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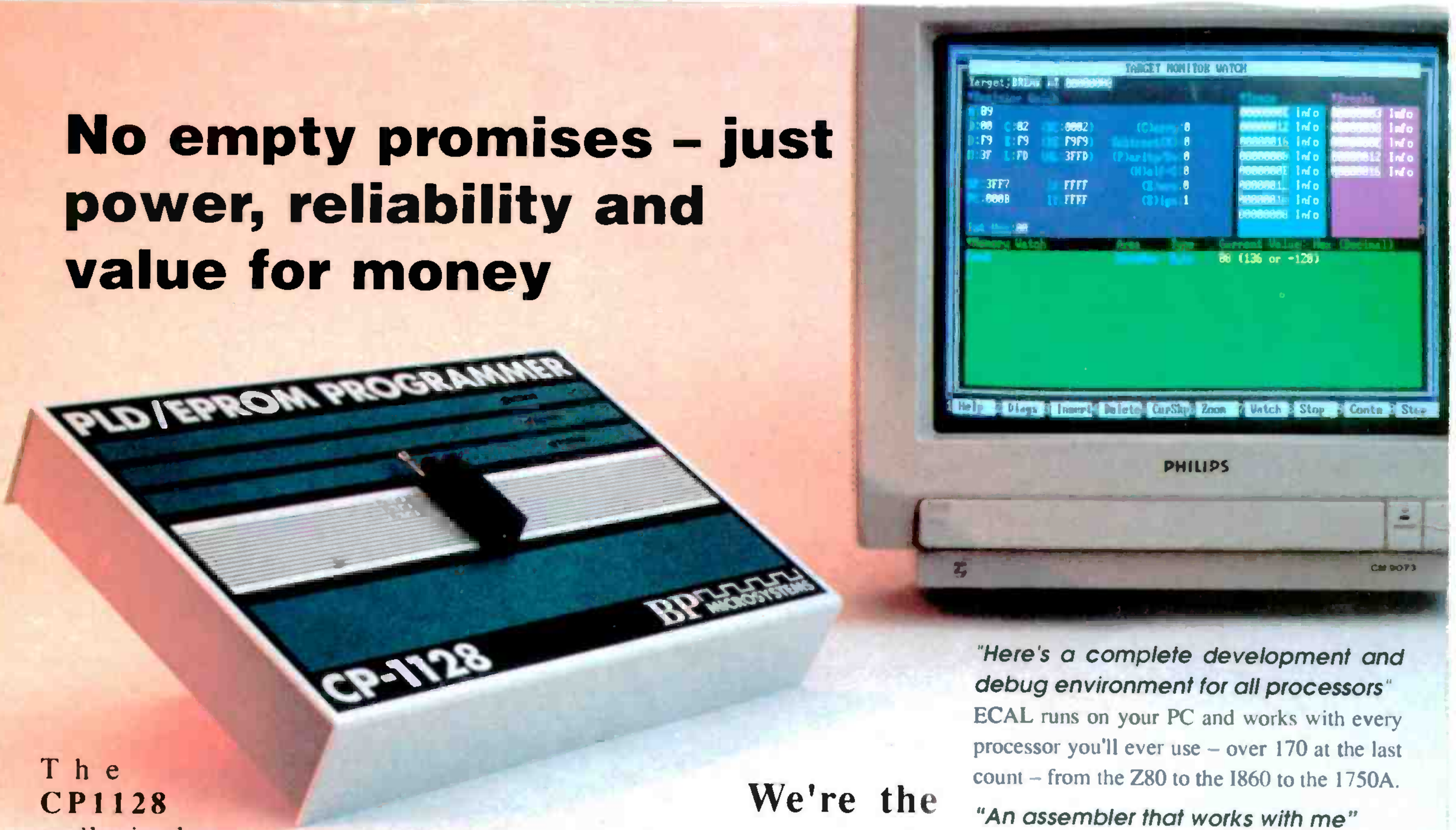

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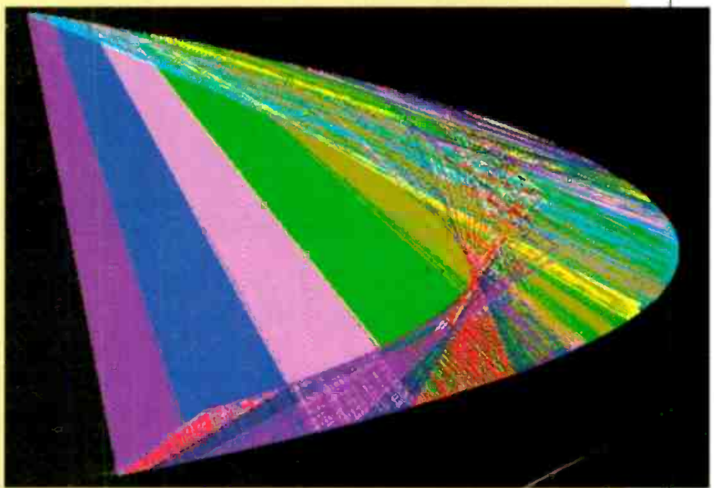
CONTENTS

FEATURES

Next month: The science of Chaos. The picture shows the colourised phase map of a chaotic system inherent in the harmonic generation of a varactor diode circuit. In short, chaos has come of age. Nick Beard considers the theory, practice and commercial software of chaos.



