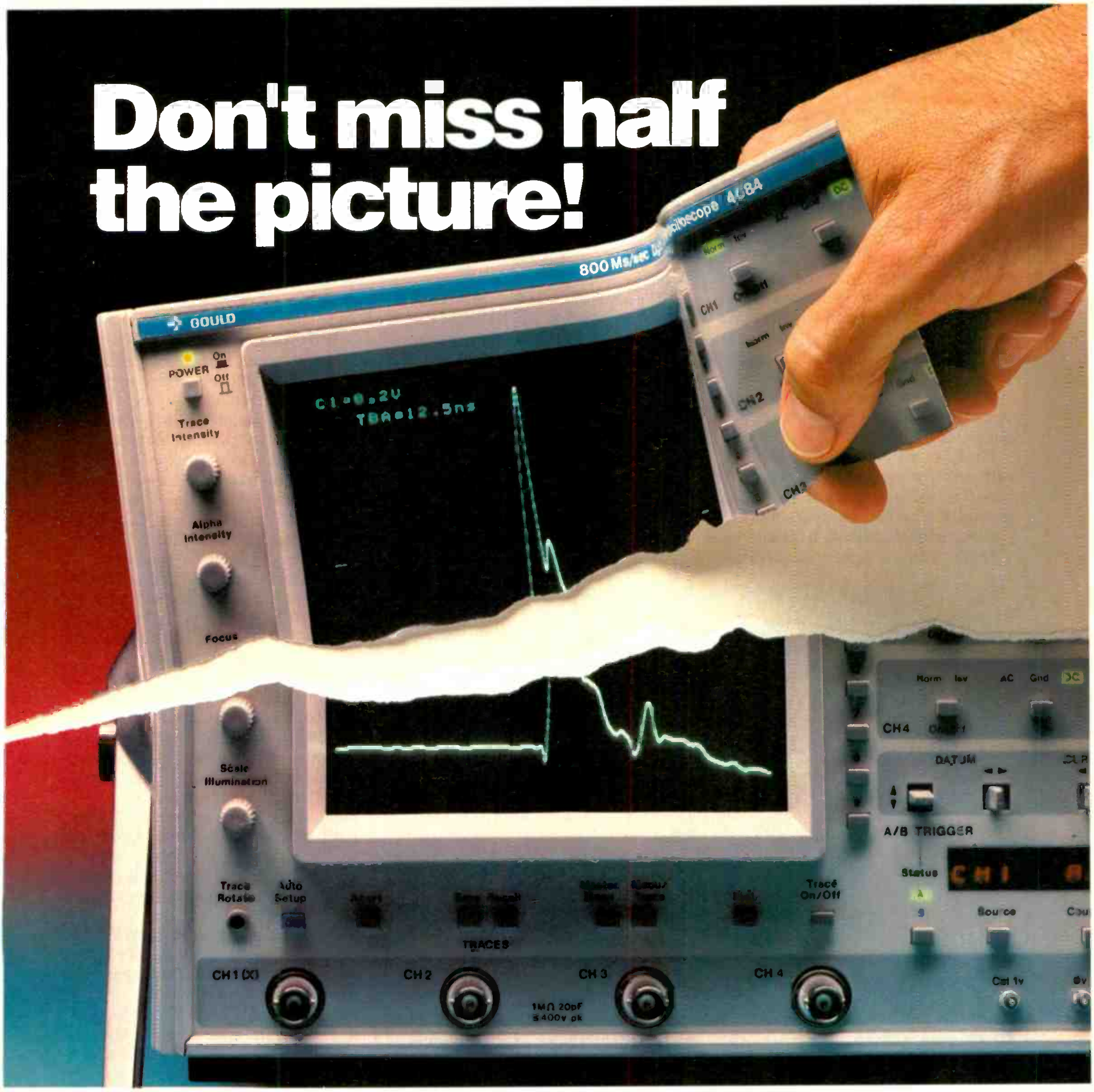
What is necessary, he says, is for scientists to develop the maths needed to explain complex gyroscopic behaviour. At the moment, theoreticians can only describe how a gyroscope behaves when all the forces acting on it are simple ones, mutually at right angles. Eric Laithwaite claims that it's relatively easy to create other conditions in which gyros behave in a way that no one can yet explain.

So, however puzzling the Japanese findings and however incomplete the published work, there's still, as Laithwaite believes, a case to answer. Not all such answers, though, are likely to cast very much light on the subject. Referring obliquely to the scientific lunatic fringe, John Maddox says he expects the months ahead to reverberate with the endless noise of the devotees of perpetual motion and levitation. ■

"This guaranteed weight loss doesn't last very long!"



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



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Boeing sued over cancer

A case currently making its way through the US courts brings into sharp relief the alleged connection between cancer and exposure to electromagnetic fields. It concerns a Boeing employee, Robert Strom, who contracted a rare form of leukaemia while working on an examination of the effects of nuclear electromagnetic pulse on avionics equipment.

Strom's work entailed frequent exposure to pulsed RF fields, a type of radiation which has been designated as harmful in a number of separate research studies. Although filed in June 1988, Strom's case against his former employers, the Boeing Company, is still waiting to be heard.

The essence of Strom's case is that, having been employed by Boeing for 22 years, he was asked to start work on an EMP test project as part of the MX Peacekeeper missile program. This was in 1983. Within a year, Strom had become ill with chronic myeloginous leukaemia and was given only 42 months to live.

He filed a compensation case in 1986. The information obtained in preparing the case resulted in his filing a lawsuit in June 1988 alleging fraud, misrepresentation, violation of human rights, negligence, civil conspiracy, and unconsented human experimentation. Defendants are the Boeing Company and others.

In November 1988, prompted by Strom's lawsuit, Boeing issued a letter to its EMP employees. The company denied that it intentionally exposed workers to simulated EMPs in human guinea-pig experiments. Without federal regulations, Boeing has gradually relaxed its in-house standard for EMP exposure. It was increased from 0.4kV/m in 1970 to 5kV/m; in 1977 the limit was raised further to 50kV/m and Boeing is said to be considering another increase to match the United States Air Force standard of 100kV/m.

The first suggestions of a link between EMP testing and disease were made more than 20 years ago. In 1968 the Boeing Company was given a USAF contract to test the effect of nuclear EMP on missile systems. Boeing soon became aware of safety questions when a number of leukaemia and skin cancer cases developed among technicians at its test site. To quote one of the technicians: "Boeing never told us that EMP exposure could be dangerous and they were asked many, many, times, especially when we saw the guys start dying. They were monitoring us about once a month".

In 1970, Boeing participated in a conference on EMP biological effects. As part of its research effort it agreed to monitor the health of people conducting EMP tests. The object was to evaluate the acute, chronic and long-term biological and health effects of exposure to EMP. This, it is claimed, was done without the knowledge or consent of the people concerned.

Shortly after this, Dr Sam Milham, a Washington State epidemiologist, advised Boeing to do an EMP worker-related study. He said that three leukaemia cases out of 160 among Boeing EMP employees represented almost 50 times the expected rate.

By 1983, Boeing already had some 15 years of experimentation with EMP and is alleged to have known that EMP was suspected of causing serious health problems. To quote Strom: "I was in the room with it. No one told me anything

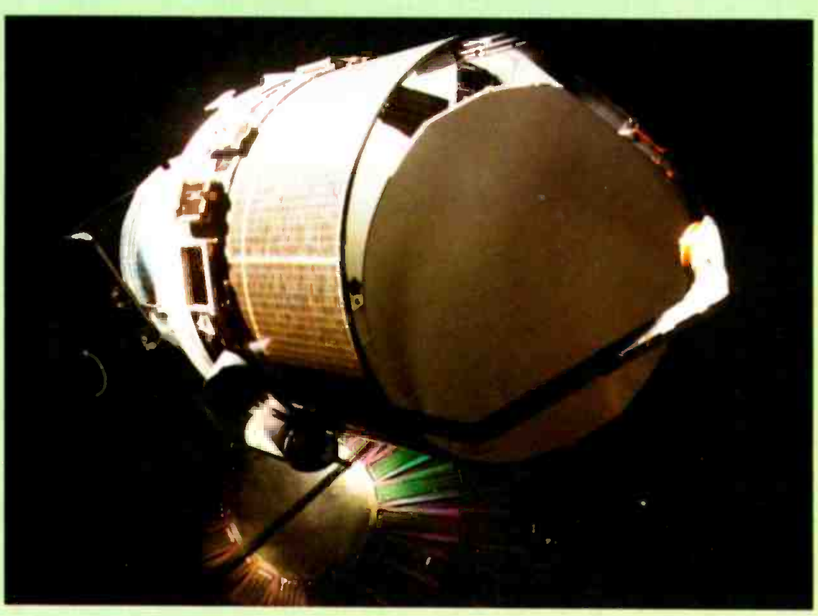
continued over page

Giotto ends four year sleep

The ESA spacecraft Giotto has woken in response to a series of commands from the European Space Operations Centre in Darmstadt.

ESOC has been preparing the reactivation for the last two years, the spacecraft having been made inactive shortly after its rendezvous with Halley's comet in April, 1986. Confirmation of the reactivation was obtained when a signal from Giotto, which is now 65 million miles from Earth, was picked up by the Madrid tracking station of the NASA Deep Space Network on February 19.

The DSN station sent commands to Giotto from the 100kW transmitter and 70m dish in Madrid. Signals from Giotto were minute, and a series of manoeuvres must now be performed to bring its high-gain antenna face-to-face with Earth to increase signal strength and provide telemetry.



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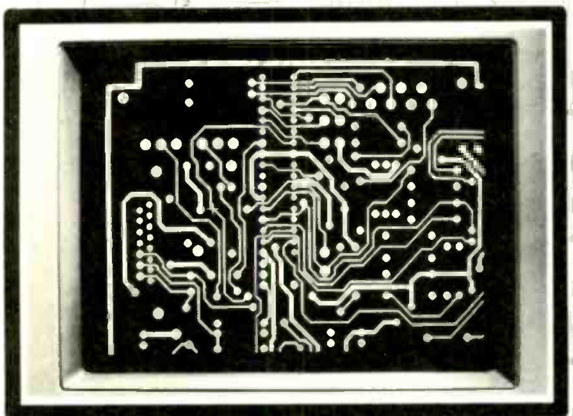

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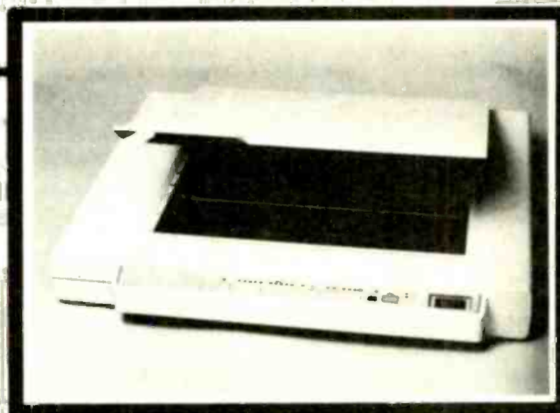

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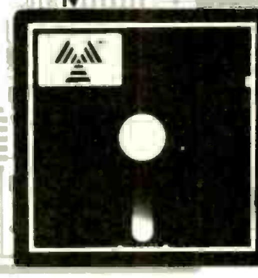

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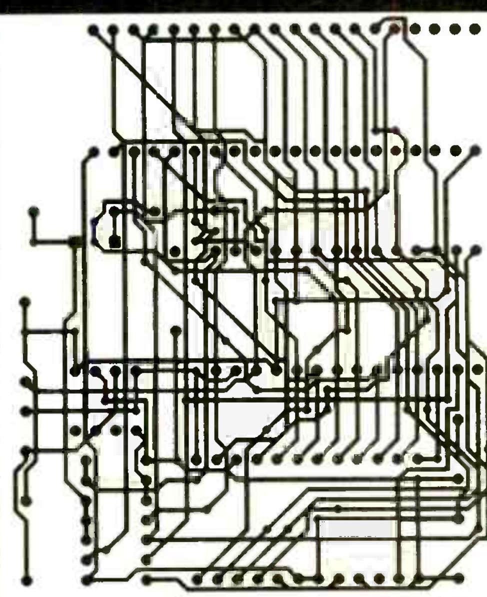

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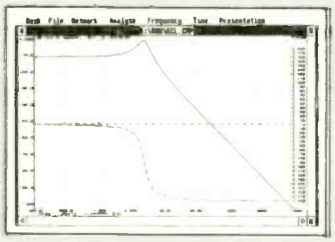

Frequency response of a low pass filter circuit

1 Frequency response
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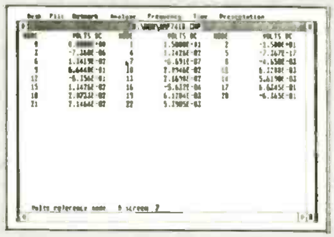

DC conditions within model of 741 circuit

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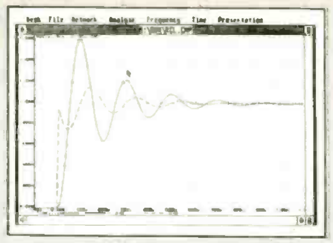

Impulse response of low pass filter (transient analysis)

3 Transient analysis
The transient response arising from a wide range of inputs can be examined. 7 types of of excitation are offered (impulse, sine wave, step, triangle, ramp, square, and pulse train); the parameters of each are user-definable. Reactive components may be pre-charged to steady-state condition. Up to 13 voltage generators and current generators may be connected. Sweep time is adjustable. Up to 4 probe nodes are allowed, and simultaneous plots permit easy comparison of results.

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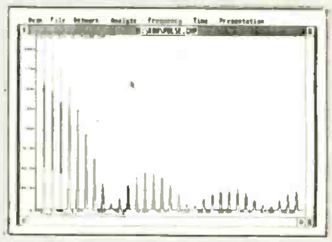

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about a hazard of being in that room. I was not informed in any way. I was exposed to high levels of EM radiation. They told me that the work was perfectly safe."

Strom had been given what he thought was a routine company physical after he started working with EMP and he got a clean bill of health. "Then the next year when I went back for another physical, the doctor told me that I had an abnormal lymph blood count. I had a rare form of leukaemia – bone marrow cancer – and it is fatal. When I heard about the deaths at the Montana test site all those years before, I didn't feel that it was chance, me going to work in an area and getting the same rare disease.

"The Boeing doctor told me that the company had a concern about leukaemia and reproductive effects. I was amazed. I said to that man: 'I have got what you are looking for!', and his words were: 'You have a valid reason for saying that as your previous physical was OK.'"

In 1986, Strom filed a worker's compensation claim. This enabled his lawyers to obtain various documents from Boeing. "Working my way through all this evidence, I saw the truth revealed. I saw that we had been used as human subjects. My wife sat in the kitchen typing what I wrote, crying. I could hear saying 'Damn them! Damn them!' For we knew then what had really happened; what the company had really done."

A spokesman for Boeing, Seattle, told *Electronics World*: "The remedy has been pursued through a workers' compensation claim. As a result, there has been no connection drawn between the employee's work and this claim. It has been appealed. That appeal has been denied also.

"The case is now in a civil process and, while it is in that process, there is nothing more I can add."

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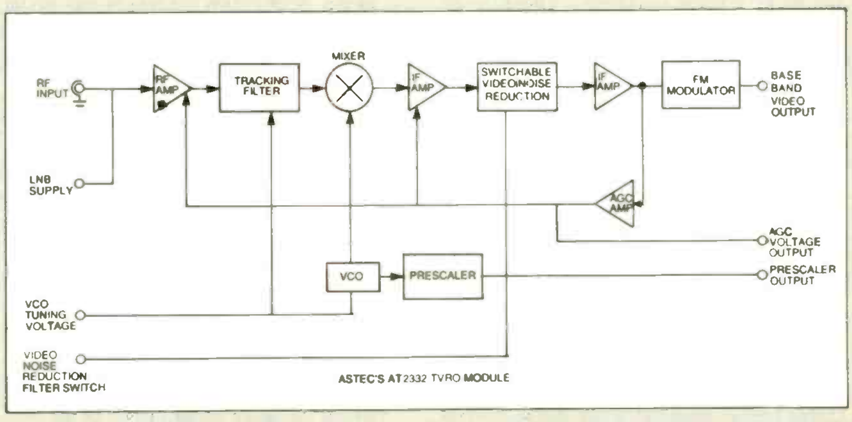

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Getting the message?

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After promising so much, Telepoint, which is based on a digital cordless telephone (CT-2) pioneered in Britain in the 1980s, has been an early disappointment. This disappointment has been worsened by the rip-roaring success of its illustrious cellular communications predecessor, which now has a million users in the UK after five years. Telepoint will be lucky to reach 5000 after 12 months.

Indeed, it was the very success of cellular which prompted the Government to make a number of initiatives in the late 1980s which were intended to revolutionise mobile communications over the next decade.

Telepoint was the first of these and the Government licenced four public service operators at the beginning of 1989. But within 12 months, three more licences were awarded for yet another form of mass market mobile communications, personal communications network (PCN).

The Government maintained that there was no conflict of interest between the two systems. Telepoint, based on the CT-2, was always intended to be a low-cost system which enables users to make telephone calls while standing in the street. PCN will be, when it is launched in 1992, a more sophisticated service allowing users to receive and make calls at home, in the office or when travelling in the same way as current netsworks. PCN will have the network capacity to support many more users than cellular. This it is hoped, will drive down equipment costs and make PCN the mass market service which cellular cannot be.

However, some observers believe that the Government has taken two bites at the cherry. When it realised that technical and marketing limitations would severely restrict the role of Telepoint, the Government was forced to bring PCN forward by as much as five years.

The equipment on which Telepoint is based has yet to prove itself as a core technology for a public communications system.

Derek Rowe, a founder of National Telephones and a designer of cordless PABX, claims that CT-2 "is a hype of sorts. It takes up an enormous amount of bandwidth to do very little. It is an over-engineered and therefore expensive replacement for your cordless telephone". Using 100kHz radio channels, the system was designed in the mid 1980s for use in the home with a few handsets addressing a single base station, like the analogue CT-1 it was intended to replace.

In a public telepoint system the base station must service a large number of users and Rowe believes systems will soon experience congestion. He says no attempt has been made to optimise the bandwidth of the radio channels. These are unusually wide, says Rowe, because the design is based on a signalling scheme developed by Motorola for wired systems.

It has been estimated that by the turn of the century 50 per cent of all telephone calls will be made by people on the move. Telepoint and now PCN are the UK Government's answer to the problem of meeting this demand.

The existing analogue cellular networks are expected to reach capacity in busy urban areas within the next few years; indeed some are already showing signs of strain. Digital cellular networks based on the European GSM standard will alleviate capacity problems when they are ready for service next year, but for how long?

Ed Candy, previously with Philips Radio Communications and now technical director of the UK telepoint operator, BYPS, believes Europe will have four million analogue cellular users in the early 1990s. "The GSM system will alleviate capacity problems, but it will reach its limit of 15m users by the end of the century," he warns.

What will then be needed is a high capacity system which can satisfy a mass market of current cellular users together with residential and business users.

The low-cost CT-2 clearly has technical limitations. It only offers coverage up to 200m, and cannot receive calls. What is needed is a more sophisticated but inexpensive product. A group of six European manufacturers including Ericsson of Sweden, Siemens of Germany and the Dutch company Philips, have spent the last year creating a specification for just such a product, the digital European cordless telephone, DECT.

Dect or CT-3, as it is called by some manufacturers, is not a cellular telephone. Its 10mW transmit power limits coverage to 250m, but unlike CT-2, it will offer a two-way service and will provide call 'handover' so calls will not be lost as a user moves from one cell

Continued over page ▶

PCN

"One of the features of changing technology is the liklihood of better things around the corner. Mobile radio is no exception." – the UK Government.

Personal communications networks (PCNs) will start the process of combining cellular carphones, domestic cordless telephones and the cordless office together on a single mobile communications network with a universal personal communicator.

To do this they will need enough capacity for up to 20m users in the UK alone, so they will operate in the spectrum available in the 2GHz frequency band. Apart from the operating frequency PCNs will look very much like digital cellular networks based on the GSM European network standard.

Pan-European digital cellular networks based on the GSM standard will be in service in 1991 and will gradually supercede existing analogue cellular networks such as Cellnet and Vodafone in the UK. The GSM network will be more reliable and, because it is based on a European standard, users will be able to make calls on one handset across Europe.

The plan is that PCNs should be operating from the mid 1990s onwards. They will make use of technologies such as GSM cellular and DECT. Implementing them on the one network will offer wide-area coverage using macro-cells (2 to 5km) and high density coverage in offices and homes using pico-cells (20 to 100m).

The dream is that PCNs will replace both cellular networks and even the fixed telephone networks by the turn of the century and each user will carry their personal communicator which could cost as little as £50 in the year 2000.

"I've got this set to STUN and if you can't show me your TV licence, I won't hesitate to use it."
The "stun gun" is actually a television detector of Swedish origin, which scans channels 21-68 and VHF. Sensitivity is settable to restrict coverage to a single house. There are, we are told, over 10 000 unlicenced television receivers in the Bristol area, where the photograph was taken.

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to another. And Dect will operate in the 2GHz frequency band where there is plenty of spare capacity.

Dect is viewed by many as the ultimate cordless telephone and the obvious choice for anyone wishing to build a personal communications network (PCN). The Government recognised this and proposed it as a possible handset technology for the new PCNs.

But there are two problems associated with Dect: it is a low power handset and so cannot be used in the large 15 km cells of a digital cellular network. Secondly, although one manufacturer, Ericsson, claims to have developed 'Dect-type' equipment already, the Dect design is not likely to be finalised by the European standards body before the end of the year.

This means that UK PCN builders must use the GSM digital cellular network architecture to provide the wide area coverage which will compete with cellular services in 1992. But to make PCN more than just another cellular service with a low cost handset and sophisticated call routeing, indeed a sensible alternative to telephones in the home and the 'cordless' office, Dect will have to be incorporated into the system.

According to Hans Boom, of Ericsson, Dect will revolutionise our use of the telephone. For example, if a GSM carphone were connected to a Dect handset and terminal, Boom says users would carry their personal communications system with them, and they would be able to use it at home with the car parked in the garage and at work using the car as a Dect base station when parked in the office car-park. "Dect is the ideal solution for PCN and it is already technically possible," adds Boom.

Is there a place for CT-2 in Europe's mobile communications networks of the 1990s? If UK manufacturers can produce compatible handsets that are reliable and low-cost, CT-2 may have a five year life in the home or even in public telepoint networks. But it is only a matter of time before something better is commercially available, and many Europeans now believe that it won't be long coming.

As Dr David Balston, technical director of mobile equipment maker Orbitel, points out, "We must recognise that Dect is an important technology and we should not be seen to be solely focused on CT-2 in the UK".

There is a revolution in mobile communications taking place and Britain is forcing the pace with the creation of PCNs. But will the uniquely British CT-2 play its part in the revolution before it is squeezed out by the next generation of equipment? The answer is probably to be found in the strange green and blue triangles which will bloom in Britain's high streets. Keep looking!

Richard Wilson,
Electronics Weekly.

DECT

"In the UK one refers to the European digital cordless telephone (DECT) standard as CT-3 technology, to stress that it could be regarded as the next generation of the CT-2 concept." – European CT-3 manufacturer.

CT-3 unlike CT-2 does not exist as a product yet. But when the European digital cordless telephone (DECT) standard is created, CT-3 will describe equipment conforming to that standard.

Dect CT-3 will operate in the 1.8GHz frequency band where there is spectrum available to support tens of millions of users across europe over the next ten to twenty years. It is a low-power (10mW) access technology which will enable it to be used in small – typically 50 to 100m – high density cells in offices, homes and in the street.

Like CT-2 it is likely to use a single two-way speech channel, but CT-3 will make more efficient use of the frequency spectrum and could have up to twice the capacity of CT-2. DECT/CT-3 will be able to transfer callers from cell to cell. This is a feature of current cellular telephone systems and is called 'handover'.

Manufacturers such as Ericsson and Siemens are developing CT-3 principally for use in offices where it would be able to replace existing hard-wired extensions and create the concept of 'the cordless office'. But DECT/CT-3 will also be able to provide small high density 'pico-cells' as part of a larger GSM digital cellular network, raising the possibility of the personal communicator which can be used at home, in the office and while travelling.

CT2

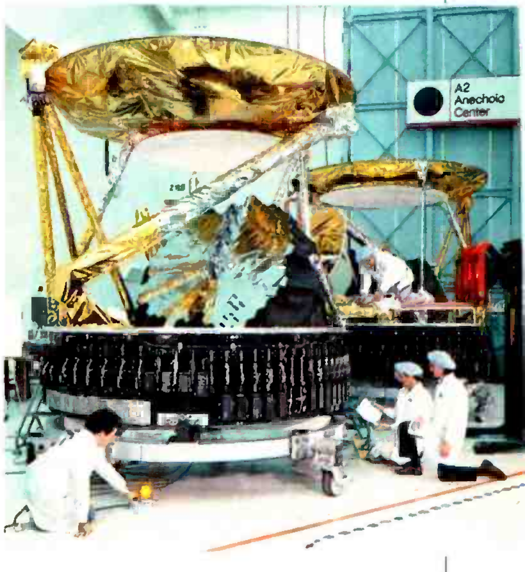
"If it has not made an impact in 12 months time it is probably a dead duck" – British CT-2 manufacturer.

CT-2 describes digital cordless telephone technology developed in the UK in the mid 1980s to replace analogue cordless telephones (CT-1) commonly used in the home and at the office.

CT-2 operates in a continous 4MHz band of spectrum between 864MHz and 868MHz divided into 40 duplex radio channels – frequency - division multiple access (FDMA). When making a call the handset selects a vacant channel which then is used to carry speech in both directions. This full duplex speech path is acheived using a time - division duplex (TDD) technique, sometimes call 'ping pong', where alternate 1ms time slots are used to carry the digitised speech packets in two directions.

CT-2 has a 10mW transmit power which enables it to operate up to 200m from a radio base station.

When operating in the home or office as a cordless extension to a fixed telephone line, the CT-2 can both receive and make calls. But when used on one of the UK's four low-cost mobile public telephone net-works (telepoint) the CT-2 can only make calls and not receive them. To enable CT-2s from different manufacturers to work on all the telepoint net-works an equipment specification called the common air interface (CAI) has been created. Two companies, Orbitel and GPT, land to offer CT-2 equipment to this standard before the end of the year.



Building satellites: the communications section of Intelsat VI. The completed satellite, launched on March 14, can carry 120 000 telephone calls and three TV channels. There willl be five Instelsat VI spacecraft in orbit by the end of 1991.

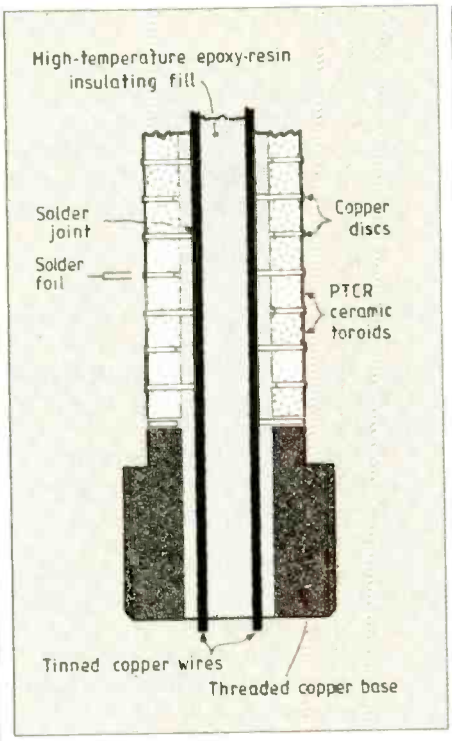
Pilots test the water for ice sensors

Faced with build up of ice on rotor blades or around air intakes, a helicopter pilot, given enough warning, can either switch on anti-icing equipment or turn round and go home. But air conditions can be extremely unpredictable, and there are several examples of pilots who have crashed because they have been given no time to take appropriate avoiding action.

Ice warning systems are already fitted to many helicopters, and do give pilots a certain amount of information on the likelihood of ice formation. But their disadvantages are that they only trigger when ice has formed, so cannot predict when conditions such as those around an air intake may lead to local icing; or have complex electronics and themselves need de-icing with associated periods of inoperation.

Plessey reckons to have found a solution to the problem by exploiting a new use for a PTCR (positive temperature coefficient of resistance) ceramic material to measure liquid water content (LWC). By carefully controlled strontium doping of semiconducting barium titanate, a ceramic material can be produced having a very steep change in resistivity over a small and selectable temperature range.

Passing a voltage through the ceramic will resistance-heat it until that very rapid increase in resistivity causes a current drop, stabilizing the ceramic at a particular temperature. Any alteration in surface cooling will produce a sharp change in current as the ceramic naturally regains its equilibrium. So the material is effectively a self stabilizing measure of any external changing cooling rate.



In the Plessey probe the barium strontium titanate has been modified to demonstrate a 100 000 times rise in resistivity between 50°C and 100°C with an equilibrium temperature of 70°C. At constant conditions, the cooling rate is proportional to atmospheric water content. In a helicopter the probe's power consumption can be combined with velocity, temperature and pressure data to calculate the atmospheric liquid water content.

The system can then trigger a warning to the pilot or can switch on anti-icing equipment automatically when icing conditions are encountered. The probe will work above and below freezing point and can respond to LWC changes in less than one second.

Calculated dimensions for the probe are 40mm long with a 4.5mm diameter, but this would demand a far higher voltage than the approximately 30V which is acceptable in this application. Plessey's practical solution is to manufacture the sensor from a number of ceramic toroids wired in parallel but stacked on top of each other to form a probe with an overall resistance of 3.5Ω and an operating voltage of 28V.

Reaction of helicopter pilots who have tried the system is said to have been "extremely encouraging" and it has been proved in MoD winter trials on Lynx, Wessex and Chinook machines.

Price is expected to be under £10 000 per installation.

Smallest squarial

STC claims a significant breakthrough in the design of the squarial – a flat, square aerial specified by BSB and intended to keep the planning people happy.

Developed by engineers at STC, Paignton, Devon, the squarial measures 38cm x 38cm and 2cm thick and is said to provide good quality reception of test TV signals from the BSB satellite. The company has received an initial contract for 50,000 squarials for delivery in the first half of 1990. To meet this and future requirements, STC is setting up an assembly line in its Paignton factory capable of producing 10,000 units per week. Some new jobs will be created to undertake the assembly work. Negotiations for further orders are under way with four receiver suppliers nominated by BSB.

ISSCC report

The US Institute of Electrical and Electronic Engineers held its 37th annual International Solid State Circuits Conference in February in San Francisco.

The world's foremost platform for announcing developments in integrated circuit technology has now decided to make San Francisco its permanent home. The propinquity of Silicon Valley and the easier journey for the Japanese were the deciding factors in cutting out the alternate years in New York.

Microprocessors showed the most dramatic advances in the various chip sectors at the 1990 ISSCC. According to the chairman of the microprocessor session, Jim Slager of Sun Microsystems, "The power of VLSI microprocessors continues to explode. This year's papers describe chips with a two-fold increase in number of transistors and performance over last year's chips and a six-fold increase over chips from three years ago . . . . . . microprocessors seem to be improving faster than other kinds of chips. Why?"

Slager offered five reasons.

— Whereas a few years ago the microprocessor market looked sewn up, with traditional vendors Intel and Motorola dominating through their installed software base and marketing clout, now the market is wide open.

— Because of the many different approaches currently being adopted to microprocessor design, from ECL chip-sets to single-chip c-mos devices with large internal cache memories to VLIW (Very Long Instruction Word i.e. longer than 64 bit) micros. This year saw the first version of a VLIW micro to be presented at ISSCC. The paper came from Philips and described a micro for embedded control, using a 200 bit instruction word.

— Because higher frequencies are pushing performance. The frequencies of the 1990 ISSCC micros "start where last year's left off" said Slager. They ranged from 40MHz to 90MHz (typical performance).

— Because, increasingly, micros are being designed for specific systems, which inevitably means greater variety of approach.

— Because the 5V power supply standard has been breached. This year's ISSCC has a 3.6V device from IBM and a 3.3V device from DEC. It is uncertain what new voltage will emerge as the standard, but it will undoubtedly be below 5V.

All these factors have led to the perception that the microprocessor market is opening up both to new comers and to new ideas, with the result that a number of companies are putting considerable resources into developing micros.

That, in turn, probably accounts for the current exploding power of the micro. And, if the micro's performance increases, then so must the performance of all the other chips if the maximum benefit is to be achieved in the final application.

One example of the other chip categories improving their performance to match the increased power of microprocessors is the eprom. Dramatic advances have been made in the access time of eproms, where read speeds have halved since last year.

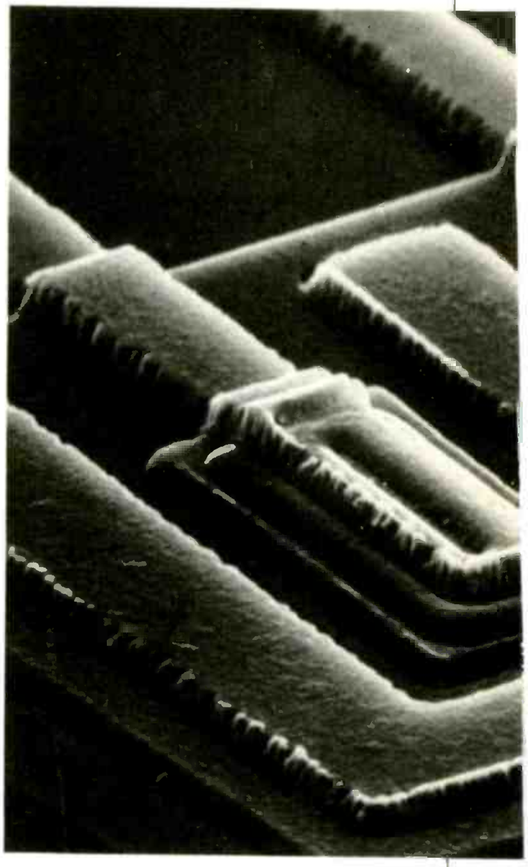
A 16ns 1Mbit eprom paper came from Toshiba and a 55ns 4Mbit eprom was presented by Hitachi. This considerable improvement in speed has come from the adoption of new chip architectures, double metal processes and the use of polycide. It also comes from new-found capabilities in scaling the eprom process. The first 16Mbit eprom to be presented at the ISSCC – by NEC this year – had a cell size that occupied 30% of the area occupied by the first 4Mbit eprom presented at the 1988 ISSCC. So eprom processes are showing a renewed potential for scaling.

One result could be that, if eprom access times continue to go down faster than s-ram access times, microprocessors could be used to interface direct with eprom without using cache memory.

The Exploding Power of Microprocessors*

	1990	1989	1987
transistors	580,000	283,000	150,000
frequency	61MHz	32MHz	16MHz
MIPS rating	58	29	13
line width	0.95 micron	1.4 micron	1.6 micron

* Averaging out the characteristics of microprocessors at the ISSCCs of 1990, 1989 and 1987.

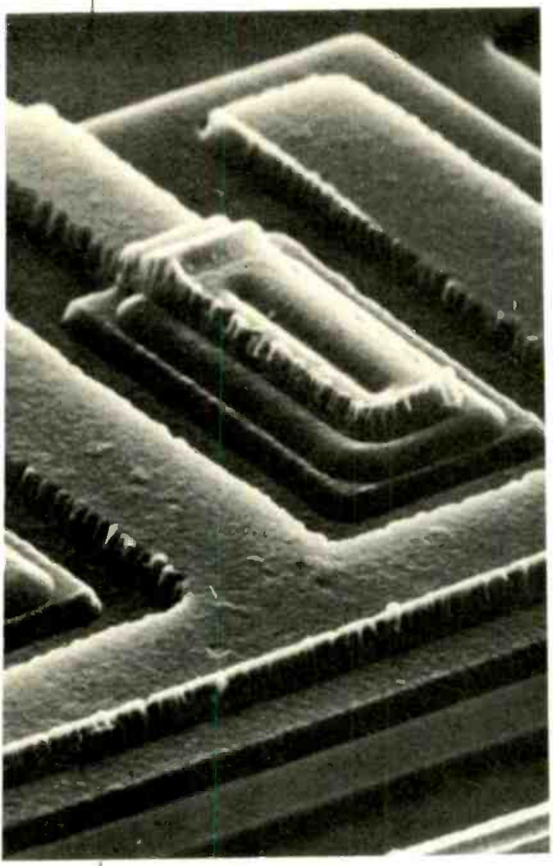


The world's fastest silicon transistor? IBM researchers claim to have produced a bipolar transistor structure which operates at 75GHz, nearly twice as fast as existing devices.

The devices, known as bipolar heterojunction transistors, were built using an alloy of silicon doped with a small quantity of germanium to enhance the transistor's electrical properties in the critical region. Processing was carried out using an ultra high vacuum chemical vapour deposition.

But eprom technology will have to run fast to catch up with the current chip used for cache memory – static ram. Whereas the fastest eprom at ISSCC for the 1Mbit density level was 16ns, the fastest 1Mbit s-rams were 5ns and 6.5ns, from Fujitsu and NEC respectively.

The two s-rams were made in BiCMOS technology, which means they have a memory array made with c-mos process technology surrounded by peripheral circuitry made with bipolar process technology. Coming from two Japanese companies, the s-rams demolish the myth that the Americans are pre-eminent in fast statics. It also means that US companies which have grown to prominence on the back of a superiority in fast s-rams like Integrated Device Technology, Cypress Semiconductor and Performance



Semiconductor will have to start looking for new products to maintain their traditionally high margins. Once the Japanese focus on a product area it usually follows that prices tumble as markets become over-supplied.

As well as these super-fast s-rams at the ISSCC were some very dense devices. NEC, Toshiba, Mitsubishi and Hitachi gave papers on 4Mbit s-rams which caused considerable surprise among the delegates: The chips had very low standby power – in the sub-milliamp range – which suggests thay had been designed specifically with portable equipment in mind; they were made using c-mos technology, whereas many people were expecting mainstream s-ram processes to go to BiCMOS for the next generation of density; and they were very fast, ranging from 15ns to 23ns.

C-mos has surprised everyone with its ability to "stretch" the performance it delivers especially in terms of speed. The 4Mbit s-ram papers will make everyone in the chip industry think again about the necessity to move to BiCMOS to achieve new generations of performance.

The limiting factor with s-ram development is the physical limit of the size of the chip itself. This is because s-ram technology, unlike d-ram technology, has not found any way to increase its density levels, except by scaling and using more physical space on the silicon.

D-ram technology, on the other hand, has found ways of building transistors on top of other transistors – "stacking" – and of digging into the silicon substrate to locate the capacitors in grooves called "trenches". These techniques make it possible to foresee new density levels for d-ram which do not require larger chip sizes.

But trenches and stacks don't work for s-ram, or not yet, and the conference reckoned that s-rams could be limited to a top density limit of 16Mbit unless they went to some kind of 3D structure or to silicon-on-insulator technology.

D-rams are usually the flagship papers of the ISSCC, since d-ram technology is commonly regarded as the chip industry's "technology driver"; however, this year was a disappointment. Last year saw the first of the 16Mbit devices and there was no advance on that at the 1990 ISSCC. It is expected that the 1991 ISSCC will see the first of the upcoming generation of 64Mbit chips.

> *"If eprom access times continue to decrease faster than s-ram, microprocessors could interface directly with eprom without need for cache memory."*

However, at an informal evening session, the Japanese telecommunications network operator NTT revealed that it had developed a 0.25 micron process which could put a billion devices on a chip. The company reckoned that such devices (for instance) 1Gbit d-rams would be "mainstream electronics technology early in the next century".

Finally, the exotica. This year, for the first time, these had a session all to themselves under the name "Emerging Circuit Technologies". Top of the bill had to be the neural networks from AT&T's Bell Labs and Matsushita. Neural nets are silicon chips designed on the same lines as the neuron cells which make up the human brain. It was pointed out that only now has chip-process technology advanced to the point where it makes it worthwhile to make a neural net in silicon rather than just implementing it in software on a computer. The Matsushita paper coined the expression 'neurochip' to describe such circuits when implemented in silicon.

The main difference between neural nets and other types of chip is their "connectivity" – their points of connection with each other are much greater than with conventional chips. That makes them useful in tasks requiring massive parallelism like pattern recognition.

For instance, the Bell Labs chip had 256 neurons, each of which had 128 connections with its surrounding neurons. It was made using c-mos process technology and reconfigurable cells. The Matsushita neural net was made using BiCMOS analogue process technology. It incorporated 64 neurons, capable of 10^{a} multiplications per second.

Finally, among the exotica was an 8bit digital signal processor using 23,000 Josephson junctions which could perform 10^{a} operations per second (1Gops) while dissipating 12mW. The paper was given by Fujitsu.

The vast expense of developing all this technology came under scrutiny at the 1990 ISSCC. Professor Bill Ouchi of the University of California nutshelled the problem in two propositions: first, it was so expensive that only nationwide R&D consortia could handle it (Sematech in the USA; JESSI in Eurôpe; SORTEC in Japan); second, it was "leaky" – as soon as it was developed everyone knew everything about it. That made the expense unjustifiable to national governments seeking advantage for their national industries.

Ouchi proposed a world where R&D collaboration would become global, so that "competition, no longer salient between companies or national economies, would instead be between individual scientists and engineers". Ouchi went on to envisage "a worldwide monopoly on research funds controlled by . . . . the World-Wide Semiconductor Technology Secretariat."

MAC VISION

Tom Woodford fights his way through the undergrowth of confusion encircling the various MAC systems of television transmission.

The launch of BSB's direct broadcasting service on April 29 will fuel curiosity in the UK about MAC. Much confusion surrounds the new standard and lack of technical competence in most of the media has done nothing to help; the anti-BSB lobby has also fogged the issue somewhat. Most ordinary people can't understand why there aren't MAC decoders on the market, just like all those FilmNet ones, or why DMAC receivers cost more than a night out with Pamella Bordes and are less easy to get.

There is a simple answer: MAC is Jolly Difficult Stuff. In the last few months many satellite-oriented magazines have published articles to clarify the subject, but all have either contained significant inaccuracies or not much about anything at all.

What is MAC?

It is still not understood that MAC is a television transmission system, not just a scrambling technique. Like PAL, NTSC or SECAM, MAC (Multiplexed Analogue Components) is a method of encoding television signals for transmission and is as different from these three existing systems as they are from each other.

It is also generally believed that MAC uses digital transmission for the entire signal. In fact only the audio and data signals are digitised; the video waveforms are transmitted in analogue form, although differently structured from conventional PAL or SECAM. A simple sum shows that even a low definition, 6-bit digital television signal has a bandwidth of well over 50MHz, which is just a little bit big for a standard 27MHz DBS transponder. The video signal is digitised in the receiver/decoder for processing, but that's another topic altogether.

NTSC, PAL and SECAM are all fundamentally black-and-white systems dating from the earliest days of television, with "extras" added to include colour information while retaining compatibility with monochrome receivers. MAC was specified for colour transmission and was originally intended to become a candidate for a World television standard for the future.

Commercial and political interests were unlikely to welcome such a global standard, and rival systems (such as the Japanese/American High Definition TV system) sprang up as alternatives. In Europe, where consumers had come to expect sophisticated facilities like Teletext and reasonable quality both of picture and content, MAC was seen as the best solution for future development.

Philips high-definition television demonstrator using the MAC system

Short history of a camel

A camel, it has been said, is a horse designed by a committee. MAC was conceived as the perfect "horse" and was to become the ultimate camel. It was pioneered by the IBA in the UK and was developed as an alternative to PAL/SECAM, to exploit the full 27MHz channel bandwidth allowed by WARC 77 for the future Direct Broadcast by Satellite (DBS). MAC could offer greatly improved picture quality, with many extra features and facilities.

The new MAC system was formally adopted by the UK in 1982 as the British DBS standard and in late 1983 the European Broadcasting Union, unable to think up anything more complicated by themselves, accepted MAC as the "chosen" future standard for Europe.

Since MAC was (even at the beginning) highly complex, it had a tendency to be treated as something "for the future". It developed in the belief that IC technology would, in due course, provide the hardware for the paper specification to be achieved in reality. MAC became a "wish-list" for the lunatic fringe of television research, and developed only as additional items appended to a specification document deep in the Library of the EBU. A few part-working prototypes could be found in development laboratories scattered around Europe.

More recently, the practical and commercial aspects of television broadcasting started to influence MAC development and the specification began to fragment into various derivatives so that MAC could be actually used for something. The ephemeral concepts were frozen before practical circuit designs had been realised. This has lumbered TV receiver architecture with a large overhead of V2LSI2 (very, very LSI indeed) for the foreseeable future. It has eradicated any commercial advantages the early introduction of MAC standards may have achieved for Europe. Had the specification been developed alongside working silicon designs, as was the case with NICAM, MAC would by now be in everyday domestic use.

Why use MAC?

PAL, NTSC and SECAM use frequency-division multiplex to combine chrominance and luminance information into one signal. The colour information is carried along with the monochrome picture using a subcarrier added to the main black-and-white signal. This encoding technique causes problems with cross-colour and cross-luminance (colour fringing and banding), particularly where the transmission distance is great.

In the MAC system, the analogue luminance and colour-difference information are time-multiplexed – they are transmitted sequentially one after the other for each line of the picture. Because they are kept separate in time, the cross-modulation problems of FDM systems like PAL are eliminated.

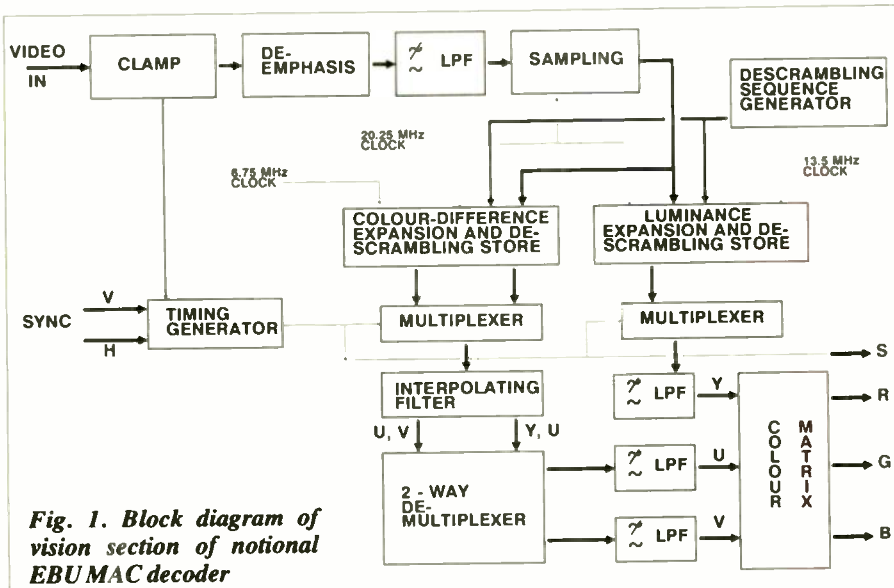


Fig. 1. Block diagram of vision section of notional EBU MAC decoder

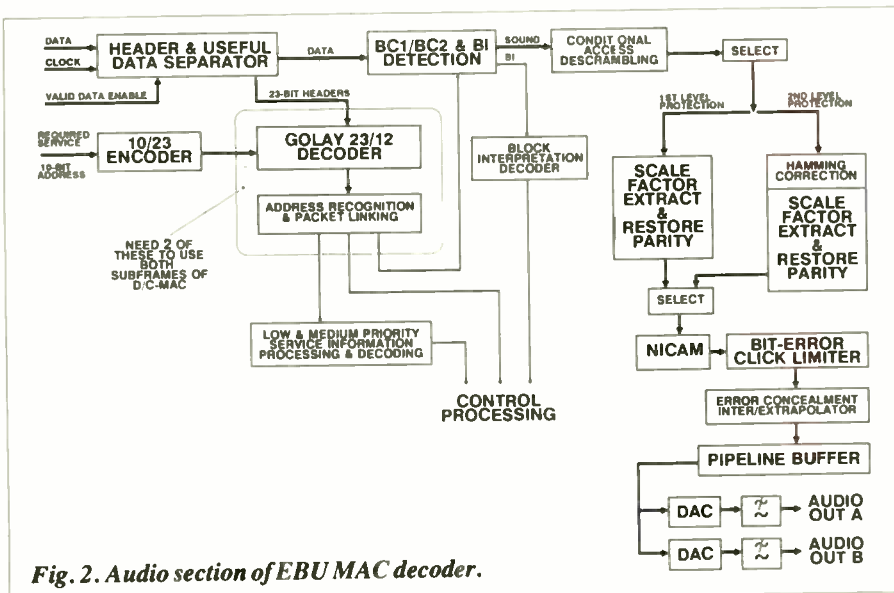


Fig. 2. Audio section of EBU MAC decoder.

MAC systems in use

The major players are C-MAC and D-MAC, because they use data rates of 20.25Mb/s. This allows easy conversion (in either direction) from the digital studio standard CCIR Rec 601, which samples luminance at 13.5MHz and chrominance at 6.75MHz. These are the equivalent frequencies obtained when the time compression (3:2 and 3:1) for MAC at 20.25MHz is applied.

Such high data rates use a lot of bandwidth, so C-MAC and D-MAC are unsuitable for terrestrial distribution by cable or conventional UHF transmitters. B-MAC and D_2MAC use lower data rates to overcome this.

C-MAC is the original EBU MAC transmission standard. It is capable of giving an instantaneous data rate of 20.25Mb/s when no video is transmitted (blank lines) or a continuous average data rate of 3Mb/s. This could provide the equivalent of eight CD-quality sound channels, but there is great flexibility for alternatives in sound and data services.

Frequency modulation is used for the video portion, with phase modulation for the audio and data periods. This complicates the receiver, since two demodulators are required.

C-MAC is used by NRK in Norway and was planned for several other DBS broadcasters, although D-MAC may eventually be chosen.

For transmission, an energy-dispersal triangular waveform is added to the video components of the C-MAC signal.

B-MAC reduces the bandwidth requirement to about 6MHz by using a multi-level data-coding method to reduce the data rate. This reduces noise immunity significantly for the sound/data services, requiring greater carrier:noise ratios at the receiver and offering little tolerance to weak signals. B-MAC signals can be re-distributed using conventional terrestrial means without transcoding and is in use by many cable services in Canada and Australia.

For a long time, the only available system offering conditional access control and (to date) unbreakable scrambling, B-MAC is used in Europe by American Forces Broadcasting and by SIS, the UK betting information service.

Scientific Atlanta have a virtual monopoly on B-MAC equipment.

D-MAC uses duo-binary encoding to reduce the bandwidth requirement without significant loss of noise immunity. The whole D-MAC signal is frequency modulated for transmission and so only a simple, conventional FM demodulator is required in the receiver. The most important aspect of D-MAC is its compatibility with the proposed European high-definition system, Eureka 95.

D-MAC, in common with C-MAC, uses instantaneous data rates of 20.25Mb/s and so can also support eight 15kHz audio channels, or their data equivalent.

The chosen system for BSB, D-MAC will probably be used by W.H. Smith in due course from their Astra transponders.

D-MAC gives a video bandwidth of 8.5MHz and requires 10.5MHz of RF bandwidth when transmitted conventionally by AM vestigial sideband, which is too wide to be carried by most European cable networks.

D_2MAC is a sub-set of D-MAC, intended to

To split the picture information in time, some form of time compression must be used; the signal for broadcast is sampled and stored at one rate and then read out for transmission at a higher rate. In addition, the sound information has to be added to the picture by tagging suitably encoded signals to the end of each compressed line. The overall information rate is therefore higher than for FDM and MAC needs more bandwidth than its PAL or SECAM ancestors.

This greater bandwidth requirement is reduced somewhat by exploiting the human eye's tolerance of reduced colour resolution. The colour difference signals are only transmitted on alternate lines of the television picture and the receiver interpolates between lines to restore the original colours. Research showed that compressing the luminance by a factor of 1.5 and the chrominance by a factor of 3 offered the best compromise for utilisation of the available 64 microsecond line period.

The video component of the transmission thus occupies 52/64 of each line, leaving 12μs per line for audio and other services. This is adequate capacity for eight digital sound channels, each of Compact Disc quality. However, this digital transmission could carry many different services, so a wide range of options exist on how the data capacity can be used. Teletext, data, and conditional addressing are simple to execute in theory, although in practice are proving complex even to specify.

Similarly there is a variety of ways in which the MAC signal can be transmitted or broadcast, with different options being suited for different applications: DBS, terrestrial TV, cable. It is these differences in transmission modulation which give the sub-sets of MAC: A, B, C, D and D_2.

Growing importance of MAC

The original intentions for MAC, as a Jolly Nice System to be developed at leisure, were overtaken by the phenomenal speed of development (and reduction of cost) of domestic consumer satellite reception equipment. The operators of the most recent DBS satellites have chosen MAC for their transmissions, since that is the intended European future standard. Indeed, the EBU recommended in 1986 that "all future television receivers should be designed to be usable with all members of the MAC packet family..." and also that "... all receivers ... must contain the descrambling circuits described...in the EBU specification".

The EBU spec was seen as so overcomplicated that few consumer electronics manufacturers took much more than a passing interest. In a market where a 58cm colour TV receiver could be manufactured for about £100, it was incomprehensible that "all future receivers" should contain decoder and descrambler circuitry costing at least three times this amount. The result was that only a handful of engineers in the whole of Europe were doing any serious work on MAC systems. Component manufacturers were basing any development effort on small-volume runs of the necessary ICs and using fabrication technologies suitable for the anticipated low-volume, low-growth market.

In recent months, the capability for over-air addressing for conditional access systems ("pay us and we'll turn you on") has become seen as the only future route for subscription-funded or restricted-market broadcasters. Service providers in the United States were amazed by the technical lengths to which hackers would go to crack scrambling systems and much egg-on-face happened over so-called unbreakable systems.

Thus SSP's (satellite service providers) originally using soft – scrambling or other low-level techniques are now making serious moves towards MAC-based systems. This has justified the original intentions of the EBU specs, if not their eventual complexity. These SSPs are only interested in MAC for its scrambling facilities – the improved performance is relatively academic. As a result, D-MAC and D_2MAC have emerged as *de-facto* standards somewhat sooner than anticipated by the original developers. The result is a severe shortage, not just of suitable reception equipment, but also of any means of making some.