REGULARS

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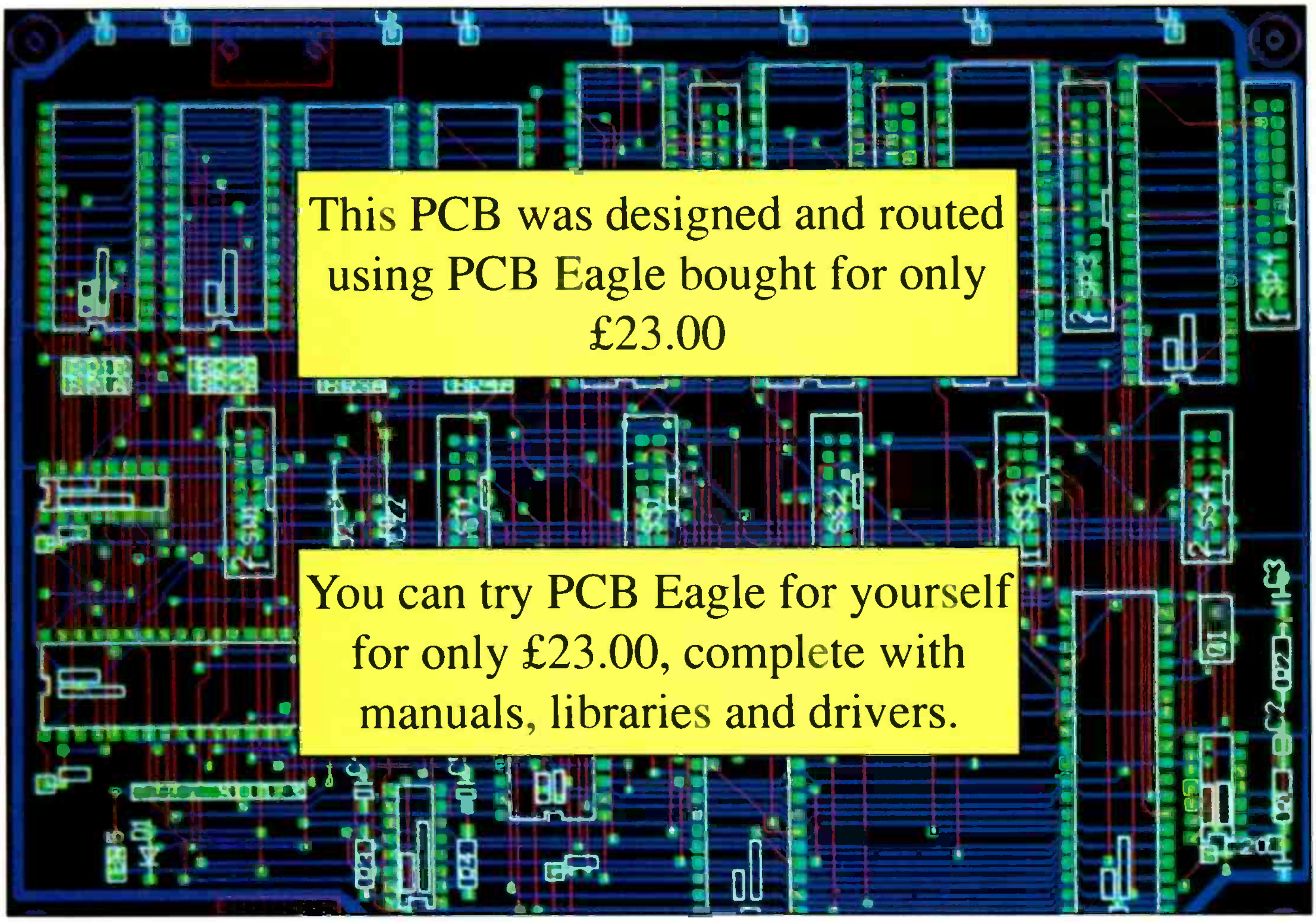

SCHEMATICS, LAYOUT, AUTOROUTE AND DRC IN ONE PROGRAM

Designing PCB layouts, drawing schematics and autorouting used to be a complex and expensive business, demanding extensive training and software costing many thousands of pounds.

UK INTRODUCTORY OFFER

PCB Eagle 2.0 allows users to be "up and running" immediately and at a cost which represents a 400% saving against comparative software. To date over 4,000 copies have been sold and now PCB Eagle is available in the UK exclusively from CAD specialists, P.M.S. (Instruments) Limited.

The primary Layout Editor module must be purchased first for the software to operate successfully. The Autorouter and Schematic modules may then be added depending upon individual requirements and applications.

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Prices of the 3 Modules are:

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HOW DO I GET MY DEMO COPY?

A demo kit is available at the special price of £23.00 inc VAT. The kit comprises complete full manual, library and device drivers which function exactly as the PCB Eagle programme (however drawings cannot be printed or saved, except demos). If you prefer to review the specification of PCB Eagle, complete the Enquiry Card or telephone Nicola on **(0628) 38036**

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REED BUSINESS PUBLISHING GROUP

Electronics can now stuff a bomb down a factory chimney. Passive entertainment is the stuff of life and any pre-teen child without its hand-held computer game is made to feel deprived. Markets are created for devices for which there has been no demand simply because they can now be made and must be sold; they are solutions looking for problems.

Eighty years is a good, round number from which to take stock. This journal (then called *The Marconigraph*) came into being in 1911 in response to the need for marine wireless operators to be kept up to date with the emerging technology. Wireless was concerned, in the main, with safety of life at sea and was quite definitely on the side of the angels.

Then came the 1914-1918 war and the cracks began to appear: wireless was used to enable reconnaissance pilots to spot for the artillery and to report on troop movements. It was no longer solely a force for good.

After the war, amateurs started to pitch in. In those days, the entertainment consisted largely of obtaining the best possible time signal from the Eiffel Tower — not absolutely guaranteed to put one's emotions in total chaos. But the spark was there, and soon the British Broadcasting Company was putting out real entertainment. Television came along, as did the second war, bringing in its train a whole raft of new uses for electronics, as it was now called, most of them being more or less bellicose in intent. Now, we have the gimmicks.

All that being so, there are those who consider the kind of engineering that pays our salaries to be not only not quite angelic, but an invention of the devil. They point to a developed world full of well entertained zombies; a world that is ruled by unnecessary computers; the reckless and cynical development of offensive weaponry; and gimmickry gone mad.

But they reckon without the benefits which, viewed dispassionately, outweigh the adolescent applications of a branch of engineering which is still, relatively speaking, in its first flush of youth. Computers do, admittedly, carry an aura of mindless, misguided domination, but it is difficult to envisage a part of modern life that has not been improved by their use. We have all heard of Gas Boards emitting bills for three and a half million pounds and thereby causing little old ladies to suffer fits of the vapours, but without the computers there would quite possibly be no gas — at least at a reasonable price. The little old ladies would probably find some difficulty in collecting their pensions, too.

In medicine, in industry, in transport (air transport, in particular), electronics in all its forms is an enabler; without it, many of the endeavours now taken for granted would not simply be more hazardous or inconvenient, but would not be possible at all.

Electronics has the capability, if properly used, to enhance our lives. Once it has emerged from its present half-developed phase, it is to be hoped that it can be seen without its glamour, as a useful, but not magical assistant. The next eighty years should be interesting. **P.R.D.**

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This issue is the last on which my name will appear — at least, as Consulting Editor. When I joined *Wireless World* as an editorial assistant thirty years ago, no one could have foreseen the changes that would take place — a computer was then a large room filled with steel racks, rather less powerful than a modern PC. But I have been fascinated to observe the changes and shall be even more interested to watch progress in the future.

Many retired people tell me that they are now so busy, they cannot understand how they ever found time to go to work. I hope to be the same. **P.R.D.**

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Navy solves question of logic

Design for a programmable array logic decoder has won a special commendation in the British Aerospace Engineering Design Prize, administered by the Design Council, for Sub-Lieutenant Peter Hoe-Richardson.

Sub-Lt Hoe-Richardson from the Royal Naval Engineering College in Plymouth, recognised the need for a decoder which would allow circuit board designers to test the programmable logic devices (PLDs) used in their work.

But existing tests for PLDs — the blank chips which allow the facility to create customised logic circuits on one component — cannot recognise a component without previous knowledge of its characteristics. So details of customised circuits have to be sent off to chip-test manufacturers for inclusion in their "library" before a test can be conducted.

Sub-Lt Hoe-Richardson found a way of by-passing this time-consuming and expensive process by designing a system which can look at a component and test it not by comparison but by analysis, from first principles. To avoid damage during test, the unknown chip is *tickled* up using low voltages and limited currents.

The system is based on an IBM computer and uses two microprocessors to produce a full report on the logic of the device under test.

It can reveal up to 30 variable functions contained in any logic device and not only tells the designer whether a component is working, but, if there is a problem, also pin-points exactly which part of it is at fault.

A prototype of the programmable array logic decoder has been built and is now being used regularly by other students at the Royal Naval Engineering College.

Sub-Lt Peter Hoe-Richardson with his prize-winning programmable array logic decoder, now in regular use.

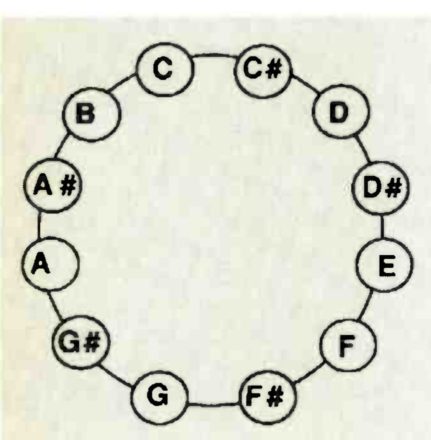
Can you believe your ears?

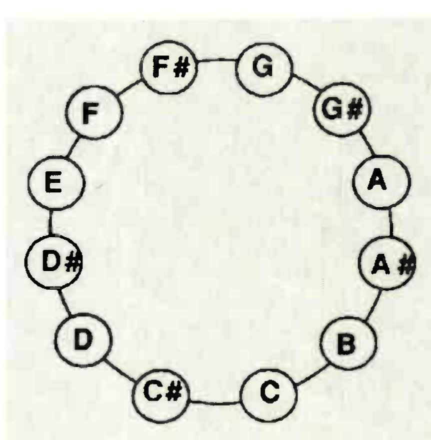
Some months ago I wrote about perfect (or absolute) pitch, the intriguing ability some musicians have to identify a note correctly or to sing a specified note to an accuracy of better than 1%.

Quite coincidentally I have come across another piece of research on music that suggests we may not all hear tunes in the same way. There appear to be acoustic equivalents of optical illusions.

Remember the wire-framed cube where a particular corner can appear either at the front or the back, depending on how you perceive it? Well, it seems that under certain conditions, pairs of consecutive musical notes can be equally ambiguous; they can appear to rise in pitch to one listener and fall to another. The reason is not that some of us have an inverted frequency response; it is because of the way our brains perceive musical pitch.

"Pitch cycles", which suggest why Californians (left) perceive a C→F# pair as falling while English students (right) hear it as rising.





Contrary to what some physics textbooks say, perceived pitch is not just a matter of the frequency of a note; the harmonic content is also important. (That's why Pavarotti's top notes often sound so high when the fundamental rarely exceeds 500Hz.)

Professor Diana Deutsch of the University of California, San Diego, decided to create a series of computer-generated note pairs with the individual pairs separated by a half-octave or tritone. Each note consists of six octave-related harmonics whose amplitudes are controlled by a fixed bell-shaped filter envelope. Listening to these organ-like tones, it's easy — with the help of a piano — to identify the pitch class (C, C#, D etc), but very difficult to assign them to any particular octave. The problem is (deliberately) made worse by the fact that a half octave rise or a half octave fall end up on the same note of the scale

When I played some recordings of these paradoxical tritones to an assortment of golden-eared BBC staff, it was instantly apparent that, for any given note pair, some people perceived the interval as rising while others heard it as falling.

Professor Deutsch says that, unlike most optical illusions, this aural paradox tends to be perceived in a consistent fashion by any one individual. It is unrelated, though, to age, sex or even musical ability.