Rules of operation

To shorten development times and get usable products to the market more quickly, various D-MAC users defined simple rules that they would obey in their transmissions. These "Rules of operation" indicate to designers the features of the MAC specifications which will (or will not) be used. With predefined service information, the designer need not include provision for unused or non-variable facilities. For example, if the type of audio, error correction, companding laws and (most importantly) the packet addresses for the sound data are fixed in advance, then several man-months of software development can be saved in a receiver design.

The EBU stated in the MAC specification appendices (rather obviously) overcome this problem by using only 10.125Mb/s data rate to offer half the data/audio capacity, i.e. four 15kHz audio channels or equivalent. D_2MAC occupies only 7MHz of conventional AM VSB bandwidth. It is obviously simple to transcode from D-MAC by discarding half the data packets, and D-MAC data is arranged in two sub-frames to allow for this.

Like C-MAC, D_2MAC has an energy-dispersal waveform added to the signal for transmission; but to the whole baseband, not just the video component.

There are currently in existence two other variants of the MAC packet specifications.

A-MAC was a very early system in which the data/sound was frequency multiplexed onto a sub-carrier at 7.16MHz. A-MAC offered very little benefit except to prove that MAC could work and is now history.

S-MAC is a version for studio use which uses a bandwidth of 11MHz to maintain the original sync and colour-burst signals for transcoding to PAL or SECAM. It is of academic interest only in this article.

Scrambling and other confusion

Much confusion comes from misunderstanding of the word "decoder". To receive MAC pictures you need a MAC decoder. This takes the incoming MAC-format transmission and turns it into signals to drive a television receiver. Your domestic receiver now contains a PAL decoder, unless you live in France or Russia. This "decodes" the incoming PAL-format transmission and turns it into signal. To receive PAL you use a PAL decoder; to receive SECAM you use a SECAM decoder; to receive MAC you use a MAC decoder.

If you are a broadcaster, you can scramble your picture signals or sound, or both, so that only viewers equipped with an appropriate descrambler can enjoy your broadcasts. Because a MAC signal can contain data, as well as sound and picture, a broadcaster can well and truly scramble the picture and sound. Then, he sends data along with the signal to tell "authorised decoders" how to unscramble them. The authorisation can itself be transmitted along with the signals, to switch on group, or even individual decoders. The fundamental advantage of MAC, apart from the great improvement in picture quality, is that the decoder can also be the descrambler. To receive FilmNet you need a PAL decoder, a FilmNet descrambler and a rat's nest of connecting leads. To receive BSB you will only need a DMAC decoder/descrambler; no more rat's nest, in theory.

Unfortunately, life is a little more complicated in reality, but then life tends to be like that.

Complexity of D-MAC

The development of new receivers is greatly complicated by the extreme complexity of the MAC encoding concept. Very sophisticated software has to be written in order to make the system work at all.

Apart from time- instead of frequency-multiplexed signal components and fully digital sound transmission, the other major difference between MAC and PAL/SECAM is with sync.processing. There are no conventional sync.signals; instead the first six bits of each line's data burst is a horizontal sync. "word" (001011) which is transmitted in true

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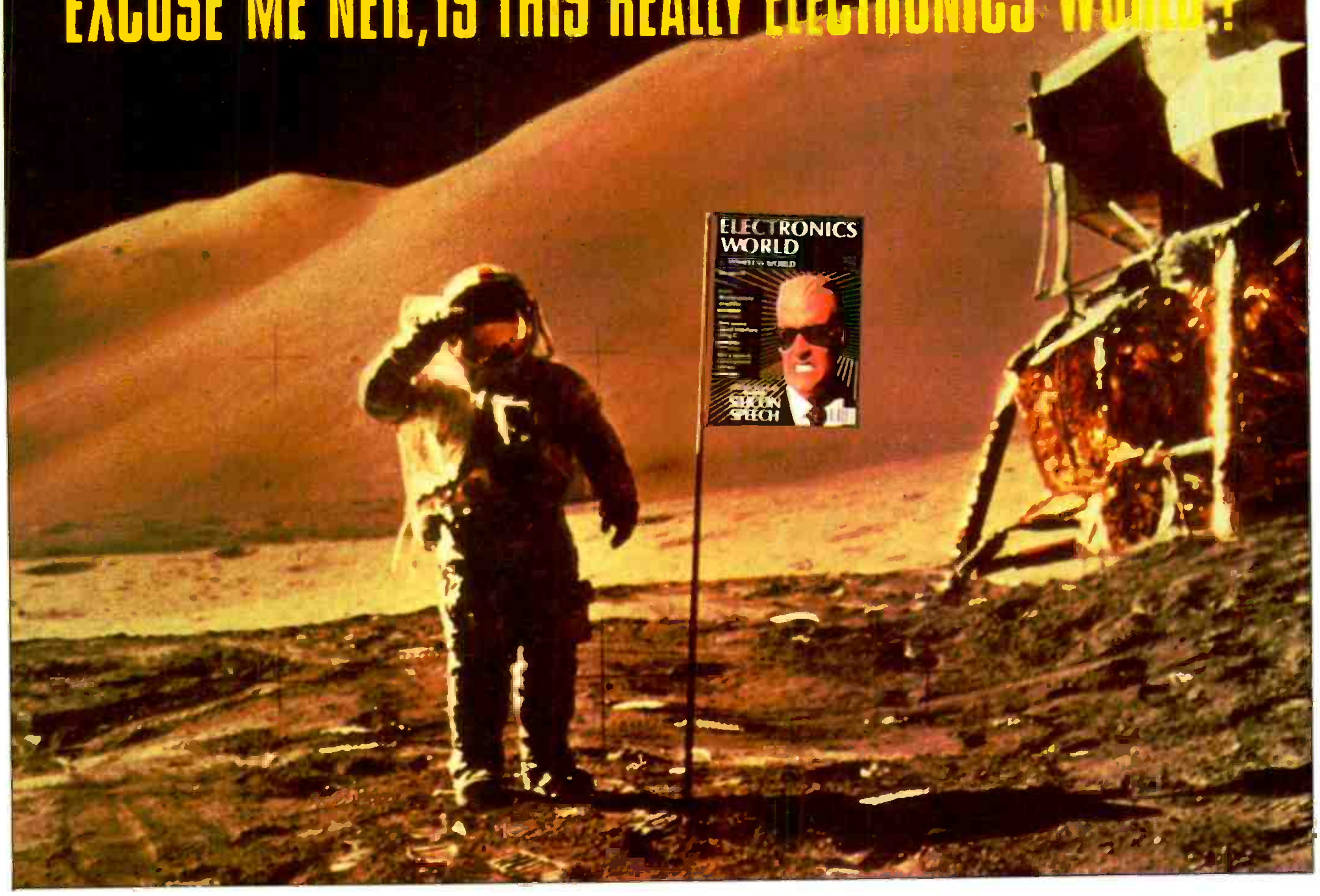

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that "It would be helpful, especially to manufacturers, if all organisations due to commence their DBS services were to make known their intentions about the details of the facilities they propose to transmit from the start and the timescale in which they may have plans to add to the facilities transmitted...". It would have been rather more helpful if the EBU had outlined a minimum MAC data standard rather than leave individual members to their own devices. If defined packet addresses for the main sound channel and primary teletext service had existed then, we would now be reading about third-generation (not first-generation) decoders. The present situation is a bit like a motorway where each driver can choose which way he goes up which lane. The motorway is defined; how to use it isn't.

France and Germany described their chosen D-MAC and D_2MAC facilities and configuration in 1985 in an addendum to CCIR document 10–11S/182. The same document gives rules of operation for sound transmission and decoding for use in first-generation receivers.

These reduced specifications and rules of operation have become known as the Blue Book. Using the Blue Book rules, designers can develop receivers for D-MAC and D_2MAC broadcasts for any transmission conforming to the Franco/German standards. This includes all now available, except BSB, which has its own rules of operation.

EBU interface

The same set of interpretations describes the use of the Eurocrypt encryption standards, allowing the definition of a standardised interface to a future access control module (ACM) for conditional access. The ACM design can be left until required, for eventual field retro-fit, as long as the interface between the MAC decoder and the ACM is defined in advance. Again, the Blue Book rules define one, known as the EBU Interface.

Hence, a receiver designer could notionally ignore ACM requirements and include an appropriate interface for future use, allowing design of decoders for all current and future European MAC transmissions.

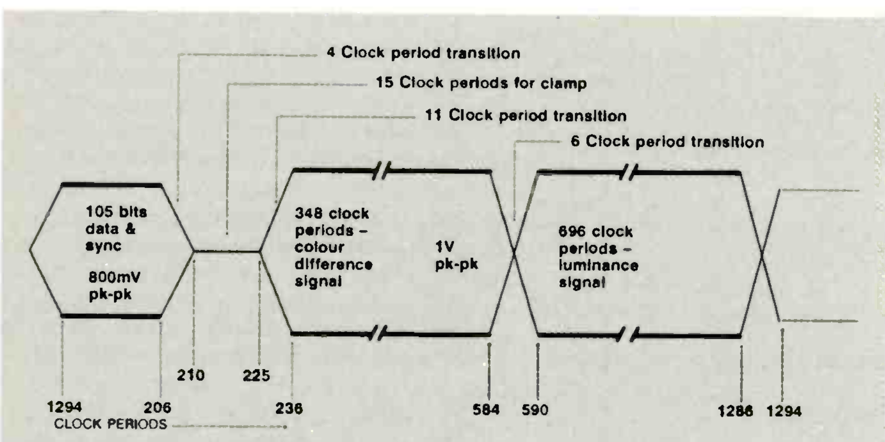
The stasis over Eurocrypt standards shows that to be a fatuous notion.

Features and facilities

One of the grey areas of MAC is the provision for teletext. Open-access text is an important aspect of DBS to provide customers with scheduling information. With the latest VCRs offering programming from text screens, this is increasingly significant. For multilingual SSPs, teletext is vital for subtitling, especially for low-budget US material where dubbing is uneconomic.

The MAC specs allow for text transmission in the video blanking interval (as with PAL) but this method provides no facilities for one of the main Eurocrypt features – selective blanking and messaging. This allows the system to display messages on specific users' screens, perhaps when subscription renewal is due. This facility's main use is for selective broadcast. For example, a channel broadcasting to the UK and Eire may want to blank the Irish screens during contraceptive advertisements. The Eurocrypt facilities allow this, but some screen message saying "intentionally blank" needs to be displayed to avoid thousands of perplexed telephone calls; similarly, for blanking the naughty bits in steamy movies to preserve delicate English sensitivities.

Fig. 3. D2MAC line structure – baseband, unscrambled signal. Clock frequency is 20.25MHz.



or inverted form on alternate lines to allow the decoder to recover correct colour after an interference burst. There is also a 64-bit vertical sync. word at the start of line 625.

The fundamental problem is of the dynamic configuration capability. D-MAC has the data capacity to support burst data rates of 20.25Mb/s; D_2MAC half this rate. Each line of the picture contains one (D_2) or two (D) blocks of 105 bits of data – the 6-bit sync. word plus 99 uncommitted bits. These bits may be sound packets, pure computer data, teletext sent as data or over-air addressing information.

The data bits in lines 1 to 623 are assembled into 82 or 164 packets of 751 bits; the odd bits left over in line 623 are thrown away. Each packet starts with a 23bit header word comprising a 10bit packet address, 2bit continuity index and an 11bit protection suffix. This header is followed by an 8bit packet-type byte to allow the decoder to identify sound and data packet types. The packet headers are four-level Golay error protected and the following 720 data bits are interleaved with a distance of 94 bits to minimise the consequence of bit error bursts. Additionally the data is scrambled by adding it to a pseudo-random binary sequence, which is cyclically re-initialised by the first sync. bit in line 1. This scrambling is done only to shape the spectrum of the broadcast signal, but knowing this doesn't make the data any easier to decode!

Having identified and extracted it, the sound data may itself be full or half bandwidth, linear or NICAM encoded, stereo or mono, on each of up to eight channels. The sound data may be Hamming or parity error-protected as indicated by the coding mode bits in the packet address word and must be decoded as necessary.

In addition, D-MAC will support different picture width:height ratios: conventional 4:3 and wide-screen 16:9. To maintain some compatibility between large and small screens, "panning vectors" are contained in, and must be extracted from, the data stream to map the smaller "window" onto the larger picture.

Line 624 is used for analogue reference levels peak white, peak black and a few chunks of grey to give the decoder something else to play with if it gets bored.

Line 625 contains no picture information but instead carries 648 (1296) data bits giving frame sync., time, date, satellite position information and data defining the overall configuration of the sound/data packets to be received and the default error-correction mechanism to be applied. This service information must be decoded and interpreted within the receiver/decoder to know what it is supposed to be doing with the incoming signals. Packet address "0" also contains service information, so that decoders can be re-configured "on the fly" in mid-frame if required.

In addition, on a scrambled system, the de-scrambling algorithms must be applied to sound, picture and data. Worse still, the configuration or service information data may not actually be valid, but could only contain pointers to data in other lines where the configuration information may actually be found.

A D-MAC decoder is not something to be "knocked up" in an afternoon!

Eurocrypt and EuroCypher

The principles of MAC encryption scrambling are simple. The analogue (chroma or luma) signals on each line are "cut" into two pieces, which are then swapped before being broadcast, effectively rendering the resulting picture garbage. If only the luma signal is cut this is "single-cut line-component rotation". If both chroma and luma are cut it is "double-cut...". Obviously, double-cut rotation is far more secure, and single cut was only introduced in case redistribution by terrestrial cable introduced line tilt problems as predicted by theory. Again, if the spec had been written after a little more practice, a lot of work (and silicon acreage) would have been saved. Subsequent measurements show that line noise masks all the predicted amplitude/phase cable effects and single cut is no better than double cut.

Whichever scrambling technique is used, to restore the original picture the decoder merely needs to know the cut points and reverse the process. Since a MAC decoder digitises each line of signal and stores it as 1296 samples in ram, this form of scrambling and unscrambling is easy to achieve as a standard function. The key to the system is knowing where the cut points are. That "key" is the clever part that the broadcaster only provides to authorised decoders, i.e. those whose owners have paid the necessary subscription. The key can be provided over the air (in the MAC data stream) or in the form of a smart card (through the post). However the key is supplied it is matched against a local "private" key built into the decoder at manufacture to unlock the cut-point algorithm. Similarly, the sound channels are easily scrambled by changing the pseudo-random sequence used for the data energy dispersal to a different pattern, or restarting the sequence at a different sync. point. Again, only authorised decoders would "know" the algorithm to regenerate the audio correctly.

Note that the audio is scrambled as part of D-MAC transmission anyway; all decoders know the standard rules to unscramble since they are a published part of the EBU specs. There is a strong lobby for all MAC video transmissions to be scrambled using similar "standard" rules and for all decoders to include a standard-rule unscrambler. Such open access scrambling gives enormous benefit to broadcasters, who merely change the rule for their transmissions to render them scrambled to non-authorised decoders. The EBU specs include details of "open access" scrambling standards, with the recommendation that all manufacturers should include such facilities in all future decoders, for this purpose. This is the Eurocrypt system.

Sadly, various vested interests have interposed additional facilities into this "open" standard, so that there are now two rival Eurocrypts. The differences between them are mostly in the facilities they provide and their external interface.

Eurocypt "M" is the standard adopted by France and Germany. It uses an 8-bit parallel data interface between the decoder and its Access Control Module (ACM), together with about 10 other housekeeping and clock signals. The facilities offered are flexible and sophisticated, which is probably why no broadcaster is using the system yet.

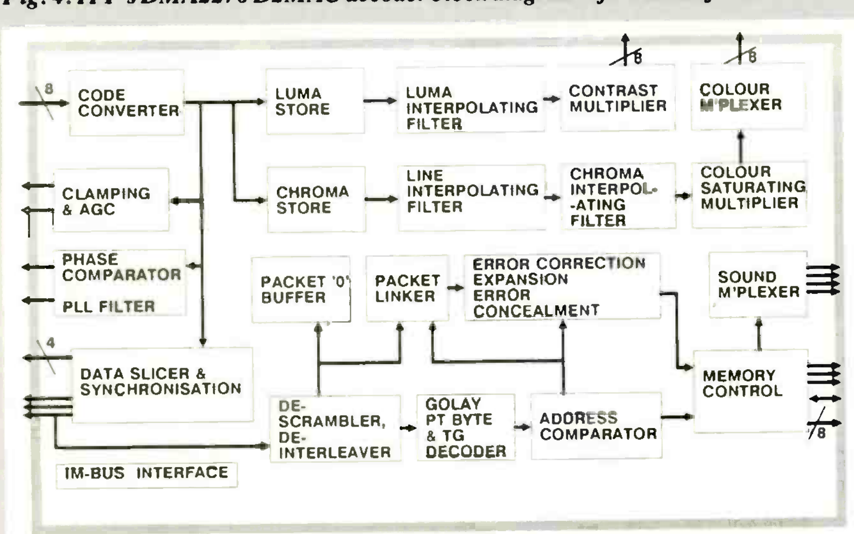
Eurocrypt "S" is the standard proposed by the UK and Scandinavia, and uses a 9600 baud serial interface. The facilities provided are less well defined than in "M", but no less complex to implement.

Note that, with these rival systems, you can kiss goodbye to the "EBU Interface" concept. Because of the quasi-static state of Europcrypt induced by the warring factions, BSB, heavily committed to conditional access, were forced to use a different system to get their service off the ground in time. BSB is using Eurocypher, a MAC-ised version of General Instruments's Videocypher II. This uses an add-on, off-the-shelf ACM card piggy-backed into the decoders.

GI and BSB have a joint venture company, ETEL, to market Eurocypher in Europe and may well end up with another inadvertent *defacto* standard on their hands.

Some broadcasters, unprepared to wait while Eurocrypt becomes available, have adopted crude forms of "soft scrambling" to protect their MAC signals. For example, Scansat is using a simple technique to scramble its D_2MAC Astra transmissions TV3 and TV1000. Their security is maintained, not because the system is difficult to crack, but because there are too few D_2MAC decoders around to crack it with.

Fig. 4. ITT's DMA2270 D2MAC decoder block diagram – first in the field



Such screen messaging has to be inserted by a local teletext generator, and thus teletext capability is an essential part of a D- or D_2MAC decoder – more software, more development, more cost. One of the differences between Eurocrypts "M" and "S" is how these selective blanking and text messaging features are provided, yet again a result of no defined minimum universal standards.

The capacity for different sound-channel structures lends further scope for non-standardisation. A sport channel may wish to offer medium-quality sound for commentaries in eight different languages. A movie channel may want four CD-quality channels for surround-sound effects. Apart from the software complexity just to decode these different requirements, some user interface has to be provided so the viewer can select the service or language required. A remote control covered in buttons is less practical than on-screen menu selection. Yet more features must therefore be incorporated into a "basic" decoder just to make it usable at all.

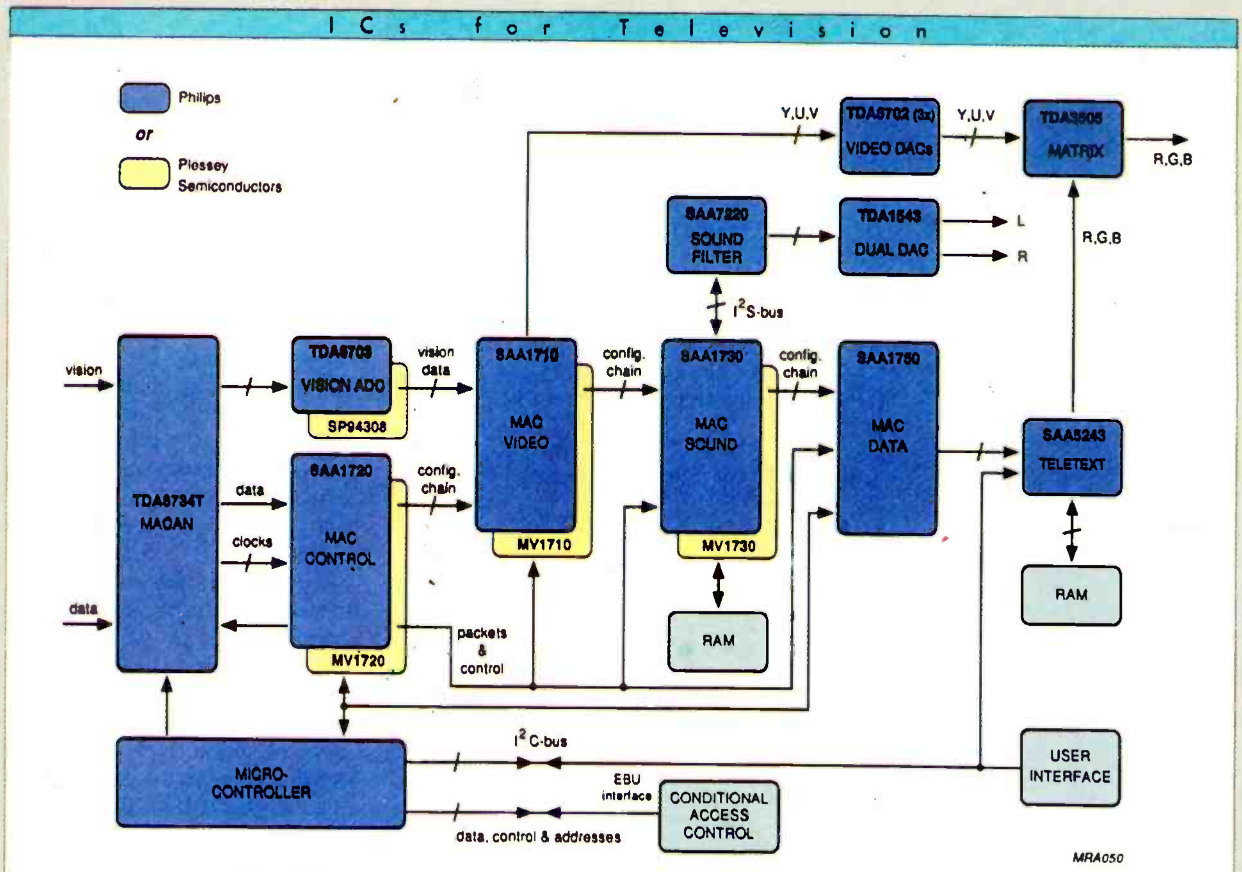
Progress and future

It may appear that MAC is a solution chasing a problem, while creating many more problems of its own. After all, if viewers cared much about picture quality they would all have expensive Yuppyvisions, not a cheapo Rentaset. FM sound on conventional television broadcasts is already of very high quality, but average sets reproduce only a distorted squawk.

The vast majority of sets in use cannot accept RGB inputs. The short-term price of MAC decoders will put them beyond reach of most consumers. Until television receivers with inbuilt decoders become available at reasonable prices, the initial market will be for set-top transcoders with composite PAL video or UHF outputs. Most viewers will be quite unaware of MAC's picture quality advantage. Perhaps herring-bone tweed and gingham should become compulsory wear for TV presenters!

The main drive towards MAC is from the SSPs in the new medium of DBS. To secure program material at reasonable cost, the SSPs are forced to limit their coverage to specific groups of viewers. Although PAL-based systems such as Videocrypt exist, they impose logistical and commercial overheads to distribute the "smart cards" required. The only secure way to achieve simple conditional access is with MAC.

The operating cost of a satellite TV



Multistandard MAC decoder

MAC silicon

ITT were first in the market with their DMA 2270 IC. Specifically for D_2MAC, this IC comes in a 68-lead PLCC package, for use with the ITT Digit 2000 series of digital TV chips. There is a companion chip, DMA 2275, to handle cut-line rotation scrambling and other encryption functions. The ITT chip-set is used in virtually all commercial D_2MAC decoders currently available.

Philips and Plessey have developed a 5-chip solution, based on the NordIC architecture, using I^2C and I^2S bus interfaces. These ICs, together with other standard items from the TV IC catalogues, provide C-MAC, D-MAC and D_2MAC decoding, with descrambling facilities inbuilt.

Major design activity for the UK has centred around BSB receivers, with Tatung, Ferguson, Salora (ITT) and Philips producing receiver/decoder/decrypters. Elsewhere in Europe Philips, Tandberg, Grundig and Luxor offer D_2MAC receiver/decoders for TDF1, Olympus and the MAC Astra channels.

Norsat, in Canada, recently won a contract to develop and supply BSB's Datavision professional data receivers, which are believed to be using the Philips/Plessey chip set.

In the UK, most MAC design expertise exists in Eldon Technology, an independent design and development operation in Bingley.

The retail price of a D_2MAC receiver/decoder is upwards of £500, with BSB "boxes" shortly available for about £400 (including dish or squarial).

D_2MAC transcoders, with baseband input and RGB outputs, are available in France for around £275, and in Germany for £375.

D_2MAC frame structure

lines per picture	625
data lines	ALL
video lines	24 310: 336 622
luminance	Y in each line
chrominance	U in odd lines: V in even lines
interlace	2 : 1
aspect ratio	4 : 3 or 16 : 9 (5.33 : 3)
luma compression	3 : 2
chroma compression	3 : 1
sampling clock	20.25 MHz
data rate	10.125 Mb/s
samples per line	1296
chroma samples	349
luma samples	697
bits per burst	105 (99 + 6 bits h. sync.)
line 624	Data plus analogue ref. levels
line 625	648 data bits (6 bit horizontal sync. word) (32 bits clock run-in) (64 bits vertical sync. word) (546 bits service information)

channel is high, and SSPs must maximise revenue somehow. For advertising-funded channels, the most obvious way is to expand the audience; W.H. Smith are understood to be moving to D-MAC for the multi-language capability. Secondly, significant income can be generated by selling spare channel capacity to third parties. BSB will be exploiting the data and conditional-access capabilities of D-MAC through their Datavision subsidiary to provide private data and vision services. These are expected to make a substantial financial contribution.

Although D_2MAC is the standard adopted by all other SSPs at present, this choice was forced upon them by their cable distribution customers, who could not handle the extra bandwidth of D-MAC. The only available silicon has been the ITT chip(s), but the appearance of the Plessey/Philips/Nordic chip set will allow development of receivers for both D-MAC and D_2MAC.

It is likely that, as cable networks are renewed over the next decade, more operators will take advantage of D-MAC's greater capacity, facilities and upward compatibility to HDTV standards. As costs to maintain terrestrial transmitter chains escalate and the price (and size) of domestic satellite equipment falls, DBS will become the normal method of delivery for TV broadcasts. Although a lot of political Euro-blood must yet be shed, D-MAC will probably emerge as the future standard for European DBS. ■

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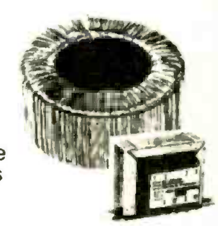

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30	10.3	9.27	6.80	6.44	5.82	5.41	5.15
50	10.96	9.86	7.23	6.85	6.19	5.75	5.48
60	11.28	10.15	7.44	7.05	6.37	5.92	5.64
80	11.88	10.69	7.84	7.42	6.71	6.24	5.94
100	12.88	11.59	8.50	8.05	7.28	6.76	6.44
120	13.28	11.95	8.76	8.30	7.50	6.97	6.64
150	14.88	13.39	9.82	9.30	8.41	7.81	7.44
160	15.46	13.91	10.20	9.66	8.73	8.12	7.73
225	18.22	16.40	12.03	11.39	10.29	9.57	9.11
300	20.18	18.16	13.32	12.61	11.40	10.59	10.09
400	26.52	23.87	17.50	16.57	14.98	13.92	13.26
500	26.88	24.19	17.74	16.80	15.19	14.11	13.44
625	30.06	27.05	19.84	18.79	16.98	15.78	15.03
750	38.42	34.58	25.36	24.01	21.71	20.17	19.21
800	43.96	39.56	29.01	27.48	24.84	23.08	21.98
1000	53.54	48.19	35.34	33.46	30.25	28.11	26.77
1200	59.08	53.17	38.99	36.92	33.38	31.02	29.54
1500	68.82	61.94	45.42	43.01	38.88	36.13	34.41
2000	84.12	75.71	55.52	52.58	47.53	44.16	42.06
2500	109.96	98.96	72.57	68.72	62.13	57.73	54.98

These prices are for single primary with two equal secondarie with 8" colour coded fly leads.

Available from stock in the following voltages: 6-0-6, 9-0-9, 12-0-12, 15-0-15, 18-0-18, 22-0-22, 25-0-25, 30-0-30, 35-0-35, 40-0-40, 45-0-45, 50-0-50, 110, 220, 240. Primary 240 volt.

AIR LINK

Air Link Transformers

Unit 6, The Maltings, Station Road, Sawbridgeworth, Herts.
Tel: 0279 724425 Fax: 0279 724379

CIRCLE ENQUIRY NO. 123 ON BACK PAGE

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P. M. COMPONENTS LTD

SELECTRON HOUSE, SPRINGHEAD ENTERPRISE PARK
SPRINGHEAD RD, GRAVESEND, KENT DA11 8HD

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A selection from our stock of branded valves

A1714	24.50
A1834	7.50
A2087	11.50
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A2293	6.50
A2426	29.50
A2599	37.50
A2792	27.50
A2900	11.50
A3283	24.00
A3343	35.95
ACSP3A	4.95
AC/S2PEN	8.50
ACT22	59.75
AH221	39.00
AH238	39.00
AL60	6.00
AN1	14.00
ARP12	2.50
ARP34	1.25
ARP35	2.00
AZ11	4.50
B716	35.00
BT5B	55.00
BT17	25.00
BT113	35.00
C1K	27.50
C3M	17.95
C1149/1	120.00
C1150/1	135.00
C1166	125.00
C1534	32.00
CCA	3.50
CD24	6.50
CK1006	3.50
CK5676	6.50
CV Nos PRICES ON REQUEST	
CX1140	495.00
CX1528	3250.00
D3A	27.50
D63	1.20
DA41	22.50
DA42	17.50
DA90	4.50
DAF91	0.95
DAF96	0.95
DC70	1.75
DC90	3.50
DCX-4-5000	25.00
DET16	28.50
DET18	28.50
DET20	2.50
DET22	29.50
DET23	35.00
DET24	27.50
DET25	22.00
DET29	32.00
DF61	3.50
DF91	1.50
DF92	1.50
DF96	1.25
DF97	1.25
DG10A	8.50
DH63	3.50
DH77	1.50
DK91	1.20
DK92	1.50
DL35	2.50
DL63	1.50
DL70	2.50
DL73	2.50
DL91	3.95
DL92	1.50
DL93	1.50
DLS10	13.50
DLS16	10.00
DM70	5.25
DM160	6.50
DOD-006	79.50
DYS1	1.50
DY86/87	0.85
DY802	0.85
E55L	49.50
E80CC	25.00
E80CF	12.50
E80F	12.50
E80L	29.50
E81CC	5.50
E81L	12.00
E82CC	4.50
E83CC	4.50
E83F	5.50
E84L	6.50
E86C	9.50
E88C	7.95
E88CC	4.50
E88CC-01	6.95
E88CC MULLARD	5.95
	5.95
E90CC	7.95
E90F	7.95
E91H	4.50
E92CC	3.95
E99F	6.59
E130L	18.50
E180CC	10.50
E180	0.50
E182CC	9.00
E186F	8.50
E188CC	7.50
E235L	12.50
E280F	19.50
E283CC	12.00
E288CC	17.00

E810F	25.00
E1148	1.00
EA50	1.00
EA52	75.00
EA76	1.95
EA79	1.95
EABC80	1.95
EAC91	2.50
EAF42	1.20
EB34	1.50
EB41	3.95
EB91	0.85
EBC33	2.50
EBC41	3.50
EBC81	1.50
EBC90	1.95
EBC91	1.95
EBF80	0.95
EBF83	0.95
EBF89	0.95
EBF93	0.95
EBL21	4.50
EC52	0.75
EC53	1.50
EC70	1.75
EC81	7.95
EC86	1.95
EC88	1.95
EC90	1.95
ERC91	5.50
EC93	1.50
EC95	7.00
EC97	1.10
EC8010	12.00
ECC32	3.50
ECC33	3.50
ECC35	3.50
ECC81	1.95
ECC81 SPECIAL QUALITY	2.95
ECC82	0.95
ECC82 PHILIPS	1.95
ECC83	1.50
ECC83 BRIMAR	2.15
ECC83 PHILIPS	1.95
ECC83 SIEMENS	2.50
ECC83 SUPER	3.50
ECC85	1.50
ECC86	2.75
ECC88	1.50
ECC89	1.50
ECC91	2.00
ECC189	2.50
ECC801S	6.95
ECC803S	6.95
ECC804	0.60
ECC2000	7.95
ECF80	1.15
ECF82	1.50
ECF86	1.70
ECF200	1.85
ECF202	1.85
ECF801	0.85
ECF804	6.50
ECF805	2.50
ECF806	10.25
ECH3	4.50
ECH4	4.50
ECH35	3.50
ECH42	1.50
ECH81	1.75
ECH83	1.50
ECH84	1.50
ECH200	1.50
ECL80	1.00
ECL82	1.50
ECL83	2.50
ECL84	1.00
ECL85	0.95
ECL86	1.50
ECL805	0.95
EF37A	2.50
EF39	1.50
EF40	4.50
EF42	3.50
EF50	2.50
EF54	4.50
EF55	4.95
EF70	1.20
EF72	3.50
EF73	3.50
EF80	0.55
EF83	3.95
EF85	0.85
EF86	3.50
EF86/CV4085	7.50
EF89	1.95
EF91	1.50
EF92	2.15
EF93	1.50
EF94	1.50
EF95	1.95
EF97	0.90
EF98	0.90
EF183	0.75
EF184	0.85
EF731	4.50
EF732	4.50
EF800	11.00
EF804S	19.50
EF805S	25.00

EF806S	25.00
EF812	0.65
EFL200	1.50
EFP60	3.50
EH90	0.72
EK90	1.50
EL32	0.95
EL34 MULLARD	POA
EL34	3.95
SIEMENS	3.95
EL36	2.50
EL38	4.50
EL41	3.50
EL42	2.00
EL71	4.50
EL81	6.95
EL83	7.50
EL84	1.50
EL84 MULLARD	4.50
EL84 SIEMENS	2.50
EL85	4.50
EL86	1.75
EL90	1.75
EL91	4.50
EL95	1.75
EL152	15.00
EL360	6.75
EL500	1.95
EL504	1.95
EL509	5.95
EL509 MULLARD	7.50
EL519	6.95
EL802	3.65
EL821	6.95
EL822	12.95
ELL80	22.50
EM34	12.50
EM81	3.50
EM83	1.65
EM84	1.65
EM85	3.95
EM87	2.50
EN32	15.00
EN91	2.25
EN92	4.50
EY51	0.80
EY70	7.50
EY81	2.95
EY82	1.15
EY83	1.50
EY84	5.95
EY86/87	0.65
EY88	1.50
EY91	5.50
EY500A	2.95
EY802	0.70
EZ35	1.00
EZ40	3.50
EZ41	3.50
EZ80	0.75
EZ81	1.50
EZ90	1.50
FW4-800	4.50
FX2535	195.00
G55/1K	9.00
G180/2M	6.95
G240/2D	9.00
GC10B	17.50
GC10D	17.50
GN10	15.00
GS10H	12.00
GS12D	12.00
GT1C	9.50
GU20	35.00
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GXU1	13.50
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GXU50SS	14.50
GY501	1.50
GY802	1.50
GZ32	4.50
GZ33	4.50
GZ34	4.50
GZ37	4.50
HBC90	1.95
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HL90	3.50
KT8C	7.00
KT33C	3.50
KT36	2.95
KT44	5.95
KT45	5.95
KT61	7.95
KT63	2.95
KT66 USA	11.95
KT88 TEONEX	5.00
KT67	9.00
KT77 GEC	14.95
KT81	7.00
KT88 USA	12.95
KT88 SELECTRON	15.00
KTW61	2.50
KTW62	2.50
KTW63	2.00
KTZ63	2.50
LB7-20	95.00
LS9B	6.95
M529	66.00
M5143	155.00
M5199	295.00

M8079	6.00
M8082	7.50
M8083	3.25
M8091	7.50
M8096	3.00
M8098	5.50
M8099	5.00
M8100	5.50
M8136	7.00
M8137	7.95
M8161	6.50
M8162	5.50
M8163	5.50
M8190	4.50
M8195	6.50
M8196	5.50
M8204	5.50
M8223	4.50
M8224	2.00
M8225	3.95
ME1400	3.50
ME1401	19.50
ME1402	29.50
MHLD6	4.00
MP25	195.00
MS4B	5.50
MU14	3.50
N37	12.50
N78	9.85
OA2	1.50
OA2WA	2.50
OA3	2.50
OB2	1.50
OB2WA	2.50
OC3	2.50
OD3	2.50
OM4	2.50
OM5B	3.00
OM6	1.75
ORP43	2.50
ORP50	3.95
P61	2.50
P41	2.50
PABC80	0.95
PC86	0.75
PC88	0.75
PC97	1.10
PC900	1.25
PCC84	0.40
PCC85	0.55
PCC88	0.95
PCC89	0.70
PCC189	0.70
PCC805	0.70
PCC806	0.80
PCE82	0.80
PCF80	0.65
PCF82	0.60
PCF84	0.65
PCF86	1.20
PCF87	1.25
PCF200	1.80
PCF201	1.80
PCF801	1.35
PCF802	0.85
PCF805	1.25
PCF806	1.00
PCF808	1.25
PCH200	1.50
PCL82	0.95
PCL83	2.50
PCL84	0.75
PCL85	0.95
PCL86	0.95
PCL805	0.95
PD500	5.95
PEN25	2.00
PEN40D	3.00
PEN45	3.00
PEN45DD	3.00
PEN46	2.00
PFL200	0.95
PL36	1.75
PL38	1.50
PL81	1.50
PL82	0.60
PL83	0.85
PL84	0.85
PL500	1.50
PL504	1.50
PL508	1.50
PL509	4.85
PL519	4.95
PL802	6.00
PL802T	3.50
PL820	2.95
PY32	0.60
PY33	0.50
PY81	0.85
PY82	0.85
PY83	0.85
PY88	0.99
PY500A	1.95
PY800	0.95
PY801	0.95
QB3-300	72.00
QB3-1750	139.00
QB5-3500	595.00
QQE02-5	19.50
QQE03-12	7.95
QQE03-20	35.00
QQE06-40	45.00
QQV02-6	19.50
QQV03-10	5.50
QQV03-10 MULLARD	15.00
QQV03-20	25.00
QQV06-40A	27.50
QQV06-40A MULLARD	39.50
QQV07-50	55.00

QQZ03-20	42.50
QQZ06-40	45.00
QS75/20	1.50
QS95/10	4.85
QS108/45	4.00
QS150/15	6.95
QS150/30	1.15
QS150/40	7.00
QS1205	3.95
QS1213	5.00
QU37	9.50
QV03-12	6.50
QV05-25	3.50
QV06-20	29.50
QV08-100B	145.00
QY3-125	85.00
QY4-250	105.00
QY4-400	110.00
R10	4.00
R18	2.50
RG1-240A	14.50
RG3-250A	6.50
RG3-1250A	35.00
RR3-250	15.00
RRE-1250	35.00
S11E12	38.00
S104-2K	10.00
SC1/1300	6.00
SP61	3.50
STV280/40	11.95
TB2-5/300	95.00
TB2-300	195.00
TB3-750	115.00
TB3-2000	450.00
TBL2-300	395.00
TBL2-500	495.00
TD03-10/D/E/F	35.00
TT15	45.00
TT21	45.00
TT22	45.00
TT100	69.00
TY2-125A	105.00
TYB-600W	365.00
U19	8.50
U26	0.90
U35	3.50
U37	9.00
U41	6.95
U50	3.00
U82	3.00
U191	0.70
U192	1.00
U193	1.00
U251	2.50
U801	3.50
UABC80	1.00
UAF42	1.95
UBC41	3.95
UBC81	1.50
UBF80	0.95
UBF89	1.00
UBL21	2.95
UC92	2.50
UCC84	0.70
UCC85	1.00
UCF80	1.00
UCH21	2.50
UCH41	2.50
UCH42	3.95
UCH81	1.95
UCL82	1.75
UCL83	2.50
UF41	2.25
UF42	2.25
UF80	1.75
UF85	1.20
UF89	2.00
UL44	3.50
UL84	1.95
UL85	0.85
UU5	3.50
UU6	1.50
UU7	8.00
UU8	9.00
UY41	3.50
UY85	0.70
V235A/1K	250.00
V238A/1K	295.00
V246A/1K	250.00
V246A/2K	315.00
V241C/1K	195.00
V453	12.00
VLS631	10.95
VP4B	9.50
VP41	4.95
VR101	2.50
VR105/30	2.50
VR150/30	2.50
VU39	2.50
W21	4.50
W61	4.50
W77	5.00
W81M	4.50
W739	1.50
X24	4.50
X41	4.50
X66/X65	3.50
X81	6.00
XC24	1.50
XC25	0.50
XFW47	1.50
XFW50	1.50
XG1-2500	75.00
XL628FT	7.50

XNP12	2.50
XR1/1600A	25.00
XR1/3200A	79.50
XR1-6400A	149.50
Y65	6.95
YD1100	75.00
YJ1060	265.00
YL1020	42.50
YL1060	195.00
YL1070	195.00
YL1071	195.00
YL1290	65.00
Z77	1.20
Z300T	6.00
Z302C	12.00
Z359	9.00
Z700U	9.50
Z759	15.00
Z803U	18.95
ZM1020	8.50
ZM1021	8.00
ZM1023	7.95
ZM1082	9.00
ZM1084	10.00
ZM1162	9.00
ZM1175	6.50
ZM1177	9.00
1A3	4.50
1AE4	3.50
1AX2	3.50
1B22	10.00
1B27	55.00
1B3GT	1.95
1B35A	45.00
1K3	2.50
1L4	2.50
1N5GT	2.50
1P28	25.00
1R5	1.50
1S5	1.50
1T4	1.50
1U4	1.75
1U5	1.50
1X2S	2.50
2A3	12.15
2AS15A	11.50
2B7	4.50
2B22	69.50
2C36	70.00
2C39A	25.00
3C39A	32.50
2C39BA	39.50
2C40	37.00
2C42	29.50
2C43	60.00
2C51	2.50
2CY5	1.50
2D21	2.25
2D21W	3.15
2E22	49.00
2E26	7.95
2J55	295.00
2K25	59.00
2K26	95.00
2K59	250.00
2K48	140.00
2K56	250.00
2X2A	5.00
3A/107B	12.00
3A/108A	9.00
3A/109B	11.00
3A/110B	12.00
3A/141K	11.50
3A/146J	7.50
3A/147J	7.50
3A/167M	10.00
3A3A	3.95
3A4	1.50
3A5	4.50
3AT2	3.35
3B22	25.00
3B26	24.00
3B28	15.00
3BZ6	1.50
3C45	39.50
3CX3000A7	650.00
3CY5	1.50
3D21A	29.50
3E22	49.50
3E29	39.50
3EJ7	1.95
3H	0.40
3J/170E	1450.00
3L	0.40
3Q4	2.50
3V4	3.50
4-65A	85.00
4-250A	105.00
4-400C	95.00
4-1000A	495.00
4B32	35.00
4BQ7A	1.75
4BZ6	1.95
4C28	25.00
4C35	95.00
4CS250R	115.00
4CV35,000	1650.00
4CV100,000	2950.00
4XC125C EIMAC	150.00
4CX250B	45.00
4CX250BM	65.00
4CX250K EIMAC	115.00
4CX250R AMPEREX	125.00
4CX350A	100.00

4CX1000A	425.00
4CX1500B	475.00
4CX5000A	1000.00
4D21/4-125A	85.00
4D32	125.00
4E27A	125.00
4GS7	2.25
4GV7	2.25
4J6A	2.95
4KT6	1.50
4T85P	150.00
4X150A	35.00
4X150D	55.00
4X500A	350.00
5A/102D	9.50
5A152M	9.00
5A163K	10.00
5A170K	6.25
5A-180M	9.00
5A-206K	10.00
5B-110M	10.00
5B-254M	11.50
5B-255M	14.50
5B-256M	15.00
5B-257M	15.00
5B258M	14.50
5C22	125.00
5CL8A	2.50
5J180E	1250.00
5JL8	2.95
5R4GY	4.95
5R4WGY	5.95
5T4	5.95
5T8A	1.95
5U4G	2.95
5U4GB	4.50
5V4G	2.50
5W4	4.95
5X4	4.95
5Y3GT	3.50
5Z3	4.50
5Z4G	2.50
6/30L2	0.70
6A/203K	9.00
6A7	4.95
6A8	2.50
6AB7	4.50
6AC7WA	2.00
6AG5	2.50
6AG7	2.50
6AH6	3.50
6AJ4	3.50
6AJ7	2.00
6AK5	1.95
6AK6	2.50
6AL5	0.85
6AM4	3.25
6AM5	4.50
6AM6	1.95
6AN5	4.50
6AN8A	4.50
6AQS	1.75
6AQ8	1.50
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	1.95
6AT8	1.75
6AU4GT	2.95
6AU5GT	4.50
6AU6	1.50
6AV6	1.95
6AW8A	3.50
6AX4GT	1.95
6AY3B	1.95
6AZ8	4.50
6B49	10.50
6B8G	2.50
6B10	1.95
6BA6	1.50
6BA7	4.50
6BA8A	3.50
6BC8	1.50
6BR3	2.95
6BE6	1.50
6BG6G	3.00
6BH6	1.95
6BH8	1.50
6BJ6	1.50
6BK4	6.50
6BL6	85.00
6BL8	1.15
6BM6	115.00
6BN6	1.65
6BN8	3.95
6BQ5	1.50
6BQ7A	1.50
6BR7	4.95
6BS7	5.50
6BW6	3.95
6BW7	1.50
6BZ6	2.50
6BZ7	2.95
6C4	1.95
6C5	2.50
6C6	3.50
6C8G	2.50
6C9	4.95
6CA4	4.95
6CA7	3.50
6CB5	3.95
6CB6	2.50
6CD6GA	4.50
6CF6	1.95
6CG7	3.50
6CG7 G.E.	5.25
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6CL6	3.25

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6CS6	0.75
6CS7	0.95
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6CX8	3.95
6CD6	2.35
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6DJ8 SPECIAL	3.50
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6DQ5 G.E.	11.95
6DQ6B	2.50
6DT6A	1.50
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6E5	3.95
6EA7 G.E.	4.50
6EA8	2.50
6EB8	3.50
6EJ7	0.85
6EM5	2.50
6EM7	2.50
6EU8	1.75
6EV7	2.95
6EW6	1.50
6EW7	4.50
6F1	2.00
6F5	5.50
6F7	5.50
6F13	3.00
6F14	1.00
6F17	2.75
6F23	0.60
6F24	1.25
6F25	1.25
6F28	1.25
6F32	1.25
6F33	7.50
6FH5	8.50
6FH8	15.00
6FL2	4.50
6FQ7	3.50
6GE5	3.95
6GH8A	2.50
6GJ7	0.85
6GK6	3.95
6GM6	2.65
6GS7	21.5
6GV8	0.95
6GW8	2.50
6GY5	4.95
6GY6	2.50
6H1	9.50
6H6GT	2.50
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6HF5	12.50
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6J4	2.15
6J5GT	2.50
6J6	2.00
6J7G	4.15
6JB6A G.E.	9.50
6JE6C G.E.	12.50
6JM6	10.95
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6L6GC USA	9.50
6L6GT	3.50
6L7	3.50
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6LD20	2.50
6LF6 G.E.	12.50
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6LU8	9.25
6P28	2.00
6Q7GT	2.50
6R7	3.15
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7Y4	2.50
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15E	5.50
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16GY5	2.95
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30L1	0.45
30L15	0.60
30L17	0.60

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50C5	0.95
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90C1	3.50
90CG	17.50
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91AG	9.00
92AG	25.00
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726A	75.00
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805	16.95
807	5.50
811A	6.95
812A	12.50
813 PHILIPS	35.00
813	19.50
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833A	65.00
845	23.00
866A	8.50
872A	20.00
873	60.00
954	1.00
955	1.00
1802	1950.00
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4212H	250.00
4471	35.00
4687A	9.50
5544	79.50
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6132	10.50
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6870	11.50
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7025S	6.95
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7119	9.00
7189	5.50
7199	10.50
7247	8.50
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7527	125.00
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7587	19.50
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IMPROVED CD ELECTRONICS

Ben Duncan points to deficiencies in the output arrangements of CD players and presents a method of overcoming them.

When they introduced the compact disc, Philips and Sony claimed "perfect reproduction". It was a rash statement, undermined by the manufacturers themselves after a succession of refinements to CD players' digital processing over the past seven years. Meanwhile, the players' analogue output stages have changed little, if at all. It should come as no surprise that the digital processing of even the cheapest player is relatively perfect while, in every case, sound quality is principally let down by the poorly executed analogue output stage.

The Philips/Marantz recipe

Philips's first players employed 14-bit D-to-A converters; the use of four times oversampling enabled them to meet the 16-bit standard. It also shifts unwanted sidebands upwards, so brick-wall filtering is not needed. **Figure 1** shows the analogue output stage of Marantz's CD-450, one of the first 16-bit players, introduced in 1986; again, it is four times oversampled. The same circuit appears (with cosmetic variations) in nearly every Philips, Marantz and Magnavox player made from 1983 to date, as well as in most of the "badged" brands based on the Philips/Mullard OEM parts[1]. This includes virtually all players made by companies in the UK, in Europe and in North America. Broadly similar circuitry also appears in many of the more recent upmarket models bearing well known Japanese names.

For brevity "P/M" will be used to signify the generic Philips/Marantz circuit. The only significant group of players which does not (and cannot easily) use this kind of circuit relies on Sony's original approach. Players in this group are almost invariably of Far Eastern origin, do not employ over-sampling and depend on brute-force filtering — ceramic or LC filter blocks (or both) rather than Sallen and Key RC filters.

Our investigation of the standard P/M output stage begins at the DAC output. Philips's TDA-1541 (a stereo DAC) and its precursor, the TDA 1540 (a mono device), are universally used in P/M 16-bit and the older 14-bit machines respectively. Both are unipolar. For a bipolar audio output, the DAC receives and decodes offset binary, which contains the polarity code. Under quiescent conditions, the DAC output is arranged to sink 50% of the full-scale current into IC_{101} virtual earth, swinging to zero for maximum negative voltage excursions,

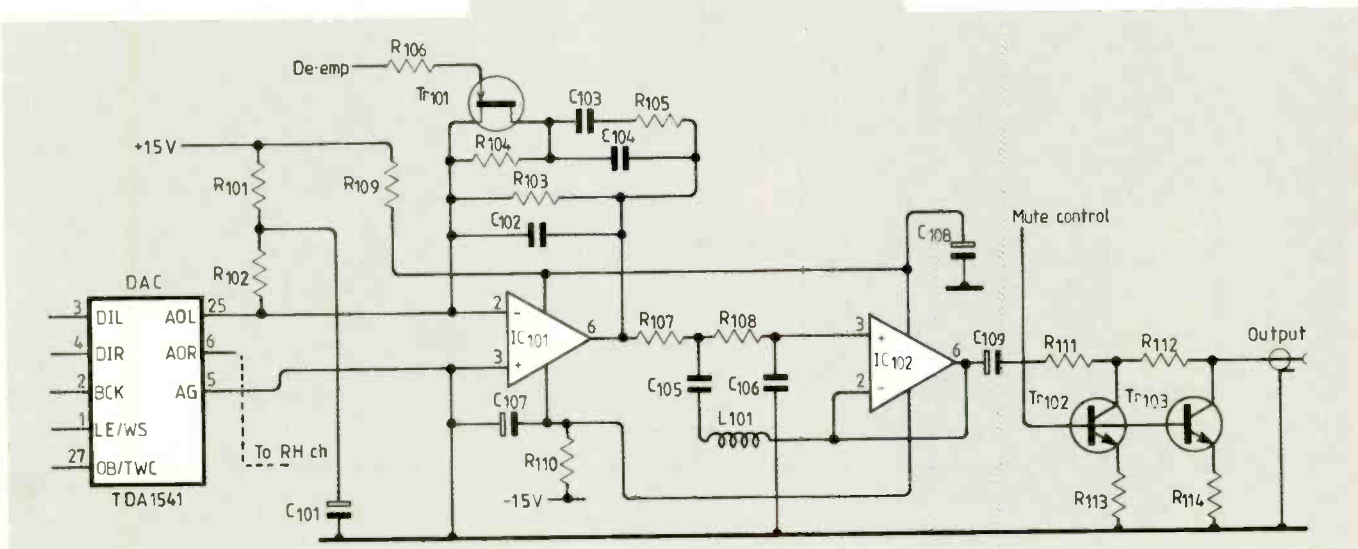

Fig. 1. Common type of output circuit used by Philips and Marantz, which has deficiencies of noise rejection and distortion due to unbalanced operation.

and to double the quiescent current ($2I_Q$) for full positive excursions. The music signal rides on this *half-scale* current, which is typically 1.95mA for any P/M player.

Left to its own devices, the current forces 1k8×1.95mA=3.5V to appear at IC_{101} output, which ties in with the CD standard's maximum output of 3.5×0.707=2.2V RMS. The second stage (IC_{102}) has unity gain, so the offset was left to run along in the earlier versions of the P/M circuit, until it reached the output DC blocking capacitor, C_{109}.

On the surface, this is fine, provided C_{109} is correctly polarised and doesn't leak. However, both op-amps are biased away from their centres. For the maximum output of 2V RMS, IC_{102} inputs are swinging from 0 to +7V, instead of 0 to ±3.5V. In effect, IC_{102} is being subjected to twice the common-mode voltage it would otherwise see. Both op-amps are potentially operating under large-signal conditions for positive audio peaks, then approaching no-signal conditions for negative-going peaks. Consequently, a variety of distortion and error mechanisms will be non-monotonic, i.e. lopsided.

In the more recent players, $R_{101,102}$ have been added to introduce a cancellation current. However, there is no provision for adjustment against DAC tolerances and a significant offset voltage of up to 100mV can still develop, so an output capacitor, C_{109}, is still required. Also, the supply rails from which the current is derived are noisy, while C_{101} offers at best only -48dB of rejection at 1kHz, and much less (if any) at RF.

The op-amp IC_{101} performs current-to-voltage conversion and acts as an integrator to smooth out the rapid current transitions. J-fet Tr_{101} introduces an extra RC integrator to compensate for pre-emphasised recordings. The two op-amps are always in a dual package; early P/M players employed Philips's own NE5532 (made by their Signetics subsidiary in the US and second-sourced by Texas, Raytheon and others), but by the National Semiconductor LM833 and a Japanese equivalent appear in some machines.

All three are broadly similar, with an unexceptional slew rate of 7 to 9V/μs, a moderately high gain-bandwidth product of 10MHz, low noise (5nV/$\sqrt{}$Hz at 1kHz) and low THD. Power supply noise rejection is average, loop gain at 100kHz is only 40-45dB, signal isolation between the two halves is distinctly poor at extreme frequencies and settling time is never mentioned.

The next stage is plainly a Sallen and Key filter with an added inductor, L_{101}, to produce a notch at 176kHz.

The average CD player's supply is noisy, since it also supplies digital circuitry, as well as the servo control for the laser. The makers have attempted to improve the noise rejection by creating RC filters with series resistors ($R_{109,110}$) in line with the supply. By using a single un-damped and un-bypassed electrolytic capacitor, the filtration breaks down above 20kHz, where it is needed most. Equally, the two halves of the dual IC are now forced to modulate each other's power rails, leading to error-feedthrough whenever the instantaneous current demand cannot be immediately and fully satisfied by $C_{107,108}$.

Other than buffering capacitive loads (the 5532 is quite well behaved in this department), $R_{111,112}$ provide shunt muting in conjunction with $Tr_{102,103}$. The collector/emitter capacitance of the transistors, which varies with signal magnitude is a potential (if subtle) distortion mechanism. The lack of noise decoupling on the base drives is equally disturbing. It is an act of commercial "corner cutting", the earlier (mainly 14-bit) P/M players being muted and de-emphasised with reed relays.

Upgrade explored

Figure 2 shows the upgraded circuit, employing the cream of analogue components. The precision 7V reference, IC_4, is the LT1031 made by Linear Technology and works in conjunction with the surrounding entourage ($R_{1,3}$, PR_1, $C_{1,2}$) to produce a highly stable and adjustable current source with ultra low noise and high supply-noise rejection. By using a *buried* (subsurface) zener, it is around ten times quieter than ordinary bandgap regulators; raw output noise is −96dB over most of the audio band. Capacitors $C_{1,2}$ reduce output noise further, as well as improving the nett noise rejection, especially where it

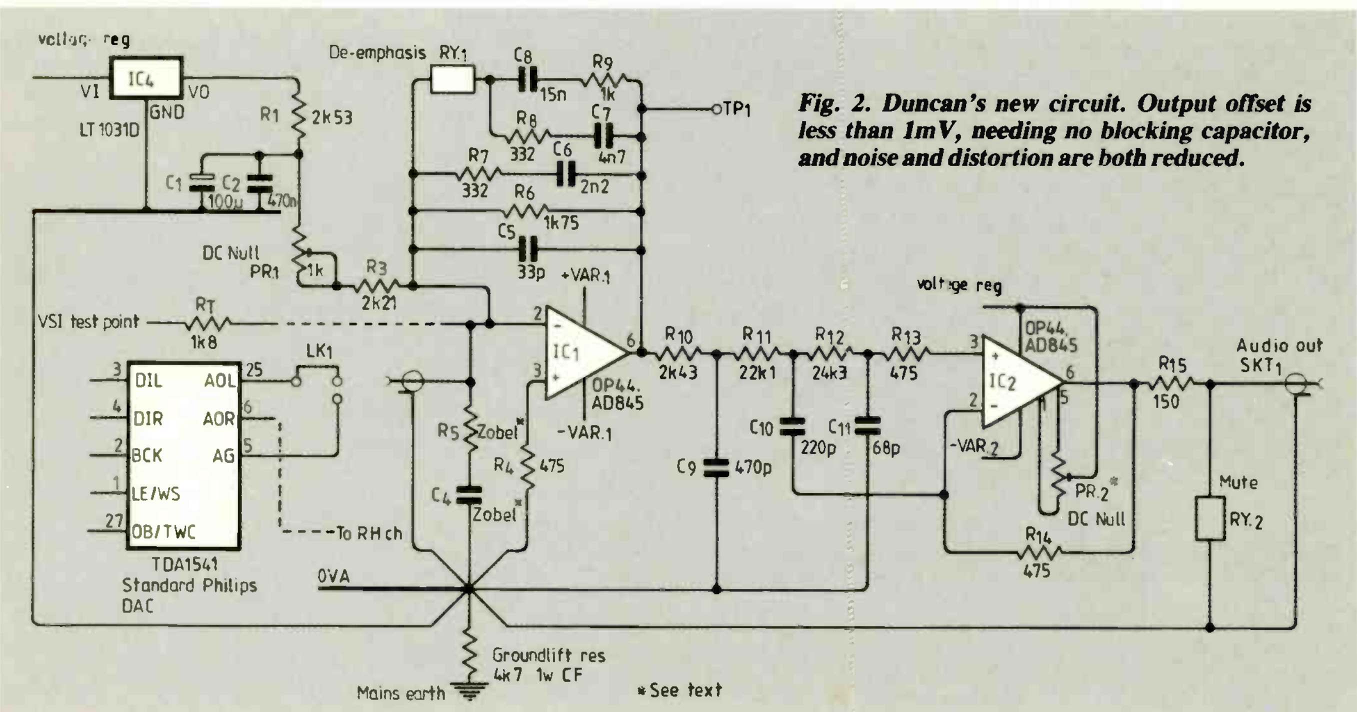

Fig. 2. Duncan's new circuit. Output offset is less than 1mV, needing no blocking capacitor, and noise and distortion are both reduced.

is beginning to fall off, at mid to high audio frequencies. Power supply noise measured across C_1 is now many orders better than the original, as well as being below 16-bit audio's best SNR. The significance of measuring across C_1 is that the voltage present here appears more or less unchanged at the output of IC_1. The trimmer PR_1 trims the current supplied to match the standing current of individual DACs for complete DC cancellation.

The first stage takes the brunt of the higher-frequency noise. Current-to-voltage conversion is best handled by a fast-settling opamp with a (low transconductance) Bi-fet or degenerated bipolar input. These types are able to settle in under 500ns, and their slew rate is in excess of 50V/μs. Owing to the unity voltage gain configuration, a high gain-bandwidth product (>10MHz) is less important than having adequate loop gain at frequencies over 100kHz. In view of the integrator action of IC_1, an output current capability of greater than 25mA is also highly desirable. Low noise is way down the agenda, considering that the CD standard's own noise floor is equivalent to 80nV/√Hz.

Suitable types for the IC_1 position include the PMI OP44 and OP42; the AD AD845 and 744 (all Bi-fets) and the Harris HA 2525 (which has a degenerated Darlington input) and HA 5137. These models have been arrived at after extensive evaluation. High-performance op-amps of this genre are almost invariably available solely as singles, which provides the opportunity for 100% power rail isolation. In turn, power supply noise rejection in the op-amp is less important.

Series resistors $R_{7,8,9}$ have been added to the integrator capacitors to set a limit on the minimum loading seen by IC_1 when provoked by high-frequency noise, preventing needless erosion of IC_1 loop gain --just where error-correction is in shortest supply. Without feedback control, C_6 becomes more of an HF bypass, rather than an integrator capacitor. With loading limited to a few hundred mainly resistive ohms, the normal integrator/filter action can be pushed up to slightly higher frequencies, along with the unhealthy intermodulation products associated with near open-loop conditions.

De-emphasis switching is carried out simply with a sealed reed relay. The relay costs more, but has none of the error mechanisms associated with a simple j-fet switch. The model chosen avoids the long term unreliability of gold and other historic contact platings when used for dry switching[2]. This is important because it may not be used very often; pre-emphasised Compact Discs are mainly limited to Japanese and US Audiophile releases. If you do not need the facility, RLY_1, $R_{8,9}$ and $C_{7,8}$ can be omitted.

In the second stage, the Sallen and Key filter's implementation has been modified. The inductor has been omitted because parasitic elements will ultimately cause a notch, followed by a sharply rising response, rather like a Cauer filter, with accompanying step changes in the phase and group-delay curves. Also, unless shielded, an inductor will be prone to pick up the RF fields emanating from the CD player's digital circuitry.

Instead, the filter's principle rolloff has been increased to – 18dB/octave by inserting a passive RC section, R_{10}, C_9; the resistor is set at the lowest value commensurate with not loading IC_1 too heavily. In turn, the values of $R_{11,12}$ and $C_{10,11}$ 2 have been rescaled so the passive section is not loaded. Finally, C_{11} has been tweaked (by iterative analogue simulation – the quickest way) so the overall response at 20kHz and 100kHz is similar to the P/M original at −0.8dB and approximately −24dB respectively. Higher up, the modified filter's response is superior. When parasitics are included, analogue modelling predicts −84dB of attenuation at 1MHz, compared to the original's −58dB.

The op-amp chosen for IC_2 is less critical than IC1, with R_{10}, C_9 taking out residual HF products before the signal meets the negative-feedback network via C_{10}. All the unity-gain stable opamps listed for IC_1 are suitable; that is, all but the OP44 and HA5137. Builders who insist that good steady-state distortion figures are the keynote indicator of sonic quality may prefer to fit NE5534, the single 5532.

Trimmer PR_2 sets the output offset to below 1mV. Considering the op-amp's unity-gain configuration, it is unlikely to be needed unless you fit an NE5534, HA2525 or other op-amp lacking DC precision. If used, be aware that nulling pin connections, supply polarity and the need for a series resistor vary from op-amp to op-amp.

Hitachi's DA-006 CD player. Designers are now paying more attention to ouput circuit arrangements.

Outside resistor R_{15} buffers the output from capacitive loads, and, much like the original circuitry, provides a modicum of final HF filtering for any rubbish picked up inside the player, working against the output cable's lumped capacitance.

The relay provides shunt muting immediately after power is applied, while discs are being loaded and at switch off; keeping the contacts out of the signal path enables a cheap "telecom" relay to be used. The contacts are wiped every time the player is switched on and off. If the player is left on at all times, or not used for some time, the contacts may tarnish, but the worst that can happen is that the muting depth is diminished. If the circuit is left powered up and muted without being connected to the DAC, the resulting 3.5V output offset causes IC_2 to run warm, since it drives 25mA into R_{15}. So, for the sake of IC_2 longevity, R_{15} should not be omitted or decreased.

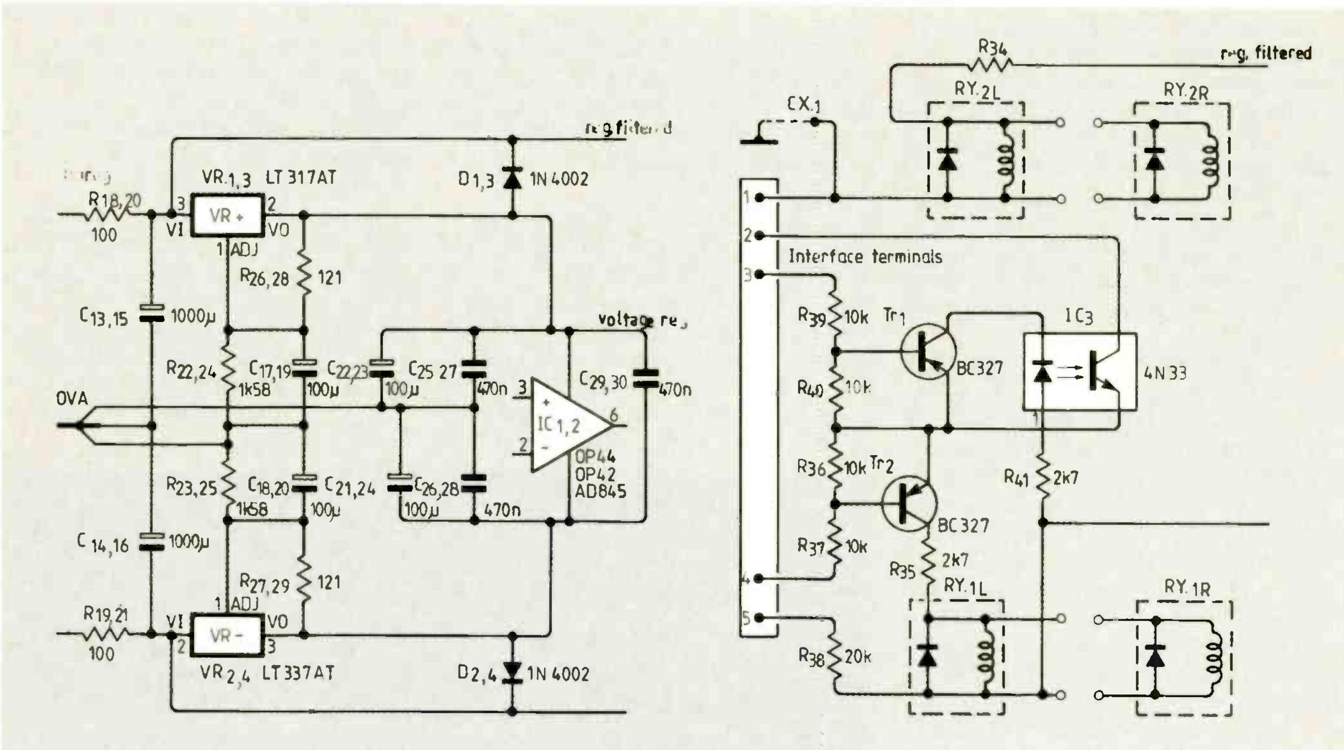

Fig. 3. Power supply and interfacing circuit for muting and de-emphasis relays.

Powering and interfacing

Figure 3 focuses on the local power regulation and the interfacing arrangements for the de-emphasis and muting relays. Since IC_1 must handle fast-changing current steps, while both op-amps' power supply noise rejection is diminished at mid to higher audio frequencies, let alone HF, each op-amp is provided with individual regulation. Incoming power is uncritical; with $VR_{1,2}$ set for +18V, any unregulated or regulated supply giving ±23V to ±30V at 120mA or more will do[3].

The output stage upgrade operates from the player's own regulated supply by reducing the regulator settings to lie comfortably below the player's own ±15V, that is, by changing the regulators' lower arm resistors ($R_{30\text{-}33}$) to 1kΩ, to give just below ±12V. Resistors $R_{34,35,41}$ need scaling down and RLY_2 changing to 12V to accommodate the lower voltage.

External powering is strongly recommended, since a separately shielded and isolated supply stands a much higher chance of being free from insuperable RF noise. This approach overcomes any risk of ground loops, as only one 0V connection is needed per channel to the player's circuitry. It also allows the op-amps to be run close to their maximum voltage of 18V to 20V, enhancing their slew limit and gain/bandwidth product, and hence loop gain.

National Semiconductor's LM317/337 series of adjustable regulators have long been a favourite with audio designers for their consistenly low and almost pure white noise output. More recently, Linear Technology have revamped the design. Linear's upgraded 317/337 (prefixed LT) have slightly lower output impedance at mid to high audio frequencies and tighter setting tolerance. The passive RC input filtering (R_{18},C_{13}, etc) is included because regulators (like op-amps) depend on feedback for proper operation, have finite loop gain and cannot be expected to cope with HF rubbish which could easily be present on the DC supply cables. The circuit also shows the local decoupling deployed around each IC.

The circuitry controlling relays $RLY_{1,2}$ has been designed to interface with the most common kinds of muting and deemphasis control used on P/M players over the past seven years. For the more recent players employing BJT transistor muting, as in Fig.1, link interface terminals 1 and 2, then connect pin 3 to the mute control voltage which appears at the muting $Tr_{102/103}$ bases in Fig. 1. Earlier 14-bit players employ a 5V relay.

The upgrade circuit presented here has developed over four years and has already been tested by over 200 audiophiles, many of them professionally involved in audio. The most upmarket oversampled CD players (e.g. Sony's 337-ESD) have benefited no less than the humblest Philips or Marantz. There has been a distinct consensus on what the improvements to sonic quality are: there is none of the stridency and 'metallicity' associated with bad CD players; the sound is more 'open'; it is much easier for the ear to focus on specific instruments; and most of all, it is possible to listen for long periods without the fatigue or boredom that is the hallmark of poorly executed audio.

Even if classic steady-state analysis of audio signals fails to see the difference, the results are very real and also make sense in the bigger chaotic and statistical scheme of things. Music is an intensely chaotic signal. The last thing it needs is to be processed by a chaotic system. Anything we can easily do to make an audio circuit's actions more consistent and less likely to become chaotic can only help. ■

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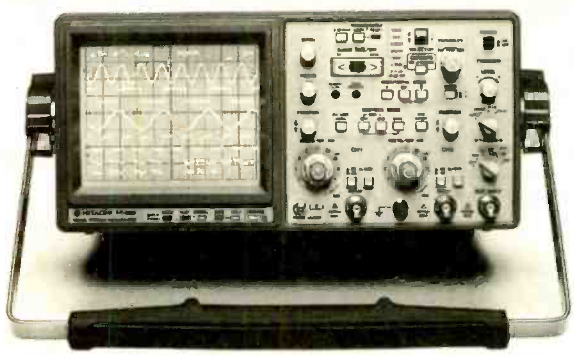

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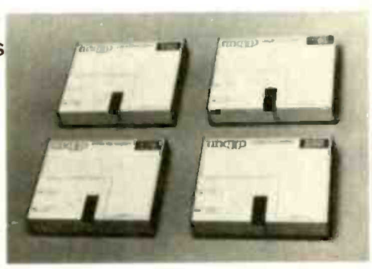

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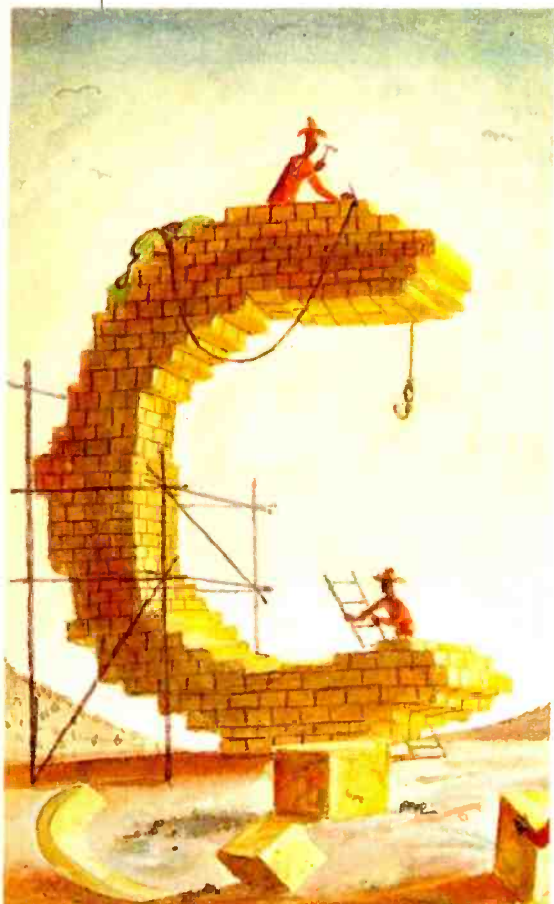


INTERFACING WITH C

PART 2

The second part of Howard Hutchings' series on C for electronics engineers deals with loops and data conversion in software.

Repetition: unconditional jumps

Repetition occurs prominently in many programming applications: C provides a number of particularly attractive and elegant constructions. In **Fig. 1.8.** we require the main body of the program (which is largely made up of the previous program fragments) to be repeated indefinitely. One possible construction which avoids using the infamous "goto" is:

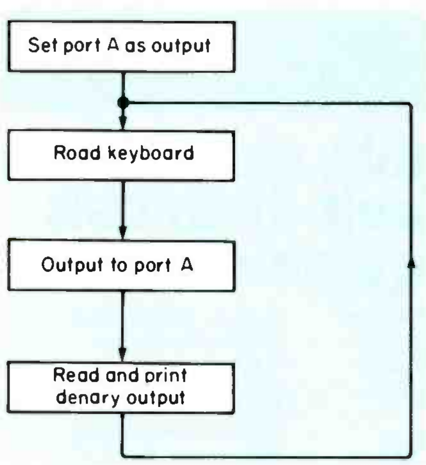


Fig. 1.8 A simple loop mirrored by listing 1.6

```
for (;;)
{
/*------------------
C CODE TO BE EXECUTED
INSIDE INFINITE LOOP
------------------*/
}
```

The program in **listing 1.6** is designed to read a number from the keyboard, to output the binary value to leds attached to port A and to read/display the contents of port A. Repetition is illustrated by the flowchart Figure 1.8.

Listing 1.6

```
**********************
**
* REPETITIVE WRITE-*
* READ DISPLAY LOOP *
**
**********************
#include<stdio.h>
#include<conio.h>
main()
{
int port-A = 768;
int control-reg = 771'
int x;
int word = 139;
outp(control-reg, word);
/*---------------------
DELCARE VARIABLES AND
INITIALIZE PORT A
---------------------*/
for (;;)
{
/*--------------
INFINITE LOOP
-------------*/
printf("Enter a No.n");
scanf ("%d",&x);
/*------------------
I/P NO. FROM KEY
BOARD
-----------------*/
outp(port-A,x);
}
}
```

Connecting the data display circuit Figure 1.7 demonstrates the effect of the program. Alternatively this program construction successfully controls the speed of a small d.c. motor. A suitable circuit is shown in **Fig. 1.9.**

Integers 0 to 15, input from the keyboard are processed through the 4-bit d-to-a and power amplifier to provide 16 unique speeds. This simple unidirectional open-loop control system provides the basis for more advanced closed-loop control.

Named constants # define

Listing 1.7 generates a squarewave of approximately 5Vp-p at a frequency of 500kHz, by causing PAo to go repeatedly high then low. As a programming exercise it demonstrates how to replace names for constants, improving the readability of the program. Most C programmers use upper-case letters when naming a #define constant: this helps to distinguish variables from defined constants. Notice that the constants are defined outside the main program and not terminated with a semicolon.

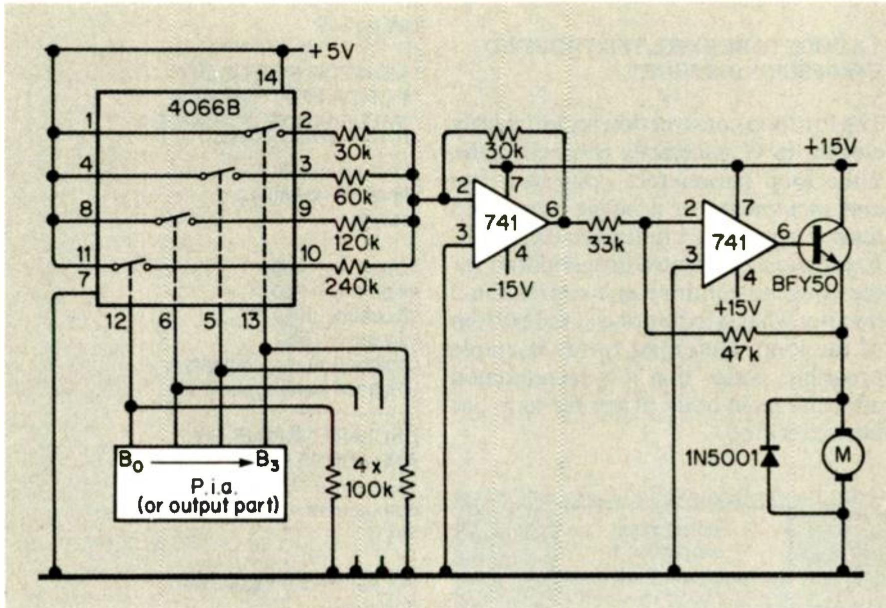


Fig. 1.9 Hardware for computerised speed control is simple: most of the work is done by software.

Infamous goto

The primative, repetitive nature of this program provides an excuse to demonstrate an unconditional jump;using the goto statement. Many of the erudite books written about C insist that it should be avoided, or used with extreme caution. This is good advice, since its use encourages unstructured programming and makes programs difficult to read. Not wishing to be contentious: we show how the structured infinite for-loop, can be replaced by the unstructured goto, without loss of readability (in this example).When the goto statement is executed, control is transferred to the C code following the label (in this case start). The label is always terminated by a colon:

listing 1.7.

```
*/***************
**
* SQUARE-WAVE *
* GENERATOR *
**
***************/
#include<stdio.h>
#inculde<conio.h>
#define ON 1
#define OFF 0
main ()
{
int port-A = 768;
int control-reg = 771;
int word = 139;
outp(control-reg, word);
start;outp(port-A, ON);
outp(port-A, OFF);
/*--------------
DEFINED CONSTANTS
---------------*/
goto start;
}
```

For-loops in greater detail — a binary counter

Educationally **listing 1.8** is particularly rewarding, because it demonstrates a number of different loop constructions in a single program. Connecting the data indication circuit **Fig. 1.7** to port A configured as an output, provides a binary representation of the current status of the count. The denary status is displayed on the monitor using the printf function. Counting from 0 to 255 is achieved using the post increment operator (i++), a versatile construction meaning i = i + 1.

listing 1.8

```
/************************
* BINARY COUNTER *
************************/
#include<stdio.h>
#include<conio.h>
main()
{
int portA = 768;
int controlreg = 771;
int word = 139;
int i,k;
outp(control_reg,word);
for(;;)
{
i = 0;
while(i++ <= 255)
/*-----------------
TEST i THEN ADD ONE
------------------*/
{
outp(port_A,i - 1);
printf("%dn",i - 1);
for(k = 0;k <= 1000;k++)
{
/*----------------------
3 PARTS OF LOOP
INITIALISE:TEST:INCREMENT
-----------------------*/
}
}
}
}
```

Inspection of the structure shows the program consists of a number of nested loops; the outer loop

```
for(;;)
{
}
```

ensures that the procedure is continued indefinitely. The actual count is controlled by the construction.

```
while(expression)
{
/* C CODE TO BE EXECUTED AS LONG AS THE EXPRESSION IN WHILE REMAINS TRUE */
}
```

The terse nature of the expression: i++ <= 255 deserves further explanation. It means test if "i" is less than or equal to 255 and then add 1 to it. Two useful features of C are the increment and decrement operators, meaning i = i + 1 and i = i - 1. The versatility of C allows you to test the value of "i" and then add 1 to it - post increment operator i++. Or add 1 and then test, the - pre-increment operator ++i. A similar construction is provided for decrementing. To produce an observable display it was necessary to introduce a significant time delay into the loop. This is exploited to demonstrate the for-construction in greater detail.

```
for(expression 1;expression 2;expression 3)
```

```
{
/* C CODE TO BE EXECUTED PROVIDED
EXPRESSION 2 IS TRUE */
}
```

The for-loop construction is particularly elegant in C, succinctly combining the three loop parameters (initialise, test and increment) in a single bracketed term. Expression 1 initialises the count. Expression 2 indicates the condition for the count to continue and expression 3 denotes what is to be done at the bottom of the loop. Referring to my example program, notice that k is incremented after the main body of the for-loop has been executed.

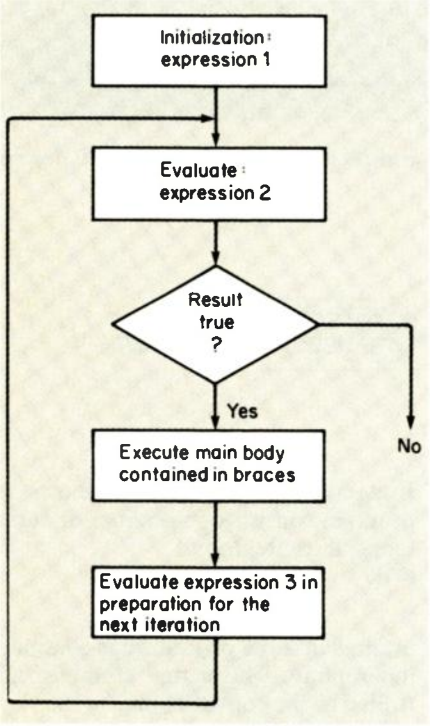


Fig. 1.10. For-loop flowchart

Monitoring port A with a do-while construction

In this example, **listing 1.9**, the program monitors the switches on port A and displays the decimal value on the screen, before latching the binary value to led's on port B. Including the conditional do-while statement ensures the body of instructions are always executed at least once, before the test is made. Thereupon, looping continues until the result of the test is false. Observe how the test monitors the input port and compares the current contents (called newcontents in the program) with the oldcontents. When this expression is false (the double equal signs == mean equal in C) control transfers to the instruction following the while-statement.

listing 1.9

```
/************************
* MONITOR STATUS OF *
* PORT A:PRINT DECIMAL *
* VALUE:WRITE TO PORT B *
************************/
#include<stdic.h>
#include<conio.h>
main()
{
int port_A = 768;
int port_B = 769;
int control_reg = 771;
int word = 153;
unsigned int old_contents;
unsigned int new_contents;
/*----------------
DECLARE VARIABLES
AND ADDRESSES
-----------------*/
outp(control_reg,word);
for(;;)
{
old_contents = inp(portA);
/*-------------
READ PORT A
-------------*/
printf("Port A contains%dn",old_contents);
outp(port_B,old_contents);
do
{
new_contents = inp(port_A);
/*----------------
MONITOR PORT A
----------------*/
}
while(new_contents == old_contents);
/*-----------------
HAS I/P CHANGED ?
------------------*/
}
}
```

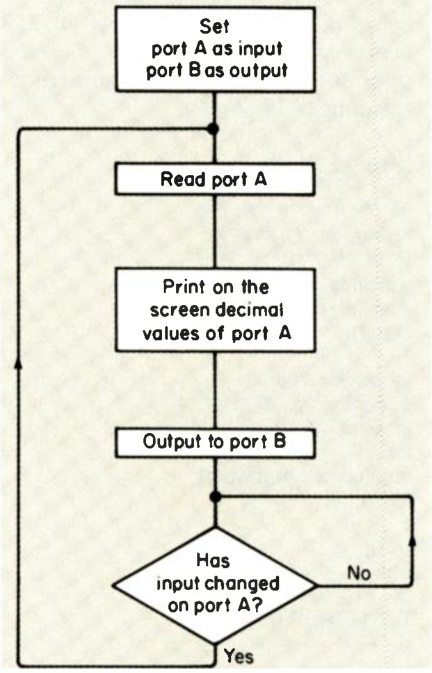


Fig. 1.11. Flowchart for listing 1.9

The versatility of C provides an alternative while-do construction, which tests an expression, and if true, permits looping to continue until the result of a test is false. At this point control passes to the next instruction in the program. These structured flowchart constructions are shown in **Fig. 1.12.** (FIG 1.12)

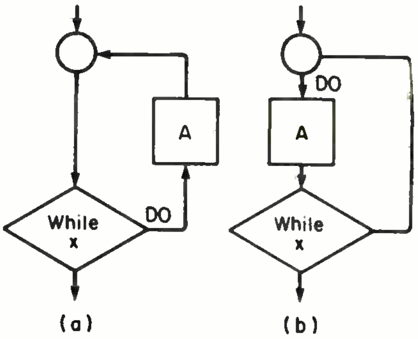


Fig. 1.12. The anatomy of structured control

Light chaser effect – write your own functions in C

This program **listing 1.10** is designed to produce the effect of a light running repeatedly across the leds connected to port A, which is conditioned as an output. It works by taking powers of 2 and writing the byte to the port. Don't imagine this is frivolous, it does have a serious side, demonstrating how to write your own functions using C. Observe how the structure is composed of the main function which controls the flow of the program. Together with an external function called power(x,n) that can be invoked and executed by a single statement in the main program. Further details of the origin of this program are to be found in The C programming language, by D. W. Kernigan & D. M. Ritchie, page 22 (published by Prentice-Hall).

listing 1.10

```
/*********************
* LIGHT CHASER WRITE *
* YOUR OWN FUNCTIONS *
* USING C *
*********************/
#include<stdio.h>
#include<conio.h>
main()
{
int port_A = 768;
int control_reg = 771;
int word = 139;
unsigned int contents;
inti,k;
outp(control_reg,word);
for(;;)

{
for(i = 0;i <= 7;i++)
{
contents = power(2,i);
/*---------------
```

```
CALLING FUNCTION
----------------*/
outp(port_A,contents);
for(k = 0;k<= 6000;k++)
{
/*-------------------
TIME DELAY IMPROVES
VISUAL EFFECT
-------------------*/
}
}
}
}
/*--------------------------
RAISE X TO N-TH POWER: N 0
----------------------------*/
power(x,n)
int x,n;
{
int i,p;
p = 1;
for(i = 1;i<= n;i++)
p = p*x;
return(p);
}
```

Communicating with peripherals

The C language has no purpose built statements to perform input or output operations. Functions must be written to communicate with external peripherals. We have already made extensive use of the functions scanf, to read data from the keyboard and printf to display data on the monitor. When a program is compiled and these functions are encountered, the linker portion of the compiler will search the function library for its definition. Hence the requirement to include the standard input-output header file stdio.h in most programs.

When Microsoft wrote the C compiler for use with the IBM PC (or any 8088 type system), it clearly recognised the additional requirements of port mapped I/O access and thoughtfully provided the necessary functions. Since typical users are unlikely to be skilled assembly language programmers, the importance of this software cannot be overstated.

The majority of programs in chapter 1 have used the functions inp and outp, contained in the header file conio.h to access I/O devices.

Associating an address with a device in a memory mapped system, using C, requires an address operator. The collective construction is made up of a pointer, together with an indirection operator. **Listing 1.1** which reads and displays the contents of specified memory locations, uses such a structure. To understand the anatomy of the program consider the fragment of code listing 1.11.

listing 1.11

```
/******************
*ADDRESS OPERATOR*
*USING POINTERS*
******************/
int *port_x;
unsigned char contents;
/*---------------------------
*port_x IS A POINTER DECLARED
AS AN INTEGER. THE VARIABLE
contents IS AN UNSIGNED CHAR
-----------------------------*/
port_x = (int*)768;
/*---------------------------
THIS CONSTRUCTION ESTABLISHES
THE ADDRESS OF THE POINTER
-----------------------------*/
*port_x = 255;
/*--------------------------------
WHEN AN ASTERISK * IS USED AS A
PREFIX TO AN INTEGER VARIABLE
NAME IT BEHAVES AS AN INDIRECTION
OPERATOR
---------------------------------*/
contents = *port_x;
/*----------------------------------
USING THE INDIRECTION OPERATOR * WE
RECOVER THE VALUE AT THAT ADDRESS
-----------------------------------*/
```

Referring to the program we notice that int *portx; is a pointer declared as an integer. Pointers always point to something, in this case the address of memory location 768 (denary). The required construction is: portx = (int*)768. When an asterisk is used as a prefix to an integer variable name it behaves as an indirection operator. It follows that the expression *portx = 255; will load 255 into address 768. In Basic the analogous statement would be POKE 768,255. Reading the data contained at this address is simply achieved by assigning the variable "contents" to portx ie. contents = *portx. The analogous Basic statement would be CONTENTS = PEEK(768).

Analogue to digital systems and circuits

Interfacing an A-to-D converter to a computer does not necessarily require a detailed knowledge of the circuit operation. Indeed if the interface is configured carefully, it will be virtually user transparent.

However, effective data conversion requires more than simply connection of an A-to-D converter to the PC bus. Certain minimum design criteria should be acknowledged: notably loss of significance, resolution and sampling rate. Potential users should question the type of signal which may be successfully processed. One should also consider the limitations which the data conversion will impose on the accuracy and usefulness of the digital output. In short, don't ignore the obvious.

Many I/O board manufacturers specify the full scale input voltage to their boards in the ranges: 0–2.5V, 0–5.0V, 0–10.0V or their bipolar equivalents. Avoid loss of significance by matching (as nearly as is possible) the maximum input voltage to the maximum input range of the A-to-D converter. This is naturally tied in with the required resolution. Will 8-bit resolution suffice or should 12, 14 or even 16-bits be employed? What limitations will this word length impose on an 8-bit data bus? Consider carefully the implications of accessing the contents of the converter in two parts, particularly in the context of high speed, real-time applications.

Sampling rate, determined by the converter chip system architecture is likely to be an important factor in the choice of converter. The majority of low cost chips use either ramp generator or successive approximation. Flash converters can perform 8-bit conversions in under 50ns.

Counter-ramp A-to-D converter

The system diagram of a counter ramp A-to-D converter is shown in **Fig. 2.1**. When interfaced to a computer, a start conversion pulse initiates conversion by resetting the counter to zero. The analogue output of the D-to-A, connected to the inverting input of the comparator, is also zero. Each subsequent clock pulse increments the counter. The digital signal is processed by the D-to-A converter generating an analogue staircase waveform. When the amplitude of this waveform exceeds or equals that of the input signal, the output of the comparator changes state, generating an end of conversion pulse which stops the clock. The digital equivalent of the analogue signal is now available in parallel form at the output of the counter.

A fundamental limitation of this sys-

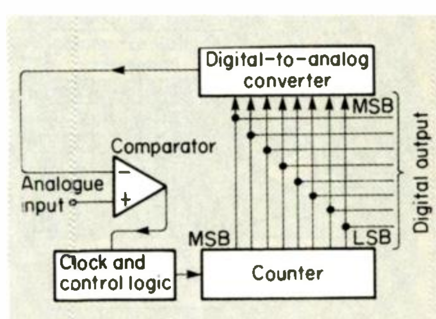


Fig. 2.1 System diagram of a counter-ramp A-to-D converter

tem is the relatively long processing time, particularly for large amplitude input signals. The conversion time T is proportional to the amplitude of the signal input V.

The conversion time is given by:

$$T_c = \frac{V_i\, 2^n}{V_{max}\, F_{clk}}$$

Where n is the number of bits, V_i is the amplitude of the input signal, V_{max} is the full-scale input voltage and F_{clk} is the clock frequency.

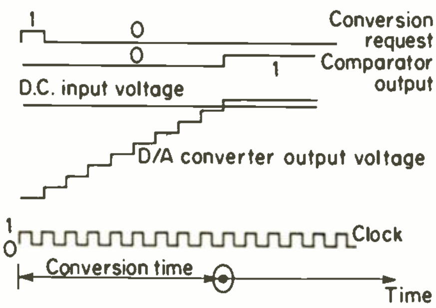


Fig. 2.2 The conversion time of the counter-ramp A-to-D converter depends upon the amplitude of the input signal

Successive approximation

Replacing the counter in the feedback loop with a successive approximation register, SAR, (**Fig. 2.3**) allows much faster conversion rates. Initially the start conversion pulse resets the contents of the SAR to zero. The next pulse enables the most significant bit allowing the D-to-A converter output to change to half its maximum value. If this voltage is less than or equal to the input signal the output of the comparator generates a logic signal causing the most significant bit to remain at logic one. Conversely if the D-to-A output is greater than the input signal, the circuit sets the corresponding bit to logic 0. On each subsequent clock pulse this process is repeated on the remaining bits, until

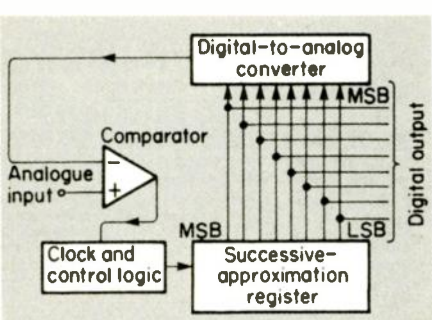


Fig. 2.3 System diagram of successive approximation A-to-D converter

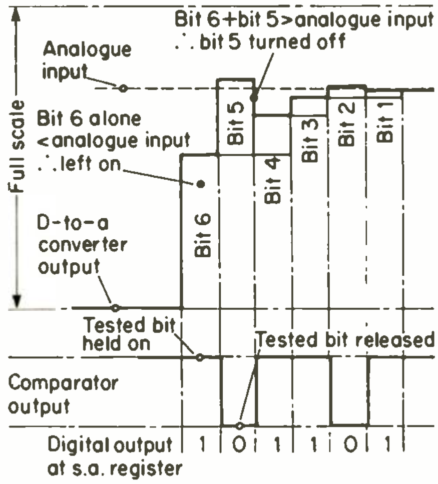


Fig. 2.4 Successive approximation speeds up conversion time with conversion rates that can stretch from 400ns to 25s. The number of conversion steps required is equal to the number of bits in the data word plus one

all the bits in the register have been tested.

In summary, an n-bit successive approximation A-to-D converter requires one clock cycle to clear the register, followed by n clock cycles to test each bit. Hence the total conversion time takes only (n+1) clock cycles, and is independent of input signal amplitude.

Flash conversion

As shown in **Fig. 2.5** this method of A-to-D conversion abandons all subtlety by using an array of 2^n-1 comparators to digitise directly an n-bit word. Since only one step is necessary to complete the conversion, this procedure is very much faster than either the counter-ramp or successive approximation methods.

Half-flash conversion offers a compromise. The architecture shown in **Fig. 2.6,** employs only 31 comparators. The analogue input is first digitised to a 4-bit level by the 4-bit MSB flash converter.

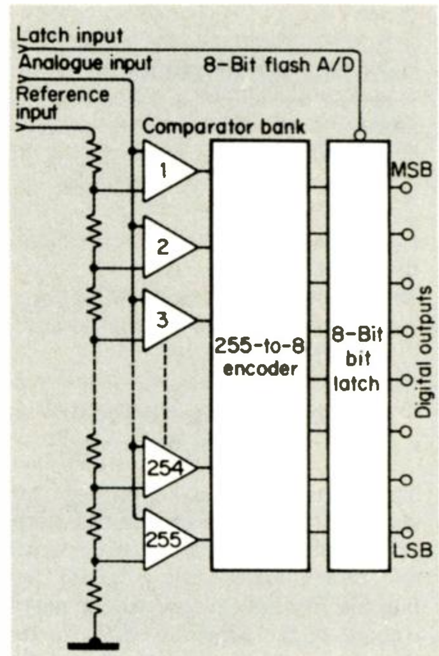
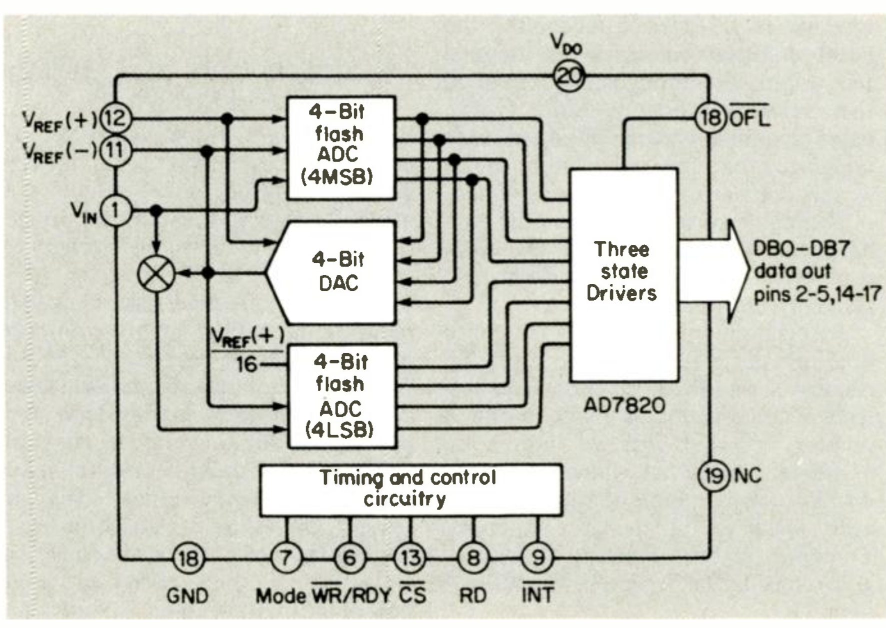


Fig. 2.5 8-bit conversion converts in one cycle.

Fig. 2.6 Half-flash conversion. AD7820 functional block diagram



While the output from the A-to-D is latched, the digital signal is reconverted to analogue form for a second conversion with a 1/16 weighted network to make up the least significant bits of the 8-bit output word.

Synchronisation and software control

Synchronisation is the key to disciplined digital design. Hardwired systems often rely on clocked flip-flops to provide the digital glue to stick asynchronous peripherals together. Real-time digital signal processing systems usually require that the time interval between captured samples remains constant and that enough samples are captured to satisfy Shannon's sampling theorem. Since A-to-D converters require externally generated start conversion pulses and themselves generate end of conversion signals upon completion, ingenious software is required to bring these peripherals into synchronisation with the computer program. Successful interface design, even for trivial uses, acknowledges these axioms.

Synchronised software control of the A-to-D converter requires a rigid operating protocol. This normally comprises a start-conversion pulse followed by a test to determine completion. These housekeeping operations require a good working knowledge of the characteristics of both the A-to-D and programmable interface or PC bus.

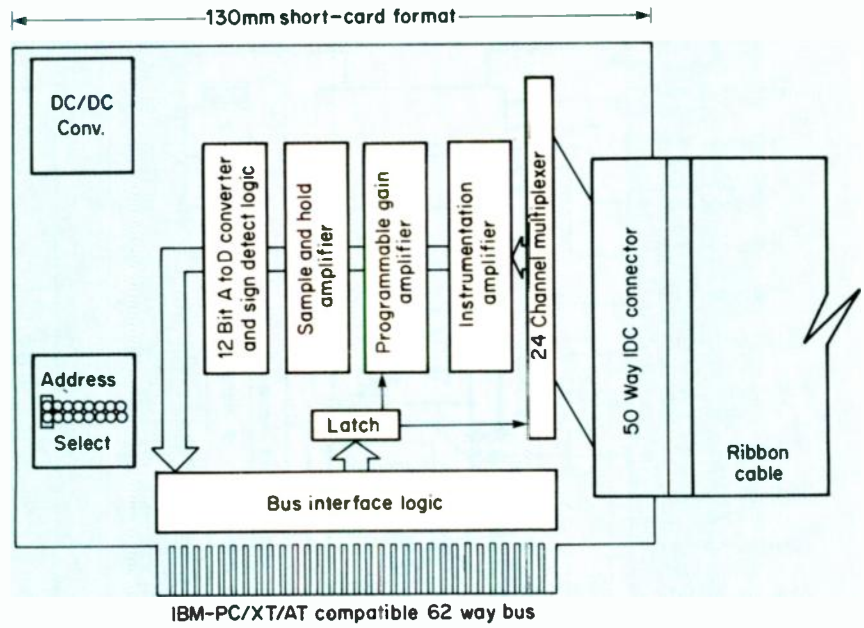


Fig. 2.7 AIP-24 functional block diagram

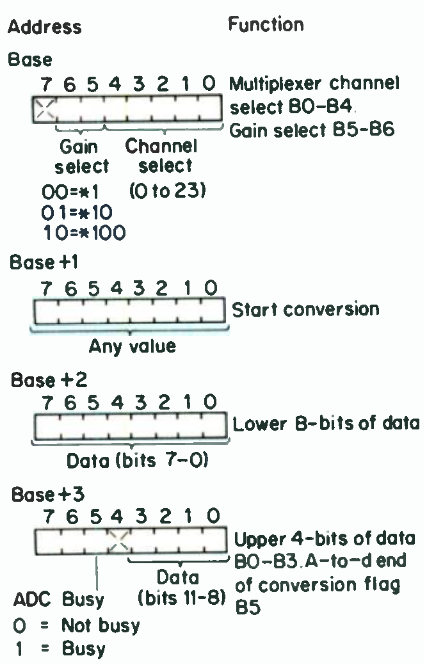


Fig. 2.8 Port map and programming model

Furthermore, strobing the A-to-D converter followed by polling a loop takes time. This restricts the sampling rate and reducing the usefulness of the digital signal processor.

12-bit A-to-D conversion

Twelve bit conversion implemented with commercially available PC cards is straightforward. This series uses the Blue Chip Technology multiplexed A-to-D, data acquisition card AIP-24 as an example. The architecture is shown in **Fig. 2.7**.. The board may be located in any expansion slot, but must be set up to appear at a specified address in the port map. As usual bus contention is avoided by making the base address selectable.

Software controlled multiplexers based on this card allow up to 24 analogue input signals to be connected to the board. The appropriate channel is defined by the status of the lower five bits of the multiplexer-select port 0, located at the base address. The selected differential signal feeds an instrumentation amplifier, which converts the signal into single ended drive before application to a programmable-gain amplifier PGA102. The gain is controlled by bits 5 and 6 of the multiplexer channel-select port 0. **Fig. 2.8** contains the necessary details. The output is then taken to a sample and hold amplifier AD585, which freezes the signal during conversion. Conversion is completed in 25ns, using the industrial standard AD574A 12-bit successive-approximation chip. See **Fig. 2.9** (over page).

IBM-PC AD574A interface

The AD574A successive approximation A-to-D interfaces to the IBM PC bus as shown in **Fig. 2.10**. Designed to be port mapped, its address is decoded from the address lines A0-A9. The address must be gated with $\overline{\text{AEN}}$ to mask out internal DMA cycles using the same I/O space. This active low is applied to $\overline{\text{CS}}$. $\overline{\text{IOR}}$ and $\overline{\text{IOW}}$ are used to initiate conversion and read data by suitable gating to CE. A0 selects two contiguous memory locations which store the eight MSB's and four LSB's of the left justified data.

Synchronised 12-bit A-to-D conversion using AD574A

Program **listing 2.1** synchronises the operation of a unipolar A-to-D, conditioned to process signals in the range 0-10V with a data capture and display routine. Because the AD574A generates a 12-bit data word, care must be exercised when reading the data which needs to be accessed in two parts. The computer may be used to recreate the data word using the algorithm:

```
word = ((15 & upper_bits) * 256) + lower_bits;
```

The complete protocol is explained in

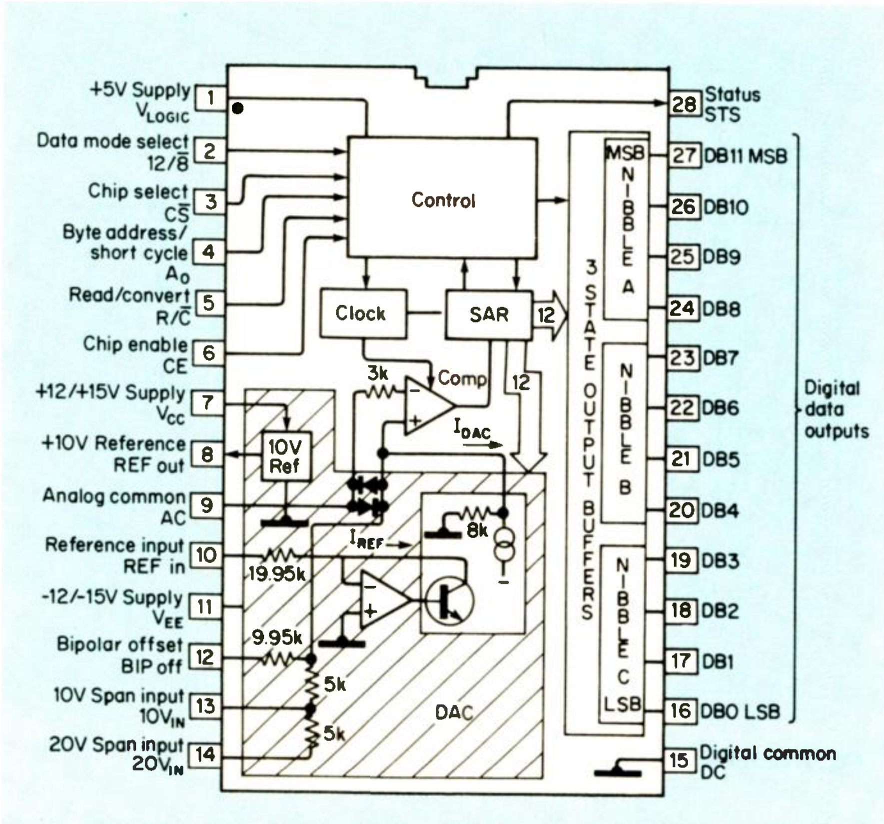


Fig. 2.9 AD574A block diagram and pin configuration

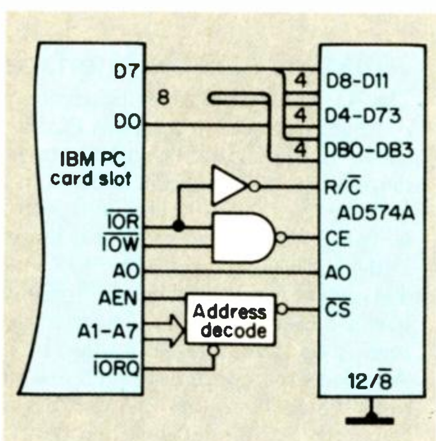


Fig. 2.10 IBM PC - AD574A interface

the program. When I initially wrote the program my main concern was simplicity. Consequently, I intended to restrict the software control of the A-to-D to strobing, followed by two-stage reading of the processed data. However, C is fast and the program reads the data ports before conversion has been completed, with disastrous consequences. Rather than simply waste time waiting for the end of conversion signal, I elected to include a polling routine to monitor the state of bit 5 (for e.o.c) located at address (Base + 3). Logically AND-ing the status of the flag with a mask (denary 32), inside the do-while loop ensures the test is made at least once. When the flag is set, it exits from the loop and the converted data may be read.

Listing 2.1 Program to synchronize A-to-D and print decimal value of input signal(0-10V)

```
/**************************
* SYNCHRONIZED 12-BIT A/D *
* CONVERSION USING AD574A *
**************************/
#include<stdio.h>
#include<conio.h>
#define BASE 512
/*-------------------------
BASE ADDRESS OF PORT-MAPPED
MULTIPLEXED A-to-D
-------------------------*/
#define START 0
/*-----------------------
DUMMY VARIABLE: START CAN BE
ANY VALUE: REF FIG(2.8)
------------------------*/
main()
{
unsigned int
lower_bits,upper_bits,word,flag;
for(;;)
{
outp(BASE,0);
/*-------------------
SELECT CHANNEL No. 0-23
---------------------*/
outp(BASE+1,START);
/*---------------
INITIATE CONVERSION
-----------------*/
do
{
flag = inp(BASE+3);
}
while(32 & flag);
/*----------
FLAG RAISED?
-----------*/
lower_bits = inp(BASE+2);
upper_bits = inp(BASE+3);
word = ((15 & upper_bits) * 256) +
lower_bits;
/*----------------------------------------
CONDITION 12-BIT WORD, ACCESSED IN
2 PARTS
----------------------------------------*/
printf("Digital value:%d\n",word);
}
}
```

Programs usually exist to be re-written. For example rather than simply print the denary integer equivalent (0-4095) of the analogue input, it would be more constructive to display the actual voltage. Simply modifying the format of the printf() function achieves this.

```
printf("Volts = %f\n",(float)10 * word/4095);
```

Scrolling the screen can be distracting. A more structured control of printf() is required to modify the display only when the input changes. Not duplicating effort is an axiom of software writing. The problem may be solved through the do-while construction used in listing 1.9.