The striking conclusion to emerge from extensive research on students was that the way a paradoxical tritone is perceived depends very much on where you acquire your native language. English students nearly always perceive a C→F# pair as rising, whereas Californians perceive it as falling

Professor Deutsch has strong evidence that we all have an in-built "pitch circle" in which — other things being ambiguous — we perceive one note as higher than another. For English people F# and G are "high" notes. The orientation of the pitch circle appears to be a developmental feature that is fixed early in life.

Such speculation is fun, but it also has three intriguing implications, the first of which is that we must all have some measure of perfect pitch in order to distinguish qualitatively between the different notes of the musical scale.

A second point is that these findings may explain why (contrary to common sense) music sometimes sounds different when transposed into a different key.

Finally, although ambiguous tritones don't occur in isolation in real music, there may remain residual ambiguity in other intervals or in situations where the orchestration leads to paradoxical harmonic content. Diana Deutsch says that music is too complex to identify differences in listener perception precisely, but she says that the "possibility of basic disagreement at the perceptual level should be considered in evaluating the issue of communication between composer, performer and listener."

In other words, what you hear when you listen to Beethoven's 5th may be quite different from what I hear.

Humming a new tune to tackle global warming

In audio equipment hum is normally an undesirable feature. But scientists who have constructed what is effectively the largest hum generator in the world hope that their research is going to be universally welcomed — particularly by those concerned about global warming of the planet.

The generator is part of an experiment now underway near Antarctica as part of a sensitive method to measure changes in average sea temperatures that might signal global warming.

It is essentially several huge underwater aluminium loudspeakers suspended 250m beneath the US Navy research vessel Cory Chouest, located in sub-Antarctic waters near the appropriately named Heard Island. The hum frequency, 57Hz, was

Organic family of conductors shows promise for electronics

Development of a series of compounds synthesised by chemists at The Johns Hopkins University may herald the next generation of electrical materials. Dwaine O. Cowan and colleagues Theodore Poehler and Thomas Kistenmacher have demonstrated that it is possible to construct organic solids composed of non-metallic elements such as carbon, hydrogen, nitrogen, and sulphur, which exhibit either metallic or superconducting properties under the proper conditions.

Latest progress in the work was described in a paper given at the annual meeting of the American Association for the Advancement of Science giving details on the newest compound in the series, an organic salt known as TTeF-TcNQ.

Cowan's work has yielded information on an entire family of materials with interesting electrical, optical, or magnetic properties in the solid state. His group created the first organic metal in 1972, and former Hopkins postdoctoral fellow Klaus Bechgaard created the first organic superconductor a decade ago.

"Until fairly recently, people did not worry about the electrical properties of organic materials," says Dr Cowan. "They just assumed they were insulators. Now we're trying to understand this class of materials to learn how to make structural changes in predictable ways."

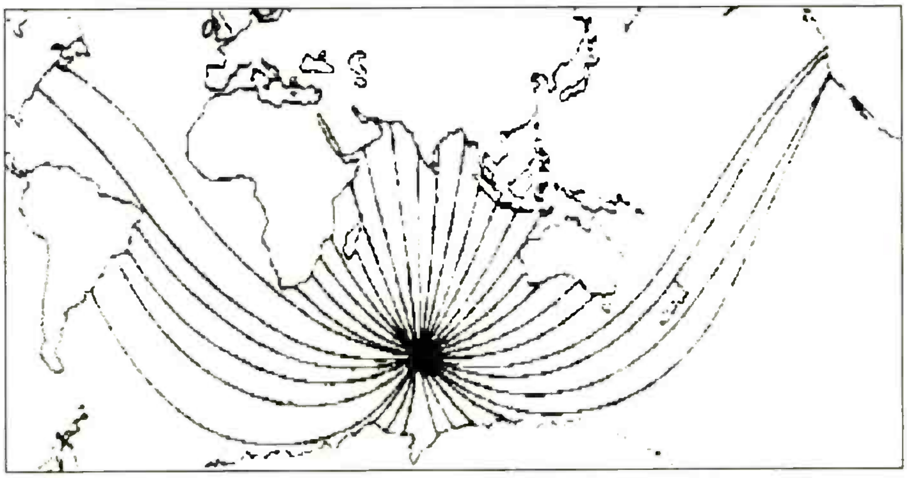
Dr Cowan has been looking for organic salts whose crystals show metal-like electrical conductivity. Below room temperature, these organic materials behave as metals do; their conductivity increases as the temperature decreases.

But below a certain critical temperature, their behaviour changes and the salts perform either as semiconductors or superconductors. The newest salt in the series, using tellurium to improve its electrical properties, remains metallic to very low temperatures, as low as 1.5K.

Dr Cowan's research focuses on understanding this behaviour by studying the structure of the crystals. In metals, electrons can move in three dimensions, whereas in organic materials electrons can generally move in only one or two dimensions.

Organic conductors are quite different from metals in many respects, and the highly one-dimensional aspect of the materials could be particularly interesting. Resistance, optical and magnetic properties are all different under different conditions. Even the researchers themselves are different; they are in the main individuals interested in bridging the gap between organic chemistry and physics (organic chemists traditionally are a little more comfortable going the other way, bridging the gap between chemistry and biology).

Compounds are difficult to make, but several groups are working in this very rapidly growing area, particularly in Japan. While new batteries, semiconductors, and other electrical devices will not be created overnight from these materials — they are expensive and require much lower temperatures than materials in use — they do hold promise for the future.



chosen to minimise interference to and from shipping, breaking waves and sea creatures.

Object of the experiment, involving around 20 measuring stations in 12 collaborating nations, was to detect the 57Hz pulses and calculate the transit time from Heard Island to different parts of the world. Sound travels at approximately 1.5km/s through water and its velocity is critically dependent on temperature.

The researchers calculate, for example, that if the sea temperature changes by as little as 0.05°C then the transit time to Bermuda will change by 105ms.

Since the experiment was switched on, all the various listening stations have picked up the sounds clearly and on time. In the case of Bermuda, hydrophones detected the signals exactly three hours after despatch — the time taken to cover 16,000km.