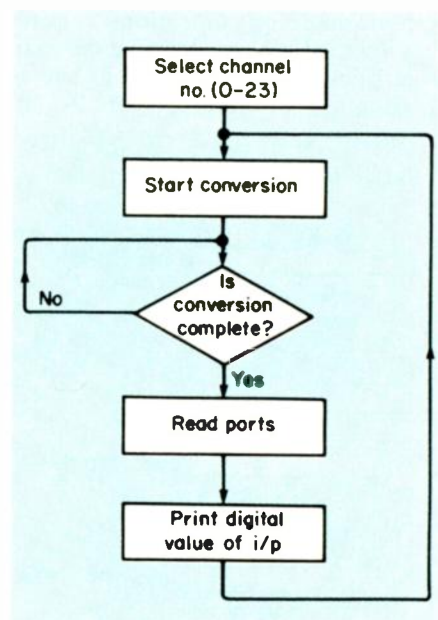


Fig. 2.11 Flowchart of listing 2.1

An interesting modification to the A-to-D program is to add a warning displayed on the screen when the analogue input exceeds a pre-determined threshold. Look at **listing 2.2.** In this example we have set the threshold at +2.0V using

```
#define DANGER 2.0.
```

Listing 2.2 software based comparator

```
/**********************
* SOFTWARE COMPARATOR *
* USING AD574A *
**********************/
#include<stdio.h>
#include<conio.h>
#define BASE 512
#define START O
#define DANGER 2.0
main()
{
unsigned int lower_bits;
unsigned int upper_bits,word,flag;
float volts;
outp(BASE,0);
/*---------------------
SELECT CHANNEL No. 0-23)
-----------------------*/
for(;;)
{
outp(BASE+1,START);
/*----------------
INITIATE CONVERSION
------------------*/
do
{
flag = inp(BASE+3);
}
while(32 & flag);
/*---------
FLAG RAISED?
-----------*/
lower_bits = inp(BASE+2);
upper_bits = inp(BASE+3);
word = ((15 & upper_bits) * 256) +
lower_bits;
volts = (float)10 * word / 4095;
/*-----------------------
WEIGHT I/P : VOLTAGE(0–10V)
-------------------------*/
if(volts >= DANGER)
/*--------------------
TEST IF I/P EXCEEDS 2.0V
----------------------*/
{
printf("Danger\n");
}
else
{
printf("Voltage = %f\n",volts);
}
}
}
```

The conditional jump structure is simply achieved by the construction

```
if (contents >= DANGER)
{
printf("Danger\n");
}
else
{
printf("Voltage = %f\n,volts);
}
```

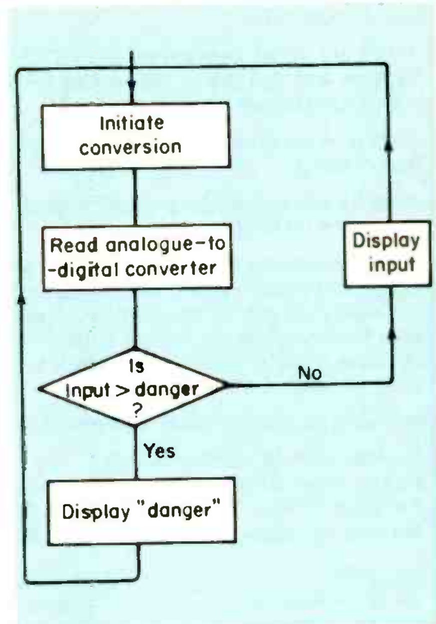


Fig. 2.12 Flowchart for listing 2.2

Part 3 examines screen graphics modes, transducer linearisation and software noise filters

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Sport Information	F7b spec. 300 Bd ASCII
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SPREAD 21 and SPREAD 51	
DUPLEX ARQ Artrac	ITA 2
TWINPLEX	F7b-1 and F7b-2 Duplex ARQ
ASCII	
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ARQ-Swe	CCIR 518 variant
ARQ-E	ARQ 1000 ITA 2-p Duplex
ARQ-N	ITA 2 Duplex
ARQ-E3	CCIR 519 ITA 3
ARQ-6	5/6 character 90 and 98
TDM 242	CCIR 242 2/4 channels
TDM 342	CCIR 342 2/4 channels
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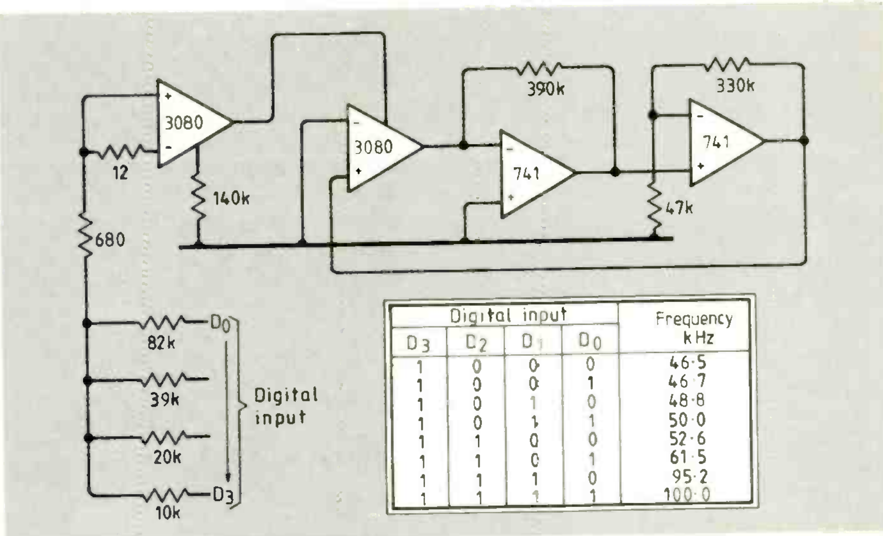
Programmable sinusoidal oscillator

There has been a lot of interest in designing digitally programmable oscillator circuits which are compatible with monolithic IC techniques.

But, because external capacitors are eliminated and design methods are based on resistance ratios, active-R circuits exploiting the frequency dependence of the op-amp gain are attractive for monolithic implementation. As an example, active-R circuits have been developed using op-amps and resistors only.

By connecting three amps in a ring configuration, making one of them programmable, it is possible to control the frequency of oscillation through control of the current in the programmable pole.

By obtaining the control voltage from the output of a passive D/A converter, formed only of resistors, a digitally programmable, electronically tunable active-R sinusoidal oscillator is feasible.



Digital input				Frequency kHz
D_3	D_2	D_1	D_0	
1	0	0	0	46·5
1	0	0	1	46·7
1	0	1	0	48·8
1	0	1	1	50·0
1	1	0	0	52·6
1	1	0	1	61·5
1	1	1	0	95·2
1	1	1	1	100·0

The circuit has been tested using the 741 op-amp, the CA3080 operational transconductance amp and a passive D-to-A converter. For a digital input from 1000 to 1111, the frequency of oscillation varied as shown in the table.

Muhammad Taher Abuelma'atti
University of Bahrain

Controlling small DC motors

These two circuits were originally designed to drive an amateur astronomical telescope. The Fig. 1 circuit uses a 4046 PLL IC and the Fig. 2 circuit a low power 555 IC.

In **Fig. 1**, accurate speed control can be realised with feedback from a multi-pole ferrite rotor used as an encoder. The speed signal is picked up using an ordinary tape recorder head with the gap widened. This is amplified by Tr_1 and compared with the VCO signal in phase comparator II of the IC. Negative phase pulses (pin 13) are amplified by Tr_2 and Tr_3 and used to drive the motor.

Some problems with loop stability may occur at very low speeds, but these can be overcome by placing extra rotational mass on the motor axis.

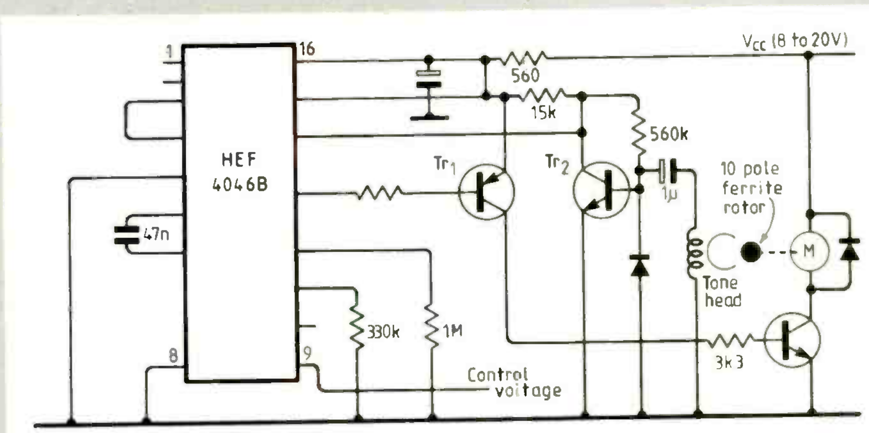


Fig. 1

The circuit in **Fig. 2** uses the induced voltage of the rotating DC motor as a feedback signal for speed control. As the motor slows down, the induced voltage drops and the filtered feedback voltage rises. When it reaches the trigger level, two thirds of V_{cc}, on pins 2 and 6, the discharge circuit in the IC is activated.

The discharge transistor (pin 7), buffered by emitter follower Tr_1, drives the motor, and the voltage at pins 2 and 6 falls back to one third V_{cc}.

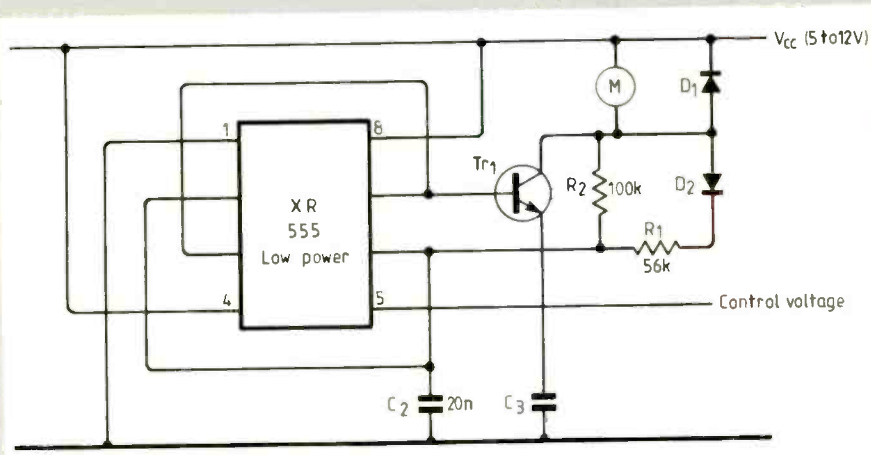
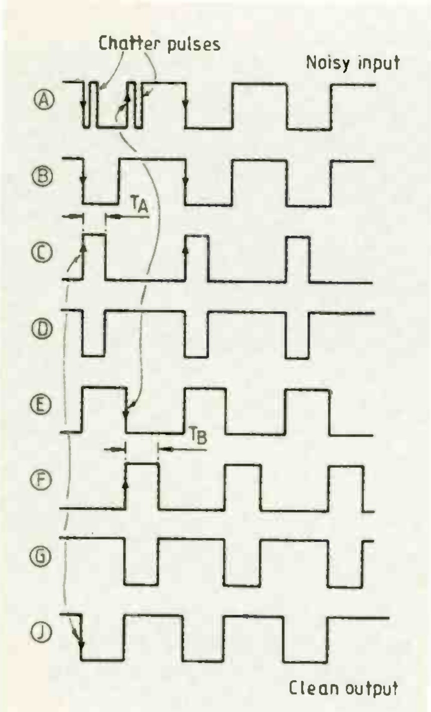
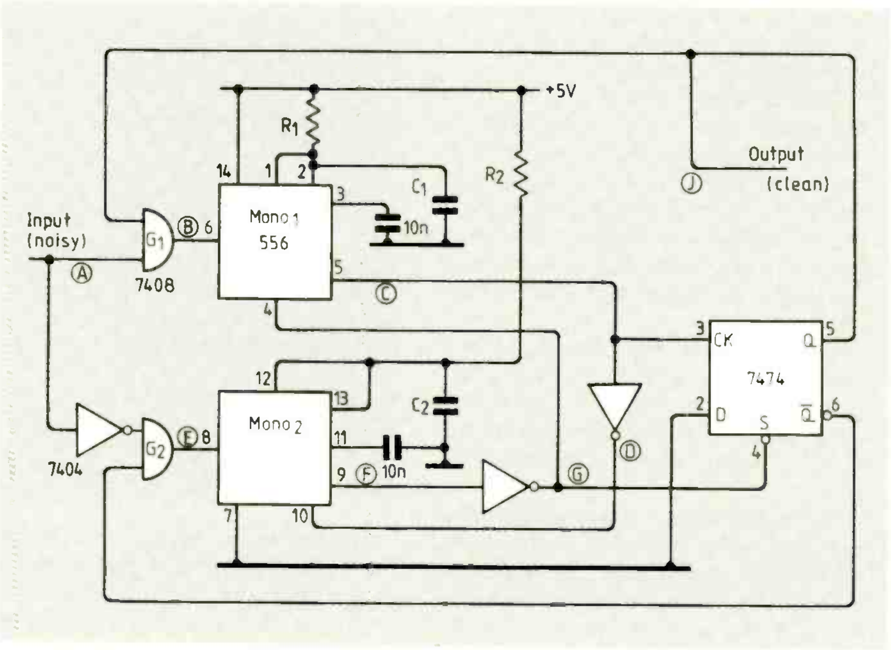


Fig. 2

Stajcar Bojan
Zagreb
Yugoslavia





Digital noise canceller

This circuit can stop noise pulses giving a false digital output. It can clean up noise from any digital signal provided the timing details of the signal are known.

The corrupted digital signal is input to an AND gate and the output of the gate is used to trigger a negative edge triggered monostable built using a 556 timer. When the logic signal goes low, the monostable is triggered and the output stays high for a time T_A. The rising edge edge of one-shot 1 resets the output of the arbitration D flip-flop to zero.

When the output of the flip-flop goes low, the AND gate G1 is disabled. Until one-shot 1 times out, further transitions at the input due to noise cannot cause any change in the output. After T_A, the positive edge of the input triggers one-shot 2 at the negative edge and the inverted output of one-shot 2 pre-sets and flip-flop to a high state.

This disables G1 and the inverted output from one-shot 2 inhibits AND gate G2. Since both gates and the flip-flop are disabled, spurious noise cannot give a false output at J, which is the flip-flop output.

The times T_A and T_B of the one-shots should be chosen such that both are less than the time when the digital signal is low but their sum is higher.

V. Lakshminarayanan
Centre for Development of Telematics
Bangalore
India

Signal envelope detector

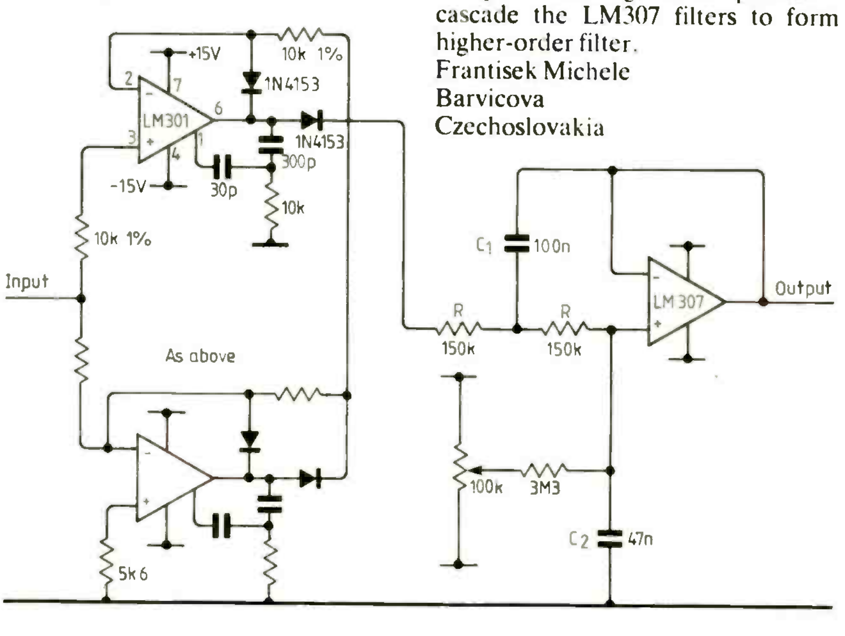
It is often necessary to use an accurate envelope detector when, for example, signal-processing data is recorded on an analogue tape recorder. This circuit implements such a precision detector and provides accuracy beyond 100kHz.

Two LM301 op-amps connected as precision rectifier use two-pole frequency compensation for increased slew rate. A LM307 op-amp connected in a Butterworth filter configuration subjects the rectifier output to a low-pass filter. It is possible to determine filter cut-off frequency (a function of the specific application) by using the equations $f_c = 1/2\pi RC_1$ and $C_2 = C_1/2$.

The DC offset in the low-pass filter becomes an important design consideration because maximum detector-output linearity is required for a low-level signal. An external-offset adjust is used to compensate the DC offset of LM307.

The filter has a cut-off frequency near 10Hz. Detector accuracy is better than 0.5dB over a 60dB range. For additional low-pass filtering, it is possible to cascade the LM307 filters to form a higher-order filter.

Frantisek Michele
Barvicova
Czechoslovakia



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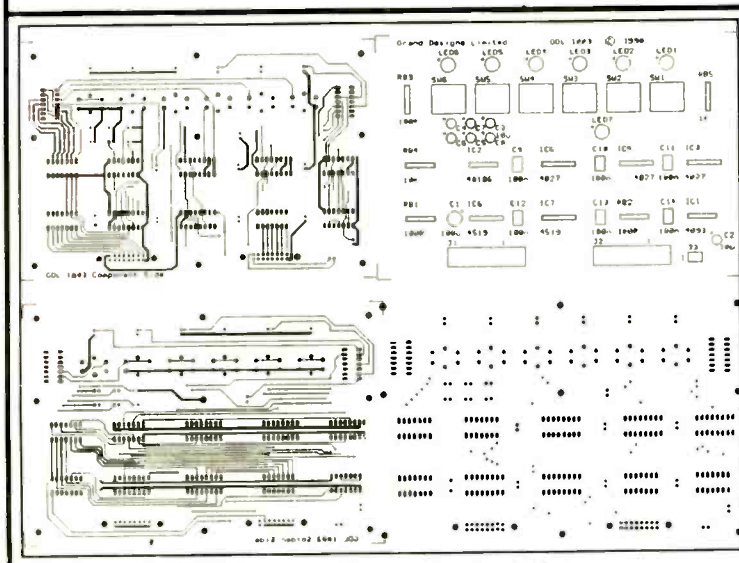

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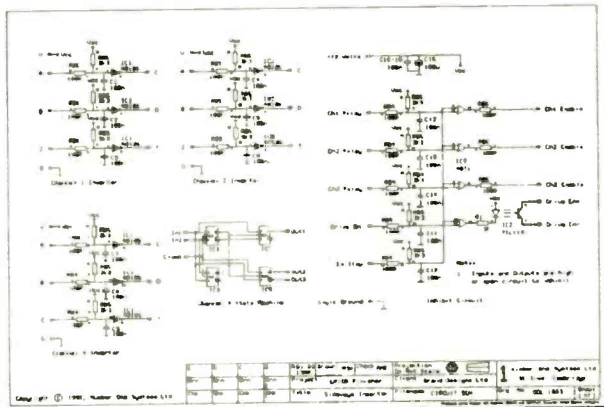

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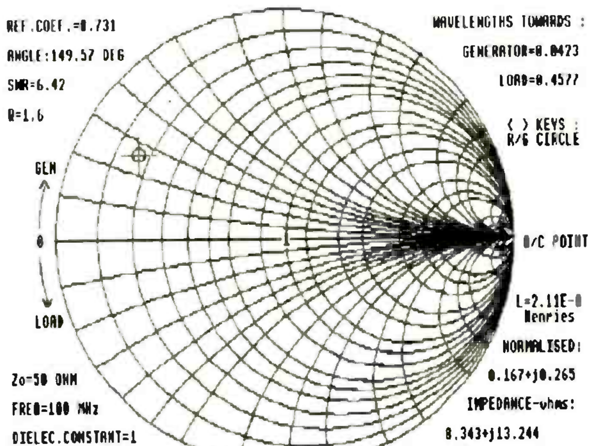

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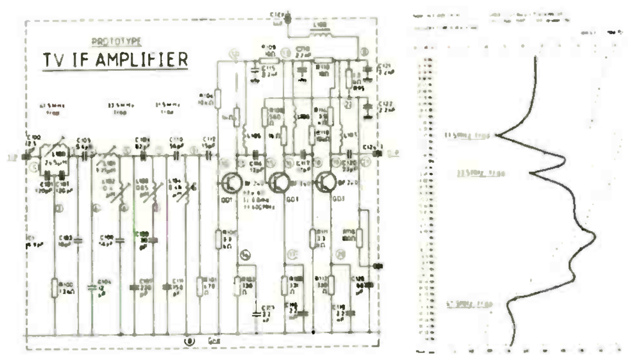

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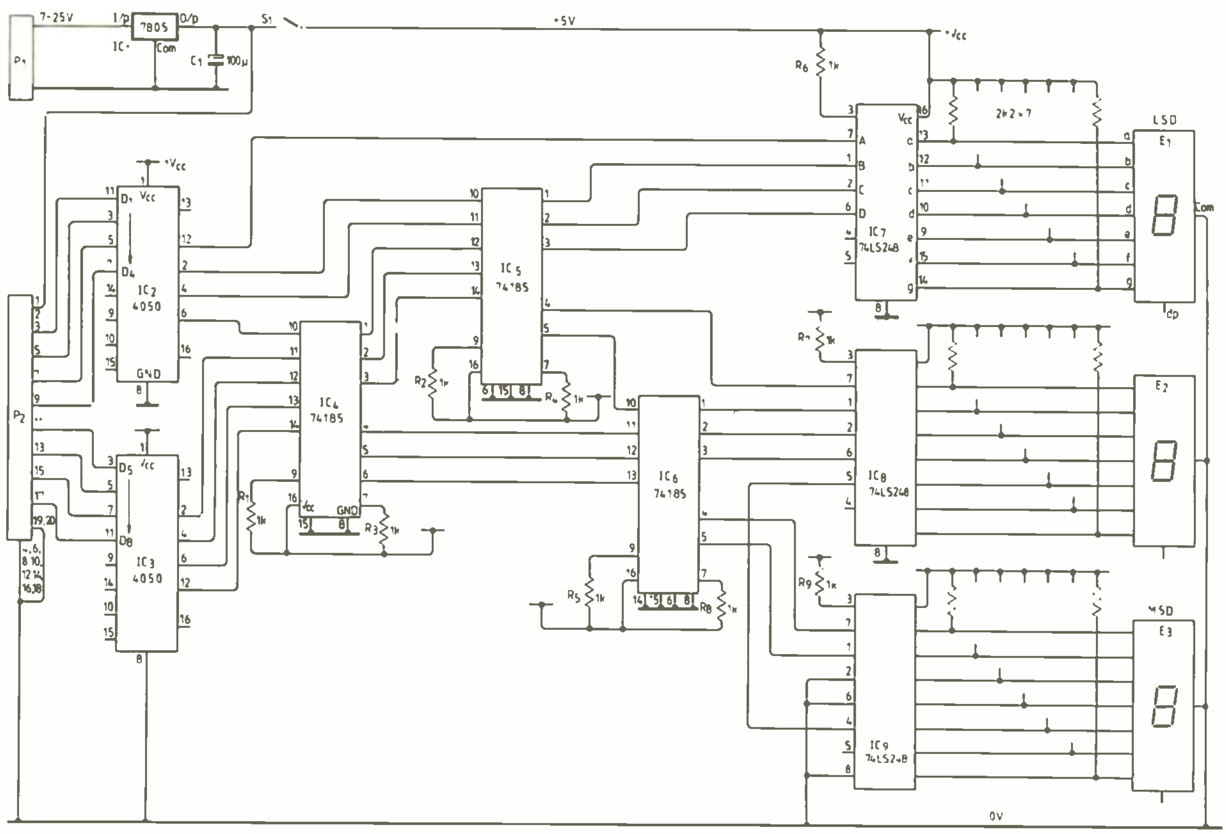


Data converter

This circuit can convert 8-bit binary data to decimal form for data acquisition quickly and accurately and display the result in digital form.

Binary data is applied at the input port via P2. The unit is powered via pin 1+2 (+5V) and 19+20 (0V) of P2 from the host unit or it could be powered separately by a +7.5V or greater via P1.

The rest of the odd numbered pins are used as data lines, pin 3 and 17 being MSB and LSB, respectively; even-number pins are grounded.

The eight signal lines from P2 are connected to IC_2 and IC_3 for buffering before the binary-to-BCD conversion is carried out by IC_4, IC_5 and IC_6, which are converter chips derived from the MSI 256bit roms. Unused inputs and outputs of the ICs are connected to logic 1 and 0 as required.

Since the integer range of the 8bit binary data is 0 to 255, only three BCD-to-seven-segment decoder/drivers, IC_7, IC_8 and IC_9, need to be used. Three packs of seven serial-in-line resistor networks have been used as pull-up resistors to make the display brighter.

K. Miah
Wexham
Slough

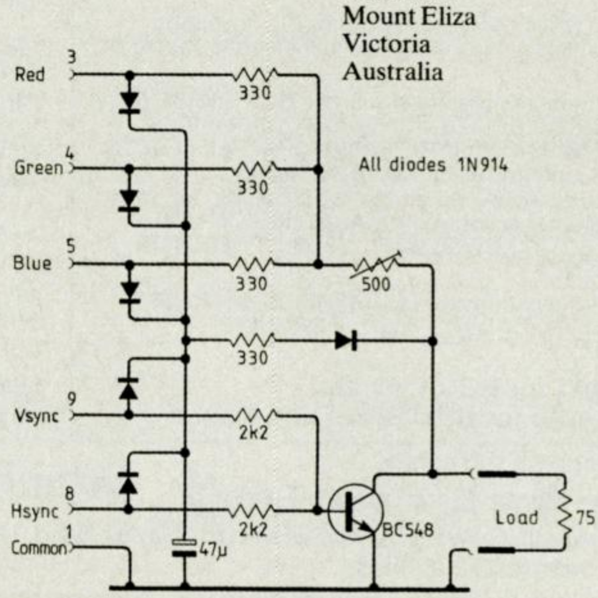
RGB to composite video without power

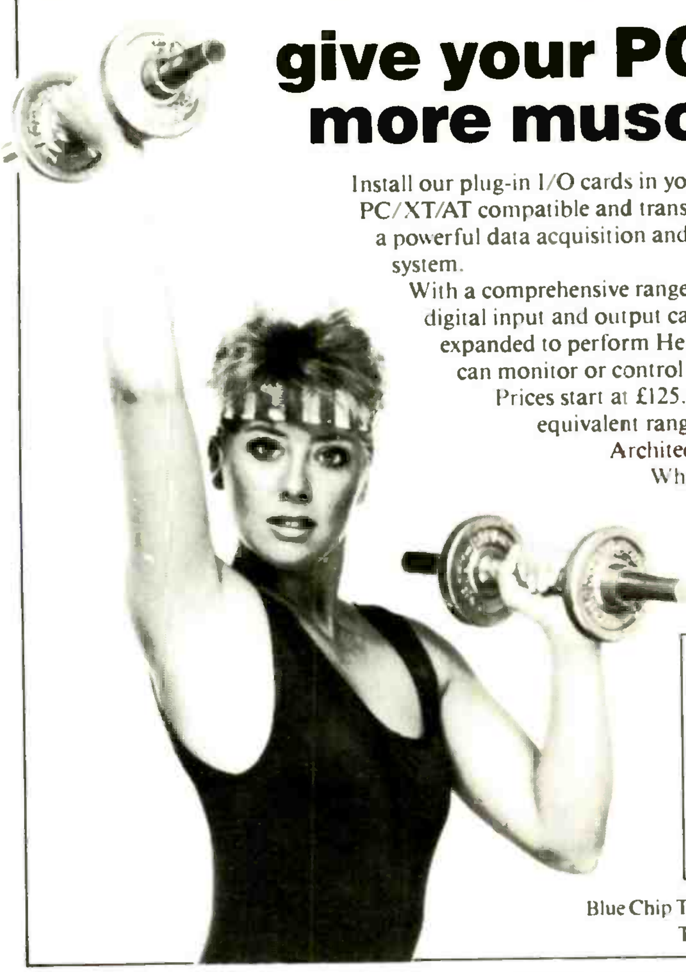
Video RGB signals can be converted into monochrome composite video without a separate power supply, even when both the incoming sync. signals are short positive pulses (4μs for line sync. and 200μs for frame on several different PCs that I tried).

The trick is to use diodes and a capacitor to produce a 1.5V supply for the sync. pulse pedestal. There is no need to shift the output as most, if not all, monitors are capacitively coupled internally.

We have tried the circuit with EGA graphics and text on several combinations of PCs and monitors.

Ron Davis
Mount Eliza
Victoria
Australia





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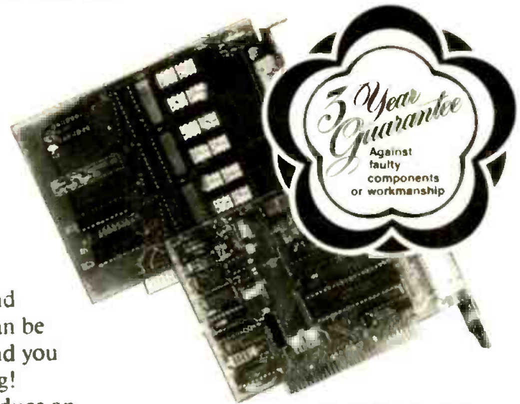

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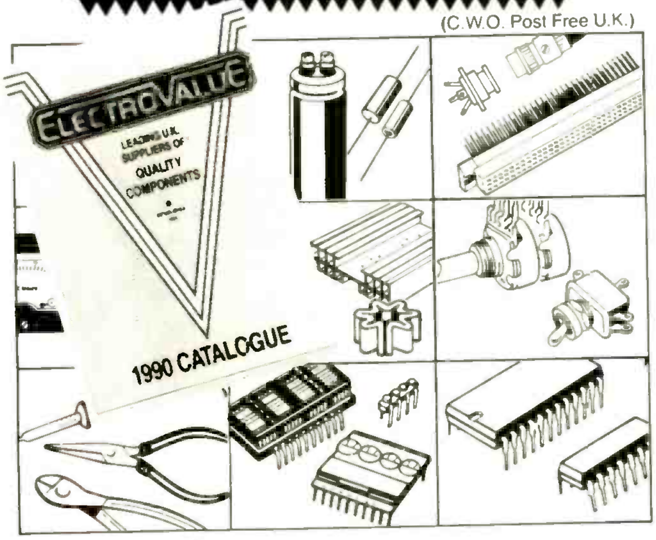

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CIRCLE ENQUIRY NO. 111 ON BACK PAGE

LIGHTNING LOCATION

The Electricity Council's monitoring equipment, described by Laura Scott, uses the Earth/ionosphere waveguide cutoff to separate signals from horizontally and vertically polarized lighting flashes

Damage caused by lightning to the UK electricity supply distribution system costs around £4 million a year. Despite this significant damage, lightning has been virtually unquantified in terms of the location, time and strength of each flash. If such information were available, it would allow equipment failures and the performance of protective devices be related to lightning occurrence. This information would, in the long term, provide a more secure electricity supply. Knowledge of the location of lightning would facilitate overhead line working and increase the safety of personnel during such operations.

Damage is caused by cloud-to-ground flashes which form about a third of what is normally called "lightning". The remaining two-thirds comprises intra and inter-cloud flashing. It is important to discriminate between these types of flash.

The requirement was therefore to provide a real-time monitoring and warning system which would log cloud-to-ground flashes. Measured parameters were to be location, time, magnitude, multiplicity (number of flashes within 100ms in the same place) and polarity (positive or negative charge lowered to the ground). To facilitate supply-system operations, a VDU map display of the flash location (with pan and zoom) was required.

Radio direction finding techniques applied to the electromagnetic radiation from lightning ('sferics) were well known. The alternative technique (time of arrival or TOA), where the arrival time of a 'sferic at several receiving stations is used to deduce the source location was considered but, because of the problems in establishing and maintaining a time reference within a few microseconds at remote unattended receiving stations, was considered too complex for the limited resources available.

Automatic direction finding

Work was therefore started on an automatic direction finding (DF) system operating at a frequency of 10kHz and bandwidth of 1kHz. This frequency was chosen largely for historical reasons, the British Meteorological Office having had a manually operated cathode-ray direction-finding system (CRDF) in operation for about 40 years at 9kHz centre frequency.

Four remote 10kHz DF stations were set up, covering the southern half of the UK and connected by telephone (data)

lines to a central computer. Propagation times of the data lines were stable to a few milliseconds and the times at which flash data were received from each DF were correlated to establish flash identity. The tangent of each flash bearing was sent together with a quadrant identifier.

DF aerials at each station were a pair of orthogonally mounted loops on square frames of 0.5m sides, each aerial being mounted on a wooden pole 10m high. Loop signals were bandwidth-limited, amplified, rectified and applied to electronic circuitry to determine the tangent of the bearing angle.

Results with this system were poor. Error triangles formed by the intersection of bearings from three stations were tens of kilometres to a side and there was often negligible correlation with known storms.

It was considered that the poor results were probably due to the presence of a horizontally polarized downcoming wave component, produced by an intermediate reflection at the ionosphere, which was interacting with the ground wave in the direction-finding loops.

This effect has been analysed and is depicted in simplified form in **Fig. 1a** where GW is the surface wave and AW a component of the anomalous (i.e. reflected) wave. H_g, E_g, H_a and E_a are the respective electric and magnetic field components of GW and AW. Component AW lies directly above PV, the Poynting vector of GW at the earth surface. The angle β between 0° and PV

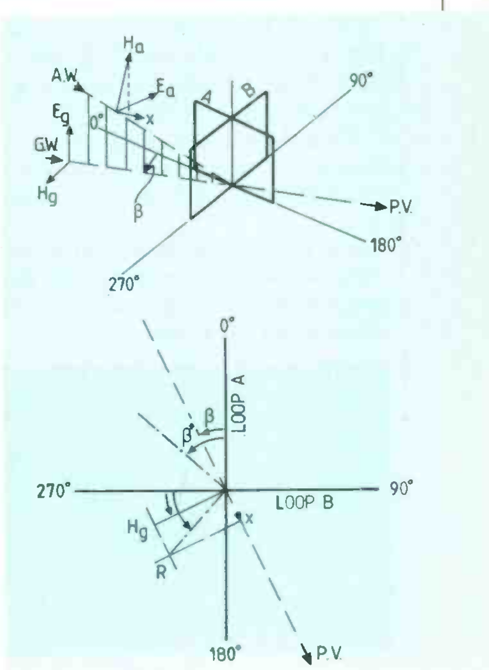


Fig. 1. Wave vectors incident on orthogonal loop pair are shown at (a), the plan view at (b) showing bearing error due to wave component x.

Pictures above are of lightning strikes in Wales, showing programmable overlays – in this case the 400kV overhead power lines in blue, 275kV in red and 132kV in white. Lower picture of central Wales shows Electricity Board boundaries in green.

Fig. 2. DF aerial with three loops at 120° apart, mounted on a 5m mast with the head amplifier near the base.

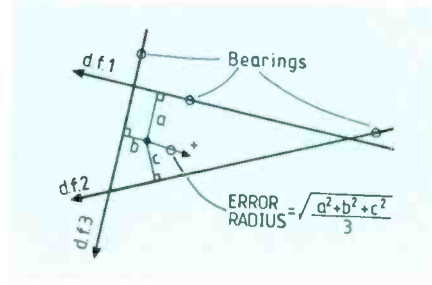


Fig. 3. Derivation of the error radius, where the cross indicates the mean of two station fixes.

is the desired bearing of GW with respect to the orthogonal loop pair A and B. Component H_a, being normal to the Poynting vector of AW, has a component x in line with GW at the earth surface. This is shown in plan view in **Fig. 1b**. The addition of H_g and x produces R which, acting in loops A and B, gives an erroneous bearing β^*.

Thus the horizontally polarized components of anomalous waves were the probable cause of the bearing errors and means were sought to overcome the problem.

Reduction of anomalous component

Following waveguide theory[1] it seemed that increasing the operating wavelength to a value equal to or greater than the earth-ionosphere waveguide cut-off wavelength would greatly reduce the magnitude of horizontally polarized waves propagating in the waveguide. Such waves are subject to high attenuation compared to the vertically polarized wave components. This attenuation is significant in the context of horizontally polarized waves produced at the ionosphere, due to interaction with the geomagnetic field.

Horizontally polarized waves caused by horizontal structures in the source lightning flash are greatly attenuated by earth coupling losses and are insignificant at ranges beyond a few tens of kilometres.

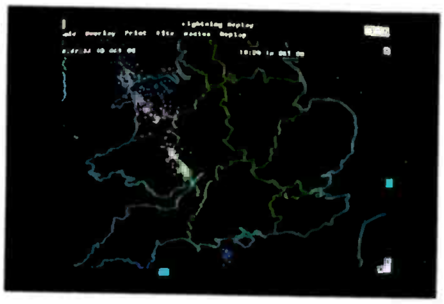
Choice of operating frequency

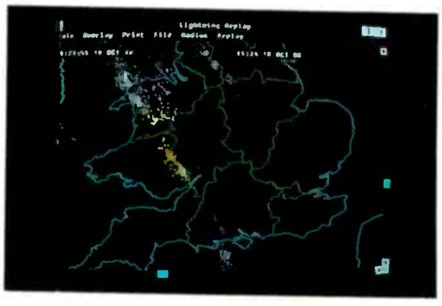
The effective daytime height of the ionosphere for VLF waves is 75km, which suggests a cut off at 2kHz for the horizontally polarized components.

An experiment was set up to check the feasibility of 2kHz operation. This comprised a vertical orthogonal pair of 1m square loops with a horizontal loop of similar size mounted below in such a way as to have negligible coupling with the vertical loops. The purpose of the horizontal loop was to detect the presence of vertical magnetic fields caused by anomalous waves. Electronic circuitry was included to measure, time and store the voltages induced in the loops by the lightning discharges.

The experiment was run during a summer season and the bearings were compared with the locations of known storms. Good correlation was observed. Signals in the horizontal loop were less than 2% in magnitude compared to those in the vertical loops. There was

Fig. 4. Replay of lightning activity on 18 October 1988. Flashes are shown in red, for 10min old flashes, green at 10-20, blue for 20-60min, magenta for 1-2h, white for 2-3h and yellow at 3-4h. Lightning is seen spreading across N. Wales while a second line develops in Lancashire.





thus a basis for a 2kHz direction finding system and effort was directed to this end.

DF aerial design

Conventional orthogonal DF loops, as shown in Fig. 1a, require the associated electronics to handle a very wide range of signals, since the bearings vary between 0 and 90° with respect to each loop. There are also problems with phase measurement, which is needed to determine the bearing quadrant. Thus a new configuration using three loops mutually at 120° has been used. With this arrangement, two of the loops always have a relatively large signal and the contribution of the third loop is downweighted as it approaches zero signal. Quadrant determination is eliminated. **Figure 2** shows a DF aerial mounted on a 5m pole with the head amplifier box near the base of the pole.

System realization

During 1985 a network of three DF stations was completed, forming a basic cell giving primary coverage to the southern half of the UK.

Stations are separated by 250 to 350km this being dictated by the geography of the British Isles and the need to maintain large subtended angles from flash locations to the DF stations for best accuracy.

Each DF reports bearings, flash strength and flash polarity as primary parameters. Flash strength is in 1.5dB increments within a signal range of 48dB. Analogue and digital signal overloads and the ratio of horizontal-to-vertical loop voltages are also sent with each flash report.

Dedicated data lines are used between the DF stations and the central computer, each having a known delay of around 10ms. Coincidence of time of flash from each DF to within 4.5ms is used to identify the flashes. Each DF can handle up to 40 flashes a second.

The DF stations have a dynamic range of 87dB, limited by the noise floor; external noise is equal to or greater than the noise floor by 6 to 8dB.

Three stations provide a measure of self checking, in that there should be good agreement on flash location from the three pairs of bearings available. To quantify this agreement a quality number was introduced; this is the radius in kilometres from a nominal flash location, given by the system, inside which there is a 2/3 probability of the flash being located. This parameter is known as the "error radius" and its derivation is shown in Fig. 3.

Performance

Location is the main requirement of the system and is the most difficult parameter to verify. Relative performance can, however, be judged by reference to a parameter such as the error radius. This can be supplemented by on-the-spot observer reports of lightning but, for the most part, these serve only to identify storm locations. A few flashes are sufficiently isolated in space and time that they can be clearly identified, but these form less than 5% of the flashes reported by careful observers.

In 1986, working from the error radii, plus a few observer reports, it was decided that there remained location errors of around 15 to 20km, the most likely cause of these errors being residual anomalous wave components.

We therefore decided to further reduce the operating frequency to obtain better rejection of anomalous components. The centre frequency was made 1.1kHz with a bandwidth of 350Hz and the lower passband limit was fixed by electricity distribution-system noise fields, which increased rapidly below 800Hz. The upper limit was set by the need to maintain a worthwhile reduction in the operating frequency.

These modifications were carried out during the winter of 1986/87 and it was apparent during the first lightning storms of 1987 that there was a marked reduction in the error radii. The mean error radius in the service area had reduced to 6km. Of the flashes reported by observers during 1987 five could be positively identified and were found to have location errors of 4-7km.

Detection efficiency is controlled by the attenuation with distance of the lightning flash signal and the strength of the flash current at source. It also depends upon the sensitivity and dynamic range of the detecting (DF) stations, but these are not limiting factors except in the case of unusually high site-noise levels.

Based on a mean absorption of 2.5dB per 100km, plus spreading attenuation, the detection efficiency appears to be 98% at 300km, falling to 96% at 400km. A lowering of the DF station threshold level of 6dB would allow a detection efficiency of 99% at 400km, but would bring in many more flashes from greater distances. These figures use the flash current population due to Anderson and Eriksson.[2]

Display units

Flashes are displayed on colour VDUs which show an outline map of the British Isles and near continent. Various programmable overlays are available. Those shown here contain some details of the overhead electricity distribution system. Pan and zoom are provided, allowing the vertical scale of the map to represent from 1600km down to 100km.

A colour printer gives hard copy of the screen display. Flash data may be stored for months in the VDU and can be replayed as desired.

Remote displays are served by BT data lines, the flashes appearing on the screen within seconds of their occurrence. The photographs in Fig. 4 are of a VDU screen showing a replay of lightning activity on 18 October 1988. ■

THE EARTH/IONOSPHERE DUCT

The Earth is surrounded by the ionosphere, which is a conducting gaseous shell with an insulating gap of 50–100km, as ELF waves are concerned. Radio waves used for communication purposes penetrate the various ionized layers up to a few hundred kilometres altitude. Their wavelength is very small compared to the ionospheric gap and it is usual to consider them as rays which are reflected back to Earth from the ionosphere.

At ELF, the ionosphere gap may be comparable to or less than a wavelength; a gap of 75km is a half wavelength for 2kHz. Thus, ELF waves generated between the Earth and ionosphere propagate round the Earth trapped in a two-plate waveguide or duct.

For the frequencies employed here (0.9–1.3kHz) the waveguide exhibits cutoff at all times to horizontally polarized energy, which therefore does not propagate to any significant extent. Vertically polarized waves (whose electric fields terminate on the Earth and ionosphere) are not subject to cutoff and propagate radially from the source.

The attenuation for waves longer than cutoff depends almost entirely on the ratio of the cutoff wavelength to the actual wavelength and is substantially independent of the shape of the guide and of the guide wall conductivity. Hence, one may calculate the attenuation for horizontally polarized waves.

References

1. Terman F.E. Radio Engineering, pp. 117–139. McGraw-Hill, 1951.

2. Anderson R.B. and Eriksson A.J. Lightning Parameters for E Engineering Applications, *Electra*, vol. 69 (1979), p.82, Fig 7.

I wish to thank the Director of the Electricity Council Research Centre for permission to publish this article.

Who's who in DSP?

Jon Mosely examines popular digital signal-processing chips and their capabilities. They are no longer slow and expensive, but can be used in almost any application where speed is called for.

Although microprocessors have been around for about fifteen years (since Intel developed their 4004), single-chip DSP devices are a more recent development. The reason is simply the performance required: if a 4004 was slow it didn't matter—an adding machine or a teletype doesn't need to be fast. But DSPs are used in real-time applications, which can't "hang on just a second": a chip with a cycle time of 10ms is of little use in an adaptive modem needing a fresh result every 100µs.

A DSP chip is used where real-time (or near real-time) performance is needed. Off-line systems can use any form of processor that is convenient, but an expensive DSP chip will only be considered for applications where fast response time is required. Early devices were slow and expensive and were used in a relatively limited number of applications, such as seismic analysis. Telecommunications was the next area of use: as processing speeds increased, chips were usable with the 3kHz bandwidth telephone system for applications like modems and echo-cancelling circuits.

Intel introduced the 2920 in the late 1970s and this is sometimes mentioned as the first DSP chip. However, it was very slow, calculating multiply operations in software, and was never especially popular. In 1980 NEC released their µPD7720, which made the 2920 obsolete—Intel scrapped it and withdrew totally from the DSP market. With a dedicated hardware multiply/accumulator, the µPD7720 can legitimately claim to be the first single-chip DSP device and all subsequent devices have drawn from its design. It was soon followed by others, most notably the Texas Instruments TMS32010 in 1983, a stalwart chip that is still popular.

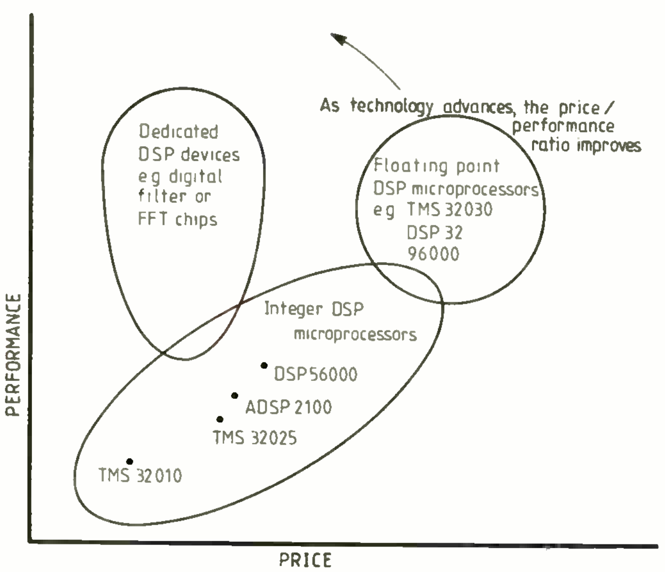
Device speeds and power have increased dramatically with each generation of processors, and DSP-based devices can now be used in a range of applications that includes graphics, control and scientific number-crunching. The new wave of devices is more powerful and easier to use than ever before—if you're designing a system for almost any fast application then these chips are well worth considering. A DSP board can be more useful than a fast, conventional processor/co-processor pair.

There is a huge number of chips produced by many manufacturers, but here is a very brief resumé, giving some figures (which are impartial, I hope) and some comments (which are not!). **Figure 1** shows how the price and power of common DSP chips have progressed.

Texas Instruments

It is impossible to discuss DSP without talking about TI; they practically invented the subject and have made it their own. Since its introduction with the 32010 in 1983, the TMS320 family of single-chip DSP devices has grown to 18 different members in three generations. Some are standard parts, some are optimised for particular specialist applications—and some are simply obsolete!

Like its contemporary, the 8088, TI's first DSP chip set a standard. Newer devices have to follow, even though this sometimes forces the chip designers into design compromises to maintain com-



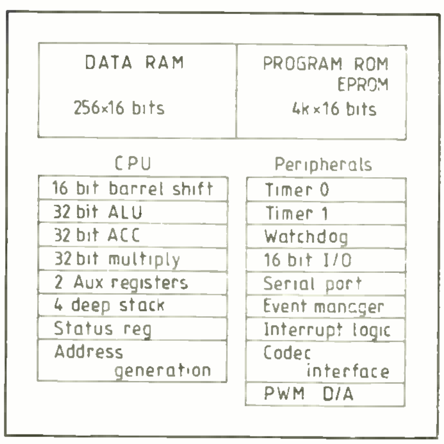


Fig. 2. Texas's TMS32014, running at 25MHz, contains the peripherals needed by a microcontroller while providing the capabilities of a DSP chip.

Fig. 1. Relative prices and performance of some common DSP chips.

patibility. The family's instruction set is now outdated, idiosyncratic and notoriously unfriendly, but it lives on. For example, branching is slow, so engineers try to avoid loops and write everything out explicitly several times (straight-line code). Consequently, programs eat memory.

More designers have chosen TI's DSP family than any other. According to the industry analysts Forward Concepts, TI has at least 63% of the DSP processor market. However, they are not exciting devices. If DSP chips were cars, then the TMS range would be Ford Sierras: worthy, reliable and popular they may be, but there is nothing to make hearts beat faster or turn heads in the street.

The Texas range has the important attraction that it is a single family of code-compatible parts. The early, simple parts such as the 32010 are well suited for control applications and are available very cheaply. There is a huge range of options, including fixed and floating-point versions, large and small memory versions, telecoms devices, controller-oriented chips and devices intended for a number of other specialist applications.

32010 was the first successful DSP chip and has been very widely used, but the series is now essentially obsolete. The exception to this is the 32014, a spin-off part released last year and intended for control applications. The block diagram is shown in **Fig. 2**. The idea is that the device has the speed and numeric ability of a DSP chip, together with the on-chip peripherals of a micro-controller. It runs at 25MHz, which TI claims makes it the world's fastest micro-controller at 5 to 10 times faster than conventional 16bit devices, although I doubt that this is still true with the release of the new risc-based controllers. In addition to its standard CPU core, the chip has five peripheral blocks, including four timers (watchdog, baud rate generator and two general-purpose blocks), 16 general-purpose I/O pins, a versatile serial channel and an event manager for fast pulse capture and generation. It is intended for use in embedded applications which would benefit from sophisticated control algorithms, such as robotics, engine management systems or fast servo-motor control.

The 32020 range was released next, with an enhanced set of 109 different instructions, indexed addressing and more on-chip memory: in many applications, these devices offer more than twice the speed of a 32010 part. The initial 32020 is now out-dated, but the subsequent TMS32025 **(Fig. 3)** is the staple product in the DSP world. While significantly faster and more powerful than its predecessors, it is pin and code compatible with the 020 and its code is upwardly compatible with the 010.

It is made in what is now a mature 1.8micron c-mos process. It is a 16bit device, with a single, standard 32bit multiplier and ALU. Internally, this chip has a modified Harvard architecture (separate buses and memory spaces for program and data) with 544 bytes of on-chip data memory and 4K internal program space; however, it doesn't extend these externally to its 128K address range, sharing the buses. It has 24 instructions more than the 32020, and an additional eight registers.

A weakness of the device is that it does not have dedicated multiply/accumulate hardware in the processor. This operation (a=b×c+d) is a fundamental one in DSP technology and is extremely important. For the 325 to calculate this operation it needs to use the separate multiplier and ALU, multiplying in one cycle and adding in the next (although pipelining can overlap these two in repeated operations). It is inefficient and slow.

For FFT applications, a DSP chip needs some very versatile memory-addressing modes: ideally the address generator should allow linear, modulo and bit-reversed addressing, with offsets. The TMS32020 was notoriously weak in this area; although it did have an address ALU, this was limited to modifying just one address register by ±1 or the contents of a register. It has no modulo or bit-reverse capability; this lack of address-generation facilities substantially limits its performance for FFTs. The 32025 had several improvements, including bit-reversal facilities. This has always been a weak point of TI chips; the 025 is better, but the competitors are better still!

TMS32030 is a 32bit floating-point device and is the latest chip to be developed for the TMS320 family. I am

What makes a processor into a DSP chip?

This is one of those tricky questions without a definite answer.

DSP chips are simply processors that are designed to execute a particular type of program very efficiently. In general, the algorithms are fairly simple; there is often a fixed program that receives data, performs an operation on it and outputs the transformed data. It then grabs the next chunk of data and performs the same operation ad nauseam.

Conventional devices generally examine the data and decide what to with it; there is a bias to conditional sections of code, with alternatives and branches. DSP algorithms are more single-minded; often there is only one path, through which all data is passed. As a result, DSP chips are almost risc-like in the simplicity of their instruction sets, with very few operations supported.

The distinction is not a clear cut one; some high performance microprocessors can perform DSP tasks better than some of the devices mentioned here and some people say that some of the above devices are better treated as fast microcontrollers, rather than DSP chips. The older TI chips are now being promoted for these applications; the documentation describes how they can be used in control applications such as anti-lock braking or engine management systems.

Data width and dynamic range.

Very early devices were all 8bit chips; now most have a 16bit data width. In conventional processing, the word size is primarly increased to speed up the processing and handle more data in a given time — the increased precision is rarely required for any fundamental reason. DSP is different; the numbers that the chip is processing represent analogue signals in the real world. If they are held to a low precision, then quantisation errors will be introduced and the usefulness of the DSP system will be severely compromised. An 8bit system has a dynamic range of only 48dB, which is totally inadequate for any practical purposes.

For the majority of signal processing applications a 16bit word length is more than enough. This gives 96dB of dynamic range, which is pushing the limits of attainable performance from the analogue circuitry, even with rounding and quantisation errors reducing this. Although few applications need more than this, the 32bit fixed-point devices are being introduced to meet the ever-growing demand for processing power and increased performance; these are the flagship components of the industry. Very few users will directly need the full 32bit resolution of these devices (192dB) but this huge word width has other advantages.