By sending the acoustic signals below the level of the bulk of the noise generated by shipping and waves and by suitably coding the pulses, the team found that the received signal-to-noise ratios were more than adequate, even over these distances.

Professor Walter Munk of the US Scripps Insititute of Oceanography, who conceived the experiment, says this is the first time man-made sounds (other than explosions) have travelled right round the world. Happily, loud though they are, the sounds do not seem to be having any harmful effects on the whales, seals and dolphins that live round Heard Island.

Although the experiment has been a success in technical terms, it cannot of course yet provide any instant answers on the subject of global warming.

Dr John Church, one of the Australian Collaborators from the CSIRO Oceanography Division, says that the underwater acoustic measurements will have to be repeated over at least a ten-year period before any long-term global temperature trends can be discerned.

But if the world is indeed warming up, the Big Hum will certainly detect it; measurements can be made of temperature changes no greater than a few thousandths of a degree.

Editorial survey: use the information card to evaluate this article. Item A.

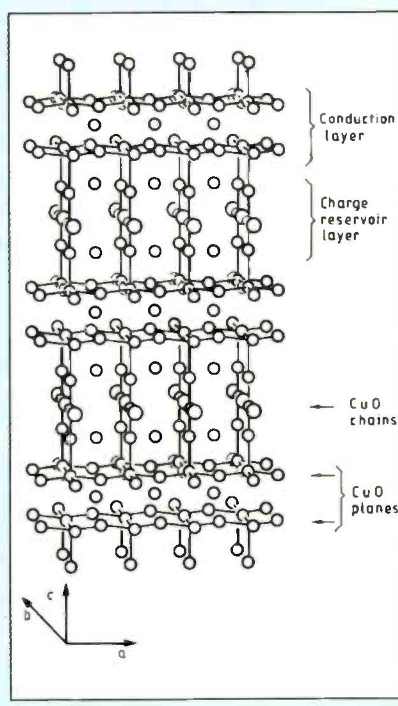
Taking the guesswork out of superconductivity

Unusually among the physical sciences, the practice of high temperature superconductivity has always been streets ahead of the theory. So much so that although there are now thousands of scientists working with the new ceramics, it is been virtually impossible to predict how a particular formulation will work.

A lot of high temperature superconductivity research has therefore been of the try-it-and-see variety and behind many of the current research programmes there still lies a cookery-book approach in which each new material is tested for its superconductivity and — just as importantly — its engineering properties.

But such guessing of how a particular new compound will behave may soon fall out of favour, thanks to the first predictive theory that has been developed.

Henning, Poulsen *et al* at the Riso National Laboratory in Denmark have shown (*Nature* Vol. 349 no 6310) that there is a link between the amount of oxygen in a superconductor and the transition temperature at which it becomes superconducting.



In the high transition temperature $Ba_2Cu_3O_{6+x}$ the conduction layer consists of two corrugated CuO_2 planes separated by yttrium atoms.

In general, the more oxygen, the higher the transition temperature.

Perhaps more significantly from a theoretical standpoint, the new work provides an explanation for why the oxygen content is significant. It examines the structure of the classic yttrium barium copper oxide ($YBa_2Cu_3O_{6+x}$) superconductor and concludes that, of the various conduction and charge reservoir layers, only the ordered CuO_2 structures are significant in terms of superconductivity.

The details of the theory are highly complex but agree remarkably well with experimental results and mean that, in future, many chemical structures can be eliminated before being synthesised in the laboratory. That in turn may help focus the direction of high temperature superconductivity research which is still producing tens of thousands of potential, but useless, materials

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

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80386	25	34	16	-	2/6/-	£ 485	£ 535	£ 595	£ 705	£850	£1100	£1280	£1395	£1485	£2150
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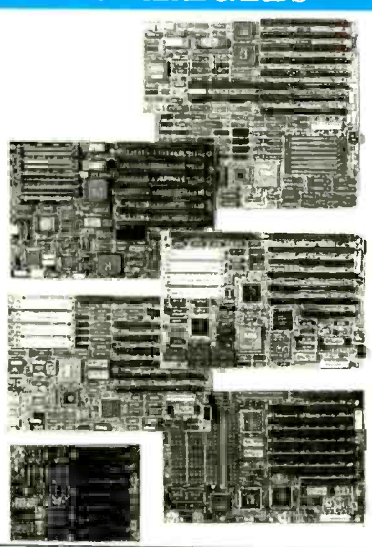
MOTHERBOARDS



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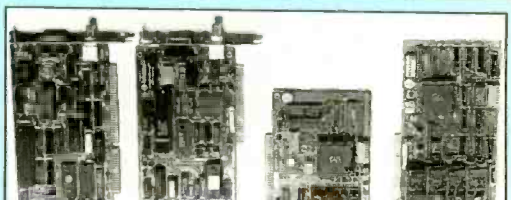