In particular, 16bit device users have to be careful about rounding errors or numeric overflow at intermediate stages of the calculation. Checking that this doesn't happen and scaling the values accordingly all takes valuable execution time. By increasing the word size so dramatically, this intermediate scaling and checking process becomes redundant allowing even 16bit applications to benefit. Motorola decided this was an extravagance; their mass-market device is the 24-bit DSP56000.

Floating-point devices have an essentially infinite dynamic range. They are intended for different applications: primarily for scientific number crunching, rather than traditional DSP applications. While the numbers associated with, say, the stresses in a finite-element mesh program will have "sensible" values at intermediate times, the results of the calculations could be very much larger or smaller than could be handled using a fixed-point representation.

not entirely certain how substantial its existence is—there are many rumours as to availability. It is a *very* fast device, offering a 32bit floating-point multiply in only 60ns, giving 33Mflops!.

A significant improvement over the 32020 is that the 32030 has two powerful address ALUs, which can operate independently and also support DMA operations. However, the core of the machine is still compatible with the rest of the family. It is a modern chip, with more than 700 000 transistors, which give it twice the integration level of the Intel 386 and allow it to take advantage of the latest developments in silicon design, such as cache storage (a 64-entry instruction cache on-chip). Unfortunately, its floating-point representation is unique to TI, so is incompatible with any other devices.

Summary. Some nice chips; the 32025 is the *de facto* industry standard, the 320C14 is an absolute natural for fast control applications and the 32030 is set to become the obvious power processor of the 1990s. They are very popular, with standard software and good support. On the down side, they are not as fast as they might be, they have a nasty instruction set, and use memory like it's going out of fashion.

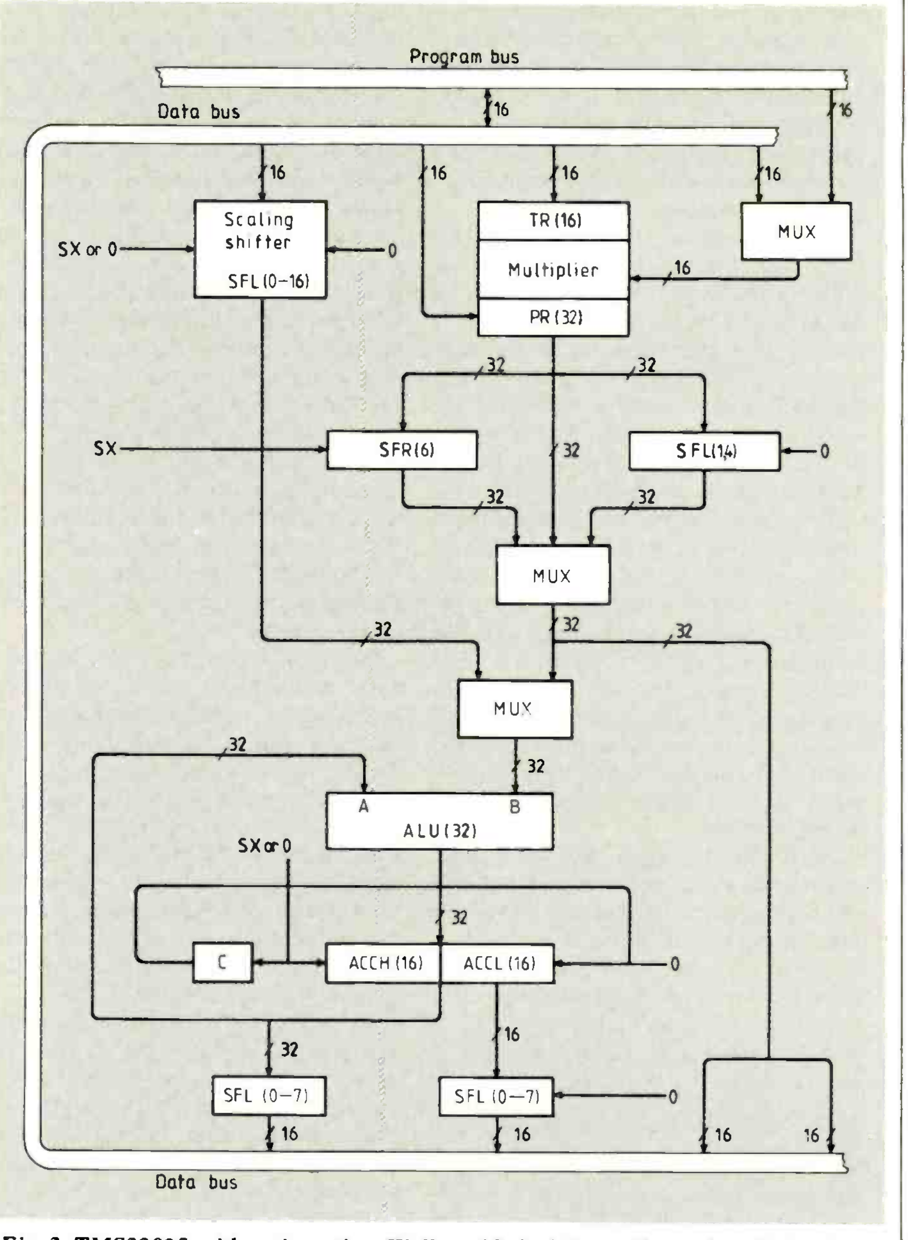


Fig. 3. TMS32025 arithmetic section. Well established, but suffering from lack of a multiply/accumulator (MAC) and inelegant architecture.

Analog Devices

This company is most famous for its precision analogue components; op-amps and the like. With a tradition of manufacturing A-to-D and D-to-A converters, it obviously seemed logical to join the two by developing a DSP chip, which they have done in the AD2100 series, which is a straight-forward 16bit integer-only processor. It is based on Harvard architecture, with all buses extended off-chip, as shown in **Fig. 4**.

The 2100 has two parallel 16bit arithmetic units; the ALU and the multiply/accumulator. They have similar structures, with four registers arranged in pairs (AX0, AX1, AY0, AY1), operations using a register from each bank at the same time as transfers to or from the other pair. As a result, up to three op-codes can execute in parallel:

AR = AX0 + AY1,
AX1 = DM(I0,M0),
AY0 = DM(I1,M1)

which adds two registers and loads two more from data memory (DM). Simultaneously the multiply/accumulator could be executing an instruction using its own internal registers:

MR = MR+MX0*MY1,
MX1 = DM(I0,M0),
MY0 = DM(I1,M1)

This will perform to indexed data transfers and a 16bit multiply-and-accumulate operation in a single 80ns clock cycle. Typically, the ALU will be used for incrementing and loop control, while the MAC executes a DSP function—an FFT, for example. The looping is tested and implemented without inflicting an overhead on the maths functions—very neat.

This type of fast processing and concurrent operation is at the heart of DSP; doing these things, and doing them fast, is what makes a processor into a DSP processor.

2100 is most interesting because of its use in an unusual application: Atari are using it as the heart of their latest arcade machine "Hard Drivin'", which attempts to simulate driving a racing-car. I have never driven a racing car, so I don't know how accurate it is, but it seems realistic and is certainly good fun! The AD2100 is used as fast number cruncher to handle the 3D trigonometry involved in the simulation and polygon transforms for the display. It is used as a co-processor with a 68000, while a TI graphics chip handles the screen; a novel use for a chip, but one that works very well.

Summary. This is a chip from a company which understands the other end of the signal processing-field; a nimble and well designed chip, with a clear instruction set. Unfortunately, it is starting to look a bit long in the tooth and

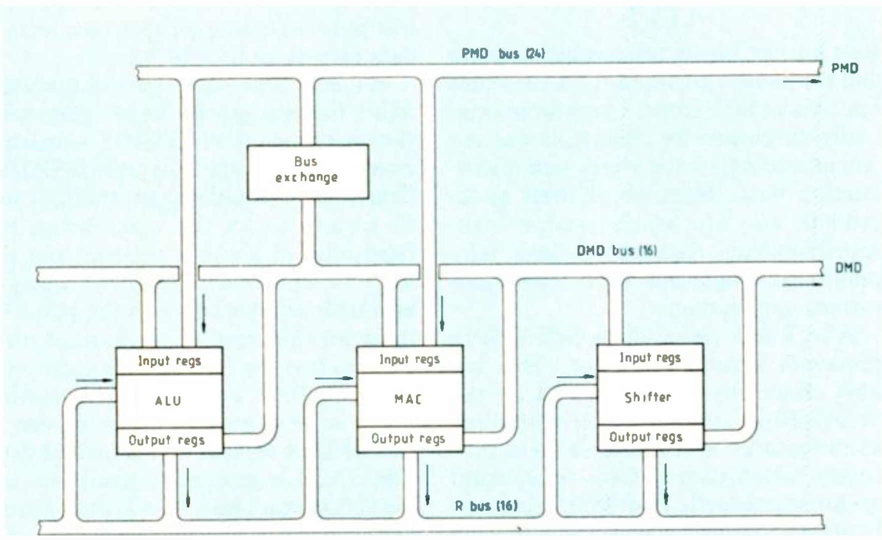


Fig. 4. Analog Devices ADSP2100 has dedicated MAC and straightforward arithmetic section.

perhaps somewhat out-dated. As you would expect from Analogue, the documentation and application support is superb.

Motorola

This company has entered the DSP arena late, evidently preferring to bide its time and wait until the market has matured and designs settled down. This has given it the enviable luxury of taking its time and designing a device from scratch, rather than being constrained by the need to remain compatible with an old architecture—an advantage it has exploited to the full. These chips also benefit from being the newest on the market; they are big devices and considerably more modern and more powerful than their competitors. There are two processor ranges: the DSP56000 is a well designed 24bit integer device, which is becoming increasingly popular, while the 96000 is a 32bit floating-point chip to be released in early 1990.

DSP56000 is a very nice device. It is a 24bit fixed-point device, with an unusual architecture which is very well suited to the needs of DSP applications. Conventional micro-processors have a von Neumann architecture, with a single memory space accessed by an address bus and a data bus, which is shared between data and code. A pure Harvard architecture has four buses to separate memory spaces entirely; one contains the program code, while the other is used exclusively for data. The attraction of this is that program reads can happen at the same time as data memory accesses, making things much more efficient. It is used in several DSP devices and risc processors.

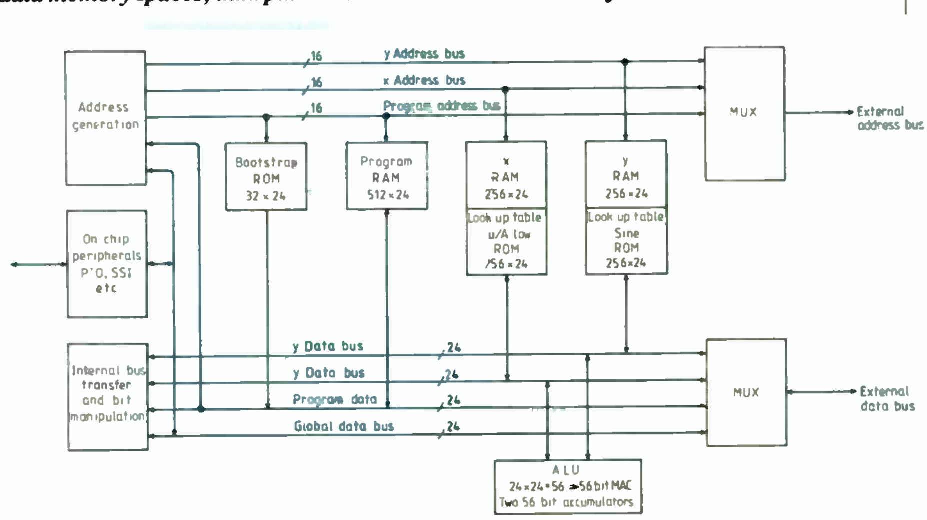
56000 extends this idea by having a program memory and two separate data memory spaces. This is very well suited to DSP applications; the two can carry the real and imaginary parts of a complex number, X and Y coordinates for a graphics system or the data and coefficients of a digital filter implementation. A classical approach would require two cycles to fetch these data pairs, with consequent delays. The 56000 can access both simultaneously, while also reading an instruction from the code space. This is shown in **Figure 5.** Whilst this is the case for internal memory, pinout limitations have imposed an unfortunate compromise: there are three external memory spaces (code, X and Y) but one bus pair (address and data), which is multiplexed. Consequently, internal data can be accessed with maximum concurrency, but external data needs two accesses.

The chip is also unique in having a 24bit data width. As applications become more demanding, the limitations of 16bit calculation become apparent, as has been seen in the conventional microprocessor market. However, for most DSP applications, 32bits could be regarded as overkill. It simply is not possible to measure or generate a real signal to that precision; when did you last see an analogue circuit that had a 192dB dynamic range?. Motorola decided to compromise and produce a 24bit device, argueing that this provides most users with the power they need while keeping the costs down.

Interestingly, the chip has two ALUs; both of them 56 bits wide; conventionally, a 24bit chip would have a 48bit-wide multiply/accumulator unit. The attraction of the 56000 is that it allows for an additional 8 bits of word growth during calculations. This increases the chip's dynamic range to 336dB; reducing the need for scaling and cutting the risks of overflow.

This chip is very widely used in audio applications. Indeed, it is often cited as the *de facto* standard. At a recent AES conference there were 24 papers on DSP; all but one of them described work using the 56000. Motorola has a lovely demonstration using the chip as a digital stereo ten-band graphic equaliser. The DSP board takes the digital output directly from a CD player and implements the twenty filters on the 44.1kHz data stream, before passing it to a converter and then to a power amplifier.

Fig. 5. Motorola DSP56000 bus structure, which has program memory and separate data memory spaces; data pairs such as X/Y or Re/Im can be fetched at once.



Big brother of the 56000 is the 96000, which is due for full release early this year. It is a phenomenally powerful chip, offering 32bit floating-point operations that are forecast to run at 40Mflops peak speed.

As with its sibling chip,the 96000 has a double Harvard bus structure, with one code memory space and two separate data memories. However, this chip remedies the failing by having two genuine external I/O ports, allowing simultaneous access to both data spaces. Both of these ports have a full 32bit data bus, a 32bit address bus (allowing 4Gword addressing) and DMA capability. The obvious application for this is to access complex numbers in one go, but it has uses in, for example, graphics applications: reading from a frame store and writing transformed image data to local memory.

Its ALU follows the standard representation for floating-point numbers (IEEE 754-1985) which makes it easy to use the chip as a very powerful co-processor for standard devices such as the 68040. The ALU is actually 96 bits wide (Motorola, rather cheekily, claim that this makes it a 96bit chip).

Finally, the device supports one other neat feature: included on chip is a circuit emulator, which is an enhanced version of the Joint Test Action Group standard test circuit. Not only does this allow testing of the 96000, but it also allows hardware engineers full control of all parts of the processor, enabling them to exercise and check any other circuit in the system.

One of the major strengths of these chips is their family background; Motorola has exploited its presence in the processor market to develop and support them. The instruction sets are compatible, and both draw heavily on that of the 680x0 family, with the same elegance and very similar op-codes. This commonality gives users the benefit of familiarity and good development tools, since it is comparatively easy for Motorola to adapt their existing systems.

Summary. The 56000 is a fast, elegant and useful 24bit chip that is deservedly becoming very popular, particularly in digital audio applications. The 96000 is due to be released early this year. These are powerful devices; they are more modern than the competition and it shows. Finally, they are produced by one of the largest and most professional processor companies in the world—and that shows, too.

AT&T

Best known for its telecomms strength and for having invented C, AT&T also has a set of DSP chips. These were originally developed for their in-house use and accordingly have a very strong production base. Because of their background, they are widely used in high-speed modems, data comms links, telephone exchanges and other communications applications.

AT&T first released its WE DSP16 processor several years ago. This has now effectively been replaced by the WE DSP16A; a faster device with some extra features. It is a fast, modern processor which uses a 16bit fixed-point architecture with two 36bit accumulators. In a similar way to the Motorola parts, this allows for word growth during operations, increasing the chip's dynamic range. It is an amazingly speedy chip, with an instruction time of only 33ns.

On chip there is 2K of fast data ram and 4K of program space; enough for most DSP applications, which need high speed and data rate, rather than size. If more is required, both rom or ram can be expanded externally up to 64K bytes.

As well as its obvious territory for telecoms usage, the DSP16 is well suited to control applications, with some very flexible I/O. It has five interrupt sources, which can be masked for different applications. It also has a fast serial port (synchronous or asynchronous) which is used to access serial peripherals, such as telecomm CODECs or the bit stream from a CD player, or as a link for multi-processor systems. Finally there is a 16bit parallel I/O port accessing peripherals, with a data rate of up to 30Mbyte/s.

AT & T also has a pair of powerful 32bit floating-point chips: originally they released the WE DSP32, which has now been replaced by the DSP32C. Convention would suggest that a C suffix merely meant the same device but fabricated in a c-mos process, but the 32C is essentially a new design, upwardly compatible with the plain 32; it has an enhanced instruction set, runs twice as fast and has a different pin-out.

The DSP32C has the major attraction that it is the only one of the new generation of 32bit devices that actually exists! The 32030 is nominally available and the 96000 won't be released until Spring this year. It is a good workhorse of a device which runs at 25Mflops sustained.

It has two parallel arithmetic units. There is a core, which runs 16bit or 24bit integer operations, used for fast processing or address calculations. There is also the powerful floating-point unit, which has a 24bit mantissa and 8bit exponent. The chip does support the IEEE-754 standard floating-point representation. Internally, there are two banks of data ram, each 512 words long. There is also 512 words of code store which can be ram or rom. If this isn't enough, the external memory can address up to 16Mbyte.

Both of the DSP 16 and 32 have a very nice instruction set—clean and elegant and highly reminiscent of C. They are well supported with development tools.

Summary. Two modern and powerful chips from one of the world's largest

	TI	Analog Devices	AT&T	NEC	Motorola
	32025	2100A	DSP16A	77C25	56000
cycle time (ns)	100	80	33	122	74
data word size	16	16	16	16	24
program word size	16	24	16	24	24
ALU size	32	16	36	31	56
ALU registers	1x32	2x40	2x36	2x16	2x56
address registers	8	24	6	2	24
max. external memory	128K	48K	64K	none	192K
on-chip ram (words)	544	none	2048	256	2 256
on-chip peripherals	1 serial	none	1 serial 1 parallel	1 serial 1 parallel	1 serial 1 parallel
interrupt sources	7	4	6	1	18
pins	68	100	84	28	88
process	1.8μc-mos	1μc-mos	0.8μc-mos	?μc-mos	1.2μc-mos
power consumption	1.4W	0.8W	0.4W	0.12W	0.6W
	32025	**AD2100A**	**DSP16A**	**77C25**	**56000**
1024 complex point FFT (milliseconds)	9.1	4.2	2.5	40.9	2.4
code size for above	23636 words	3161 words			2804 words
IIR biquad filter (nanoseconds)	1000	560	125	1098	296

electronics companies. The DSP16A is a very fast 16bit integer chip that is well suited to DSP or control applications, the newest device the DSP32C, a powerful 32bit floating-point chip.

NEC

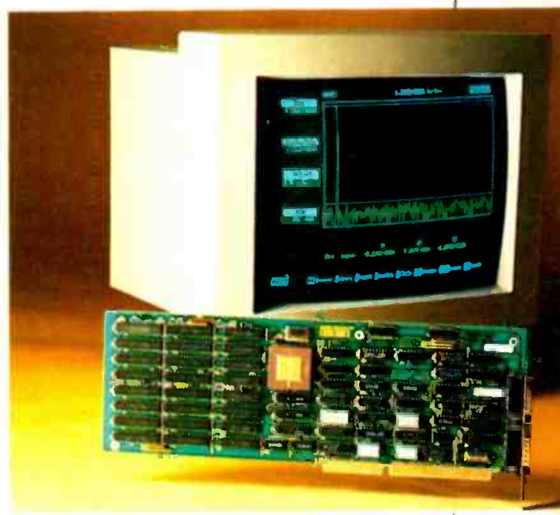
When NEC launched its 77C20 back in 1980, it was legitimately claimed to be the first genuine DSP chip. It possessed a dedicated hardware multiplier and its architecture was optimised for passing data rapidly through the processor. It used a Harvard-style bus structure, which separates the instruction and data paths and allows two fetches to occur simultaneously. In addition, there were several pipelines and different processing units could operate concurrently; conventional now, but unique in 1980, when its speed was quite striking.

The 77C20 has now been replaced by the 77C25; a faster, slightly more complex device which uses the same architecture. Both devices are intended for embedded application, in which the processor is configured as a slave device with a very restricted interface to the outside world and only runs from a rom or prom. Both have three internal memory spaces: program rom, data rom and data rom of 256 16bit words.

Intriguingly, the instruction rom is 23bit wide. In much the same way as risc devices, the layout of each instruction is rigidly defined with a fixed structure; all instructions are one word long and all execute in a single cycle. Code memory is 2048 words long. The data rom is used to hold fixed coefficients or a look-up table for a program. In the C20, this was 512 13bit words, but has expanded to 1024 words of 16bits in the newer device.

The C25 cannot address external memory. While this is not often significant for code space (very few DSP programs are longer than 2K), it is a major limitation on the number of data points that can be processed.

Summary. These devices are showing their age. Their design (slave-only mode, no external memory space) suggests that they were developed for a particular in-house application, perhaps in telecomms or control, before being generally released. ■



AT&T's newest 32bit DSP chip, the 50MHz DSP32C, calculates at 25 million floating-point operations a second, can evaluate a single-tap, finite-impulse-response filter in 80ns and perform a complex 1024-point FFT in 3.2ms.

The picture is of the Burr-Brown ZPB34, a 32bit floating-point DSP board for PCs, which uses the DSP32C chip. It provides up to 576K of ram.

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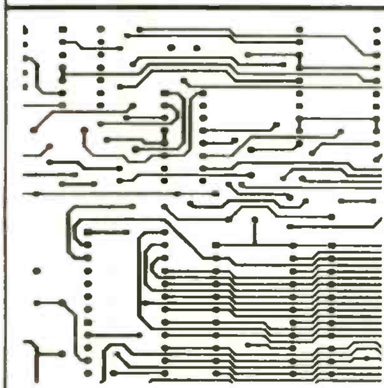

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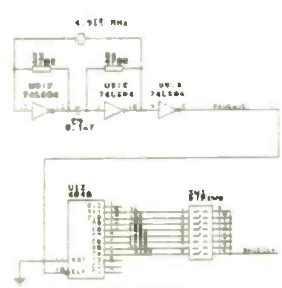

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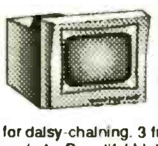

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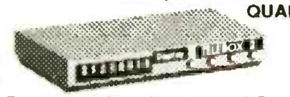

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CIRCLE ENQUIRY NO. 112 ON BACK PAGE

Wideband video buffers

A new monolithic, closed-loop, unity-gain buffer amplifier, the Siliconix Si581, features a bandwidth of 450MHz, signal distortion of −65dB at 20MHz and complements existing families of D/CMOS video switches and multiplexers.

Modern wideband switches and multiplexers require high-performance impedance transformation to and from a 50-ohm or 75-ohm environment without significant transmission loss. To drive coaxial cables or any reactive load, the wideband buffer may be used alone or in combination with a suitable wideband op-amp. Reactive loads require a low-impedance source (less than 50Ω) to preserve the operating bandwidth. Features and characteristics of the new buffer are listed in Table 1.

Circuit description

The device is fabricated with a complementary bipolar process which provides high-frequency n-p-n and p-n-p transistors with gigahertz transition frequencies.

The input stage is a complementary pair of differential transistors connected in parallel to provide excellent symmetry, overload recovery, and low noise. At the input, the n-p-n and p-n-p transistors have slight mismatches that give rise to the net bias current specification; depending on the direction of the mismatches, the bias cyrrent may flow into or out of the input terminal. The symmetrical class AB output stage provides current sourcing or sinking and relatively constant output impedance during load excursions.

Forward and reverse gain

An ideal buffer has exact unity gain from input to output, irrespective of load; the characteristic called forward gain. An idea buffer also allows a variety of complex (RLC) loads to be driven at the output without modifying the existing input conditions; this characteristic is called reverse gain and should be zero. Because of the wideband nature of the buffer, forward and reverse gain are specified in S-parameters, which are reflection and transmission coefficients used to describe a linear two-point network in the same way as Y, Z, or h parameters. Short or open circuits are misnomers in RF circles: instead, the network is defined in terms of incident and reflected waveforms. Waveforms are easier to measure, and the results are more realistic,

Fig. 1. Wideband 8×4 crosspoint using DG538 multiplexers and Si581 buffers. Decoupling of Si581s should be same as that for DG538

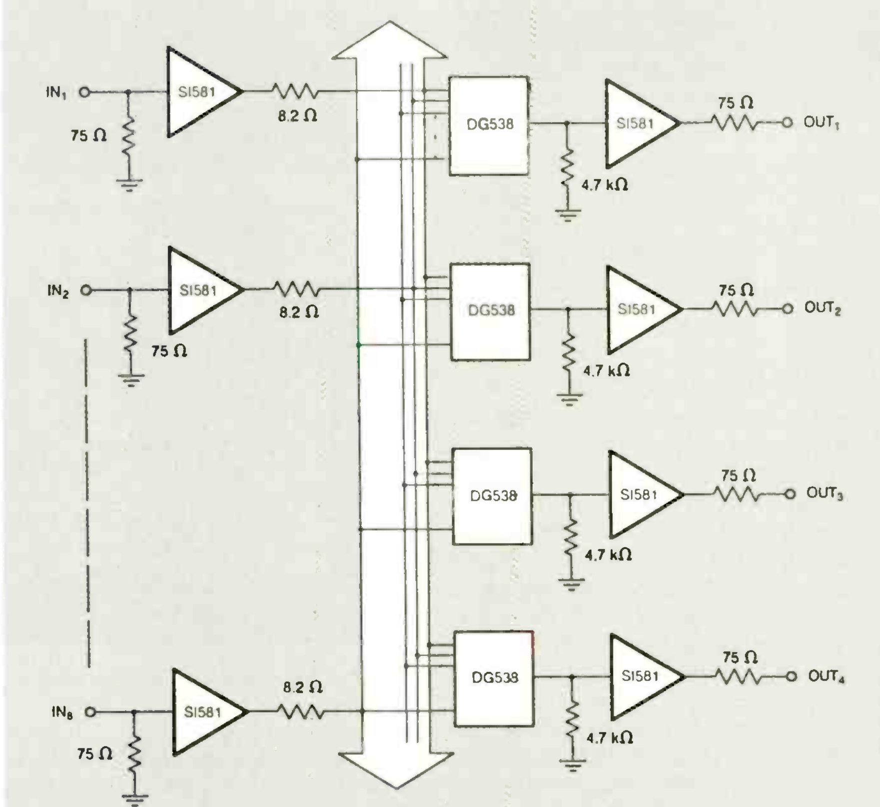
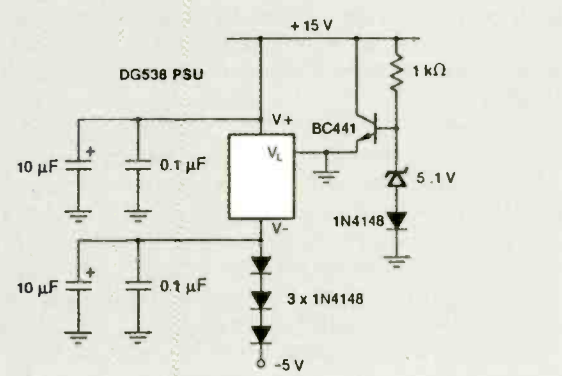


Table 1. Typical characteristics of the Si581 wideband buffer amplifier (R_L=100Ω)

Parameter	Condition	Si581
DC output current	R_L=100 Ω	±70 mA
slew rate	±5 V supplies	800 V/μs
−3dB bandwidth (MSBW)	V_0=1 V_{pp}	450 MHz
−3dB bandwidth (LSBW)	V_0=5 V_{pp}	90 MHz
voltage gain	V_0=5 V_{pp}	0.97
output offset voltage	V_0=5 V_{pp}	2 mV
input bias current	V_0=5 V_{pp}	±20 μA
dc output resistance	V_0=5 V_{pp}	2 Ω
power supply rejection	V_0=5 V_{op}	50 dB



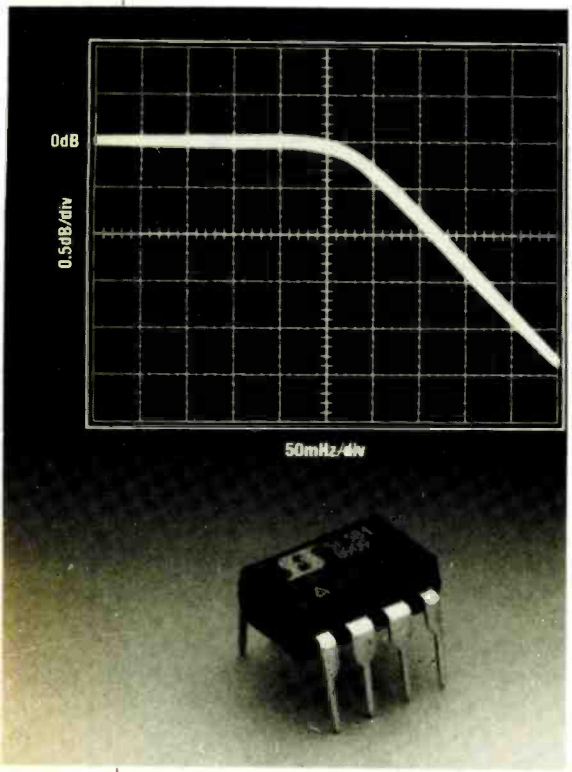


Table 2. Wideband 8×4 crosspoint using DG538 multiplexers and Si581 buffers

−3 dB bandwidth	145 MHz
−0.3 dB bandwidth	50 MHz
phase shift to 100 MHz	0 to −97°, linear slope
differential gain	−0.03% EBU test signal
differential phase	−0.03° EBU test signal

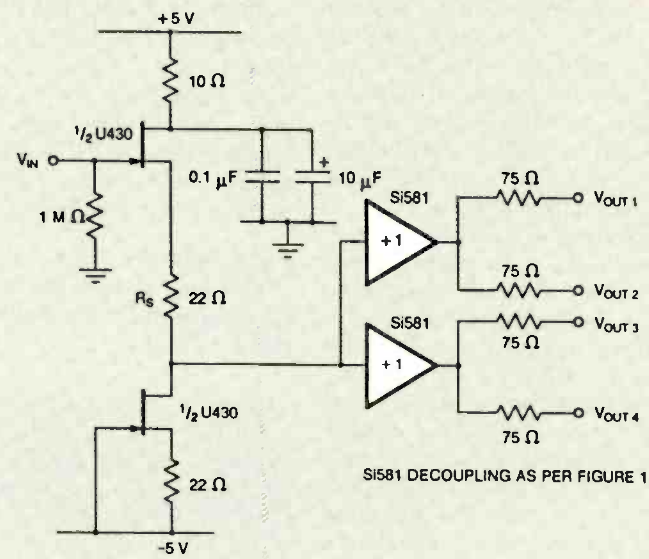


Fig. 3. Multiple-output high-performance buffer

above 50 to 100MHz.

At 500mV signal levels, the buffer's forward gain S_{21} is −0.2dB, +1° at 100MHz. At the same frequency and amplitude, the reverse gain is −60dB, +145°.

Video switcher

Figure 1 shows one application for the Si581: a wideband crosspoint system for a broadcast video studio switcher or a financial data distribution system. The 8×4 wideband crosspoint is formed by four DG538 8-channel multiplexers with their inputs connected in parallel.

Each input bus created by the crosspoint represents a considerably reactive load to the input signals, which would cause unacceptable signal degradation if it were connected directly to the 75Ω input sources. The input buffers provide a stable input termination, a low output impedance to drive the input bus, and a high output-to-input isolation. These features enable the input conditions to remain independent of the multiplexer loading.

The output buffers provide a 'high' impedance to the multiplexer outputs, which reduces the inevitable transmission loss if the load resistor is 75Ω. The low output impedance of the buffers allows a single series resistor in each output to provide a reverse termination of 75Ω. When correctly terminated, this resistor causes a nominal −6dB loss at the output, but also isolates any load

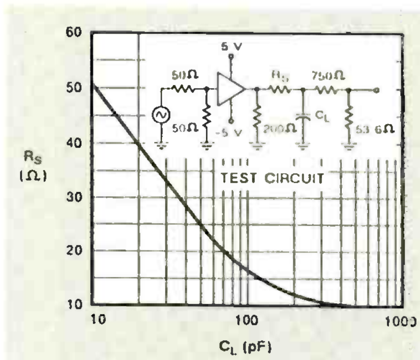


Fig. 2. Series isolating resistor and C_{LOAD} selection

capacitance from the buffer output terminal (load capacitance causes amplitude peaking in the passband). The series 8.2Ω resistor at the input buffers also isolates the switch reactance from the buffer output. Measured performance of this system is shown in Table 2.

To prevent the 6dB loss at the output, a wideband amplifier, such as the Si582, **configured for a gain of 2, may be used.**

Performance depends significantly upon high-frequency ground-plane techniques, symmetrical layout, and the correct use of the series isolating resistor. Where different capacitive loads are encountered (e.g., an 8×2 crosspoint employing two DG538 multiplexers), the curve in **Fig. 2** will assist in selecting the correct isolating resistor. As with all high-frequency work, resistors should be non-inductive.

In a design similar to that in Fig. 1, the Si581 may be used with the DG54× family of wideband switches to perform IF and/or bandwidth switching in numerous receiver applications.

Multiple-cable driver

Feeding several cables from one high-impedance wideband signal source is **the function of the circuit shown in Fig. 3. For optimum broadcast performance** <0.1% differential gain, <0.05° differential phase (EBU) the buffer should be restricted to driving two reverse-terminated 75Ω loads. This would give a nominal 75Ω total output loading.

The input stage is a compound source follower. It uses a matched pair of JFETs and equal value source resistors to reduce the input-to-output offset from several volts without correction to approximately 40mV. The output impedance of the input stage is $1/g_{fs}+R_s$, which drives the inputs of the paralleled buffers; the total input-to-output offset includes the buffers. For low-impedance signal sources (50Ω, 75Ω), the JFET stage is not necessary. ■

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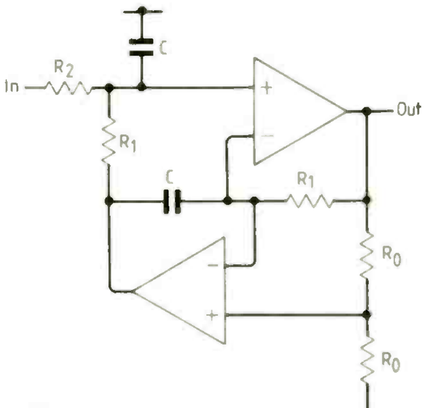
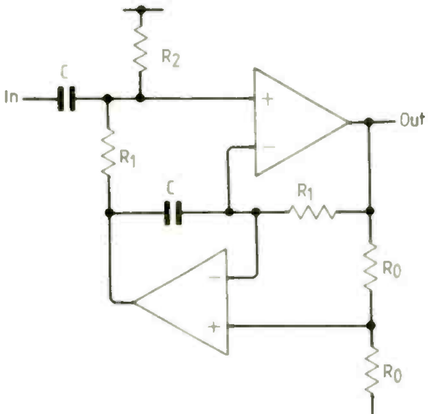
CIRCUIT IDEAS



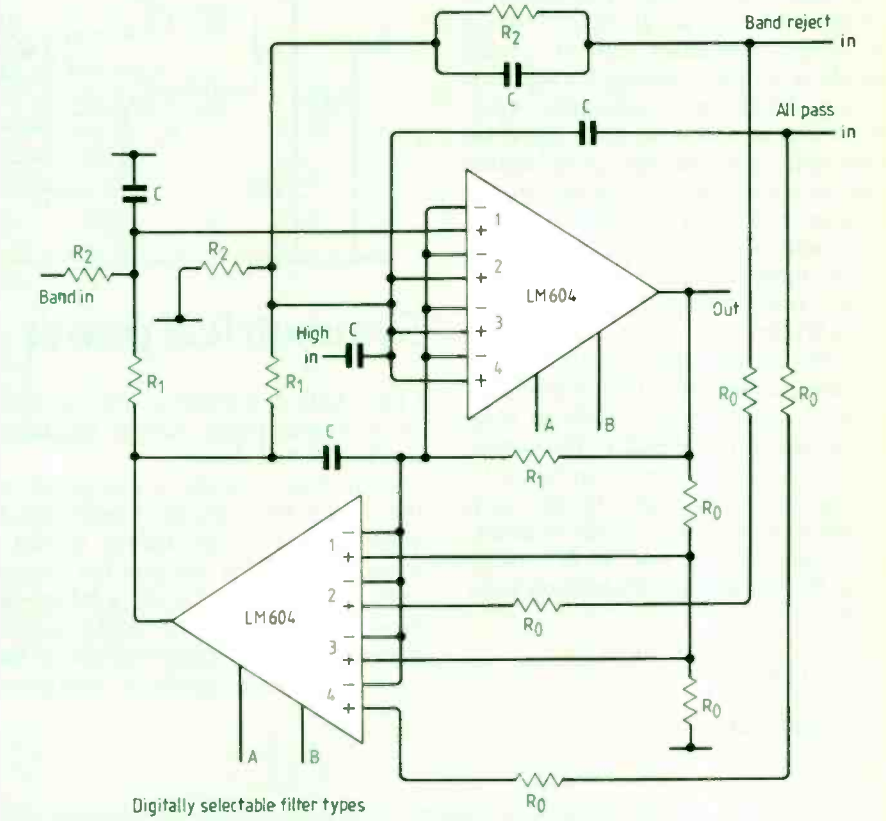
1: Bandpass

$$\frac{V_{out}}{V_{in}} = 2\,\frac{sCR_1^2/R_2}{K}$$



2: High pass

$$\frac{V_{out}}{V_{in}} = 2\,\frac{s^2C^2R_1^2}{K}$$



Digitally selectable filter types

Digitally-programmable filter functions

A recently developed multiplexer op-amp – the LM604 – can be configured to provide four digitally-selectable filter functions, namely band-pass, high-pass, all-pass and band-reject.

Four binary values at inputs A and B each select one of the four filter operations. In all four cases both the cut-off frequency ω_o and Q factor are given by these expressions.

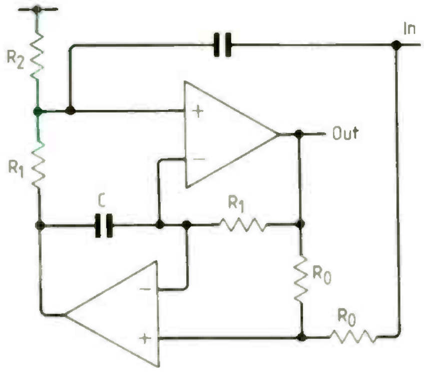
$$\omega_o = 1/R_1C$$

and

$$Q = R_2/R_1.$$

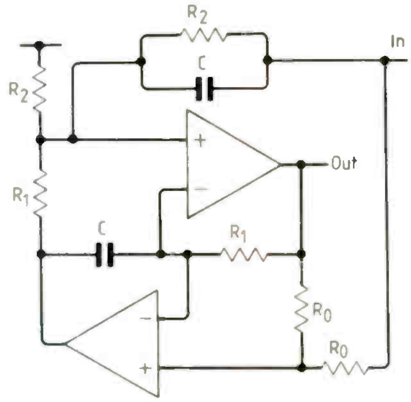
Supposing that C and R_o are fixed at 0.1µF and 100kΩ respectively, the circuit comprises only several external components with a value of either R_1 or R_2. These can easily be chosen according to requirements, which makes the configuration suitable for further integration.

Kamil Kraus
Rokycany
Czechoslovakia



3: All pass

$$\frac{V_{out}}{V_{in}} = \frac{1+s^2C^2R_1^2}{K}$$



4: Band reject

$$\frac{V_{out}}{V_{in}} = \frac{1-sCR_1^2/R_2+s^2C^2R_1^2}{K}$$

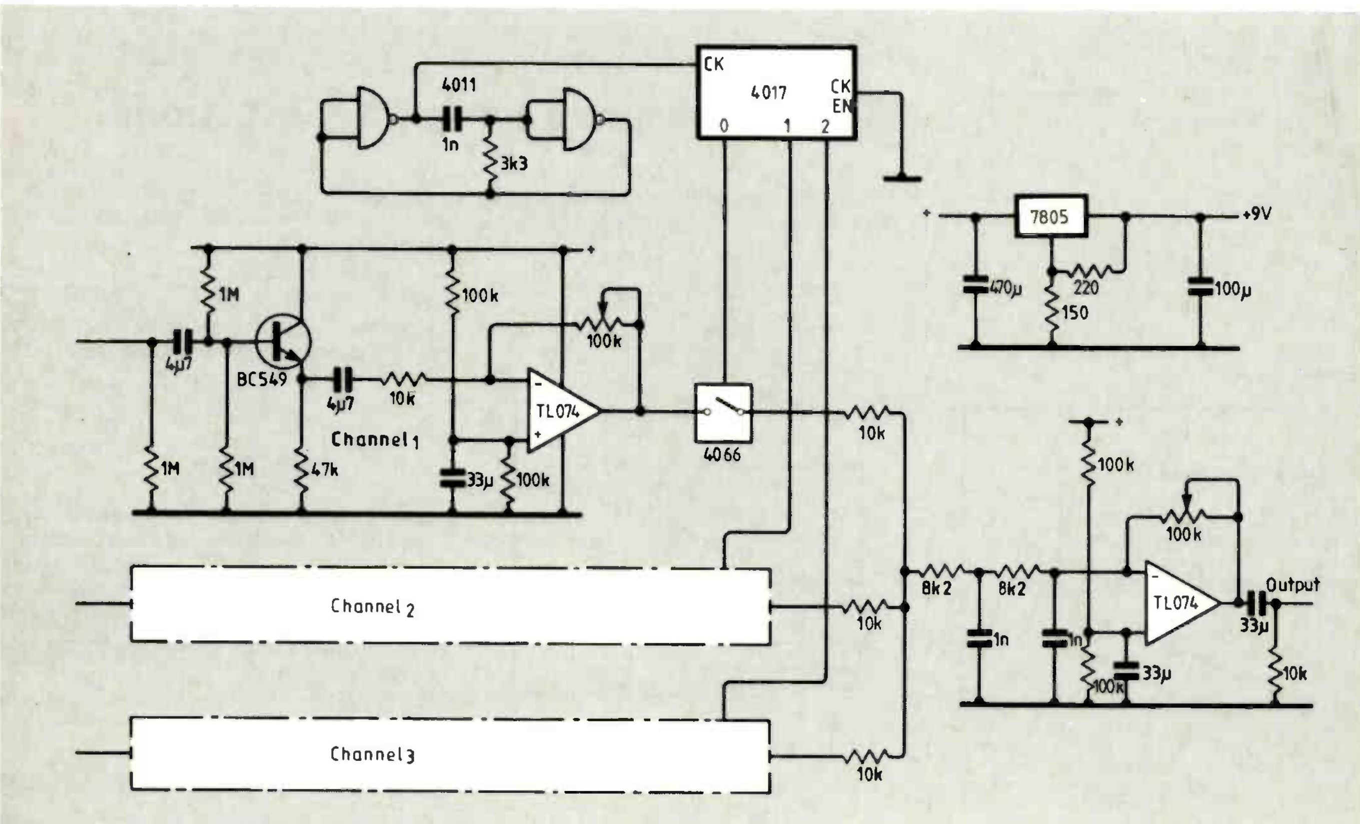
Sampling audio mixer

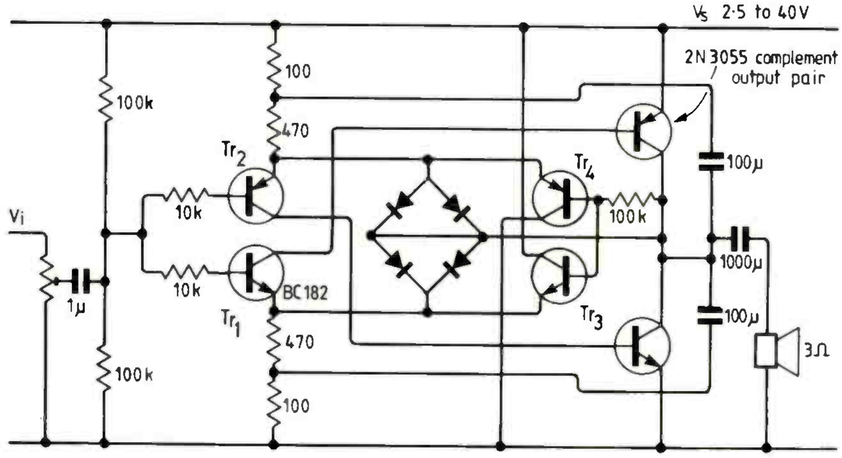
This circuit uses a different approach to mixing audio signals. Instead of taking the usual continuous sum of all the signals, it samples each signal at approximately 40kHz in a sequential order. The bonus of this is a better signal-to-noise ratio since only one of the mixing resistors is switched on at any one time.

Because it is not a continuous sum, the volume of each input can be set with greater independence of the other two inputs. Each counter output runs at about 40kHz.

When mixed, the signals feed a second-order low-pass filter with a 3dB point of approximtely 10kHz to filter out the sampling frequency. The system can be expanded for up to ten inputs by moving the reset input to the next unused output of the decade counter. The clock should run at N×40kHz where N is the number of channels to be mixed.

Darren Yates
French's Forest
New South Wales





Symmetrical power amplifier

I have built and tested several versions of a symmetrical power amplifier; one is included above.

Cross-over voltage is controlled by the emitter-base turn on of the feedback sensors, $Tr_{3,4}$. The buffer provides adequate linearity for very low supply voltages of 2.5V and drives a 3Ω speaker or filament lamp. For higher supply voltages the quiescent current in the output pair rises rapidly so cross-over voltage is reduced further by high current cross section diodes from a 2A bridge rectifier. ($I_q \simeq 17mA$ at 6V supply).

Without the diode bridge connected the "buffer" gives slightly greater than unity voltage gain because of the 100kΩ lever to the feedback sensor node.

P.J. Ratcliffe
Stevenage
Hertfordshire

12-bit analogue-to-digital converter

This simple design is based on a bidirectional ramp counter type of converter and is useful for designs where cost is more important than the stunning results of ready-made packages.

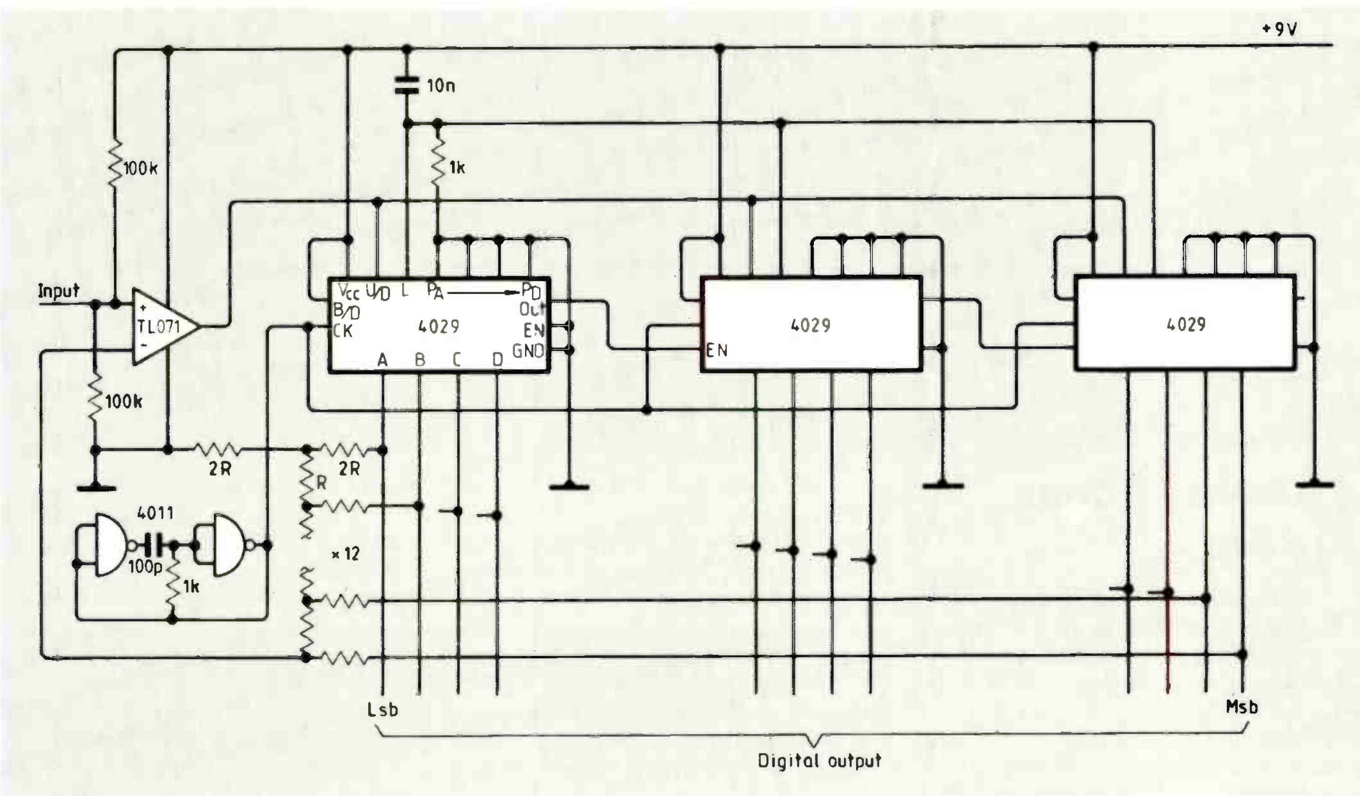
Starting from the front end, the analogue signal comes into the non-inverting input of the op-amp. Assume that input stands at 1V DC. At power-up, the 0.01μF capacitor allows a pulse through to the LOAD point on each of the three counters, loading 000 into each. This is transferred to the outputs of the counters and thence through a resistor network acting as a d-to-a converter, converting the counter value back to a voltage. Initially, with the counter at 0000, this voltage is zero, which is fed into the inverting input of the op-amp; thus its output is high, which tells the counters to count up.

The three counters are connected so that they count synchronously in either direction to reduce any large errors while counting. Hence the counters count up (at a rate of about 4MHz) until such a point arises that the voltage from the resistor network is slightly above the input volage. This causes the op-amp to go low, and start the counter counting down again, until it goes below the input voltage and the counter counts up again, and so on.

This small ripple is an error of one in 4096, which is quite small and will not be too serious. Only half of the 4011 is used in the square wave clock; you might like to use the other half as an added buffer on the clock output or as a Schmitt trigger on the output of the op-amp.

The most critical part of the design is the resistor network. I suggest you use 1% tolerance resistors or small mini-pots and measure accurately their values, which must be in the R-2R ratio for it to work correctly. Layout is critical only in the clock because of the low value capacitor; keep those leads as short as possible.

Darren Yates
French's Forest, New South Wales



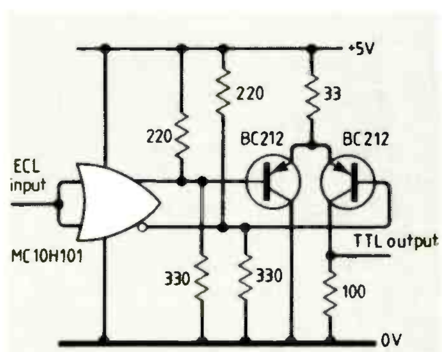
ECL-to-TTL converter

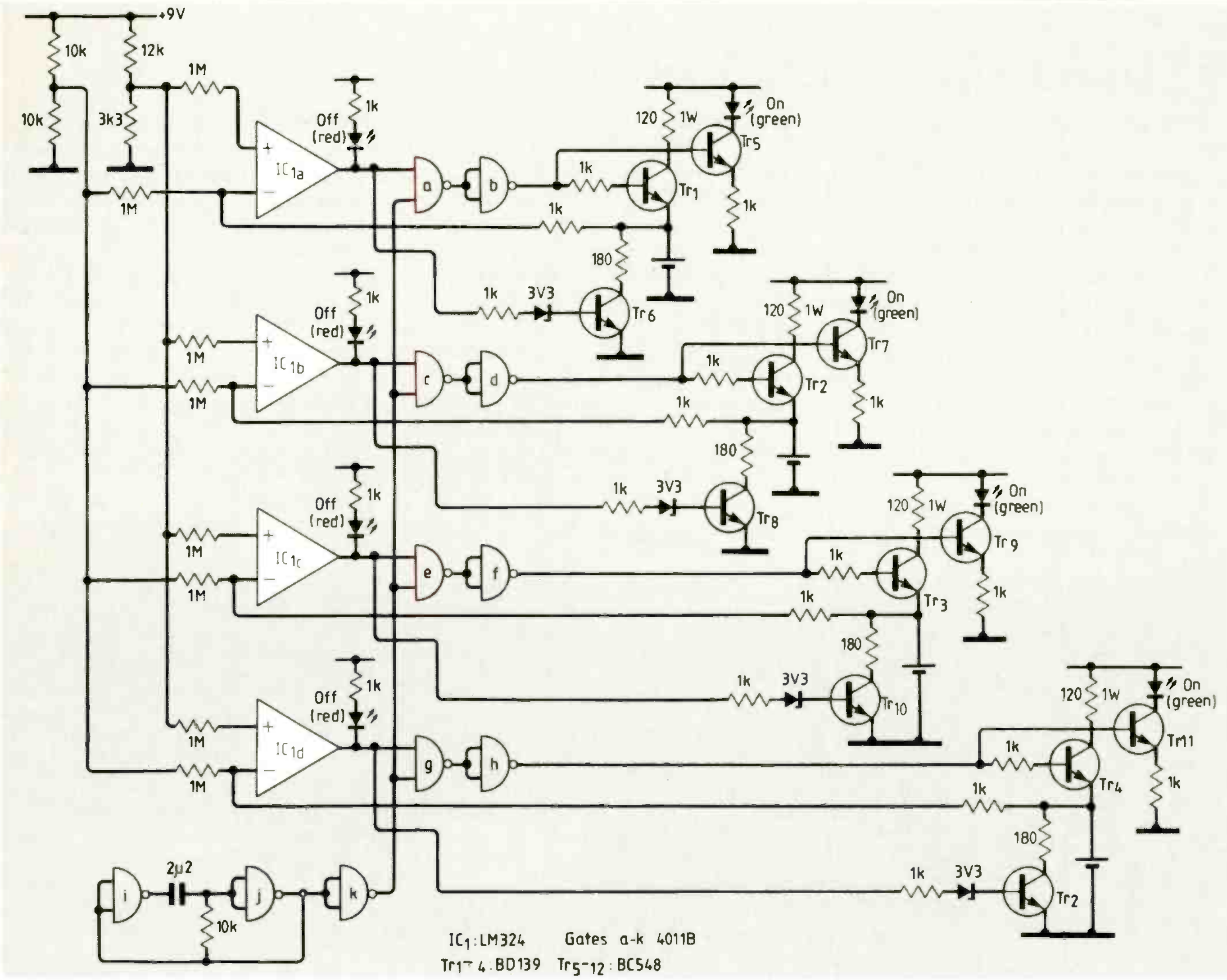
To remove the need for a dual supply rail, ECL and TTL devices are often driven from the same 5V rail. Where this is the case, it is possible to make a 10K and 100K-compatible converter with just two transistors.

The Or/Nor gate drives a differential amplifier which provides TTL voltage levels at its output. We have used the circuit at 50MHz with no problems although the output should be buffered (e.g. with a 74F244) when driving a long connection or a capacitive load at high frequencies. It should work with most small-signal p-n-p transistors and most ECL gates having complementary outputs. When using the complementary outputs of a bistable IC, however, we found that the device misbehaved, so this should be avoided.

This circuit is far cheaper than an equivalent IC (e.g. Brooktree Bt501 at about £12) when you only need to convert one or two signals.

P.N. Zarucki and Dr J.K. Hulbert
Electronic Equipments Ltd
Birmingham





Charger for four dry cells

Benefits of this relatively simple circuit are that it can recharge four R6 (AA) size dry cells in 12 hours. Other size cells can be accommodated by reducing the value of the 1W resistors.

Direct-current charging of dry cells can cause leakage and explosion due to steam build-up. This circuit, which relies on a 50% duty cycle square wave, causes only slight cell warming over the 12-hour charge, and has not been the cause of any leakage or explosions. Charging occurs during one half of the square-wave cycle and discharging occurs during the other. This improves charge retention.

Part of the cell voltage is fed back to the op-amp's inverting input. When this level reaches about 1.6V, the op-amp output goes low and output of the second gate connected to it follows it.

Battery voltage drops a little until the op-amp output returns high, gating the clock back on and again recharging the cell. This produces a flickering effect when the cells have reached the set voltage for both leds.

When no cell is connected, the red led is constantly on. When a cell is charging correctly, the green led flashes and when the cell is charged, both green and red leds flash; if the leds flash immediately on connection of the cell, the cell is faulty.

Darren Yates

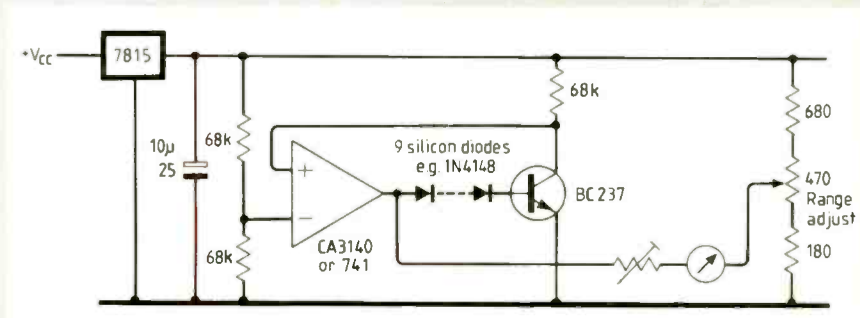
Simple but accurate thermometer

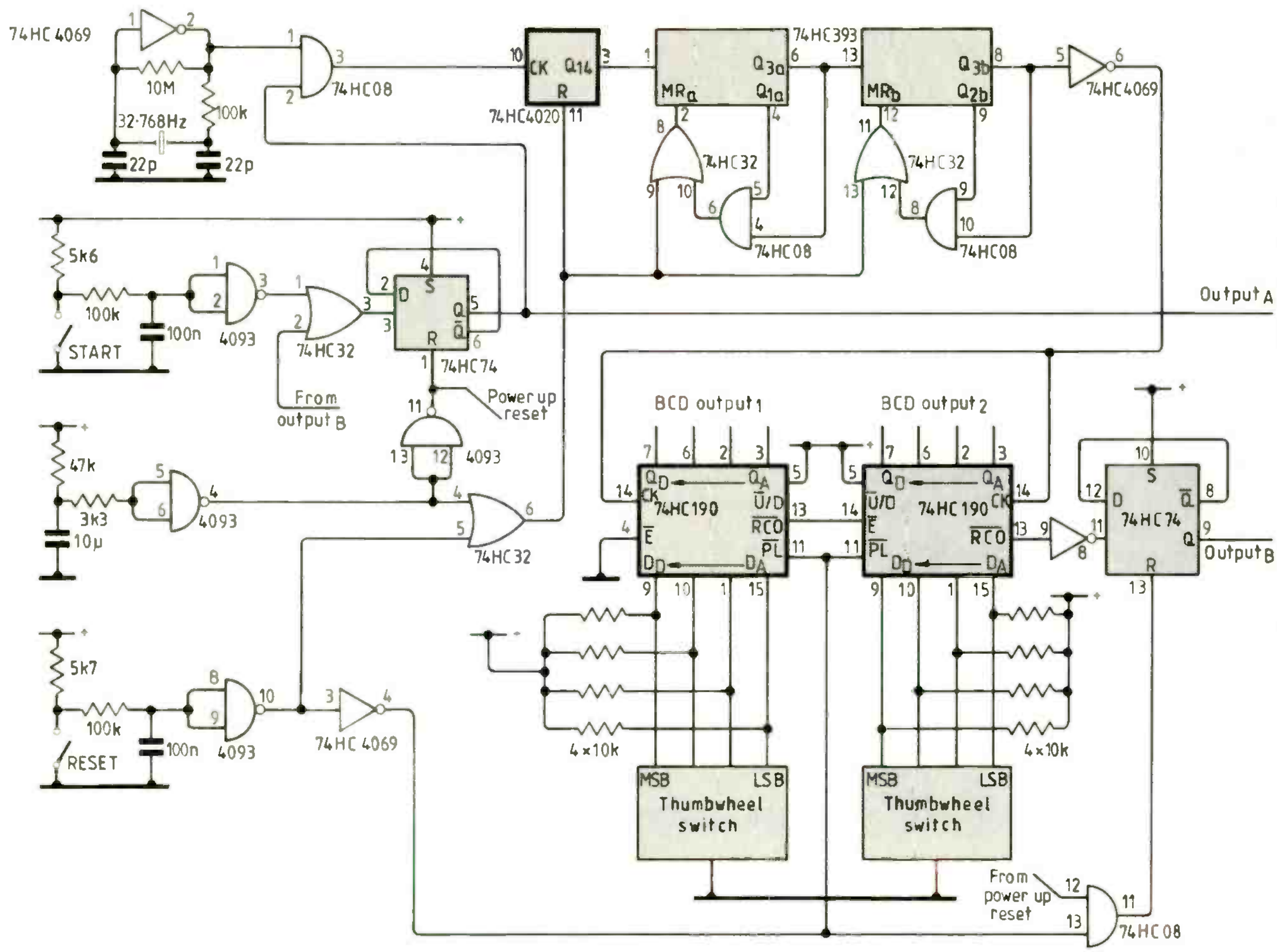
Normally, using semiconductors as sensing elements to measure temperature has the drawback that accuracy is limited by op-amp offset.

In this circuit, offset problems are greatly reduced since the nine silicon diodes exhibit a similar characteristic to the transistor p-n junction.

Output of the circuit – which can form either a switched-range thermometer or part of a thermostat – is 20mV/°C. The transistor should have an h_{FE} of 100 or greater.

Salvador Espin Carreras
Balearic Island
Spain ■





Precise minute counter

When timing a precise number of minutes, the required count is set up on complemented-output BCB thumbwheel switches. Two outputs are available, one which goes high for the duration of the count (output A) and one which goes high at the end of the count (output B).

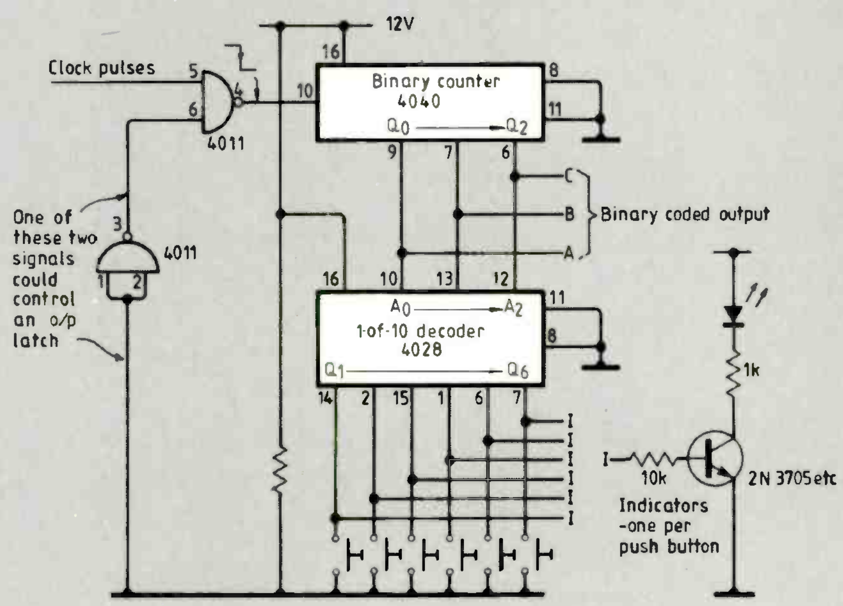
Push switches start and reset the count.

S A Young
Bradford

Binary switch encoder

In my application, data from this binary push-button encoder was latched by other circuits but you could add an independent latch controlled either by the falling edge at pin 3 of the 4011 or the rising edge at pin 1.

F. Miners
University of Exeter



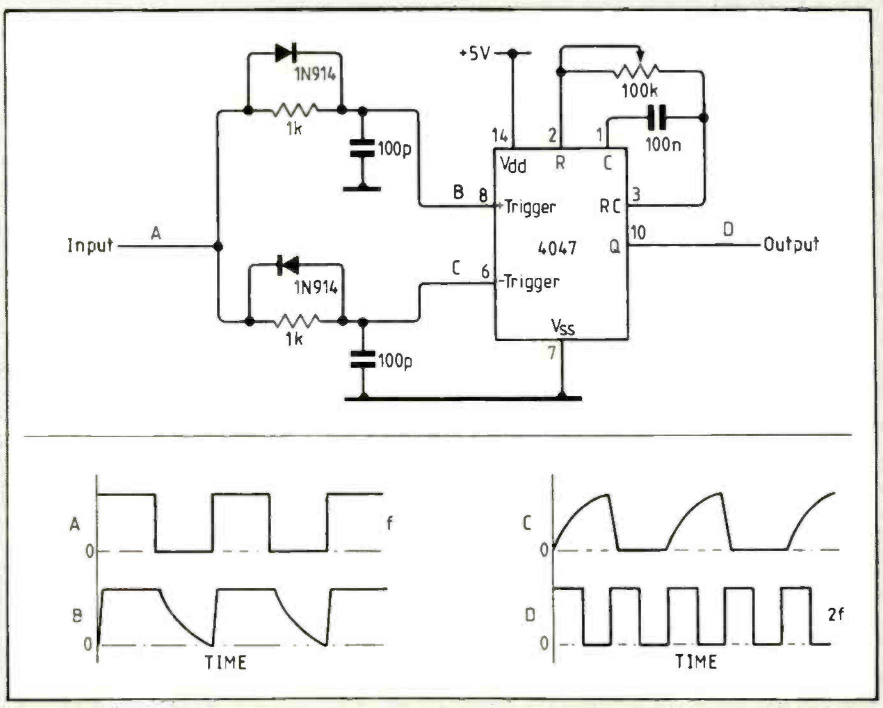
Variable duty-cycle frequency doubler

Only one IC is used in this frequency doubler. The monostable multivibrator can be triggered directly by a low-to-high or a high-to-low going signal.

Two RC integrators detect the leading and trailing edges of the digital input signal. Transition spikes of the integrators are used to trigger the monostable at both edges, effectively doubling the input signal frequency as shown in the timing diagram.

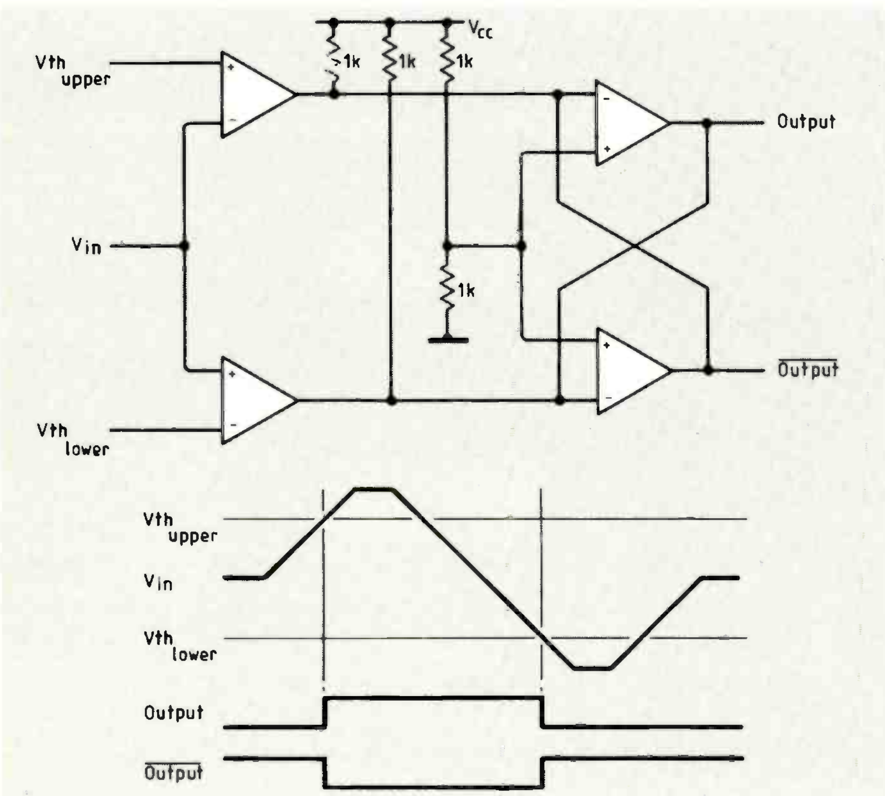
A potentiometer varies the duty-cycle of the output pulse train by up to 100%.

V Lakshminarayanan
Centre for Development of Telematics
Bangalore
India



Schmitt trigger with independently-programmable thresholds

Standard Schmitt-trigger comparators suffer from interdependency of upper and lower switching thresholds and output voltage levels. Also feedback is applied to the non-inverting input, so the source impedance of the voltage on this point (whether signal or reference voltage) needs to be kept low, or well defined, to preserve hysteresis as intended.



My circuit uses a single quad comparator such as the LM339. It features independent high-impedance inputs for upper and lower threshold references, and complementary outputs compatible with any standard logic family.

Two of the comparators detect the signal crossing the upper and lower thresholds, and the other two form an SR bistable multivibrator, using the open-collector comparator outputs for wired-AND functions. Hysteresis is unnecessary for the input comparators because of the latching action of the bistable device and consequently the threshold levels can be set accurately, the only errors being the comparator offset voltages.

Threshold voltages can be taken, for example, from op-amps or from D-to-A converters, opening up the possibilities of adaptive signal-level detection and dynamically tracking thresholds.

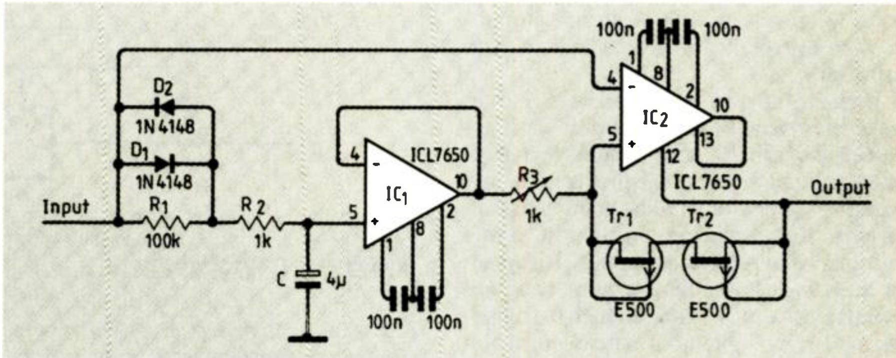
B V W Isaacs
Plymouth

Fast DC-coupled trigger

This broadband trigger is immune to DC offset and base-line wandering. It permits high-quality performance over a wide range of input signals applied to the ICL7650 amplifier, IC_1, through the charge-storage network R_1, R_2, D_1, D_2 and C.

Diodes D_1 and D_2 quickly charge capacitor C to the input voltage. Output of IC_1 is then compared with the original signal at IC_2. Here, hysteresis is set by two p-channel field-effect transistors, $Tr_{1,2}$, wired as diodes in the IC_2 positive feedback loop; R_3, Tr_1, and Tr_2 ensure that the level of hysteresis is maintained for any DC offset at the input. Resistor R_1 provides a zero level for input signals whose amplitude is smaller than one diode drop and R_2 protects the input signal source.

In the circuit as shown, the output of IC_2, a chopper-stabilized operational amplifier, is fed back to the internal oscillator which helps square the output pulses. That is, the output at pin 10 is directed to the oscillator's input at pin 13 and a new output taken from pin 12 which is the amplifier's clock output. Because the oscillator has a divide-by-two counter the output will be one-half the input frequency.



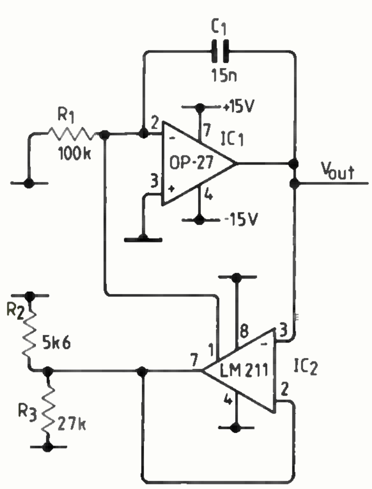
The trigger has a reliable triggering level and responds fast, its speed being limited only by the time constant $(R_{D1,D2}+R_2)$ C and can be adjusted to meet the requirements of practically any biomedical application.

Kamil Kraus
Czechoslovakia

Ramp generator with wide frequency range

Only two integrated circuits and a few passive components are used in this ramp generator for a signal with adjustable level and frequency.

Negative current through R_1 produces the ramp's positive slope and causes the output of op-amp IC_1 to increase linearly toward +15V. Because the amplifier's output becomes the comparator's (IC_2) negative input, the comparator's output transistor switches on when the negative-input voltage exceeds the positive-input voltage.



Switch voltage of the comparator is determined by the R_2R_3 divider. Switching IC_2's output transistor on forces the junction of R_2 and R_3 to 0V (value on negative input of IC_1). Current from R_2 decreases the discharge time of C_1 and allows IC_1's output to fall rapidly toward −15V. The comparator remains on until its negative-input voltage drops below 0V.

Output frequency can be expressed as

$$T_1 X \frac{1}{(V_{ON}-V_{OFF})/15}$$

where $T_1=R_1.C_1$; $V_{ON}=30$

$$\left(\frac{R_3}{R_2+R_3}\right)-15V;\ V_{OFF}=0V$$

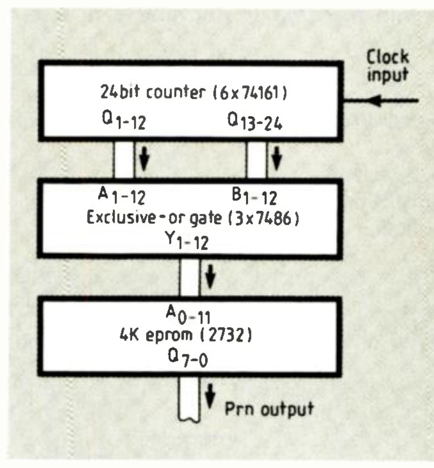
Thus R_2 and R_3 provide adjustments for variations in both output frequency and peak-to-peak value of output voltage, then R_1 and C_1 for variation of output frequency only. This circuit works well in output frequency range from approx. 0.1Hz to over 100kHz.

Michele Frantisek
Barvicova
Czechoslovakia

Extending random number sequences

In this method of generating longer pseudo-random-number sequences from smaller ones, it is assumed that sequentially stored samples of a PRN sequence in a memory when read out randomly give another sequence.

In the circuit shown, samples corresponding to a 4Kpoint PRN sequence are stored in eprom and addressed by a 12bit counter. For larger sequencers, the most significant bit of the counter (13th bit onwards) are Exor-ed with the corresponding least significant bits and given as the address to the rom. This way the 4K PRN data is read out in many combinations and output as a different sequence for each possible combination of the most significant bits of the counter; as a result the sequence length is increased. This circuit has a maximum sequence length of 2^{24} clocks.



A. Dhurkadas
Naval Physical & Oceanographic Laboratory
Cochin
India

Intro scan for compact-disc players

When selecting tracks for programming into a compact disc player, using the track search button can be tiresome. This design, when fitted to any player with a subcode output, allows a scan of the first ten seconds or so of each track.

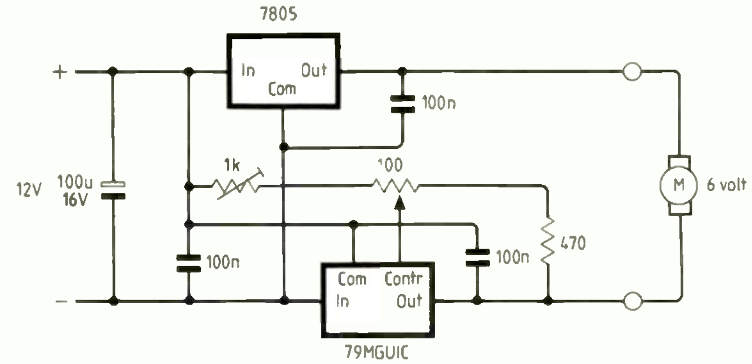
Pressing the start button causes IC_{1a} to go high and operate the play button via IC_{2a}. During the scan, IC_3 latches high. When IC_{1b} goes high as a result of the first track being located, IC_5 produces a low-going pulse of around 10s depending on the RC time constant. Monostable device IC_6, triggered by the rising edge of this low pulse, creates a 400ms pulse which is long enough to trigger the next-track button but not so long as to start any auto-repeat facility that may be built into the player.

Once the next-track button has been operated, IC_{1b} will go low while the next track is located. On returning high, this IC retriggers the timer.

When IC_{4b} pulses high, IC_7 is triggered. This creates a 30ms pulse which is longer than the time taken for IC_{1b} to go low after the next-track button is operated. The end of this pulse triggers triggers IC_8, creating another 400ms pulse. If at the start of this pulse IC_{1b} is still high, i.e., the disc is still playing because the next-track button failed to find another track, as would be the case at the end of the disc, IC_4 will pulse high for 400ms, operating the stop button and resetting IC_3.

I have tested the design on a Pioneer PD5010 unit, obtaining the 'not-playing' signal from pin 1 of the subcode output socket.

G.J. Aspland
Bury St Edmunds
Suffolk



Motor control

Adjustable voltage regulators make very good motor speed controllers but devices such as the LM317 cannot give an output lower than about 1.35V. In my application, motor voltage had to go to zero and control at low speeds had to be good. This circuit is my solution.

One side of the motor connects to a 5V rail produced by a 7805 fixed-voltage regulator. The 79MG is a four-terminal negative regulator with a separate control terminal. It gives an output from −5V to −12V, resulting in a voltage over the motor from zero to about 7V. Since the 7805 produces 5V at all times, output of the 79MG cannot be reduced below −5V.

Zero motor voltage is set using the 1kΩ potentiometer. The tab of the 79MG is connected to the input pin, which is also ground, so both ICs can be bolted to the same heat sink without insulating washers.

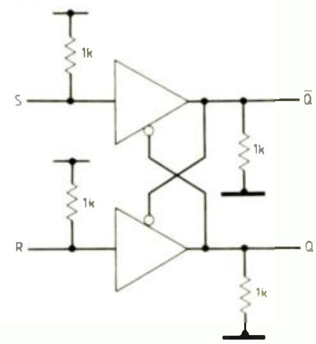
I.W. Berry
Manchester

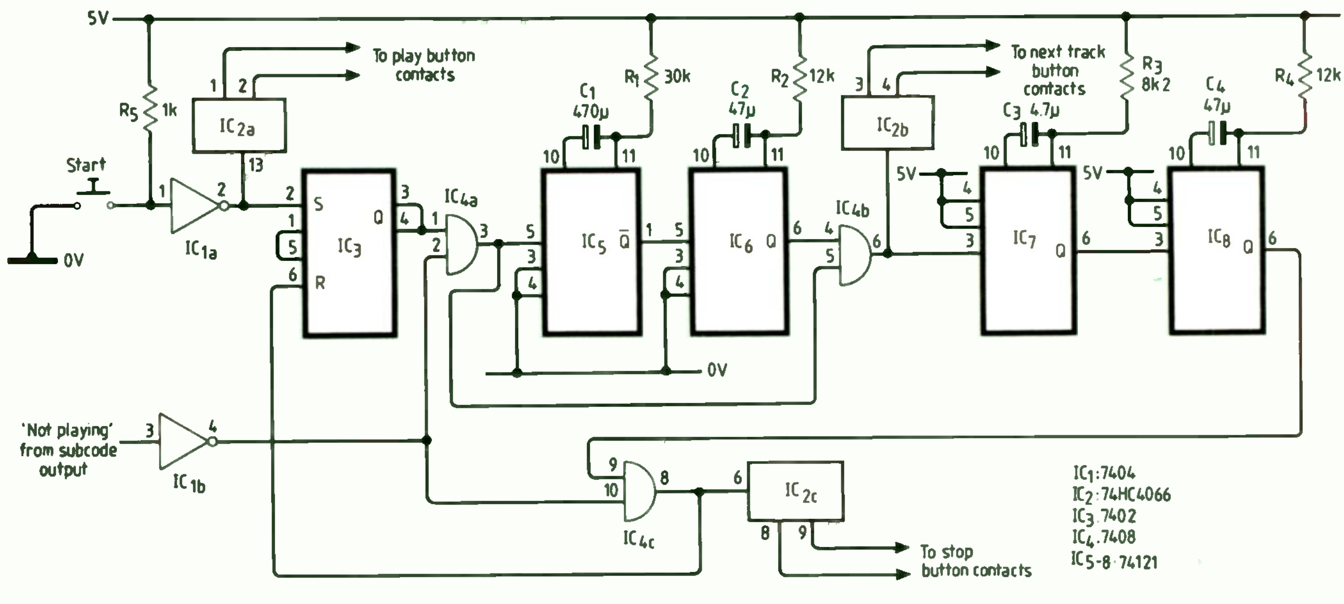
Novel RS bistable

Two spare non-inverting gates from a tri-state IC such as the 74125 can be connected to form an RS bistable multivibrator.

Assume that Q is high. The upper gate is high impedance so its output resistor pulls $\bar{Q}$ low. A negative pulse at R makes Q go low, enabling the upper gate. When the upper gate's output goes high, the lower gate is disabled and thus Q is pulled low.

P.M. Delaney
Wargrave, Berkshire





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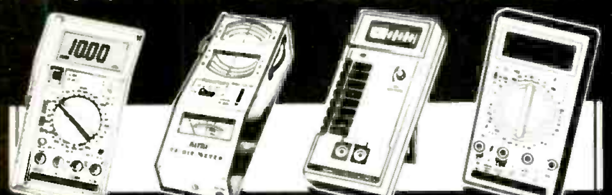

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CIRCLE ENQUIRY NO. 114 ON BACK PAGE

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CIRCLE ENQUIRY NO. 115 ON BACK PAGE

Electronic Circuit Designer

Mike Tooley reviews a software package which promises to "take the tedium out of designing the more common electronic circuits".

Like most PC users, I must confess to being an avid collector of public-domain and "shareware" software. What makes the whole thing worthwhile, of course, are the few (of the many) packages which one comes across that can be justifiably called "invaluable". Electronic Circuit Designer (ECD) from Ohio-based Diatom Software is one such gem.

As its name implies, ECD is aimed at those engaged in the design of electronic circuits. The package provides no less than 49 options and is suitable for use by the enthusiast working from home as well as the professional electronic engineer and technician.

ECD is claimed to offer a "what if?" facility and the 14 individual sub-programs provide the designer with a means of changing component values, specifications, or operational parameters of a number of common circuit configurations and examining the effects produced. The program is largely self-documenting and uses a menu-driven format.

ECD is written in GW-BASIC and thus requires the GW-BASIC interpreter to be present in order to operate. As an experiment, I loaded the program into GW-BASIC, saved it in ASCII format and then loaded into Microsoft Basic Version 6.0 in an attempt to compile it. Unfortunately, the module level code appears to be too long to be acceptable by this version of Microsoft Basic, despite attempts which I made to reduce the length of the file, which is well in excess of 65kbyte. Doubtless, someone else (perhaps even Diatom) may have attempted this and been more successful.

On inspection, the GW-BASIC listing appears to be a tangled web of code containing no REM statements or other landmarks. The code is reasonably typical of that produced by an engineer in a hurry and is consequently somewhat lacking in overall structure. Lines such as

```
900 GOSUB 14010:PRINT
    A1$D$C$"#2":GOSUB12230:LOCATE
    13,1:PRINT TH$"A "D$A1$;:PRINT C$"
    "YN$""EN$FR$
```

provide few clues to what they actually do! Indeed, those who subsequently wish to make modifications to the code will not find the task particularly easy.

Operating environment

Electronic Circuit Designer is supplied on a 5.25in disk and it should run on almost any IBM PC or compatible microcomputer system. I successfully installed the package on a number of systems, including the modern AT-compatible machine (DSC Turbo) in my workshop, the trusty Olivetti M-24 in my office, and an Atari-ST with a Condor/Beta Systems Supercharger which graces my study. In all cases, the software was installed and operated without hitch using the batch file supplied.

Shareware

Diatom states that ECD is distributed though the "User Supported Software" concept. This is Diatom's way of stating that the program is shareware; the software is freely available for examination and evaluation but users are asked to register the product if they decide to make use of it (in which case they become eligible for support and upgrade information). Diatom says that anyone may obtain a demonstration copy of the package by sending $10 to cover the cost of the diskette and mailing.

Alternatively, would-be users are invited to "borrow a copy from a friend and make a copy of The Electronic Circuit Designer for yourself". If users find that the product meets their needs, they are encouraged to send $25 for a registered copy of the software and a "User's Guide". Otherwise, potential users can simply send $25 and register straight away, in which case they will receive the latest disk version together with the documentation.

User's guide

The manual consists of 35 A4 pages; unfortunately, the pages are not numbered and no index is provided. Each of the main and sub-menu functions is discussed and illustrative circuits are included, together with a few formulae. The circuits are somewhat more legible duplicates of those which appear on-screen when the program is running. This is, perhaps, a good argument for registering the package and sending for the manual! In any event, the owner of the manual will avoid having to dump the screen to a printer or making a hand drawn sketch whenever a circuit has to be remembered.

I consider the guide to be "par for the course" for this type of software. It is neither worse nor better than that supplied with similar shareware offerings and probably reflects the state of most of the embryonic software concerns which trade collectively under the shareware banner.

Circuits

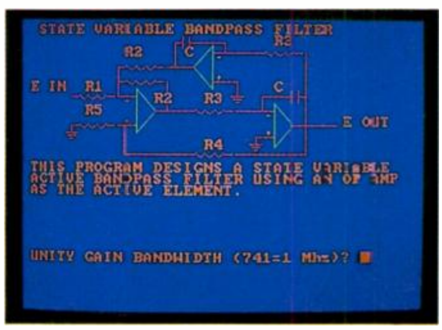
ECD is concerned with circuits under a number of headings, including passive and active filters, operational amplifiers, power supplies and timer circuits. The user selects the circuit type from the main menu and then, in most cases, proceeds to make further selections from a sub-menu. The following sub-programs make up the package.

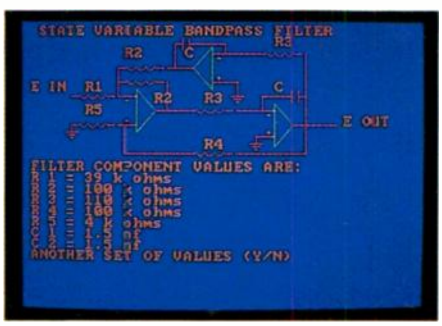
Passive filters. Fourteen types of passive filter, including low-pass, high-pass, band-pass, and band-stop types based on pi- or T-sections, are catered for using both the m-derived and constant-k models. The user simply inserts the desired frequencies and the program calculates the required values of capacitor and inductor. Nothing could be simpler!

Active filters. Eight varieties of active filter are provided: active, state-variable and multiple-feedback bandpass filters, as well as Wien-bridge and twin-T band-stop (notch) types. Two forms of active low-pass filter (simply described as #1 and #2!) are also included, as well as the Butterworth-Thompson low-pass arrangement.

Power supplies. Four power supply designs offered include conventional regulated units based on bi-phase (two-diode) rectifiers, full-wave (four-diode) bridge rectifiers and a circuit which as dual stablised outputs (based on a single bridge rectifier and a transformer having a centre-tap or dual secondary windings). Finally, a somewhat lethal transformerless power supply is included, of which more later!

Each of the conventional power supply designs is based upon a three-terminal regulator and the program provides essential information relating to the secondary alternating voltage and current, the transformer rating in VA, and





The screens are crude but functional. The program modules are inflexible. Even so, most analogue designers would find them of some use: a (small) fistful of dollars well spent.

the recommended reservoir capacitance. The program also computes the worst-case voltage developed across the regulator (i.e. between input and output). This worst-case condition applies when the AC line input voltage takes its maximum value and the load current is minimal.

In the case of the transformerless power supply, the load is not isolated from the supply and the circuit is accompanied by a "health warning" in the manual. However, there is no mention of the fact that the voltage developed across the 1000μF reservoir capacitor (of unspecified voltage rating) would rise to approximately 340V when operated from a UK mains supply! The capacitor would almost certainly explode if the unfortunate constructor had made use of a conventionally rated component.

One further option is provided within the power supply sub-program. This involves determining the maximum time for which the AC supply can be interrupted when given the unregulated voltage drop, the minimum voltage drop allowable across the regulator, the load voltage and load current and the value of the reservoir capacitor. This facility is, of course, particularly useful in computing applications when the integrity of data within a system may be at risk in the event of even the briefest of interruptions in the mains supply.

Operational amplifiers. ECD can be used to design two basic forms of operational amplifier circuit: inverting and non-inverting. This is, perhaps, one of the weakest areas of the program and is one which could usefully be extended to encompass circuits such as bandwidth-limited amplifiers, precision rectifiers and integrators.

Class-A transistor amplifiers. ECD provides a means of calculating resistor values for use in a conventional, stabilised, common-emitter transistor amplifier stage. The program requires the input of supply voltage, maximum and minimum values of common-emitter current gain and emitter current, and then computes the requisite resistor values and base bias voltage. For anyone involved in the design of class-A amplifiers, this facility should be instrumental in avoiding many repeated calculations.

555 timer circuits. The 555 timer features in ECD in both astable (oscillator) and monostable (timer) modes. Users can experiment with values and/or parameters and note the effect on the output.

Tuned circuits and inductors. ECD

provides a number of sub-programs which are designed to simplify the task of producing tuned circuits. The required input parameters are frequency, capacitance, inductance and resistance for tuned-circuit design; and inductance, former diameter, winding length and permeability of the core material for inductor/coil design. A group of sub-programs are provides an alternative approach to resonant circuit calculations. Users are encouraged to experiment with both groups of programs in order to find the group which is most appropriate to their needs.

Transformer turns ratio. Transformer impedances and turns ratios are covered under this heading. In comparison with ECD's other offerings this sub-program is rather weak and offers no particular advantage over the use of a basic calculator with a square root facility.

Bypass capacitor calculation. When designing transistor amplifiers, it is frequently necessary to determine the minimum value of emitter bypass capacitor to ensure effective decoupling. This sub-program determines the value of decoupling capacitor required to bypass a given emitter resistance at a specified lower cut-off (−3dB) frequency.

Decibel conversion. ECD converts ratios of voltage, current and power to decibels. This again, is fairly trivial and the program could have been usefully extended to cope with conversions from dB to voltage, current, or power and also from dBm and dBV to power or voltage.

Voltage standing wave ratio. ECD will compute the voltage standing wave ratio (VSWR) in a transmission line when given the forward and reflected power levels. An option to determine the reflected power level given the value of VSWR and forward power would have been a useful addition.

Capacitive and inductive reactance. The program can be used to determine capacitive and inductive reactances but, here again, this task could again be very easily accomplished using nothing more than a basic calculator.

Resistor calculations. ECD provides several options which can be useful when determining the effective resistance of several resistors of different values connected in parallel. The program can also compute the nearest preferred value of resistor to that specified by the user.

Wire size and current. This final option allows the user to determine the minimum wire gauge in AWG sizes which is suitable for carrying a specified current. This problem is conventionally solved by reference to standard wire tables.

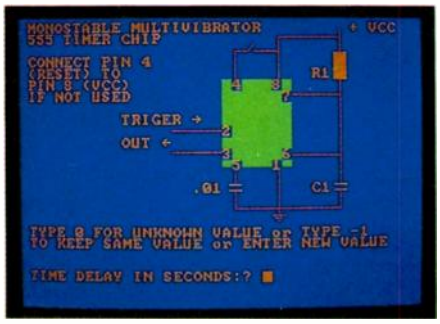
ECD in operation

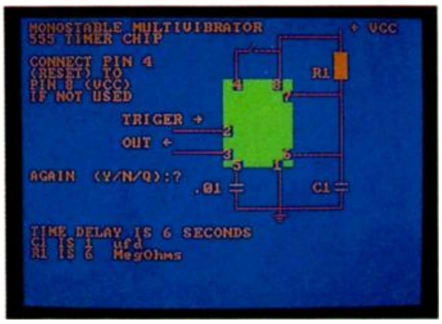
I put ECD through its paces by using the package to solve a number of simple problems, including the design of a low-pass pi-section filter for use with a 6m VHF transceiver, a 12V 1A DC regulated power supply, a high-Q Wien-bridge 1.75kHz notch filter and several inductors for use in a 1.8MHz aerial tuning unit. The suggested circuits and component values were checked against separate calculations and all were found to be well within normally acceptable tolerance limits.

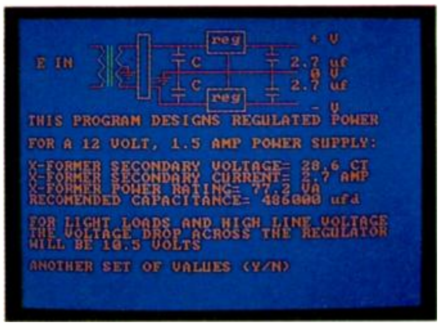
The only area in which the software failed to produce satisfactory results was in the case of a 555-based 1kHz pulse generator. With the given parameters and values, the software suggested that the duty cycle of the output should be 42.3% when, in fact, the result should be nearer 57%. Since a 555 timer is incapable of producing a duty cycle of less than 50% (the "off" time can never be less than the "on" time), it would appear that Diatom has not used the correct relationship for this particular parameter.

Overall, the software proved to be very easy to use, with one or two minor exceptions. Several of the functions are of rather limited use and could be removed from the package without limiting its appeal overmuch. Other facilities could benefit from further refinement to make them more generally applicable. In this respect, one can only hope that Diatom will continue to support the product with upgrades. The package should certainly have a niche in the electronics world and it would be a great pity if it were not to be further developed.

At the price, one can make allowances for the occasional lapse in presentation and the unpolished "User Guide". These will, in any event, be minor considerations for the designer who is primarily interested in producing a quick and accurate result with minimal fuss. This is where ECD excels; it is not particularly earth-shattering but, where most electronic engineers and enthusiasts are concerned, it will certainly earn its keep for many years to come. ■







Supplier

Diatom Software is at 297 Timber Lane, Northfield, Ohio 44067, USA. Telephone USA (216) 468 2230.

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CIRCLE ENQUIRY NO. 136 ON BACK PAGE

Heterodoxy and scientific publishing

The recent claim by Fleischmann and Pons to have achieved cold fusion has evoked considerable misgiving among serious scientific commentators. Their results were divulged under *force majeure* from the lay press and other publicity media. The scientists would have preferred to await further results from their experiments.

Such episodes as these, when soon followed by doubts and disputes, engender a lack of confidence in the public perception of science, and only serve to reinforce a drift to irrational alternatives.

Another level of disquiet must occasionally arise among readers of technical and scientific journals. I am referring to articles such as those on "magic gyroscopes", or "proving" that Einstein was wrong.

I find worrying the heterodox but often plausible ideas published by scientists and technologists respected in their own fields. These generally elicit responses from supporters of the orthodoxy, whose counter arguments appear equally plausible. As we follow the ding-dong controversy in the relevant journal, perhaps for weeks or months, those of us on the sidelines become depressed or cynical, depending on our degree of involvement and philosophical outlook.

Take the dispute between Herbert Dingle and William McCrae in *Nature* in the early 1970s over the "Twins paradox" in special relativity theory. How many followed the detailed arguments week after week? Whose memory now is of a victor, if there was one (McCrae?), rather than of a disturbing disputatious episode?

At the other extreme, and editorially excluded from the pages of *Nature*, is the theory of "morphic resonance" proposed by Rupert Sheldrake. Its propagation of the idea that animate and inanimate matter can organise itself in a particular way once a distant prototype has done so was deemed to be an outrage against rational thought. However, *New Scientist*, inclined to tolerant curiosity.

Last year, it was *Nature's* turn to be tolerant, at least for a time, when Jacques Benveniste wished to report results that claimed to show a positive effect of a solute at a dilution greater than Avogadro's number. After publishing the paper, an on-the-spot investigation by *Nature* led to the journal's repudiation of the claim although Benveniste continued to uphold it.

The journal that seems to specialise as an outlet for unorthodox views is, of course, *EW+WW*. Over the last ten years, and probably longer, it has hardly been possible to open its pages without reading, for instance, a demolition of the theory of relativity, a rejection of Maxwell's concept of displacement current, or yet another twist to the "magic gyroscope" saga.

I am not criticising either the dissidents or yourselves for giving them space; indeed, some have aired their views in *Nature* and *New Scientist* as well. The difficulty is in picking out the wheat from the chaff and being sure that the discarded chaff doesn't contain a few grains of truth – like the five-dimensional space proposed in the early 1920s by the young Soviet physicist Theodor Kaluza. Kaluza's theory, although received sympathetically by Einstein, was ignored by the physics community for some 60 years. Rediscovered in the 1980s, it was extended to become the basis of superstrings, the line-particles that are invoked to explain current theories of supergravity.

While the motives of most of the dissentient authors are no doubt unexceptionable, there appears to be a core of iconoclasts convinced, on the one hand, of the errors of orthodoxy and on the other, hasty and uncritical in their support of every unconventional idea that comes along. They are the scientific analogue of the doubters of Shakespeare's authorship.

Perhaps we need an unofficial, impartial body of scientists and engineers to study and report on these heterodox claims. Such a body might come from the increasing number of emeritus academics resulting from early retirement and the university "bulge" of the 1960s, at present kicking their heels in various country retreats.

The true impartiality of such a panel would be ensured by the inclusion of academic freethinkers in the mould of Sir Fred Hoyle, John Hasted and Eric Laithwaite, along with the doughty defenders of orthodoxy.

R.V. Harrowell
Cambridge.

Even the most impartial panel must be hamstrung by traditional thinking. EW + WW will always give the benefit of the doubt in publishing. It would be tragic for a truth to be lost through caution. – Ed.

"Neural" networks

It is inconceivable that the simple unit described by Douglas Clarkson (Living Computers, *EW+WW*, March) could ever imitate neuronal action in the animal central nervous system (CNS). Input dendritic endings in living nerves have no means of distinguishing between a '0' and a '1' since synaptic action is known to depend on an "all-or-nothing" principle. If such a mechanism exists, it must reside within the axon or nerve cell. Even then, information theory requires a decoding delay for any recognition process and this implies that the governing principle is that of "waiting", not "weighting". In other words, the animal CNS is phase-modulated, for which conventional binary arithmetic is useless. The relative FSK method described by F.R. Connor in the December issue is a much closer approach to successful neural networks, since it takes account of frequency modulation as well.

B. E. P. Clement
Crickhowell
Powys

Gyroscopes and contradictions

I have read Alex Jones' letter in *EW+WW* for April 1990, and feel I must criticise his experimental technique for detecting the forces produced by an orbiting gyroscope. The problem with his apparatus is that the forces he is attempting to detect are very small indeed compared to the weight of the apparatus. His "near frictionless surface" has significant static friction (due to deformation of the glass and balls). A better setup is to suspend the gyro from a long thread. Ideally, the thread should be long enough so that the period of pendulum oscillation is long compared to the rate of orbiting. I tried this using a bicycle wheel as the gyro: the point of suspension moved as would be expected from Newtonian physics.

Geoffrey Rutter
London W9

Plotted PCB resist

Following the interesting series of articles on CAD for PCB design, your readers may be interested in the method I use. My work involves system design and building, from PCB making to software, data analysis and final report writing. The PCB making side is only a small proportion of the work so we cannot justify some of the very nice prototyping equipment now available.

I use Generic CADD, Level 3 to do the artwork for the PCB, making full use of the layering facilities to ensure that, for example, the solder side pads and the solder side tracks are on different layers.

The heart of the system is a Roland DXY-1100 plotter, which has magnetic rather than electrostatic paper hold down. The base copper PCB is placed on the plotter bed, and held in place by a steel rule magnetically attracted to the bed. Blutack can be used to assist. The etch resist is plotted directly onto the copper using an oil-based pen, 0.3mm thick, intended for overhead transparency plotting. It is important to ensure that all plotting is confined to the area board, as the pen tip will be damaged by trying to ride up the board edge. It is very easy to make a trial plot on paper first, using a water-based pen.

Working with material 1.6mm thick was a rather tight fit until a file had been applied to the plastic mould flash on the underside of the pen-actuating underside of the pen-actuating solenoid level. The boards must be flat; they often seem to be slightly curved, but can be easily hand straightened immediately before plotting. Maximum clearance is obtained by operating the plotter in the near-vertical position.

Plotting is done twice, giving the ink time to dry between applications, as one thickness does not resist the ferric chloride etchant adequately. For double-sided boards, a couple alignment holes may be drilled before plotting the second side (the Generic CADD WINDOW MIRROR command is used to produce the correct handeness of drawing). Then a layer consisting only of the alignment holes is plotted and, if adjustments to the position of the board are needed, this step should be repeated until alignment is correct. Then the second layer is plotted.

Etching in ferric chloride is done normally, and methylated spirits used to remove the ink before tin plating. Following plating but before drilling, the component overlay and other information can be added, but using an old pen, as the ridges of the tracks can damage the tip of the pen.

Although, for moderate production runs, this would be a tedious process, I find it suitable for prototyping and producing up to 20 boards of one design. The ease and flexibility of proofing on paper, then plotting straight to copper is most useful during the early stages of design. Although the plotter is a moderately expensive piece of equipmenyt (advertised at around £600), no UV light box is needed, plain copper instead of photo-resist boards are cheaper and no sodium hydroxide developer bath is needed. Also, it is so easy to add a component overlay. The plotter finds many other uses in the computer room!

Stephen J. Temple
Tea Research Foundation
of Central Africa
Mulanje
Malawi

Amplicon PC99

Thank you for reviewing our PC99 in your March issue. We were naturally disappointed by the negative presentation of the production, which I realize is the reviewer's prerogative. However, there were a number of omissions or errors in the review to which I would like to draw attention.

1. The compressed screen (on VGA) is eliminated if the common line switch is set correctly.
2. PC99 works on standard PCs through to 386/33MHz machines, not just ATs
3. PC99 has 8, not 78, traces.
4. There are no anti-aliasing filters on the inputs.
5. The actual sampling rate is switchable from 2.5kHz to 25MHz.
6. PC99 offers simultaneous generation and acquisition.
7. Arbitrary waves and FSK can be generated using the Advanced Wave Generation Package.
8. The significant advantages that PC99 has over conventional instruments is that the computer can perform calculations on measurements made, can read and write disk files, can generate arbitrary waves and acquire simultaneously, can store set-up states, and can demonstrate complex maths functions.

It also seems a pity that the reviewer did not discover the mixed mode of acquisition and generation and that he did not investigate the Advanced Wave Processing Package, which gives further benefits to the user. I would also have expected him to suggest an increase in buffer memory size, a point that would not become obvious unless the board was used in a real application.

The PC99 is not intended to replace an oscilloscope, but to open up a whole new way of tackling instrumentation problems using a PC as a virtual instrument.

Although we have supplied substantial numbers of the PC99 to industrial customers without returns or complaint, we are certainly taking your reviewer's comments seriously and will be taking a long hard look at the product and its presentation, particularly with regard to the user manual and the supply of an input pre-amplifier, which is already in design. Perhaps when we have completed these changes, you might consider reviewing the product again.

Although the general opinion within Amplicon is that your reviewer has done everything he can to kill our product, I am of the firm opinion that there is no such thing as bad publicity and certainly appreciate the time and trouble you have taken to cover the PC99.

Jim Hicks
Managing Director
Amplicon Liveline Ltd
Brighton
East Sussex

Relative FSK

In the third postulate of my new theory, (December 1989, p. 1189) I used the very important word *effectively*, which implied additional signal processing of the sum and difference signals to remove the noise from the system. The noise correlation is due to the fact that the total noise power in the sum signal gives rise to a *single* phase-noise voltage of random waveform, which modulates the two VCOs in push-pull. The modulation produces frequency errors in the two correlated signals which *add* arithmetically.

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amplifier. A mathematical analysis and a practical implementation of the negative feedback system are the only ways to prove whether the system will work in practice and not by any superficial comments made by casual readers like Bell and Walters (February). Incidentally, with additional cicruitry, it is also possible to use negative *feedforward* between the sum and difference signals, to squeeze out any residual phase noise from the difference signal.

However, in some applications, it is possible to transmit a single carrier signal and to derive two *offset* carriers from it by using the stable frequency source at the receiver. In this case, the noise in each channel is highly correlated, even before employing correlation processing, because it is derived from the same carrier source. A system based on single-carrier transmission which uses relative PSK rather than relative FSK is described elsewhere[1].

Furthermore, Shannon derived his equation without the use of a feedback channel. If Shannon had used negative feedback, he probably would have derived another equation! It is incorrect for L. C. Walters to compare unlike with like; he should compare like with like. Just as the velocity of light appears to have a limiting value in the physical world, so too, the channel capacity appears to have a limiting value in the wireless world. Any attempt to exceed the Shannon limit might lead to additional errors due to intersymbol interference.

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F. R. Connor
London SE25

Leukaemia at random

There is one point in your editorial on leukaemia (January 1990) with which I take issue, namely that it is predominantly a childhood cancer. This is true in the sense that other forms of cancer, such as malignant tumours, affect older people of all ages have died of leukaemia and deaths of those under 15 have been only 10 to 5% of the total.

The proportion of childhood deaths has tended to fall, perhaps because of the increasing success of medical treatments such as bone-marrow transplants and radiation therapy.

It is not commonly noted that at all ages there is a small but persistent sex bias, in the sense that slightly more males than females die of leukaemia.

People want to associate "clusters" of leukaemia cases with sources of nuclear or other radiation. It is very difficult assess the significance of a cluster unless one is a professional statistician (which I am not) but a simple example of testing for randomness may help to explain the difficulty.

Suppose you toss a coin for "heads" or "tails" many times then you expect to get approximately equal numbers of each and if you do it proves the trials are unbiased, but does not prove that the result of each toss is independent of the previous one.

There is no reason why "heads" and "tails", should occur alternately and, if they did alternate regularly, the sequence would obviously be declared non-random.

A long random series will include groups of 2,3,4... and in a very long series groups or "clusters" for which one may be tempted to seek a cause.

In the binary series it is easy to calculate the probabiliyt of a group of given size, but it is not so easy when one has two-dimensional space plus time plus human factors plus possibly unknown factors. That is why it is difficult to identify the cause of a suspected non-random cluster.

D.A. Bell
Walkington
Beverley

Cooking fields

There seems to be a need for more data to assist in determining the potential hazards of mains frequency electromagnetic radiation.

I propose that information be gathered on abortion and abnormalities at birth, in relation to the type of cooker used in the kitchen.

Measurements indicate that the domestic electric cooker is one of the strongest localized sources of low-frequency field in the home brought about by the combination of high current and internal wiring practice.

Only in kitchens that "cook electric" will the foetus be optimally located for maximum field for a few minutes every day.

Douglas Dwyer
Dolton
Devon

The Riddle of Inertia

Graneau *(EW+WW*, January 1990, pp 50-62) sees mysteries where there are none, and creates yet more confusion in his attempts to explain them away.

Galileo's "stunning discovery" that a 100lb canon ball takes the same time to fall to the ground from a given height as a half lb musket ball was contradicted by Aristotle 2000 years earlier, and arrived at by Galileo only after much experimentation on bodies moving under gravity on inclined of rates of fall must be so, and is independent of any theory, as the following simple argument shows.

If we take two 0.5lb musket balls, since there is no difference between them or between their respective experimental situations, they must fall in the same manner and so take the same time to fall.. Similarly for any other 0.5lb balls. So 201 balls released simultaneaously must strike the ground simultaneaously with the one free ball. If the bonding between the 200 balls is made stronger, the same will be true.