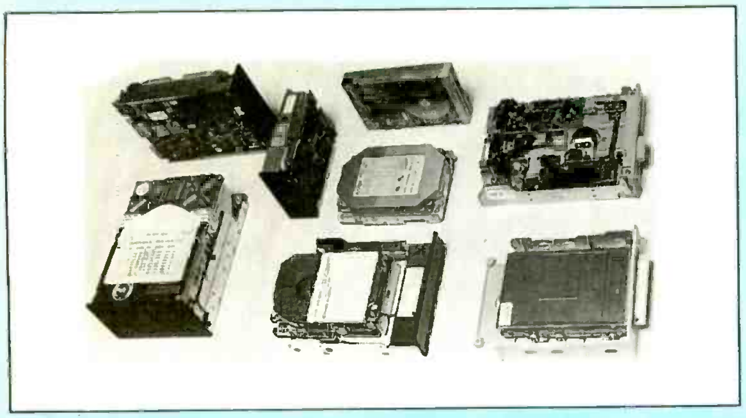

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RLL	YES	8KB	690K	16-bit	£ 76
RLL	YES	32KB	1.1M	16-bit	£ 99
IDE	YES	depends on drive		16-bit	£ 25
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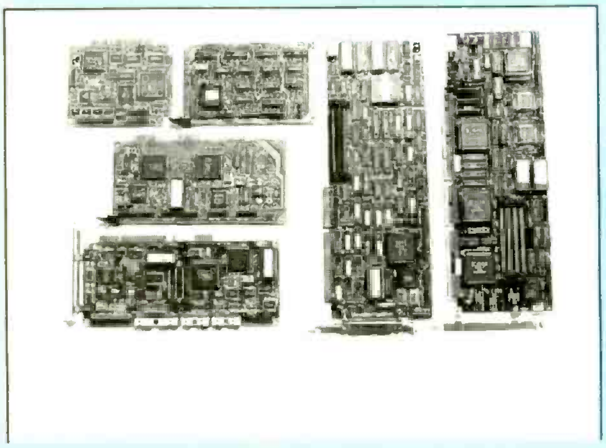

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Warranty period 12 months on all equipment (except computers MDS –3 months).

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CIRCLE NO. 118 ON REPLY CARD

Circuit breakers for optical circuits?

Researchers at the Department of Electronics and Computer Science, Southampton University have come up with a fusing system to prevent optical fibres from blowing out at high power levels.

Optical fibres, particularly the germanium doped variety, are liable to damage from the so called fibre fuse effect. For instance, if a section of fibre is disturbed while transmitting high optical power, a process of thermal runaway may be initiated which can lead to the melting of the glass core. This occurs as the result of a shock wave which propagates along the fibre in the direction of the source of energy, permanently damaging the fibre core and preventing it from guiding light. "High" in this context means power levels above 300mW.

Initiating processes include localised heat, the cleaving of the fibre or contact of the fibre output tip with absorbing materials. The breakdown process is analogous to the damaging SWRs which can occur at breaks in microwave waveguides.

The progress of the fibre fuse can often be seen as a bright spot of side-scattered light which propagates back along the fibre towards the source of light. The destruction of over a kilometre of fibre due to this damage mechanism has been reported.

Damage mechanisms have been observed using both a continuous wave argon and Nd:YAG lasers indicating that the effect is probably wavelength independent.

One solution for single mode fibres has been the inclusion of a tapering section of fibre where the core diameter is reduced by 8%. Such a circuit breaker element has been found to stop the advance of a fibre fuse produced elsewhere in the fibre. This work indicates that low-loss tapers could be inserted into a fibre link at regular intervals in order to reduce significantly the length of optical fibre which may have to be replaced as a result of a fibre fuse event. Tapering, however, of multimode fibres has so far not proved successful.

Douglas Clarkson

Bullish book-to-bill

Semiconductor order books are filling up on both sides of the Atlantic with book-to-bill ratios rising significantly last month. The ratio, which relates the total value of forward bookings in a month with the total value of delivered components over the same period, provides a barometer of business prospects: the higher, the better. In the UK, a high level of order intake is expected to continue into the early summer when the annual ordering cycle normally reaches its peak.

Components body ECIF said that the book-to-bill ratio rose to 1.28 in February, having risen from 1.07 in January, and 0.98 in December last year. Analysis shows that ratios of 1.24, 1.23, 1.29 and 1.28 have been recorded in the years '88, '89, '90 and '91 respectively. In the US, the book-to-bill rose to 1.09 at the end of February from 0.96. This was due in part to semiconductor distributors and users refilling their inventories after trimming them last year.

A spokesman for the Semiconductor Industry Association in the US said the industry has been recovering since December.

Reaching for the sky: ***Georgia Tech believes in stretching its engineers when it comes to antenna technology. The new Georgia compact antenna has been designed to combine the small size and inexpensive construction of microstrip antennas with the performance of conventional units. But fitting it onto the positioner for testing requires an altogether less compact design of experimenter.***

Big Blue blesses all Japan PC

IBM has agreed to licence personal computer technology to 11 leading Japanese companies in an attempt to establish its own PC architecture as a standard in the Japanese market.

This follows IBM's recent move to make its internally developed Japanese language version of the dos PC operating system available.

IBM will agree to licence VGA PC graphics technology and, possibly, its MCA bus system together with OS/2 to third parties. These include laptop maker Toshiba, ICL-parent Mitsubishi and the big consumer electronics companies Matsushita, Sharp and Sony. These companies already manufacture PCs for external markets.

Efforts to sell clones in Japan have been hampered by lack of software written with Japanese dialogue. IBM hopes to encourage software companies to write products for the domestic Japanese market through availability of totally Japanese hardware.

At the moment, Japan's PC market is dominated by non-standard machines made by NEC, just about the only major electronics company not involved in the deal.

Cells for hot cellphones

In April, Britain's Home Secretary Kenneth Baker launches Crime Prevention Week. He will make headline news by announcing that the theft of cars is rising by over 20% a year, nearly twice as fast as crime in general. It is most unlikely that the Home Secretary will admit that many car thieves could be caught if only the police understood, and used, available technology which is already available.

More than a million people in the UK now have cellular telephones on the Cellnet and Vodafone networks. Around half of them are installed in cars and, if the vehicle is stolen, will give telltale clues to the whereabouts of the car and identity of the thief. But the police have no guidelines on setting the traps which are available: individual officers are completely ignorant of them.

This squandered opportunity to detect crime is typified by the sorry tale of best-selling author Margaret Drabble's car, which was stolen over a weekend from outside her home in Hampstead, North London. Her husband, historian Michael Holroyd, tried 'phoning the Cellnet cellular telephone in the car. A man answered, telling Holroyd "I'm the thief who has stolen your car. Get lost!".

Ms Drabble telephoned Cellnet, hoping that as network operator it could trace her car by telephone calls which the thief made or received. Cellnet told Drabble she must wait until Monday morning and talk to her Service Provider, Motorola. Cellnet did, however, stop further use of the stolen telephone. The Hampstead police came and said there was nothing they could do.

By coincidence, Motorola also supplied Cellnet with the computer "switches" which route calls round its network and should therefore know better than any company how the system can be used to trap thieves. But Motorola told Drabble that call tracing on Cellnet was "not yet possible", although it could be done on the rival Vodafone network, which uses switches made by Ericsson. In fact both types of switch can trace calls.

Although the networks are reluctant to discuss security matters, both Cellnet and Vodafone have private call-tracing arrangements with Scotland Yard; both networks allow tracing in similar fashion. But unwritten policy says that that this is only done where human life is at stake or a serious crime is involved. Neither Cellnet nor Vodafone know the names of subscribers. These are held by the service providers who allocate numbers given them by the network operators. It is only as special concession that Cellnet and Vodafone will now block calls from a cellphone if the user reports it stolen at night or over a weekend.

The key point is that if an attempt at tracing is to be made, the subscriber should not block calls immediately, but the police and Service Provider must have the initiative to offer this advice. Also the subscriber must feel confident that the police will act on information obtained.

The network system keeps track of the mobile so that it can route incoming calls to any mobile via the nearest base station which has spare channels. It does not normally make a permanent log of this location information, but if the police request a "trace" the system can start to record; information is most accurate in busy cities where the cells are small. There are additional tricks which the network operator can play to sharpen the location.

Neither network will undertake the intensive manual work involved in tracing mobiles in "real time" (rather than from logs after the event) unless they are convinced that the police will show a similar commitment to real-time detection. Both networks have high-level contacts with Scotland Yard and use them to check whether requests are as important as a junior officer claims. The unspoken policy of both Cellnet and Vodafone is that, unless the police take car theft more seriously and someone pays for the time it takes a cellphone network to trace mobiles, such crimes should be solved by the insurance companies, not technology

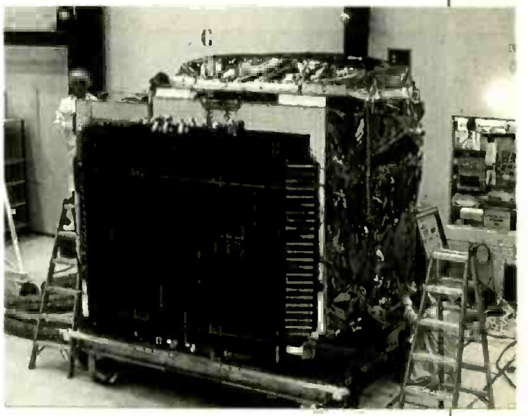
The Crime Committee of the Association of Chief Police Officers is responsible for setting police guidelines. It confirms that there is no guideline for police action following the theft of cars fitted with cellphones; action is left to individual forces and officers. The Home Office's Crime Prevention Centre knows of no guidelines either. At local level, the Crime Prevention Office for Hampstead knew of no special action to be taken when dealing with the theft of cars with cellphones.

We could find no-one at any level in the police who knew anything at all about cellphone call tracing. The Home Office and local crime prevention officers could only suggest removing telephones from cars or marking them with ultraviolet ink. In practice, most carphones cannot be removed and removing them would prevent their being used to trace the car.

To add to the confusion, Cellnet advises subscribers to use a lock, either mechanical or electronic, on their telephone to prevent its being used. This would also prevent tracing.

We have deliberately omitted any description of the simple procedure which would allow the police to catch car thieves with very little detection work. Currently, only beat officers with interest and initiative, or senior officers investigating serious crimes, use it. We have offered to discuss this loophole in the system with the ACPO's Crime Committee for inclusion in guidelines.

Barry Fox



Astra 1B, which is larger than 1A and has a longer designed life.

Pan-Europe aim for Astra 1B

The newest Astra satellite is bigger and more powerful than its predecessors and is intended to last longer. Peter Willis reports from Kourou

Astra 1B satellite, launched from Kourou early in March, will not only double the system's channel capacity; it will also play an important part in extending Astra's coverage throughout Europe.

The flight, originally scheduled for February 21, was delayed briefly after routine checks by Arianespace on another rocket's engine revealed an anomaly in the start-up sequence.

Target markets for 1B are France and Spain, with some consolidation in Germany, where three channels were the first to sign, and in the UK, where the target is three or four more channels. Sky has already announced it is taking two of them, to complete its five-channel service. Other names in the frame are the Children's Channel and Discovery (possibly sharing a transponder) and as outsiders, CNN and Disney. Thames Television, an Astra shareholder, has options on two transponders. However, it is likely to hold back until the launch of 1C in 1993, or at least until after the current ITV franchise round.

1B will transmit on 11.45-11.70GHz, adjacent to 1A (1.20-11.45GHz). Existing receivers — including 16-channel Amstrad models — can be retuned to pick up the new services, and Astra will be publishing leaflets on how to do this for the more popular models. Astra also plans to give greater promotion to the radio services it carries.

Launch technology

The new satellite, like 1A, is built by GE Astro-Space and carries 16 transponders, plus six spares, but differs from it in several important respects. It is bigger, with a wingspan of 24.4m (19.3m on 1A) and heavier, weighing 2550kg at launch, 1246kg in orbit (1812/1042kg for 1A). It is also more powerful. Its TWTAs (travelling-wave tube amplifiers) have an output of 60W, instead of 45W, and the footprint of the vertical-mode transponders can take in the Canary Islands, although at least a 1.2m dish will be needed.

1B has also been blessed with a considerably longer design life. With good housekeeping and no unforeseen difficulties, it is expected by its owners, SES, to remain in orbit and transmitting for at least 14.5 years, and possibly longer.