There is no point at which different behaviour will occur, as the bonding is strengthened. Eventually, if the 200 balls are melted down and recast to make a 100lb cannon ball, there is no reason why this should fall at any different rate, and so we should expect it to fall at the same rate as the remaining 201st musket ball. It is legitimate to question this reasoning, but the matter could be put to experimental test, as Galileo claimed to have done. To have obtained the predicted result seems to me quite ordinary; I do not understand why Graneau thinks it "stunning".

Why should the more massive ball be expected to fall more quickly than the less massive ball? Graneau thinks that some special force, which he calls inertia, is needed to oppose gravity and so bring about the equality of rate of fall. There is no such force; the gravitational force acts equally on two equal masses, and doubly on the two when they are joined together to form one double mass. Thus gravitational force is necessarily proportional to the mass of the attracted object, so causing all objects to accelerate equally (assuming no other force is acting, e.g. air resistance). There is nothing remarkable in all this. It could not very well be otherwise.

Since there is no "force of inertia" there is no call to account for it; a *fortiori* there is no need to seek to attribute it to the effects of the fixed stars. There is no need therefore, to discuss Mach any further; he is irrelevant, as is all theory which invokes the so-called "Mack's principle".

The concept of field, too, is non-physical. A field is a convenient mathematical device for simplifying calculations. So are the square root of -1, conformal mapping, matrices, etc., but a matrix or -1 are not physical objects, and when mapping from one space to another the physical object of study does not change its form accordingly. Likewise, a field is a *mathematical* concept whereby if the force on one body at a given point is known, the force on other bodies at that point can be quickly and easily calculated. But a field is not a physical object, and to attempt to attribute some kind of reality to it, as to inertia, creates confusion and puts obstacles in the way of understanding.

These and many other misconceptions over the past two centuries have caused such confusion that there is now no way forward. We must go back to basic and build up physics again, with minds free of 20th century metaphysics and myths. By succumbing to the force of myth, Graneau has put yet one more obstacle on the path to truth.

R. A. Waldron
Dept. of Mathematics
University of Ulster

The article The Riddle of Inertia written by Peter Graneau in the January edition has prompted me to give a dynamicist's view of the question of inertia.

Firstly, I would like to make a few observations regarding any physical laws. Two major tests of the acceptability of a law are: do predictions made by the law agree with measured data to within the accuracy of the best measuring equipment? And does the theory give a simpler appreciation of a phenomenon than any other theory?

The first is a question of sound experimental practice but the second is often a matter of opinion.

In the realm of mechanics the classical methods satisfy the first test, provided that relative speeds do not approach the speed of light and that the concepts of mass length and times are axiomatic. That is that mass is conserved, space is Euclidian and time (based on some periodic system) is independent of the motion of the observer. From these premises the structure of mechanics is developed in accord with experience.

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 proportional to the time rate of change of the moment of momentum.

Force is regarded as a defined quantity because it is possible to set up a system of mechanics without the use of force. However, this is rather like running an economy without cash and relying on barter. So we have the definition of force as being that agency which produces a rate of change of momentum, or in more detail: A force is the action of one body upon another which, if acting alone, would produce an acceleration (relative to an inertial frame of reference). Now that the definition of force is that which produces acceleration there is no need to postulate an inertia force to balance the applied "real" forces. Indeed this is contrary to the original definition, Since inertial force does not fit into the classical scheme it is not surprising that it does not obey Newton's third law.

Inventing a fictitious inertia force is a useful device because it enables theorems in statics, such as those relating to virtual work as in D'Alembert's principle, to be used. Also in cases where it is convenient to use non-inertial frames of reference these ficticious forces are useful, as seen in the application of the Coriolis theorem.

The association of force with matter means that the body responsible for the force must be identifiable. Force is to matter as a hole is to a doughnut: No doughnut, no hole.

An example of difficulties which can be generated was given by a series of letters in a learned journal on the question "What keeps the moon up?" Here the proposition that centrifugal force (an example of inertia force) balanced the force of gravity was one solution offered but this leads to the problem of the origin and nature of this centrifugal force. A simpler answer is found by first restating the question as "What keeps the moon *down*?" The answer to this question is quite simply gravity since, if gravity were suddenly switched off, the moon would continue on a straight line, its distance from the Earth increasing. In this case gravity is providing the centripetal force to produce the centripetal acceleration. Regarding the anecdote of the jerking subway train, if the passenger had been wearing roller skates and had had his eyes closed he would not have been aware that the train had jerked; at least not until he made contact with the end of the carriage. This shows that it is the friction force between the soles of his shoes and the floor which gave rise to his imbalance.

The views which I have expressed here are, I believe, the generally accepted views of the majority of contemporary dynamicists and is not a statement of right or wrong. I refer the interested reader to Mechanics, 3rd Ed. by Keith R. Symon, Pub. Addison-Wesley 1972 and to references 10, 12 and 21 quoted therein.

H. R. Harrison
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De Sitter and the aether

Apropos the recent remarks on this topic by Busby and Busby[1] and by Aspden[2], de Sitter's suggestion about binary stars has been stated to be the best evidence that there is for the correctness of Einstein's invariance postulate. If de Sitter is shown to be wrong, therefore, the special theory would be shown to be false. It has been shown that the distances of binary stars, their orbital geometries, and other factors are extremely unlikely, in the case of visual binaries, to be such that de Sitter ghosting effects would be observed. Spectroscopic binaries, however, are sufficiently far away, and in some cases the ghosting effects have been observed. For further discussion see references[3] and[4]. Thus de Sitter *is* contradicted, and Einstein's theory becomes untenable.

However, it should not be necessary to disprove the special theory experimentally, for Einstein's two basic propositions, the invariance postulate (as if a physical theory could ever be based on a postulate!) and the principle of relativity, are incompatible with each other. The invariance postulate contradicts the principle of relativity, and it is this fact which leads to other contradictions such as the notorious clock paradox, so-called. This contradiction at the very core of Einsteins's theory does not merely disprove the theory; it renders it unworthy of any consideration whatsoever as a possible physical theory[5].

R. A. Waldron
Dept of Mathematics
University of Ulster

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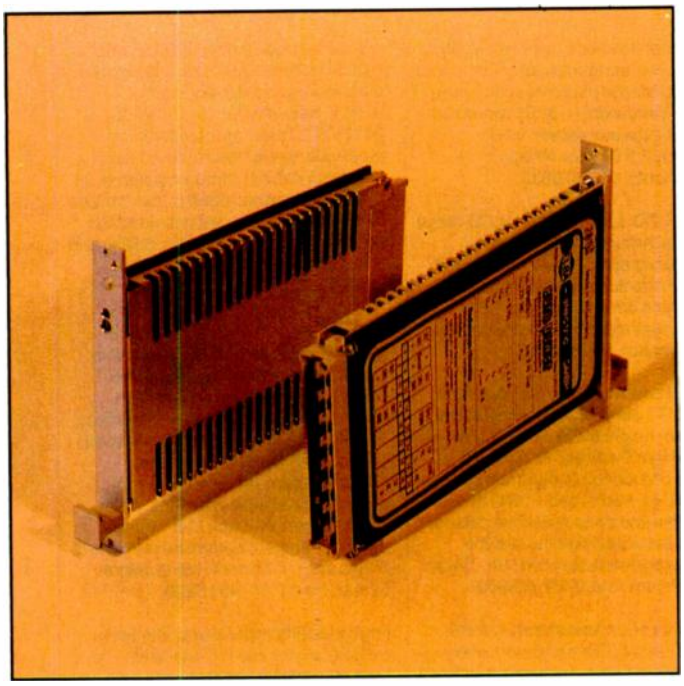

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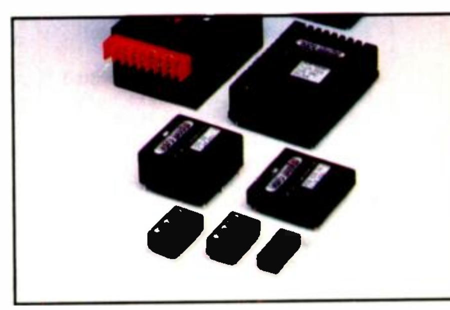

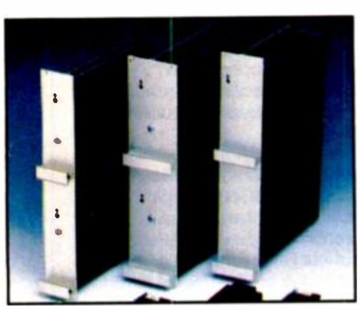

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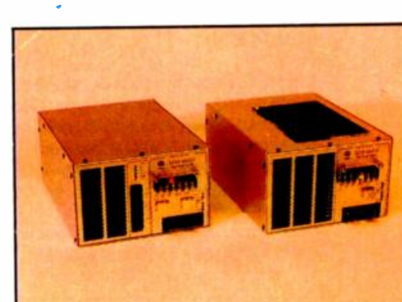
- ✱750W, 1000W, 1500W
- ✱Single or three Phase input
- ✱DC inputs from 24VDC to 220VDC
- ✱Power factor correction
- ✱M.T.B.F. 130,000 hours



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ACTIVE

Asic

Low cost risc. Samples are now available of the Advanced Micro Devices AM29005, a pin compatible addition to the AM29000 family of risc microprocessors. The AM29005 operates at 16MHz and is priced at £44.50 each in quantities of 1000. It is designed to bring risc performance to low-end to mid-range applications in the six to nine mips range. The AM29005 is a 32-bit microprocessor with three bus architecture, and is built in 1μm c-mos technology. It is available in a 168-lead plastic-quad-flat-pack (PQFP) package. Production is scheduled for Q2, 1990. AMD (UK) Ltd, 0483 740440.

High speed arrays. Tektronix has put together a family of semi-custom analogue IC arrays with NPN transistors capable of speeds up to 8.5GHz. The Tektronix QuickChip 6 family consists of IC arrays of uncommitted high speed bipolar transistors, capacitors, resistors, vanadium schottky diodes, and P-channel j-fets which can be easily interconnected. The variety of components makes possible a diverse range of applications that includes RF amps, mixers, sample-and-hold circuits, fast recovery amplifiers, high speed op-amps, high speed comparators, and mixed analogue/digital functions including interfaces. Tektronix, 06284 6000.

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

Simple cascade dacs. 2001 Electronic Components can supply the Maxim MAX500, a c-mos quad 8-bit voltage-output digital-to-analogue converter (dac). The device includes four output buffer amplifiers and input logic for two- or three-wire serial interface that can be cascaded. So with several MAX500s, only one serial data line is required to load all the dacs. Three reference inputs allow the range of two of the dacs to be set while the other two track each other. MAX500 dissipates 500mW single or dual supplies. 2001 Electronic Components, 0483 742001.

Power saving. Datel has developed the ADS-193 – an upgraded type 9003 12-bit 1MHz sampling A-to-D converter. All dynamic specifications measure –0.5dB below the full scale of the input range and power dissipation is reduced by more than 40%. Benchmark parameters include in-band harmonic specification of –81dB and a total harmonic distortion of –78dB. Signal to noise and distortion is –70dB with an effective bits specification of 11.25. Input range is ±2.5V bipolar or 0 to –5V unipolar. Datel UK, 0256 469085.

Discrete active devices

Brighter leds. Hero Electronics has introduced a brighter range to replace the Telefunken TLSR3201 and 5201 range which has recently been dropped by Telefunken. The leds from Hero have a round flat face and are available in red, green, yellow and orange with a viewing angle of 100° and luminous intensities up to 3.2mcd at 10mA. The wide viewing angle combined with high luminous intensity and flush mounting make this led suitable as a front panel indicator. Hero Electronics, 0525 405015.

Stackable leds. The 3421 range of stackable right angle mounting leds for flexible edge-or-board indication from IMO Electronics, has been designed with dovetails for easy side by side stacking in any colour sequence. The black polypropylene mouldings stack on an industry standard pitch. IMO Electronics 01 452 6444.

Power rectifier. Twin-chip common-cathode Schottky power rectifier modules 82CNQ025 and 82CNQ030 from International Rectifier have low forward voltage drops and load currents of up to 80A (rectangular waveform) and 72A (sinusoidal waveform). Peak reverse voltage ratings are 25V and 30V respectively. International Rectifier, 0883 713215.

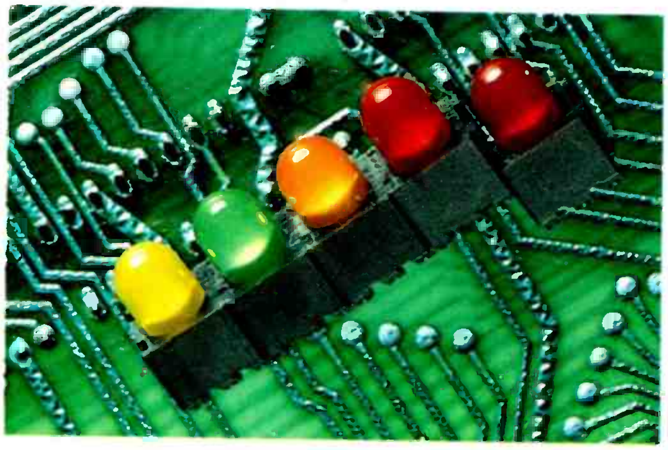
Feedback laser. The CQF62/D long wavelength distributed feedback (DFB) laser module from Philips Components is intended for multi-gigabit digital applications in the 1.3μm window. The laser diode is coupled to a single mode fibre, a monitor diode, a thermoelectric cooler, a temperature sensor and a bias "T" in a package pin compatible with a DIL-14. Bandwidth (–3dB) is more than 4GHz and the eye pattern is fully opened at 2.5 Gbits/s. Philips Components, 01 580 6633.

Backlit LCD. Latest Stanley LCD range available through STC Mercator, comprises graphic LCD modules, with cold cathode fluorescent lamp back illumination driven by a 5V or 12V supply together with a low-cost inverter. STC Mercator, 0493 844911.

Large character LCD. The Varitronix single LCD glass of 3½ or 4 digits and character height of 2in can be obtained from Trident Displays. VI-50302 (3½ digit) and VI-50402 (4 digit) can operate at –10°C to +60°C and –30°C to +84°. Reflective and trans-reflective polariser options allow backlighting and the displays are readable from 50ft. Trident Microsystems Ltd, 0737 765900.

Low saturation transistor. A series of "Super E-line" ZTX transistors offering high gain but without saturation-voltage problems is available from Zetex. At 100mA, the collector-emitter saturation is 0.1V. Being capable of switching loads of up to 2A when driven directly from c-mos level signals, the transistors can be used for interfacing digital circuits, including microprocessors. Low saturation voltage also makes them candidates for battery-powered applications. With gains of 500 at 100mA collector current, the transistors can handle voltages of up to 120V. At higher currents, gain falls but a 20V device still has a gain of 400 when working at its maximum continuous collector current of 2A. Zetex plc, 061 627 4963.

Stackable, right-angle mounting leds by IMO



Linear integrated circuits

High speed op amp. Analog Devices' current feedback monolithic op amp AD9617 offers 190MHz small signal bandwidth at closed loop gain of +3V/V, and its AD9618, 160MHz (+10V/V). These pin compatible op amps guarantee maximum values of second and third harmonic distortion at three frequencies: 4.3MHz, 20MHz and 60MHz. Worst case second and third harmonic components are –55dBc and –62dBc. Analog Devices, 0932 253320.

Sensorless motor controller. Micro Linear has developed a sensorless controller for brushless DC motors, including those used in hard disk drives. The ML4410 sensorless spindle motor controller eliminates the need for Hall-effect sensing devices. Using phase locked loop techniques, the ML4410 uses the back EMF of three motor windings to determine the correct phase angle for commutation. Micro Linear Corp, (408) 433 5200.

High stability regulators. The Seiko range of c-mos linear ICs available from Pedoka, is designed to provide high stability voltage. Current consumption is 30μA and is combined with an input/output differential of 2V on most models. Pedoka Electronics Ltd, 0493 440047.

Audio T switch. The SSM-2402 IC from PMI is a dual analogue T-switch for high-performance audio applications. It features "clickless" audio switching with low distortion and noise over the audio range 20Hz to 20kHz, at signal levels up to 10V RMS. Precision Monolithic Inc, 0276 692392.

Low noise op amp. PMI has developed the SSM-2139, a low noise, high speed dual audio op amp internally compensated for gains equal to, or greater than, three. It is a monolithic bipolar amp offering a typical voltage noise performance of 3.2nV/√Hz. Guaranteed specification is 5nV/√Hz Max at 1kHz. Precision Monolithic Inc, 0276 692392

Wideband multiplexer. Siliconix has developed the DG534, a logic selectable four channel or dual differential multiplexer that can select one of four RF or video signals to a common output. The DG534 provides a DC to 300MHz bandwidth, low crosstalk (–97dB at 5MHz), a TTL-compatibility, and address latches all on a single chip. Siliconix Ltd, 0635 30906.

Low power PWM. The bi-cmos TSC18C46/47 series has a maximum supply current of 2mA at 500kHz. The low current draw means that an SMPS can be designed for off-line operation with fewer and smaller components for the bias supply. Rise and fall times into a 1000pF load are 150ns max and there is a minimum pulse width of 450ns with 200mV step to Ix pin. The ICs are available with inverting and non-inverting outputs. Typical pricing for commercial versions is $2.52 in 10,000 piece quantities. Teledyne Semiconductor, 01 571 9595.

Switchmode controller. The TSC9115/9116 is a monolithic switchmode controller IC from Teledyne Semiconductor designed for a wide range input voltage, 10-300V DC, high efficiency implementations of popular single-ended current mode SMPS topologies. The TSC9115/9116 have automatic start-up, current-mode operations, and can self-power from an output. They are suited for use in SMPS up to about 100W. Teledyne Semiconductor, 01 571 9596.

Logic building blocks

Driver/receiver. The uPD471X family of RS-232C driver/receivers from NEC aims to fulfil the complete RS-232C specification with only a single 5V power supply. It incorporates defined power-on, reset and power off conditions, eliminating external switches to the communications lines. Features include a low-power standby made. NEC Electronics (UK) Ltd, 0908 691133.

100μA pal. Philips Components PLC18V8Z programmable logic device is available from Quarndon Electronics. Its standby current is 100μA; active current is 1.5mA per MHz. Standby mode is automatically selected if there have been no transitions on any of the inputs 35-40ns. The chip comprises 10 inputs, 74 product terms and eight microcells and is capable of emulating all common 20-pin pals. Quarndon Electronics Ltd, 0332 32651.

Shift register. SLS6016/6216 ultra high speed shift registers from STC Semiconductors offer 16 parallel TTL-compatible inputs and ECL-compatible serial inputs and outputs operating at data rates up to 450MHz. The SLS6016 operates from a single 5V rail. The SLS6216 runs from a dual-rail +5 and −5V for split-rail ECL-TTL systems. STC Semiconductors, 01 300 3333.

Mosfet protection. Adaptive power-control is now available from Siliconix through its Si9910 power mosfet driver IC. This single-channel, non-inverting driver adapts to the power mosfet's operating conditions, providing mosfet protection as well as optimising gate drive. Use of this adaptive technique eliminates the need for designing motor drives for worst-case conditions or for adding external devices to guarantee safe operation. Siliconix, 0635 30905.

Memory chips

C-mos electronically erasable. Available from Austria Mikro Systeme is a family of nine c-mos Peel devices. Direct replacement devices are Jedec-file-compatible replacements for the 24 pin pal devices and 20 and 24 pin FLPAs. Superset devices emulate most of the standard 20 and 24 pin PLDs and also offer designers many new architectural and performance features. Low power is a key benefit. A pal comparable Peel device offers a normal standby current requirement down to 10mA, with the active supply current typically adding 0.7mA/MHz switching frequency. AMS Ltd, 0793 537852.

Mask rom. Fast access times of 150 and 200ns are a feature of the megabit static c-mos mask rom, type S631000/S631001 from Austria Mikro Systeme International; The device is TTL compatible on all inputs and outputs and memory expansion is facilitated by allowing outputs to be OR-tied to other devices. AMS Ltd, 0793 537852.

Microprocessors and controllers

Boosted chip performance. Mitsubishi Semiconductors has introduced several new devices to its range of 8-bit and 16-bit c-mos single chip microcomputers. The 8-bit M50747 with 8K rom, 256 bytes ram; 8 input 8 output and 40 I/O ports; serial port and three 8-bit timers on board, now operates at a clock speed of 12MHz. The M37450 has similar features to the 747 but includes A/D and D/A converter circuitry and a PWM output for control purposes. Mitsubishi Electric UK Ltd, 07072 76100.

Low-cost risc. A low-cost 16MHz version of the 88000 risc microprocessor family has been developed by Motorola. The 88100 MPU, with floating point maths and integer execution units on a single chip, is priced at $148 in 1000 piece quantities; 88200 cache memory management unit is $175 in 1000 piece quantities. At 16MHz, the risc chip set executes at 13.6mips and thus costs $11 per mips. Motorola Ltd, 0296 395252.

Hard-disk controller. Up to seven hard disk drives can be controlled by NEC's ESDI interface chip, μPD7262. Designed for direct connection to the host processor, μPD7262 incorporates 27 commands, significantly reducing CPU activity during drive access operations. Data separator and PLL circuits are eliminated in the ESDI design, being integrated into the drive itself. NEC Electronics (UK) Ltd, 0908 691133.

PASSIVE

Passive components

High voltage. The ML high voltage potentiometer from Citec provides a voltage proof specification of 2.5kV in AC condition. The rugged package offered in a range of linear, log and inverse log laws from 100Ω to 2MΩ, or down to 10Ω in the cermet version. It is fully sealed, and the cermet version will dissipate a 2W of power at 70°C. Citec, 0793 611666.

Common-mode choke. In AC power-line applications, wide-band noise suppression normally takes two chokes – one for the higher frequencies; another for lower frequencies. PLH20H series common-mode chokes from Murata combine the features of both, providing over 35dB loss from 500kHz to 10MHz, and 20dB at 50MHz. Applications include switching power supplies, digital circuits, monitors, TVs and analogue signal-processing equipment. Murata Electronics (UK) Ltd, 0252 811666.

Film capacitors. The MKT 1823 series metallised polyester film capacitors from Steatite Roederstein are available in three voltage ranges covering a capacitance range of 1000pF to 0.47μF. They will replace multilayer ceramic types. Capacitances of 1000pF to 6800pF are rated at 100VDC/63VAC, 0.01μF to 0.01μF at 63VDC/40VAC, and 0.15μF to 0.47μF at 50VDC/30VAC. Steatite-Roederstein Ltd, 021 643 6888.

Solid capacitors. Solid capacitors, developed by Sanyo Electric, with organic semiconductive electrolyte, are now available from Techmost Electronics. The OS-CON capacitor can withstand reverse voltages up to 20% of rated voltage and has high temperature life of ten times aluminium electrolytics. Permissible ripple current is four and ten times higher than aluminium electrolytics and tantalum solid capacitors respectively. Techmost Electronics, 0279 652444.

Connectors and cabling

Miniature connectors. Belling Lee's MCX miniature connectors are designed for minimum board space but with good screening and signal transmission characteristics. Rated at up to 3GHz, the connectors are suitable for high speed communications applications. Mounting is by a vertical style socket with a PC footprint of 3.8 x 7.3mm, or a right angle version with a footprint of 6 x 6mm, and a mounting height of 6mm. Moving contact parts are beryllium copper, and all parts are gold plated. Belling Lee Ltd, 01 363 5393.

High density connectors. Fujitsu 210 and 220 series half pitch connectors have been made available through Devlin Electronics. High density mounting is achieved by 1.27mm pitch contact, two row configuration and terminals spaced in a four row zigzag array. They can accommodate double sided independent PCBs to a thickness of 1.6mm and are available as two piece and card edge devices with a range of contacts. Devlin Electronics Ltd, 0256 467367.

Crystals

BT-cut crystal. IQD is manufacturing BT-cut crystals in prototype and production quantities. The fundamental frequency of the BT cut crystal extends to 35MHz. Its quartz blank is 1.5 times thicker than that of an AT-cut, making it economically practical to produce at higher fundamental frequencies while at the same time retaining a parabolic temperature coefficient. IQD Ltd, 0460 74433.

Instrumentation

True RMS multimeter. High resolution and true readings of RMS AC parameters are two of the features of the Man 2000 digital multimeter from Advanced Measurement Electronic. The instrument has a 4½ digit liquid crystal display and is able to measure up to 650V AC, true RMS, 650V DC, 300V at high frequencies, 15A AC, true RMS, 15A DC, 20Mohm, 1,999.9Hz and 19,999rpm. Accuracy is rated at ±0.1%, resolution is 0.005%. Input impedance is 10MΩ. AME Ltd, 0753 696433.

Solid capacitors from Techmost

NEW PRODUCTS CLASSIFIED

Interference detector. Chase EMC has launched the CIT-9600 hand-held interference tracer for diagnostic sourcing of radio frequency and electromagnetic interference (RFI/EMI). Two detector modes, average and peak, permit identification of continuous and intermittent signals. An audio oscillator providing a pitch tone proportional to the input signal, makes interference location easy. Usable frequency range is from 50Hz to 500MHz, with a dynamic range of 50dB. PP3 battery operation gives around four hours of continuous operation. Chase EMC Ltd, 01 878 7747.

Test signal generator. The D2-MAC substitution-signal IF modulator SBKE from Rohde & Schwarz produces a standard video/sound IF test signal to German FuBK specifications. During program breaks or failures, this pattern can be applied as a substitution signal to the transmitter section of the broadband communication systems via the automatic switchover circuit. Rohde & Schwarz (UK) Ltd, 0252 811377.

Thermometer strips. Temperature measurement of electronic components is the aim of the Tempscale mini-thermo-strip, from Specialised Labels. Size of the strip is 3mm x 11mm, available in 10 ratings. Each rating consisting of four temperatures in 5°C intervals between 40 and 260°C. Price per 45 indicators of each rating is £3.00. Specialised Labels, 0332 382421.

Field oscilloscope. The compact Trio-Kenwood CS-3035 portable dual-trace oscilloscope is available from Thurlby-Thandar. Despite its small size (216 x 89 x 298mm) and weight (4kg), the CS-3035 offers a professional specification. It can operate from an optional battery pack for two hours continuously, from an external DC source of 11.5 - 13.5V, or from AC mains. The CS-3035 uses a rectangular high-intensity tube giving an 8 x 10 division display, with each division measuring 6.35mm. Bandwidth is 20MHz. Sensitivity of 5mV per division is available on both channels up to full bandwidth. Thurlby-Thandar Ltd, 0480 412451.

Digital tape recorder. Earth Data has developed a 64-channel version of its EDR128 instrumentation tape recorder allowing mixed-bandwidth digital recording on a standard VHS video tape cassette. The EDR128 can digitise analogue signals using either 12-bit conversion, with a bandwidth of 40kHz, or 16-bit mode with a bandwidth of 30kHz. Earth Data Ltd, 0703 869922.

Digital disk recorder. The Instrument Systems Division of Gould Electronics has introduced DataGraf, a portable 16 channel digital recorder. Once stored, recorded signals can be replayed many times from disk, and can either be expanded or compressed in time to achieve the required detail. Gould Electronics, 01-500 1000.

Magnetic field meter. A 50Hz magnetic field meter, model IER-119 with 2 to 2000 milligauss range (0.2 to 200 microtesla) and a bandwidth of 11Hz can be obtained from Perspective Scientific. The hand-held meter has LCD display and programmable alarm (audible and visual), backlighting and a strip chart recorder output with optional AC adaptor. Maximum sensitivity is 1 microgauss (0.1 nanotesla). Linearity creates a ±0.1% precision and repeatability. Calibration is ±2%. Single quantity price is $595. Integrity Electronics and Research Inc, (0101) 716 886 7283.

Microwave analyser. Marconi Instruments has launched the 2386 microwave spectrum analyser covering the frequency band 100Hz to 26.5GHz with an extended range of 10Hz to 30GHz. A feature of the 2386 is its resolution with spans as narrow as 100Hz and bandwidths down to 3Hz. Measurement of third order distortion products at least 90dB down is possible. To prevent accidental damage from DC overload, the input can be switched from DC to AC coupled. Price is around £39,500. Marconi Instruments, 0727 59292.

Rotek's model 4800A multifunction calibrator, available from PPM Instrumentation, has been designed for calibrating analogue, 3½ and 4½ digit multimeters and many 5½ digit models. It provides AC and DC voltage up to 1100V; AC and DC current up to 1A; and resistance from 1Ω to 10MΩ. Resolution is 1ppm on all ranges except ohms. AC frequency range is 40Hz to 50kHz and a digital error percentage display for the unit-under-test is also incorporated. Accuracy is better than 45ppm on DC volts, 0.045% on AC volts and current, and 0.015% on DC current. PPM Instrumentation, 0483 301333.

Power supplies

DC/DC converter. D Series, 24-pin DIP DC/DC converters from Amplicon Liveline provide single (5, 12 and 15V DC) and dual (±12 and ±15V DC) regulated outputs with short-circuit protection and Pi input filtering. Other characteristics include 20mV p-p ripple and noise; 300V DC isolation; efficiency of 50% and switching frequency from 40kHz to 70kHz. Amplicon Liveline, 0273 570220.

High temperature cells. Saft (UK)'s VTD series rechargeable, sealed NiCd cells has polysulfone insulating seal rings and plastic negative electrodes to help achieve a maximum operating temperature of +70°C. The series is designed for use in luminaires meeting the requirements of ICEL 1001 1986 Part II and expected life is at least four years. Rated capacity is 4Ah at 20°C, nominal voltage is 1.2V and charging current is 400mA for 16 hours. Saft (UK) Ltd, 01 979 7755.

Linear regulator. Low noise is the aim of the L series linear power regulators from Schroff UK. All the units in the L series have five selectable mains input ratings, conform to VDE 0875 (curve K) RFI/EMI emission, are open frame and are available with single, double or triple output rails. Output powers range from 15 to 116W with over 26 available. Schroff UK Ltd, 0442 40471-9.

COMPUTER

Computer board level products

PC diagnostics. The Logimer diagnostic system from Amplicon has been designed to speed repair of IBM PC/XT, 80286 and 80386 compatible boards. The system comprises a plug-in card with an alphanumeric display for tracing "screen-dead" faults and a replacement bios which can make more than 1000 individual tests in less than 60s. Failed chips are identified saving unnecessary replacement of other suspect devices during the normal fault finding procedure. Amplicon Liveline Ltd, 0273 570220.

16 channel A/D. The PC 27 analogue data acquisition board from Amplicon is a 16 channel 12-bit A/D device with a typical conversion time of 10μs, 12-bit resolution and linearity figures better than ±1 LSB. It features successive approximation conversion with three trigger modes; external, an on-board timer or software. The PC 27 has two input ranges; ±4V and 0 to 8V. It has a 4MHz on board reference running one 16 bit counter. Price is £125. Amplicon Liveline, 0273 570220.

Data communications products

HF data transmission. Harris Long Range Radio has developed a HF data system for voice and high-speed data transmission over HF radio channels. The RF-3266A is a complete rack-mounted system built around the Harris RF-3200 HT transceiver, with data operation controlled by the RF-3466A universal HF modem. In the FSK mode, the system can operate with any binary FSK system using data rates of 50 to 1200bps. Harris RF Communications, (0101) 716 244 5830.

Software data acquisition. Data Translation has launched Global Lab, a high performance, menu-driven data acquisition and analysis software package. Global Lab can perform a gap-free data acquisition and storage to disk to the maximum rates of board and system configuration, up to 250,000 samples per second. No programming is necessary. The package runs under dos and combines the flexibility of subroutine libraries with real-time displays and mouse-/menu-driven ease-of-use. Data Translation Ltd, 0734 793838.

Design interface. Racal-Redac has developed the Visula plus CAE system for schematic capture and simulation of analogue, digital and mixed analogue-digital systems incorporating both ASIC and PCB technologies. The Visula system allows simulation to be performed concurrently with circuit design. Racal-Redac Group Ltd, 0734 782158.

Circuit simulation. Latest release of the PC-based logic circuit simulation package, LCA.1, is ten times faster than its predecessor according to distributor, Those Engineers. It also offers file output to other software so that, for example, ATE programs can be constructed from it. LCA.1 memorises every point and event within a circuit and allows data to be spooled to external applications. Those Engineers Ltd, 01 435 2771.

Computer peripherals

Precision plotter. Available ex-stock from Thurlby Electronics: the 681-XA digital plotter. Using four pens, it features a plotting speed of 400mm/s in the axial direction and 565mm/s at 45°. Acceleration in the axial direction is 1G. Distance accuracy is 0.3% ±0.2mm with repeatability of 0.2mm and pen-exchange accuracy of 0.2mm. Thurlby Electronics Ltd, 0480 63570.

Software

Bus control software. BVM has developed Target488 software to accompany its IP488 IEEE488/GPIB bus controller module. Target488 provides control of the IEEE488 bus through a library of C functions. High level language for driver software simplifies production of GPIB bus applications. The IP488 is based around the TMS9914A controller chip and can be configured, through software, to be either a bus master or slave. BVM Ltd, 0703 270770.

RF EQUIPMENT

LOW NOISE GASFET PREAMPLIFERS

Aligned to your specified frequency in the range 30-1000MHz. Masthead or local use.

TYPE 9006. NF 0.6dB. Gain 10-40dB variable. In the range 30-250MHz **£85**

TYPE 9006FM. As above. Band II 88-108MHz **£85**

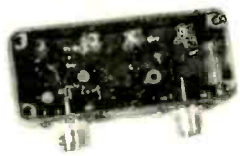
TYPE 9002. Two stage Gasfet preamplifier. NF 0.7dB. Gain 25dB adjustable. High Q filter. Tuned to your specified channels in bands IV or V **£112**

TYPE 9004. UHF two stage Gasfet preamplifier. NF 0.7dB. Gain 25dB adjustable. High Q filter. Aligned to your specified frequency in the range 250-1000MHz **£112**

TYPE 9035. Mains power supply for above amplifiers **£43**

TYPE 9010. Masthead weatherproof unit for above amplifiers...... **£13**

TYPE 9006



TYPE 9002

WIDEBAND AMPLIFIERS

Monolithic microwave integrated circuits in a fully packaged microstrip module format. Full-wave shottky diode protected inputs. Temperature compensated bias circuitry. Voltage regulated local or remote operation.

TYPE 9007. 100KHz-900MHz NF 2.3dB at 500MHz. Gain 20dB...... **£150**

TYPE 9008 Gasfet. 100MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Power output +18dBm, 65mW **£150**

TYPE 9009 Gasfet. 10MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Power output +20dBm, 100mW **£150**

TYPE 9011 100KHz-400MHz NF 2.8dB at 300MHz. Gain 30dB. Power ouput +14dBm, 25mW **£150**

TYPE 9113

TYPE 9252

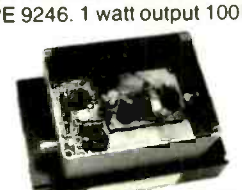
PHASE LOCKED LOOP FREQUENCY CONVERTERS

TYPE 9113 Transmitting. Converts your specified input channels in the range 20-1000MHz to your specified output channels in the range 20-1000MHz. 1mV input, 10mW output (+10dBm). AGC controlled. Gain 60dB adjustable −30dB. Will drive transmitting amplifiers directly **£396**

TYPE 9114 Receiving. Low noise Gasfet front-end. NF 0.7dB. Gain 25 dB variable. **£396**

TMOS WIDEBAND LINEAR POWER AMPLIFIERS

TYPE 9246. 1 watt output 100KHz-175MHz 13dB gain **£135**



TYPE 9176

TYPE 9271

TYPE 9247. 4 watts output 1-50MHz 13dB gain **£135**

TYPE 9051. 4 watts output 20-200MHz 13dB gain **£135**

TYPE 9176. 4 watts output 1-50MHz 26dB gain **£285**

TYPE 9177. 4 watts output 20-200MHz 26dB gain **£285**

TYPE 9173. 20 watts output 1-50MHz 10dB gain **£340**

TYPE 9174. 20 watts output 20-200MHz 10dB gain **£340**

TYPE 9271. 40 watts output 1-50MHz 10dB gain **£680**

TYPE 9172. 40 watts output 20-200MHz 10dB gain **£680**

TYPE 9235. Mains power supply unit for above amplifiers.......... **£180**

PHASE LOCKED SIGNAL SCURCES

Very high stability phase-locked oscillators operating directly on the signal frequency using a low frequency reference crystal. Phase noise is typically equal to or better than synthesized signal generators. Output will drive the Types 9247 and 9051 wideband linear power amplifiers and the Types 9252 and 9105 tuned power amplifiers.

TYPE 8034. Frequency as specified in the range 20-250MHz. Output 10mW **£140**

TYPE 8036. Frequency as specified in the range 250-1000MHz. Ouput 10mW.......... **£195**

TYPE 9182. FM or FSK modulation. 20-1000MHz. Output 10mW **£248**

UHF LINEAR POWER AMPLIFIERS

Tuned to your specified frequency in the range of 250–470MHz. 24V.+ DC supply

TYPE 9123 250mW input, 5 watts output **£289**

TYPE 9124 2-3 watts input, 25 watts output **£335**

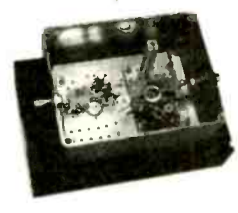
FM TRANSMITTERS 88-108MHz. 50 watts RF output

TYPE 9086. 24V + DC supply **£1,040**

TYPE 9087. Includes integral mains power supply **£1,220**

TYPE 9182FM exciter ±75KHz deviation. Output 10mW **£248**

TYPE 9263



TYPE 9259

TELEVISION LINEAR POWER AMPLIFIERS

Tuned to your specified channels in bands IV or V. 24V + DC supply.

TYPE 9261. 100mV input, 10mW output **£218**

TYPE 9252. 10mW input, 500mW output **£280**

TYPE 9259. 500mW input, 3 watts output **£320**

TYPE 9262 500mW input, 10 watts output **£580**

TYPE 9263. 2-3 watts input, 15 watts output **£440**

TYPE 9266 10 watts input, 50 watts output **£1,745**

See below for Television Amplifiers in bands I & III.

TYPE 9105

TYPE 9158/9235

TMOS RF LINEAR POWER AMPLIFIERS

Tuned to your specified frequency in the range 20-250MHz, or your specified channels in bands I or III. 24V +DC supply.

TYPE 9105. 10mW input, 1 watt output **£250**

TYPE 9106 500mW input, 10 watts output **£310**

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PIONEERS

A.A. CAMPBELL SWINTON
Master Prophet of electronic television

It is perhaps a little ironic that a man who was a great experimenter is now best remembered for an idea he was unable to put into practice and did not live to see succeed. In the early years of this century, Alan Archibald Campbell Swinton had the extraordinary imagination and foresight to suggest the basic structure of an all-electronic television system. The idea was way ahead of its time and was not achieved in practice until the 1930s. Though he is remembered for that now – at least in television engineering circles – at the time his other successes, such as X-ray photography, seemed more notable.

Swinton's ideas on electronic television first appeared in print in a letter to the science journal *Nature* on the 18th June, 1908. Even before that there had been speculation over "distant electric vision". This was inevitable once the three basic properties of television were known: the conversion of light into an electric signal; photoconductive properties of selenium, (1873); the transmission of electric signals by telegraphy (1837) and the conversion of electricity into light (incandescent lamp, 1879).

By the turn of the century, however, Swinton was aware that the situation had changed a little. By then he was well acquainted with cathode ray experiments and the Braun oscillograph invented in 1897 (the first basic oscilloscope). Though nothing seems to have been published at the time, he revealed in 1926 that he had experimented with electronic television as early as 1903/04: "... not long after the production of the Braun oscillograph in 1897 ... I actually tried ... around 1903/04 ... some not very successful experiments in the matter of getting an electrical effect from the combined action of light and cathode-rays upon a selenium-coated surface ..."[1]

With two assistants, he had attempted to make a camera tube ("transmitting apparatus") out of a home-made Braun oscillograph. The normal fluorescent screen was replaced by a selenium-coated metal plate onto which the optical image was focussed by a lens, "... the end of the cathode-ray beam being caused electromagnetically to traverse the projected image".[1]

Swinton also attempted to build an electronic receiver. "Experiments were also tried in receiving with a Braun tube ... but in its then 'hard' form it proved very intractable."[1] That Swinton had even thought of using cathode ray electronic scanning at both the camera and receiver end of the television chain at that early date marks his proposals as the first for electronic television. That he also attempted some "not very successful" experiments makes it a double first. The nearest similar idea was Rosing's cathode-ray display tube at the receiver (1907).

Swinton's 1908 letter to *Nature* was his earliest simple description of his ideas. These were elaborated in 1911 during his presidential address to the Roentgen Society in London, when a circuit diagram was included of how electronic television might be achieved. It was "an idea only," he said, "a suggestion of a direction in which experiment might possibly secure what is wanted."

Scottish descent

When he died on the 19th February 1930, Swinton was widely known, respected and honoured. He had been born in Edinburgh on the 18th October 1863 into the landed gentry of Scotland. He had two brothers and two sisters. His father was a professor of law at Edinburgh University and his family traced their ancestry back as far as the time of Alfred the Great. Alan's great grandfather's marriage to the daughter of the head of the Campbells had introduced that name to the lineage. His many distinguished ancestors had married into other leading families, as did his father, for his mother was Georgiana Sitwell.

Alan was brought up at the family home in Berwickshire. By the age of six he was displaying his inventiveness and practical aptitudes and was learning to use a wood turning lathe. By ten he had begun his life-long hobby of photography, sensitising his own paper and building his own camera. His first publication was on his invention of a transportable darkroom tent.

At eleven, Swinton started his first formal schooling, which he enjoyed until he transferred to Fettes College, Edinburgh. There the curriculum was not to his liking and he looked back on his three years there "with horror".

Two years after Bell's announcement of the invention of the telephone, Swinton managed to build a working model at school, but was ordered to dismantle it. It was not long before he persuaded his parents to allow him to leave the school. "I never passed, or tried to pass, a single examination," he wrote, "examinations are a woeful waste of time."

On leaving school he spent nine months in France perfecting his French before taking up an apprenticeship with a ship builder near Newcastle-upon-Tyne. In his spare time he wrote a textbook: "Principles and Practice of Electric Lighting", which was published when he was 21, one of the many remarkable achievements of his life. Naturally he was asked to introduce electric lighting to the warships the yard was then building. He soon extended the brief to include other electrical applications, including a gun-firing control. During his five year apprenticeship he mastered many types of electrical and mechanical machinery and even applied for a dozen patents.

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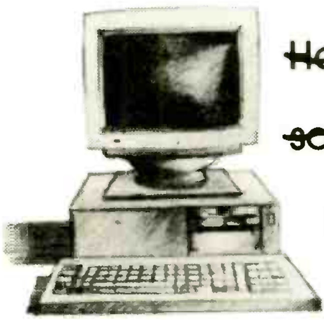

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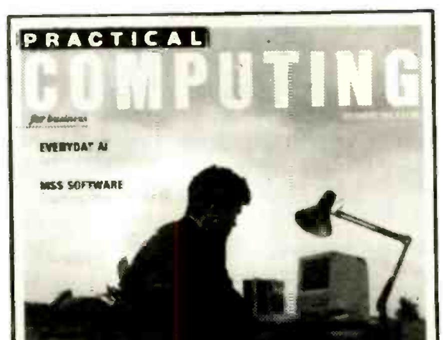

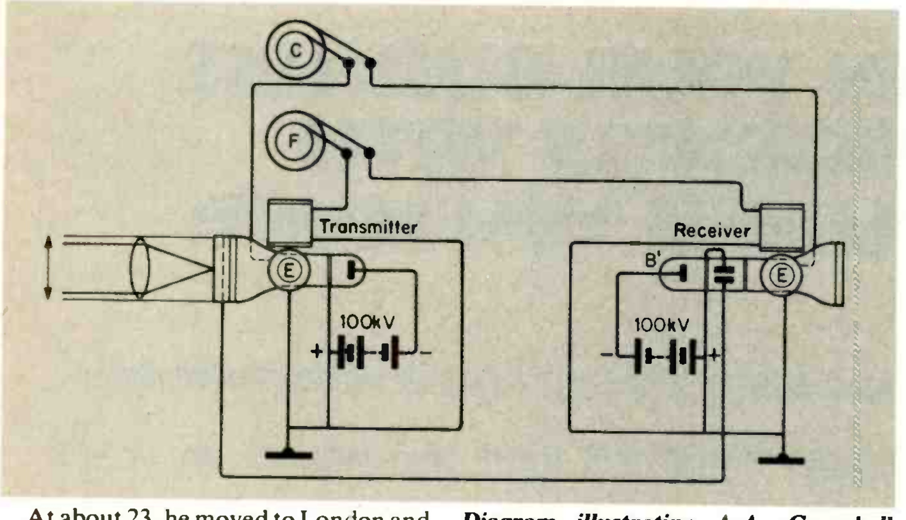

Diagram illustrating A.A. Campbell Swinton's ideas for "distant electric vision."

At about 23, he moved to London and established himself as an electrical consultant and contractor covering electrical supply, lighting installations, telephones and the like. He also found time to lecture and to begin scientific experimentation, and to become the London agent for C.A. Parsons & Co. Ltd. Charles Parsons had produced the first practical steam turbine in 1884 and Swinton took a deep interest in it.

The two became friends as well as business associates and Swinton was able to contribute to improvements to the turbine and was a founder-director of the Marine Steam Turbine Company. When, in 1897, a turbine-driven boat sped past the Diamond Jubilee Naval Review at Spithead at the unheard of speed of 34 knots, Swinton was on board and probably enjoying every minute of the sensation they were creating. His association with Parsons continued and he became a director of a new Parsons company, set up to build torpedo boats. Years later in 1918 when Parsons lectured on his experiments on the production of artificial diamond, he acknowledged Swinton's (and others') help. That particular path seems to have begun in 1907 when, as one of Swinton's experiments, they had turned diamond into coke. Swinton subsequently made artificial rubies.

X-Rays

To say that Swinton's interests were varied seems a hopelessly inadequate description. As well as turbines and electrical contracting, he studied hydro-electric generation, electric arcs, HF discharges, a 10kV storage battery ("care has, of course, to be taken not to touch the connections"), patented a new bicycle handlebar and developed what he called the "new photography" – X-rays.

W.K. Roentgen discovered X-rays in November, 1895. The following January, Swinton read a report of the discovery and produced X-ray photographs the same day, his photographic skills proving invaluable. He announced his success in a letter in the *Evening Standard* on the 10th January.

A few days later he succeeded in photographing the bones of his right hand – using a 20 minute exposure! One wonders what harm he did to himself during all these experiments. By the 23rd January, his technique had improved sufficiently to publish the results in *Nature*. He also lectured on the subject to the Camera Club in London and, on at least one occasion, took X-ray photographs during the lecture, including one of the chairman's hand. These were developed on the spot and shown to the audience. At another demonstration he X-rayed the Prime Minister's, Lord Salisbury's, hand.

As always, Swinton was quick to perceive long-term uses for the new discovery and speculated on future medical applications. His own laboratory in Victoria Street was soon being used by the medical profession. Although Swinton became an acknowledged authority on the subject, it was still something of a fascinating sideline for him, his principal business remaining electrical consultancy. One can begin to see why it was remarked that he was too busy ever to get married.

The other big novelty at the end of the 19th century which naturally occupied Swinton's mind was the arrival of radio telegraphy. As usual, he was involved almost from the start, tracing his interest back to about 1890 when he met David Hughes, who had experimented with radio signalling before an understanding was gained as to what he had achieved.

When Marconi arrived in London in 1896 seeking a home and funds for his radio telegraphy system, it was Campbell Swinton who was first to recognise the potential of Marconi's equipment and, indeed the man himself. Invited by Marconi's uncle to a demonstration in London, Swinton was quickly convinced. Knowing of the Post Office's interest in a "wireless" communications system, Swinton wrote to William Preece, the Post Office Chief Engineer, to introduce and recommend Marconi. The rest is, as they say, history. It would not be unreasonable to view Swinton, in a small way, as the catalyst of Marconi's success in Britain.

It is hardly surprising that a man who gained such distinction in so many areas of science and engineering should have gathered a bagful of honours and public appointments. They ranged from directorships of companies, including the electrical manufacturer Crompton and Company, to Vice-president of the Institution of Electrical Engineers, member of the board of the National Physical Laboratory, Delegacy of the City and Guilds College, consultant engineer to the Metropolitan Police, Freeman of London, etc. But the most prized of all was election to Fellowship of the Royal Society, which came in May 1915, the ultimate scientific accolade that Britain could bestow. Swinton celebrated with a sketch of himself as a winged angel clutching an FRS certificate and accompanied by the words, "Joy, joy for ever, my task is done. The gates are past, and heaven is won!"

But his tasks were not yet wholly done, and would not be until he drew his last breath in 1930. In the early 1920s he again unsuccessfully attempted to build an electronic television pickup tube and argued with others on the subject through the letters column of *The Times*.

As always, his mind was ever turned to practical solutions to problems. When his housekeeper wanted a way to discourage dogs from urinating on the front doorstep, Swinton waited for a warm dry day and put calcium phosphide down ... it bursts into flames on contact with water.

He enjoyed watching one more successful experiment! ■

Reference

1. T.H. Bridgewater, "A.A. Campbell Swinton," Royal Television Society, London, 1982. This article is largely based on this monograph.

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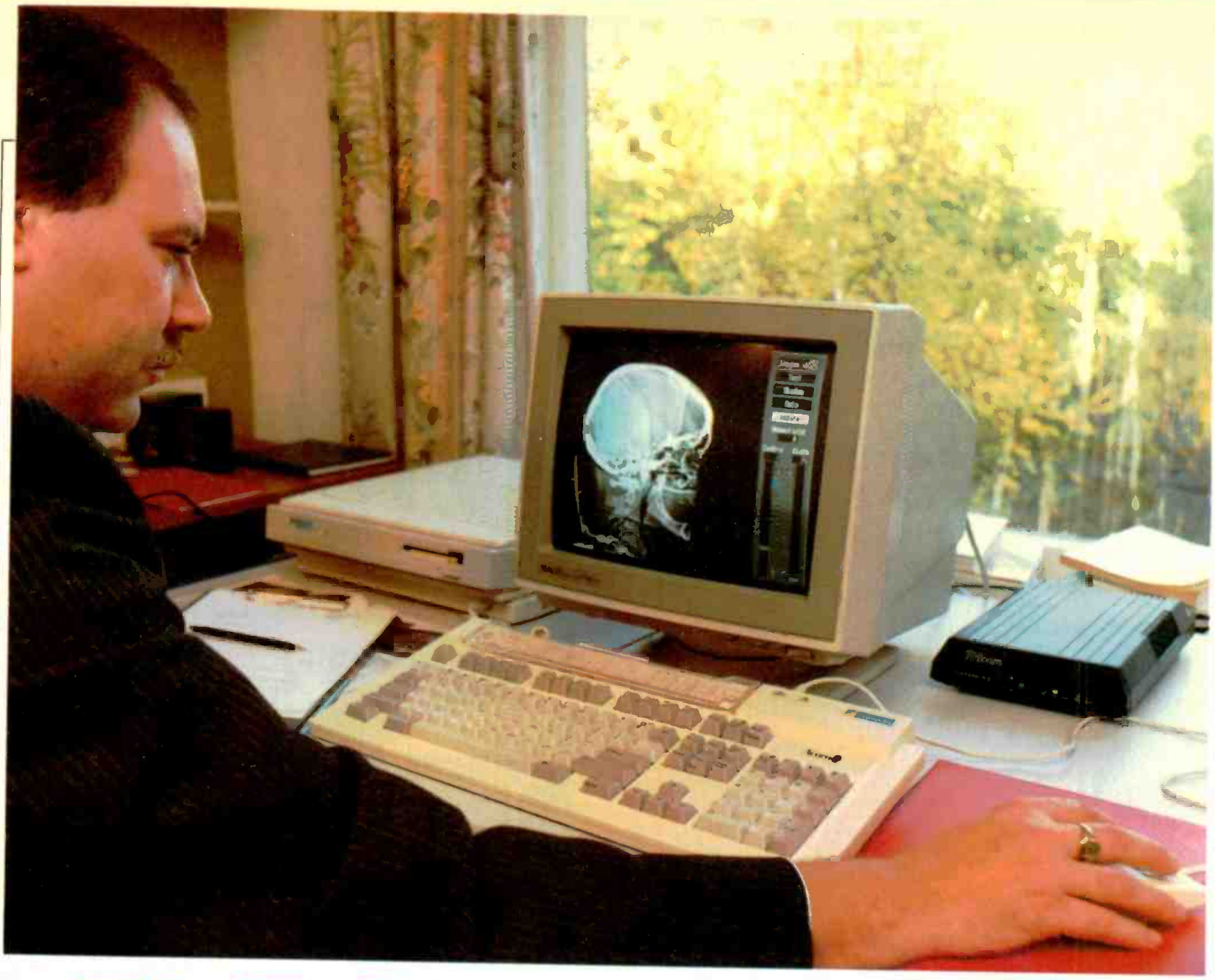


ELECTRONICS IN MEDICAL IMAGING

Roger Dewell describes the use of electronics in non-invasive techniques such as tomography and angiography, which reduce risk to the patient and speed diagnosis

Technology development in medical equipment is continuing at a significant rate. New terms have arisen during the last few years that reflect this advancing technology: computed tomography (CT), digital radiography (DR), radio nuclide imaging (RN), digital subtraction angiography (DSA) and magnetic spin resonance tomography (MR). All are for medical diagnosis.

The advent of such techniques as computer tomography is improving diagnostic results, such as in the detection of tumours at an earlier stage of development and at a smaller size. The combination of lower X-ray dosages with higher image qualities, non-invasive procedures (that is without introducing anything into the patient's body) and other benefits are leading to a quicker and simpler diagnosis and reduced patient risk and inconvenience.

Historical perspective

X-rays were first discovered by Wilhelm Conrad Röntgen in Würzburg, Germany, on November 8, 1895. Röntgen discovered these rays (using 'X' to denote their unknown nature) while investigating the effects of cathode rays through gases at low pressures. Some of his discoveries during his investigations were that X-rays affect photographic emulsions or can cause materials to fluoresce when they are exposed to these rays, and that some materials are more or less transparent to X-rays than others.

These earliest imaging techniques involved exposing a photographic film by placing the subject between a photographic emulsion and a source of X-rays. The X-rays were absorbed by the subject in varying degrees, depending on the composition of the area con-

Fig. 6. The trend to smaller and more powerful dedicated computer systems will allow a specialist to provide consulting advice without leaving his office. This system is under active development in the United Kingdom. *See p444.*

cerned. Bones absorb X-rays particularly well; skin tissues very little. The process, using photographic film or a fluoroscope, has remained relatively unchanged ever since.

These kinds of photographic image have a major disadvantage, in that once they have been taken they are fixed. No other information can be gained from them in terms of the state of the subject.

Electronic technology has greater potential. Digital imaging equipment, made possible by the advent of powerful digital computers, has been with us since the late 1960s. The first successful computer tomographic equipment was constructed in England by Godfrey Hounsfield in the early 1970s, work that led to a Nobel Prize in 1979 for Hounsfield and physicist Allan Cormack.

The CT scanner was under intense development during the years 1973–1976, and its success prompted the investigations of other computer-based imaging techniques, such as MRI, DSA and so on; developments are continuing today. The earliest scanning technique was referred to as computed axial tomography (CAT), since it only took slices 'across' the patient. However, current techniques allow scans to be taken in the 'coronal' or 'downwards' direction as far as the patient is concerned. The head can be scanned directly in the coronal plane. So the term has been generalized and shortened to CT.

The first magnetic-resonance images were taken in 1973 by Paul C. Lauterbur of the State University of New York. Although MRI images had been taken some years before, all the information had been superimposed, and there was no way of telling from where in the field of view of the equipment the resonance characteristics came. Lauterbur's technique, however, successfully incorporated a way of encoding the signals so that their position could be derived.

The medical fraternity was excited by the remarkable image quality, and soon afterwards laboratories in the United States and Europe were working on the technique and generating their own images. Another benefit of MRI, beside the image quality, was the absence of harmful radiation, since this technique is essentially free of any radiation hazard.

Angiography has been a method of studying the behaviour of blood vessels of many kinds for several years. Initially, the method involved injecting fairly large amounts of radio-opaque medium into the patient's blood stream by threading a catheter through the major arteries and taking rapid sequences of X-rays in many planes to study the progress of the medium. This procedure generally requires an overnight stay in hospital. However, work done at the Universities of Arizona and Wisconsin between the years 1976 and 1980 using digital computers demonstrated that the simple intravenous injection of small amounts of contrast material and the use of a digital acquisition and imaging system allowed angiographic information to be successfully obtained. This improved technique reduced the risks associated with catheterization and adverse effects produced by the radio-opaque substance itself, and lowered the levels of X-ray dosage required.

Scanning equipment and image data

The sight of advanced imaging equipment in hospitals is becoming more common. These days, 25%—30% of radiological examinations are done with digital imaging equipment, making this type of equipment a very important component in radiological departments. Modern image generating equipment allows a specialist to sit at a high-resolution digital display and review the image data as it is generated by the diagnostic equipment, as in **Fig.1**. High-resolution image monitors provide 1024×1024 pixel resolution as standard equipment and an extensive range of grey scales is presented on the display screen for the identification of different image components. A note of caution was sounded by Dr Richard Dawood of St Mary's Hospital in London, who points out that digital techniques have reached, but not yet exceeded the resolution of film-based methods.

The kind of image that can be generated is shown in **Fig.2**, which shows two CT scans of a skull. The specialist selects the required increment of movement of the patient for the feature to be investigated, and the patient is moved in a straight line through rotating X-ray heads, the scanner taking 360± sections through the part of the body concerned. Sections are typically taken every few millimetres. The image processing software displays the successive two-dimensional image slices or, if required, builds

Fig.1. Digitally acquired images reviewed by radiologists. High-resolution monitors are used to display and manipulate the information. Images can be rapidly recalled for examination, three-dimensional constructions performed and radiological image data efficiently stored or transmitted to other specialists.

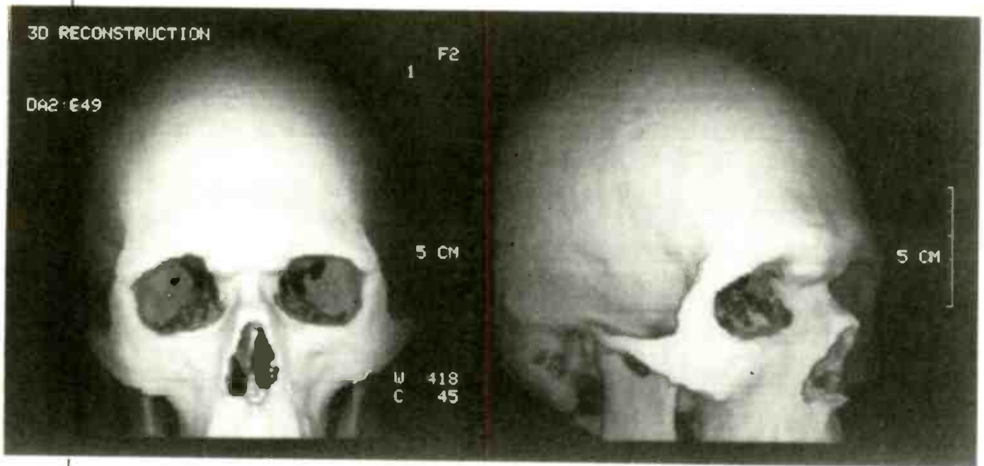


Fig. 2. CT scans of skull. The bones of the skull can be examined in full three-dimensional views without any surgical procedures being performed.

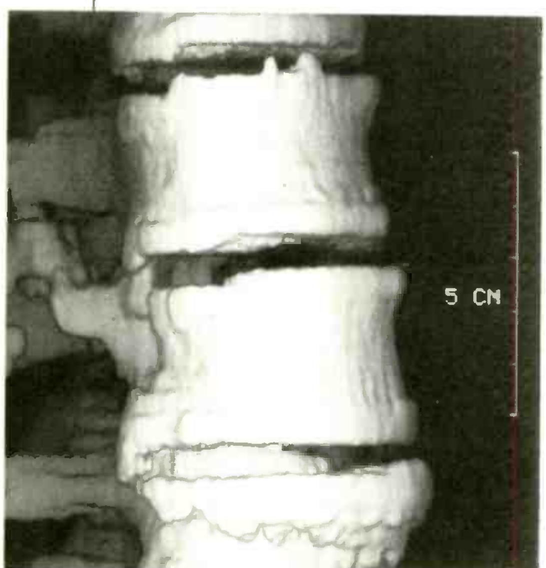


Fig. 3. CT scan of spine

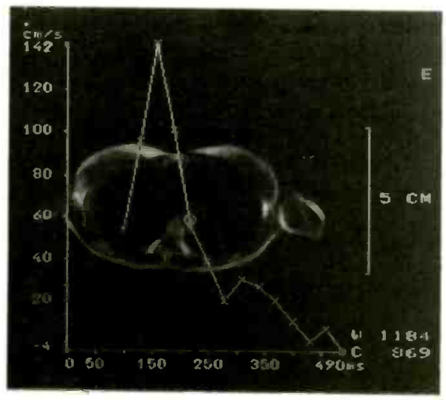
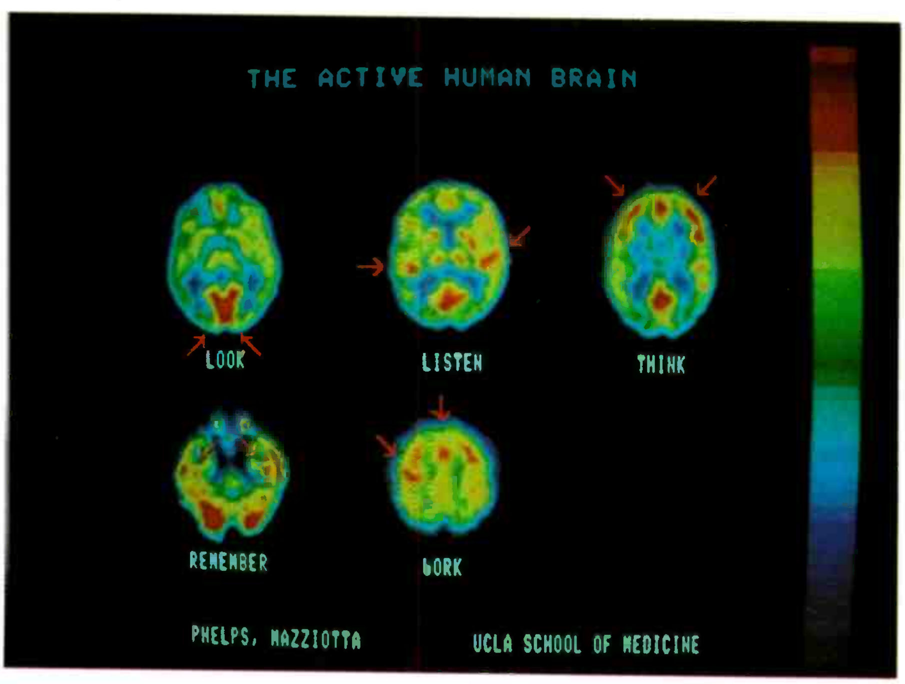


Fig. 4. MRI image of blood flow across an aorta. By being able to vary the intensity of the MRI signal coming from blood actually within the vessel, the pattern of blood flow can be determined and analysed.



up a three-dimensional representation of the subject. A second image (of a section of the spine) using the same techniques is shown in **Fig.3**.

Successive complete images can be built up and sequenced on the screen, rather like a movie sequence, so that the specialist can build up an impression of the area of investigation. He can, therefore, form a detailed opinion of the extent and placement of the radiological signs before any further exploratory work is undertaken.

Although it is obviously not possible to show here a continuously rotating radiological image such as would be seen on an viewing screen, imagine the effect of 50 or 60 images of the type shown in Fig.2 displayed in rapid sequence, simulating the actual movement of the subject. Such a manipulation of images requires extensive software to build up the three-dimensional information and to simulate the subject's movement.

Another technique, magnetic resonance imaging, relies on the properties of the atoms of the human body when exposed to a strong magnetic field. **Figure 4** shows an analysis of blood flow characteristics of an aorta, plotting the blood flow across the cross-sectional image of the vessel.

I am told that the characteristics of colour have not been widely developed in the imaging of medical diagnostic data. The colour dimension does not seem to add a great deal of information to the basic image and can, in fact, prove distracting. One application where colour has been studied is in the representation of activity levels of the human brain, where the extra dimension of colour allows relative activity to be represented. **Figure 5** shows this activity taken with MRI equipment.

The MRI technique has enormous possibilities for the detection of physiological (or functional) information about body tissues. The scans of **Fig. 5** show the various active areas in the brain and their degree of physiological activity in various mental states. This type of information was not possible before the advent of techniques such as magnetic resonance imaging.

Fig. 5. MRI image of brain activity. In these images a high activity level is represented in red, the least active areas in blue. These five images show the patient in five different mental states: looking, listening, thinking, remembering and working. Note the extensive areas that are obviously in use in the remembering state.

Digital scanners in hospitals

But how is this advanced equipment being used in the day-to-day working of a hospital? To assess this, I was fortunate enough to be able to talk to Dr Baddeley, Director of the Paul Strickland Scanner Unit at Mount Vernon Hospital in Middlesex. The scanner unit at Mount Vernon is equipped with CT and MR imaging equipment.

During our conversation I asked Dr Baddeley about the advantages of using this kind of digital imaging system instead of more traditional X-ray equipment. He told me that the benefit was in the ability to differentiate more clearly the body components contained in the image. The chest X-ray, for example, contains all the information required (and usually more) superimposed from front-to-back on the flat image of the X-ray film.

The ability to pick out areas with much greater contrast allows more information to be presented in the digital image. A problem with traditional X-ray imaging is that scattered X-rays, in passing through the body, do strike the emulsion at skewed angles, causing blurring of the image. The reduced radiation levels used in digital acquisition techniques drastically reduces these effects.

I saw areas of the brain just inside the skull of a patient injured by a fall. Such images, taken by CT scan, allow far greater resolution of brain tissue and the examination of the status of various areas than would be seen on an ordinary X-ray film of the same subject.

Image data is routinely stored and archived on magnetic tapes for future reference; however, off-line reporting is done with film-based media, since it lends itself to easier identification and recall for later reference. Dr Baddeley feels that, even with the advent of optical-disk technology, significant bulk data storage problems will have to be overcome to compete with the hard-copy image format.

Differences in imaging techniques

Both computed tomography and magnetic resonance imaging are commonly used digital techniques. So, what is the difference between them?

In using MRI equipment, the specialist can isolate other components than with a CT scan. Whereas bone areas show up very clearly against tissue areas in a CT scan, bone areas do not show up at all on an MRI image, thereby making certain tissue disorders more clearly definable. This is particularly useful for the examination of areas embedded in surrounding bone, for example. Multiple sclerosis, apparently, is more easily investigated, as are tumours in the lower regions of the brain, by using MRI techniques, whereas bony and calcium-containing lesions are usually better investigated using computed tomography. CT scans make use of X-ray tubes, but MRI uses radio sources which are non-ionizing—a distinct advantage of the MRI technique.

The different signals obtained from normal and abnormal tissues makes the MRI technique extremely useful for the non-invasive diagnosis of many diseases, including cancer. Whereas the CT scan and previous techniques show structural features, there is another side which is missing from such images: the functional or physiological information. This is an area where MRI is so powerful, in showing the physiological changes in patients. Very often, the onset of disease is shown in altered functioning of tissue areas, such as for major

Magnetic resonance imaging

The basic principles of nuclear magnetic resonance have been used over the last forty years by scientists to discover complex molecular structures. However, the use of such techniques in the biological sphere is relatively recent.

The technique relies on the behaviour of nuclei when placed in a strong magnetic field. Normally, the atomic nuclei (of hydrogen, or other elements susceptible to MRI techniques), appear as rotating 'magnets', having a random orientation of their poles, as in **Fig. 7a**. In the presence of a strong magnetic field, these random directions align themselves (Fig.7b). In the MRI technique, a simultaneous, small magnetic field is induced by a pulsed radio wave in a coil also surrounding the subject. In this situation, the orientation of the magnetic poles precess, or wobble, as in Fig. 7c. This precession induces an extremely small alternating field, which can be detected and amplified. The secret in coding the spatial information is to graduate the strength of the magnetic field (Fig. 7d). This produces a variable signature, since the nuclei magnetically resonate at higher frequencies in stronger magnetic fields.

The nuclear resonance signal detected in the coil falls away in a characteristic time, which varies with the presence and distribution of different surrounding atoms. The frequency of the radio waves can be tuned to produce natural resonance in several types of nucleus, such as hydrogen, phosphorous or sodium. Hydrogen is particularly useful for study, since it produces a much stronger received signal, and is present in much greater quantities in the human body than are other susceptible isotopes.

MRI studies can be tailored to the particular tissue under study, or the disease being to be looked for. The relaxation time, or time required for the resonance of the atomic nuclei to cease, varies if the tissue becomes diseased, or if it is starved of blood.

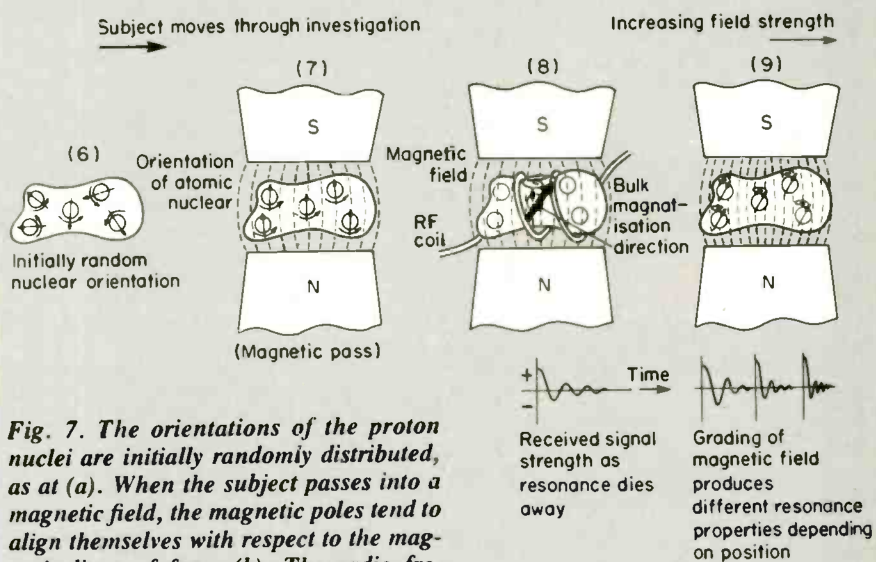


Fig. 7. The orientations of the proton nuclei are initially randomly distributed, as at (a). When the subject passes into a magnetic field, the magnetic poles tend to align themselves with respect to the magnetic lines of force (b). The radio frequency stimulus of the magnetic orientation of the bulk magnetisation direction causes this orientation to precess, as seen at (c). By graduating the strength of the magnetic field, the frequency of the ringing of the magnetic poles can be used to determine the position of the characteristic signals within the field of view of the equipment

CT has become a standard method of radiological analysis.

psychoses, where brain tissue may appear structurally normal, but simultaneously show functional abnormality.

Data storage and archiving

The problems associated with image data storage are very significant, since a single image of 1024×1024 pixels with 10—12 bits of grey-scale resolution will contain megabytes of data. Currently published estimates put the data volume of an average facility performing 120 procedures a day at 1.5Gbyte. Optical disk storage seems the only practical method of manipulating this quantity of data, but these devices are still not in widespread use.

The future

In further developing these imaging systems, manufacturers are working closely with medical staff in hospitals to further refine the facilities available.

The image generating equipment and techniques discussed above lend themselves to interconnection, since they all generate digital data. Generation, processing, storage and retrieval operations can be co-ordinated so that a specialist at work-station in another office, building or even another country, can call up these images, discuss them with local specialists and diagnose remotely.

Such systems, dubbed PACS (Picture Archiving and Communication Systems) can represent a powerful radiological diagnostic and image-processing system, as well as being a significant teaching aid. Being an integrated resource, such a system gives the possibility of being upgraded and can be interconnected with other PACS systems or work-stations by optical-fibre or other high-speed data links.

Desktop imaging system

In common with most areas of technology, miniaturisation, coupled with increases in processing capacity and a decrease in costs, is now making possible the development of a small-scale system for consultation from a consultant's office. An installation being studied jointly in the UK by Siemens and Acorn consists of an Archimedes 420/1 risc-based microcomputer with a high-resolution screen and conventional (low data-rate) modem. This is shown in the picture of **Fig. 6**. ■

Acknowledgment The pictures for this article were kindly supplied by Siemens plc, who also provided valuable product information.

Digital subtraction angiography

The traditional method of utilizing this technique involves injecting a radio opaque substance into the patient's blood vessels and taking X-ray images via an image intensifier and a television camera. These sequences are stored on videotape for subsequent play-back. By watching the progress of this injected material, the specialist can evalute the state of these blood vessels. The problem with traditional methods is that, for sufficient material to be injected into the area of interest, a catheter must be threaded through the patient's arterial system, whilst viewing its progress on a fluoroscope.

In translating this method to digital techniques, image processing equipment needs to process data at video speeds, which is where the computing power of modern machines makes the system feasible.

To develop a high contrast image, an initial 'mask' image is taken of the subject area of interest. The radio-opaque material is then injected intravenously into the patient, the mask image then being digitally subtracted from subsequent X-ray images as the opaque material passes through the the patient's system. The images remaining after each image subtraction process are therefore only those areas containing contrast medium, which highlights the vessel areas of interest.

One drawback of the DSA technique that has had to be overcome is the image quality obtained. The X-ray image is generally displayed on a fluoroscope and recorded by a television camera, as shown in **Fig.8**. The original image quality of the technique was totally dependent on the resolution of the video system, a resolution that has been improving markedly as video technology has progressed.

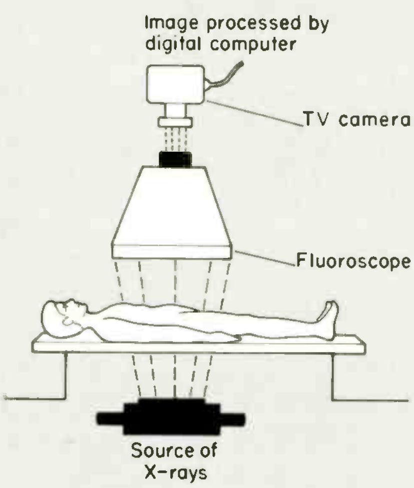


Fig. 8. Digital subtraction angiography images, from an X-ray source and displayed by a fluoroscope, are recorded by a camera, the image from which is processed by a computer

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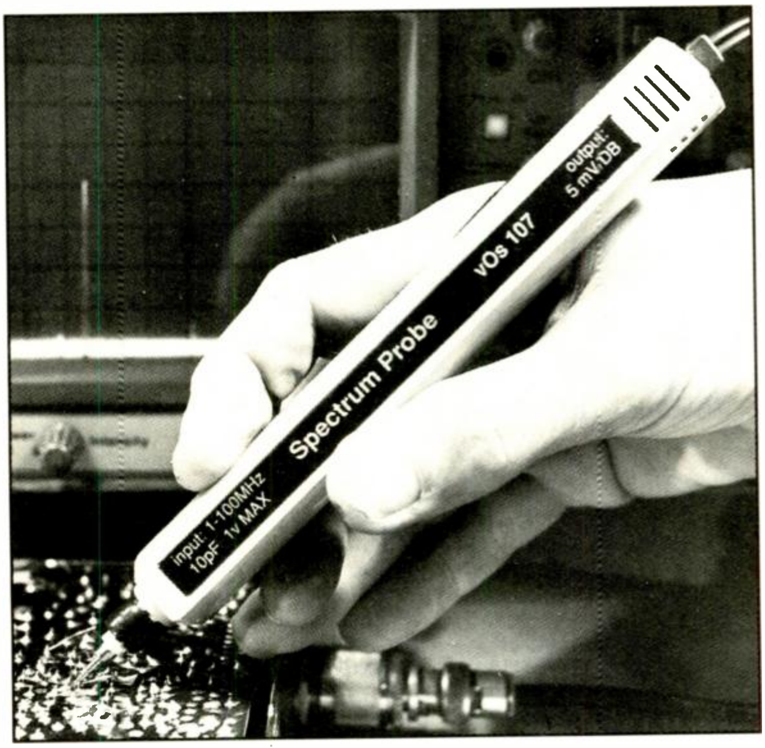

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PC SIGNAL ANALYSIS

Hypersignal Workstation 1.2 provides an array of signal processing and signal analysis facilities. Allen Brown investigates.

Hypersignal Workstation version 1.2 is made by Hyperception in Texas and is distributed in the UK by Loughborough Sound Images, The Technology Centre, Loughborough, Leicestershire LE11 0QE.

The price of the HSW software is £695, plus VAT, and DSP56001 expansion card from Loughborough is £2995, plus VAT.

A growing number of application programs provides a wide array of signal-processing analysis tools. Although most of them are commendable, very few of them provide the opportunity for the engineer to investigate signal processing in real-time. The Hypersignal Workstation (HSW) version 1.2, when combined with a suitable PC expansion card, does precisely this.

To review the effectiveness of HSW, it was used in conjunction with an expansion card from Loughborough Sound Images, hosting the Motorola DSP56001 digital signal microprocessor (DSMP). The software and expansion card combination were loaded onto an OPUS VII 20MHz 386–PC with a VGA colour display. HSW software comes on three 1.2Mbyte floppy discs and is easily installed on the hard disc. After prompting for the graphics adaptor type, the program was up and running within a few seconds.

Hypersignal workstation environment

HSW works under a DOS MetaWindows environment, which is loaded from the start-up batch file, and the layout of the options offered is presented in three columns. Each option is activated with a scroll bar which leads to greater refinement of choice for the chosen option (Fig. 1). HSW options can be broadly grouped into six categories: analysis functions, digital filter design, real-time processing, data acquisition, instrument functions and system utilities.

HSW is an expanded version of Hyperception Plus and its ability to access directly the features of a range of DSMP expansion cards makes it a particularly attractive product. It can be configured as a front-end software interface for several resident DSMP expansion cards in the PC and serves as a convenient means for accessing the facilities on the cards. Other Loughborough Sound Images DSP expansion cards that work with the HSW include the Texas Instruments TMS320C25, the AT&T DSP32C and the Analog Devices ADSP – 2100. By choosing the SYSTEM CONFIG. option from the utilities menu in **Fig.1**, the user can assign various functions to the DSP expansion card(s).

An exciting feature of HSW is the way it embraces the power of the DSMP expansion card by using it as a process accelerator. Whenever possible, the analytical processing is performed on a DSMP card, which is achieved by assigning the DSMP expansion card to the status of an accelerator card. This removes the intensive signal-processing analysis from the PC's CPU and the enhanced speed is quite evident. For example, a 1024 FFT is performed and displayed in less than 0.2s.

Analysis functions

The option menus include a range of signal-processing analysis tools. It is reasonably comprehensive and contains the standard FFT, inverse FFT, power spectral density, phase spectra and convolution. However, the speed of operation of the analytical functions is most impressive through the off-loading of the processing onto a DSP expansion card. On the spectral display in **Fig. 2**, a cross-wire cursor, with coordinate measurements, can be evoked which allows the user to zoom in and expand an area of interest. Alternatively, if there is a requirement to examine the spectral evolution of a non-stationary signal, the 3 – D spectral display can be used to good effect, as seen in **Fig.3**.

This device is useful in speech analysis, as indeed is the spectrograph option in **Fig.4**, which gives information regarding the change of a spectrum with time where the colour intensity relates to the signal magnitude. This feature is rare in DSP analysis programs, but unfortunately does not work in real-time. However, a section of the signal can be isolated with the cursor and played back through one of the digital-to-analogue channels on the DSMP expansion card.

Digital filter design

A not entirely universal method for designing digital filters is included in HSW. An engineer who has not experienced the perils of filter design previous to using this package will probably find it a little bewildering. When designing a low-pass filter, for example, why should you be asked for a central frequency, which has no relevance.

Setting this aside, FIR (finite impulse response) filters using either the Parks McClellan or window design technique can be evoked and the four types of recursive IIR (infinite impulse response) filter options (Butterworth, Chebyshev I and II and elliptical) are also available.

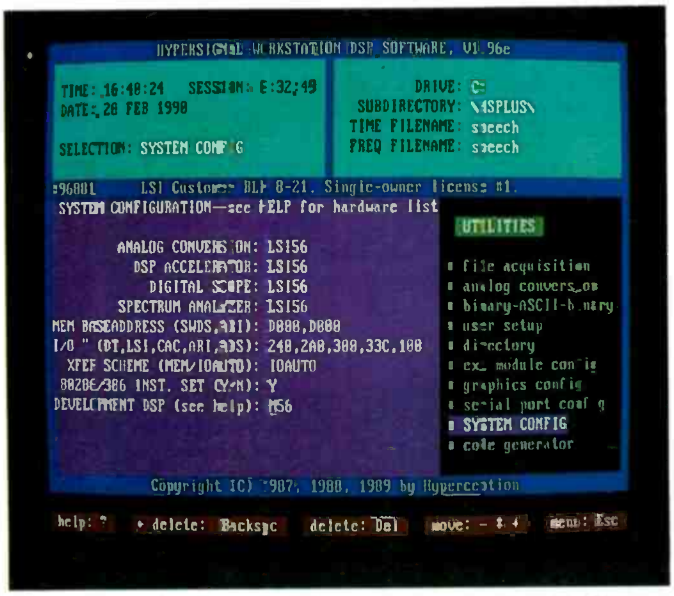

Fig. 1. Menu of options – in this case, System Config is highlighted in the Utilities list and shows its own menu in the left-hand column.

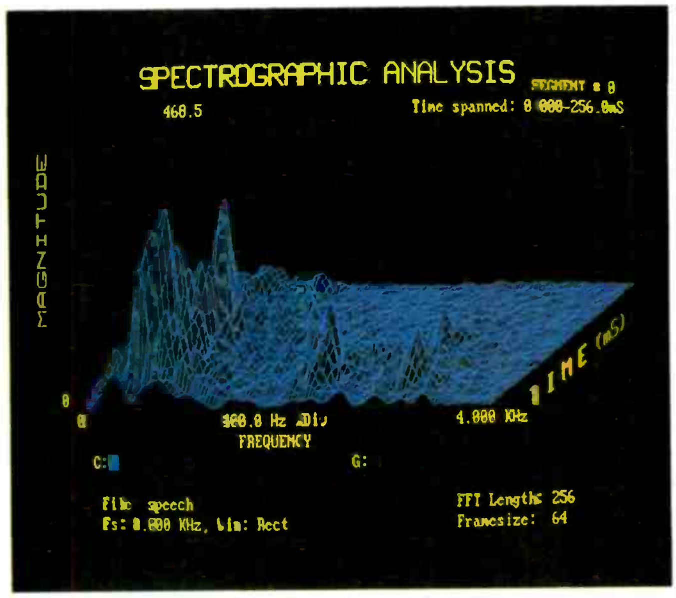

Fig. 3. Three-dimensional spectral display for showing development of a signal.

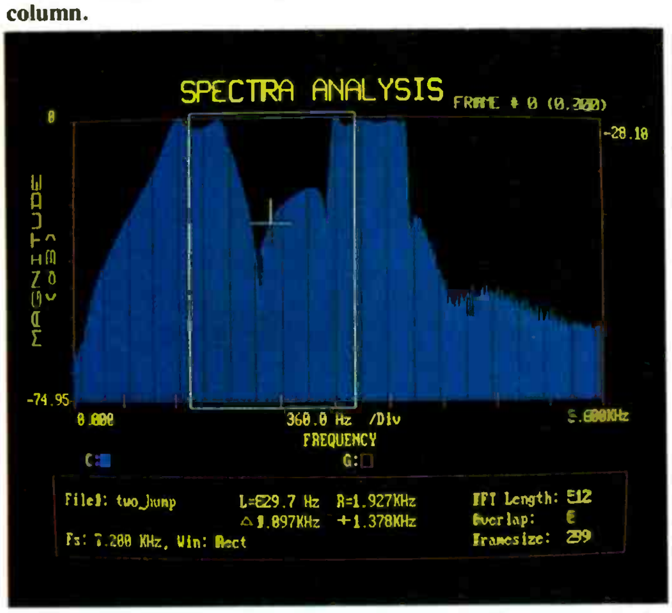

Fig. 2. Spectral analysis. Box and cross indicate area to be zoomed.

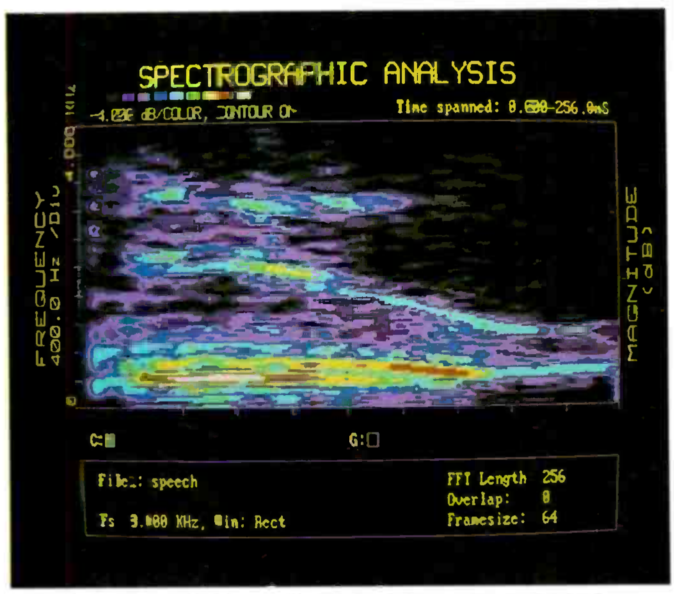

Fig. 4. Spectrographic mode displays a spectrum which changes with time, a facility often used in speech analysis.

Filter specifications having been entered, the design envelope is graphically displayed. It can be adjusted in the graphics plane and, when this process is completed, the required filter can be constructed (**Fig.5**).

Performance of the filter is simulated with an impulse function to give its transfer function characteristics. A high degree of control can be exercised over the filter coefficient accuracy and this can be used in conjunction with one of the options in the frequency domain list, which allows the poles and zeros to be viewed in both the Z-plane or the S-plane, as in **Fig.6**. Being able to view the positions of the poles and their relative closeness to the unit circle of the Z-plane gives the designer an indication of stability of the filter.

Real-time processing

Once a digital filter has been designed and simulated, HSW comes into its own. By using the SYSTEM CONFIG option, with a named DSMP and the CODE GENERATOR option, the digital filter can be realised in assembly language code for the DSMP on the expansion card. The code is assembled and downloaded to the expansion card and run in real-time. Loughborough Sound Image's DSP56001 card has two analogue inputs and two analogue outputs. With its input and output channels it can be used as a stand-alone digital filter unit.

A possible application of real-time processing would be in the analysis of a control system where there is a troublesome resonance. By inserting the DSMP expansion card into the closed loop, the transfer function of the system could be measured and the resonances identified with the spectrum analyser. A

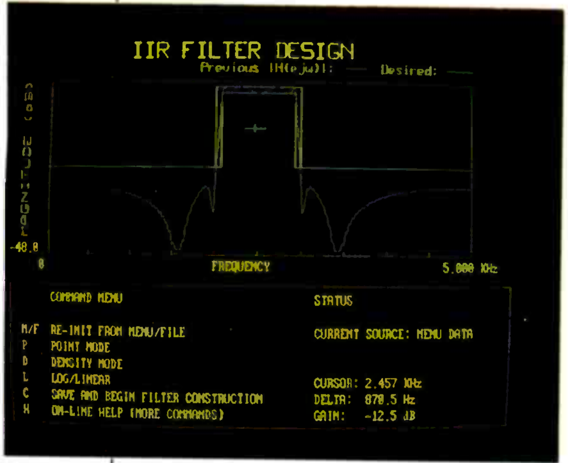

Fig. 5. Design envelope of an infinite impulse-response filter.

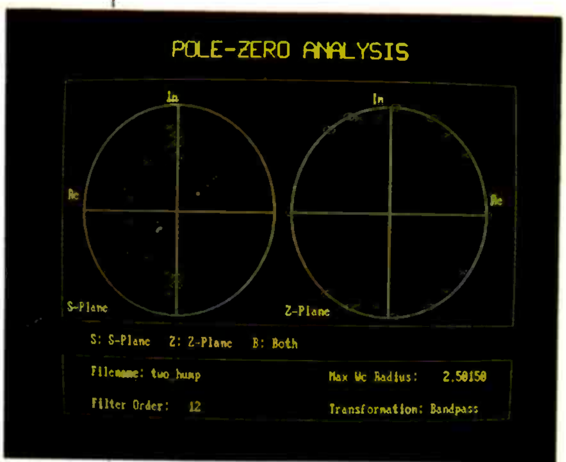

Fig. 6. Poles and zeros can be shown in both Z-plane and S-plane diagrams.

Fig. 7. Displays from spectrum analyser and oscilloscope can be combined in one frame.

notch filter could therefore be designed to remove the effect of the resonance and implemented on the DSMP expansion card, which would become an active component in the control loop by shaping the transfer function.

Data acquisition

Two of the options in the utilities menu, file acquisition and analogue conversion, enable data to be imported from the ADCs on the expansion card or from disc files created with other application programs. To complement this process there is a binary/ASCII/binary option to allow conversion between HSW binary files and ASCII files and the reverse. Once configured, disc file data is imported into HSW and channelled through one of the output DACs on the DSMP expansion card to provide an analogue signal. The analogue conversion option of HSW has a dual role: either to output data through a DAC channel or acquire data through one of the ADC channels on the DSMP expansion card.

Once the required number of samples has been defined, the samples can be partitioned into different frames, each containing the same number of samples. Subsequent analysis will therefore be performed on the frames separately and this allows a history of spectral profiles to be constructed, as seen in Fig. 3.

Instrument functions

In addition to the many signal processing functions, HSW also possesses two instrument functions: a digital oscilloscope and a real-time spectrum analyser. Depending on the DSMP expansion card, two input channels can be configured and the instrument functions can be displayed separately or combined, as shown in **Fig.7**.

Maximum bandwidth of the system is limited by the adjustable anti-aliasing filter in front of the ADC on the DSP56001 expansion card. The maximum sampling rate is 0.2MHz and, in principle, the bandwidth could be as large as 0.1MHz. Control can be exercised from the keyboard over gain, timebase and frequency range. A number of triggering options is offered for setting up the oscilloscope display, but there may be problems, depending on the trigger setting on the DSMP expansion card. A choice of window functions is offered for spectral display.

The screen refresh on version 1 of HSW has too much flicker, but this problem will be addressed in future versions of HSW to provide a clear, flicker-free refresh. Future versions will also be expected to have a three-dimensional spectral display, where each new spectral trace overlays the previous one, which is pushed downwards. This gives a 3D waterfall effect and is useful for observing spectral changes of non-stationary signals.

Instrument functions on HSW are very attractive features and are straightforward to operate.

Operating environment

286 PC or 386 PC or compatible computer
30Mbyte hard disk unit
Minimum EGA graphics and colour monitor.

General overview

HSW makes efficient use of the PC as a host platform, with its direct memory access and the support for a large variety of graphics formats. To the casual observer, the range of options offered by HSW may appear to be rather sparse, but getting the best from each option does take a lot of practice and a reasonable amount of understanding.

Because HSW and DSMP expansion card come from different manufacturers, the cross documentation tends to be weak and difficulties were experienced getting HSW to recognise and input data from the expansion card. This was only resolved after removing the card several times from the PC to adjust jumper setting; the default settings were inappropriate.

One of the HSW floppy discs has a wealth of sample files which proved to be invaluable in the early learning stages. However, the 600kbyte file of pop music, lasting just over seven seconds in playback, must be of questionable value! The user's manual probably contains all the information required to exploit the features of HSW to the full, but its layout is old-fashioned and difficult to read; it needs to be repackaged with a fresh presentation.

The screen prompts in many of the options do not convey intuitive information and one has to resort to the help menu, evoked from F1, which appears to reproduce most of the users's manual and is far too detailed. When requiring help with one type of expansion card you do not really want to know about all the other cards which are supported by HSW. HSW contains some very powerful features and on the whole, when combined with a high-performance DSMP expansion card, is an impressive product. Generally, it is well designed and provides the user with an extensive range of signal-processing tools. The opportunity for implementing real-time signal processing must be one of its most attractive aspects. The additional facilities for capturing and analysing non-stationary signals gives HSW distinct advantages over purpose-built digital spectral analysers. ■

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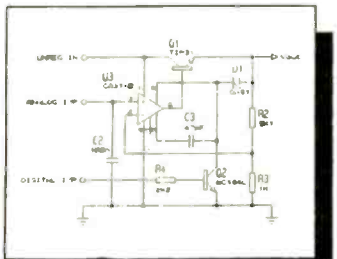

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6	12	25.81	3.45
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10	20	43.34	4.41
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Parker code for digital HF?

In the item The problems with HF packet (RF Connections, *EW+WW*, November, 1989, pp. 1120–1121) I discussed some of the effects that degrade digital signals transmitted over difficult radio paths, as encountered on HF or VHF/meteor-scatter circuits. As then noted, HF signals may vary in strength by 20–40dB and sometimes up to 80dB, while multipath propagation can result in time differences from 1 to 3ms and sometimes up to about 10–12ms when operating well below the maximum usable frequency. Doppler shifts due to travelling ionospheric disturbances or from airborne or space transmissions can result in significant frequency shifts.

Over the years, a number of techniques has been developed to improve the effectiveness of HF teleprinter circuits, including 7-unit ARQ (automatic request for repetition) error-detection codes for two-way circuits and forward error correction (FEC) where a return link is not available. The SITOR/AMTOR system, with its short three-character transmissions, can provide good performance with the standard 32-character Baudot code, although a few errors may go undetected. On the other hand, as noted last November, the AX25 HF packet protocol, developed initially for use by amateurs on line-of-sight paths, with its full ASCII 132-character-set and relatively long "packets" which are not printed unless 100% correct, is much less satisfactory on difficult paths and often requires very large numbers of repeats for each packet.

Both SITOR and packet are normally transmitted using frequency-shift keying (carrier or audio tones), a mode which ideally needs diversity reception and relatively high-power transmission. Some 30 years ago, investigations by Marconi engineers and by the Post Office Research Laboratory at Dollis Hill showed that the relative merits of various digital modulation systems varied in accordance with propagation conditions and depended on whether automatic error correction was used. There was evidence that two-tone or multi-tone systems could produce better copy than FSK in the absence of diversity reception. A notable example of this approach has been the various forms of Piccolo, developed by the Communications Department of the Foreign & Commonwealth Office and eventually endorsed by the equipment industry. Originally, for HF, this used 32 audio tones spaced at 10Hz intervals, a different tone being allotted to each of the 32 tones and transmitted throughout the period of each character. It was claimed in 1963 that this system permitted the transmission of 100 words/minute in a bandwidth of 470Hz with less than 0.2% errors, the signal being 4dB below the noise level.

The system required a very high degree of frequency stability, both in the equipment and over the propagation path, and was later modified to use eight and then six tones; this may soon be increased to 10 tones. The number of major changes does seem to imply that Piccolo is not without problems in some circumstances.

Following from the November item, H.E. Dempsey of Threshold Communications Systems (PO Box 188, Brampton, Ontario, L6V 2LI, Canada) has written pointing out that a radically different system for digital/teleprinter transmission over difficult paths exists in the Parker code developed by B.D. Parker in the 1960s at the Decca Radar Company (British Patent No 860, 830 etc.) and later implemented by Dollman Electronics Canada Ltd (forerunner to Threshold Communications Systems).

Dempsey writes: "It seems to me that it is time for the amateur radio fraternity and readers of *EW+WW* to rescue the UK technological community from the wilful blindness of its telecommunications Establishment. Those who wish to make the best of HF digital communications under adverse propagation conditions should consider the use of the Parker code. A Parker Communications Club might get things going.

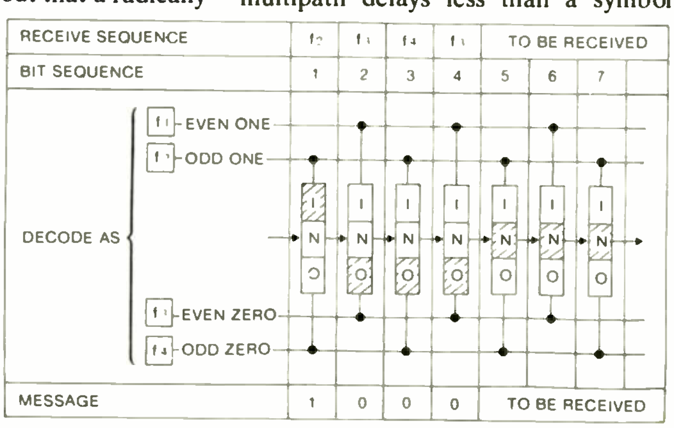
"In one application of the Parker code four tones are used. It is not, repeat not, the use of dibits. Any bit stream which is provided is identified as a sequence of odd and even symbols as well as a sequence of '1' and '0' bits. If the odd/even sequence of received bits does not occur, then there is an error. By bracketing the message space with two bits in a forbidden sequence, which is allowed in the bracket space, multiple errors can be detected in the message space. Total overhead four bits.

"Among other uses, this code has been in operation over HF RTTY links in the Middle East and is a powerful error detection and anti-multipath technique when properly used.

"Some of the advantages of this system are: detection of multiple bit errors with four bits overhead; self-clocking, with bit rate equal to the symbol rate; elimination of inter-symbol errors from multipath delays less than a symbol

		1	2	3	4	5	6	7
MESSAGE		1	0	0	0	1	1	0
BIT SEQUENCE		1	2	3	4	5	6	7
ENCODE AS	EVEN ONE — f_1						X	
	ODD ONE — f_2	X				X		
	EVEN ZERO — f_3		X		X			
	ODD ZERO — f_4			X				X
TRANSMITTER SEQUENCE		f_2	f_3	f_4	f_3	f_2	f_1	f_4

Message encoding in Parker code.



Decoding of the received signal.

dwell time; it can use classic FEC, and be adaptive with ARQ.

"The primary disadvantages of the Parker code are: invented in England; academic community presently unable to analyse the system for public print because it uses a 'logic' error-detection scheme instead of an 'arithmetic' error-detection scheme and so does not seem to be able to be interpreted by Hamming methods; and ability to use modern FEC by embedded error-correction coding not yet found.

Mr Dempsey enclosed three papers from the 1970s in which he presented details of systems using the Parker code: A Canonical Error Detection System (IEEE Canadian Conference on Communications & Power, Montreal, October 1976); Automatic Management of Digital Communications on HF Radio Networks (International Electrical Electronics Conference & Exposition" Toronto, September 1977); and Dollman System Design Principles for Digital Communication over HF Radio (IEEE Canadian Conference on Communications & Power, Montreal, October 1978).

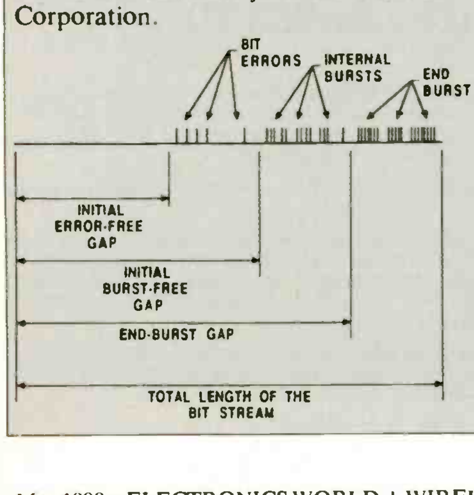
The last paper introduces the Dollman system as follows. "The Dollman digital communications system, when used on HF radio networks, utilizes non-synchronous transmission and the unique Parker Code with four audio tones in a multifrequency shift-keying modulation scheme. On transmission, the bit stream provided by the source is manipulated into a Parker code sequence and the appropriate phase-continuous audio tones, generated by a microprocessor, are fed sequentially into the radio transmitter audio circuit. On reception, the sequence of audio tones provided by the receiver is amplified, limited, and passed via four filters to envelope detectors for non-coherent detection.

"Error detection of the received signal is carried out by utilizing the odd-even sequence properties of the Parker code, data format markets, and three-state decision processing. Error correction is performed by means of an automatic request for repeat of the data block containing an error and comparison with the previously received block. During error-generating propagation conditions three blocks are compared at the standard bit rate if required, and a further three blocks can be made available for comparison after low bit-rate transmission if desired. The difficulties of communicating on HF radio circuits are mainly due to the characteristics of ionospheric propagation, although the problems of co-channel interference, atmospheric noise and back scatter can, on occasion, outweigh those due to the ionosphere alone . . . The modulation technique, which is the key to effective communication, is not always chosen with due regard for the propagation characteristics of the actual channel, but sometimes with respect to the operation of an ideal channel with additive Gaussian noise."

In this system, each audio tone is produced for the same number of cycles; the duration of each tone thus depends on its audio frequency, so that a bit length depends on the location and value of the bit in the bit stream. As implemented, it is claimed that the system effectively counters the problems caused by propagation time spread (multipath), the effects of fading and of frequency excursions; the key being the manipulation of the bit stream so that sequential signal signatures cannot be identical. For unattended HF radio-teleprinter operations under adverse conditions, the selection of dwell times with a capability of handling a time spread of 10ms also allows the loss of signal for about 4ms provided that the equipment will accept fading depths of 53dB with filters able to accept frequency excursions of up to 30Hz.

Improving meteorburst communications

The special problems involved in improving the throughput of messages on meteor-burst channels continue to form the subject of academic and defence-industry investigations. Two reports in *IEEE Transactions on Communications*, November 1989, are "Variable-rate coding for meteor-burst communications" by Michael B. Pursley and Stuart D. Sandberg of the University of Illinois and "An investigation of ARQ and hybrid FEC-ARQ on an experimental high-latitude meteor-burst channel" by Kenneth Brayer and Subramaniam Natarajan of the MITRE Corporation.



The first report concerns the performance of variable-rate Reed-Solomon error-control coding in which the code-rate is allowed to vary from codeword to codeword with each packet. The optimum number of codewords per packet and optimum rates for the codewords are determined as a function of the length of the message and the decay rate for the meteor trail. It is pointed out that the majority of meteor trails are "underdense" with an electron density small enough to allow the signals to penetrate the surface. Such signals are reflected from individual electrons within the trail, which expands as it decays. The resulting multipath causes an exponential decay of the amplitude of the received radio signals. With the relatively few "over-dense" trails the signals are reflected from the surface, presenting fewer problems.

The MITRE work is based on an experimental link in Greenland between Thule and Sondestrom on 65.133MHz, using five and six-element Yagi antennas, with a gain of about 11–12 dBi and 1kW transmitters (an extra 5dB loss at Thule is due to transmission line and environmental losses). Modulation was differential phase-shift-keying, with a data rate of 4.8Kbit/s, using odd-parity ASCII code. This project has shown that early in a trail, where transmission is usually near error-free, an ARQ (automatic request for repetition) system will function.

Brayer's article says: "By adding forward error-correction (FEC) the initial errors that occur after the first error-free gap can be corrected and this time duration of operation can be extended. While it takes 10min to reach a maximum probability of message delivery, about 40% of data can be delivered in the first 30s after an attempt. If FEC and non-FEC results are compared, it can be demonstrated that the probability of successful message delivery can be increased from a few percent to values in the order 90–100%. The data collected shows a period of random errors between the error-free gap and the end burst. This means small amounts of FEC will improve communication performance." ■

RF Connections is written by Pat Hawker.

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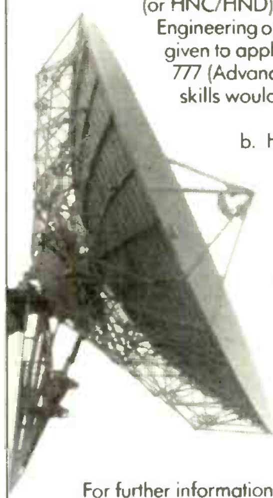

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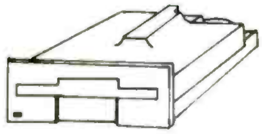

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Printed in Great Britain by Carlisle Web Offset, Caxton Road, Newtown Trading Estate, Carlisle, Cumbria CA2 7NR, and typeset by PPC Limited, Leatherhead, Surrey KT22 7LA, for the proprietors, Reed Business Publishing Ltd, Quadrant House, The Quadrant, 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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The Programmer that fits your Pocket - £495

S3 is a product which has shaken the industry. It is in all the big-name catalogues. It is used by all the big-name companies. That's because S3 has an elegance and fitness-for-purpose that puts it in a different league from old fashioned bench programmers. But you don't have take our word for it. You can get an S3 on NO-RISK APPROVAL and find out for yourself.

S3 doesn't only program EPROMS

S3 programs any (E)EPROM you can put in the socket. Choose manufacturer and device from a menu and S3 will select one of 80-odd algorithms. But programming memory devices is only a part of S3's repertoire. It's not the be-all and end-all. If you need to program EPLDs, CMOS PALS, NOVRAMS, SINGLE-CHIP MICROS and the like, S3 is still the best tool for the job. Dataman provides dedicated modules and software, which are much cheaper than any other solution because the S3 you already own acts as a "mainframe". These products don't just exists in our imagination. We have them on the shelf, ready to ship.

Software upgrades are FREE

When new programmable parts are released, Dataman provides new software to program them. This software is FREE. It is also easy to install. The original program comes in a ROM. You place it in the socket (see picture) and press the HELP button. It loads in a few seconds. And you only have to do it once. S3 retains its program - and your data - in non-volatile memory, even when switched off. We post the new program on our Bulletin Board. If you have a modem, you can download it. There are lots of other useful programs available too. Give our BB a call on 0305-251786.

Terminal Program with S3 Driver

We offer a TERMINAL PROGRAM which supports four COM ports simultaneously at speeds up the 115,200 baud. This program is useful in its own right. It also has a FRONT-END DRIVER for S3, with MENUS and HELP screens. This gives you Remote Control of all S3's functions. You can Upload and Download files, change configuration and do everything remotely that you can do with S3's keyboard. Some companies make a song-and-dance about their software drivers, - and charge you at least £100. Ours is free. Not 'free' when you buy something, but FREE to any Company requesting literature.

Universal Assembler & Editor

S3 is also a MEMORY-EMULATOR. Use it with an Assembler and you have a complete Microprocessor Development System. It happens that Dataman sells a fast full-featured Editor/Assembler, called SDE, for use with S3 (or without).

RS232 socket (DB25) on the back, for remote control.

Emulator lead (supplied) plugs in beneath.

S3 programs and emulates 25 and 27 series EPROMS up to 27512.

The 80 character LCD shows ASCII and HEX.

Quality keyboard for fast data entry.

S3 will program hundreds of PROMS without recharging.

Charger unit (supplied) recharges S3 in 3 hours.

Socket is used to program PROMS and load software.

A single keypress will Assemble and Link the source file(s), download to S3 and start the program running on your target system. SDE has some amazing features. If it finds an error when assembling, it puts you back in the source-file at the error line. It will tell you the absolute address of any line of source code. That saves the chore of printing listings when debugging. SDE comes in single or multiple processor versions. Do try it. You will like it.

Specifications and Price List

S3 has a 64 kbytes CMOS RAM buffer for storing USER programs and ROM/RAM EMULATION -access time is about 120ns. There are also 8K bytes of program RAM, a serial interface at 300, 600, 1200, 2400 4800 and 9600 baud for remote control and uploading and downloading files. S3 comes complete with Manual, Mains-charger unit, ROM emulator lead, write-lead and software to program and emulate (E)EPROMS and FLASH EPROMS. Re-charging takes 3 hours and does not prevent normal use. Typically one charge per week is enough. S3 measures 7.3 x 4.4 x 1.8 ins and weighs just over 1lb. **£495.00**

SDE Editor/Assembler/Comms single-processor **£195.00**

SDE Editor/Assembler/Comms multi-processor **£395.00**

S3 Developer's Package Reveals all S3's secrets. Contains Circuit Diagrams, Source Code, BIOS calls and Editor/Assembler (as SDE above) for NEC78C06 processor in S3. Lets you write your own custom software - even make S3 into a something completely different. **£195.00**

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