There is really only one factor which influences the life-expectancy of a spacecraft, and that is the amount of fuel it can carry for its station-keeping manoeuvres. In the case of 1B, two factors have allowed this to be maximised. One is a change in the design of the apogee engines, which are used during the launch for the transfer from launch orbit to geostationary orbit. Previously, they used solid fuel. The new engines, made by Royal Ordnance, part of British Aerospace, use the same fuel — liquid hydrazine — as the attitude-control motors. Thus, any fuel unused in launch can be saved to extend the lifetime. In addition, Astra's co-passenger on Arianespace Flight 42 is a lightweight weather satellite (MOP 2), which means spare payload capacity, taken up by 1B with additional fuel.

These factors are added to the natural advantage provided by Arianespace's near-equatorial location at Kourou. The site gains maximum benefit from the boost given by the Earth's rotation, thus allowing heavier payloads to be put into orbit. This advantage is quite considerable: the ESA (European Space Agency which operates the Guiana Space Centre) at Kourou, has calculated that the same rocket, if launched at Cape Kennedy only 23° to the north, would be 15% less efficient.

Kourou is a classic example of the French capacity to seize opportunities and exploit even the most unpromising assets.

French Guiana, which is mostly swamp and jungle, has never been good for much more than a naval staging post, but has for 40 years been run as a department (county) of France, and still is. Now, however, it is the home of the world's most advanced space-launch centre.

Kourou is completely industrialised and run on a production-line basis. The site is criss-crossed by railway lines so that one rocket can be rolled-out from hangar to launch base while the previous launch platform is being returned to the hangar for the next campaign.

Elsewhere on the site, preparations for the "next model" are well under way. Ariane 5, due for roll-out in 1995, will have a payload of 6800kg, compared with 4200kg on the present 4 series, and 1800kg on the first Ariane rocket in 1979. Already in position is the stump of a new-style umbilical mast which will replace the present gantries and greatly simplify hook-up procedures.

At present, practically everything to do with Arianespace is imported into Guiana. For Ariane 5, however, the solid fuel will be manufactured and tested on site.

Although Ariane is thought of as a French project, it is in fact pan-European — with, however, a majority French shareholding of 58.5%, followed by Germany with 19.6%. Sadly, the UK has only 3.2%, roughly in line with its contribution to the actual rocket, which consists of the Spelda, a sort of circular pallet which holds and separates the two satellites.

Astra 1B is the 42nd launch from Kourou since December 24, 1979. Of the previous 41, over 90% have been successful. The four failures were flights 2,5,18 and, in February last year, 36, which blew up when a piece of rag blocked the water supply to one of the four rocket motors.

By the time Astra 1D is launched in 1994, Ariane will be approaching, or may even have passed, its 100th flight.

Peter Willis

No fuss No mess
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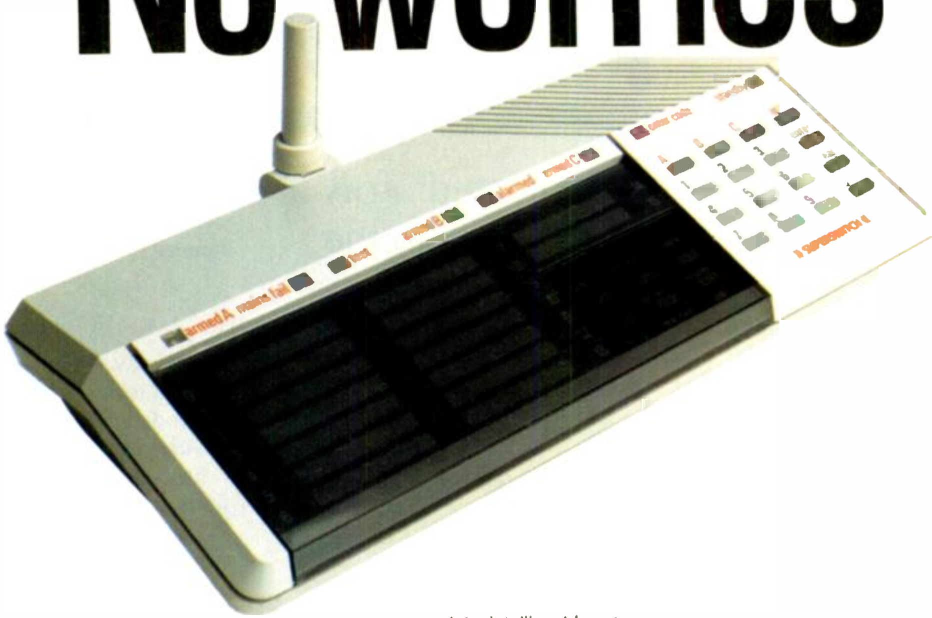
No worries



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The system provides status indications at the controller and offers 24 hour protection using portable emergency/panic transmitters and photo-electric smoke detectors.

The SUPERSWITCH WireLess system is approved by the DTI and complies with BS 6799.3.

Like the entire SUPERSWITCH range, which includes electronic time controls for domestic applications, this is a rare example of advarced technology making life simpler for a change.

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CIRCLE NO. 120 ON REPLY CARD

PLUG-IN PC POWER

Is "dedicated" now a dirty word in the world of instrumentation? PC cards could be our real flexible friends says Steve Rogerson.

There are three basic ways a PC can be used in an instrumentation environment. It can act as a controller (via an IEEE488 bus); it can have a bus extension card linking to a box containing various data acquisition cards, or it can function as a normal PC with cards slotted in transforming it into an instrument in its own right.

Bus extension is an area that is generating a lot of excitement at the moment — especially with introduction of the updated 488.2 and its associated command language SCPI (standard command for programmable instruments). Users can control instruments from different manufacturers using a common set of English language type commands, specific commands being related to common test and measurement functions.

But it is the normal PC with cards slotted into its back to turn it into an instrument in its own right that is the main interest of this article.

PC instruments

Prime advantage of the PC-plus-cards method is that it is a lot cheaper than buying a dedicated instrument — assuming the user has a PC in the first place.

Storage and analyses of results is easier through accessing the full resources of the PC and automation is simplified as users can write programs to handle complete data collection.

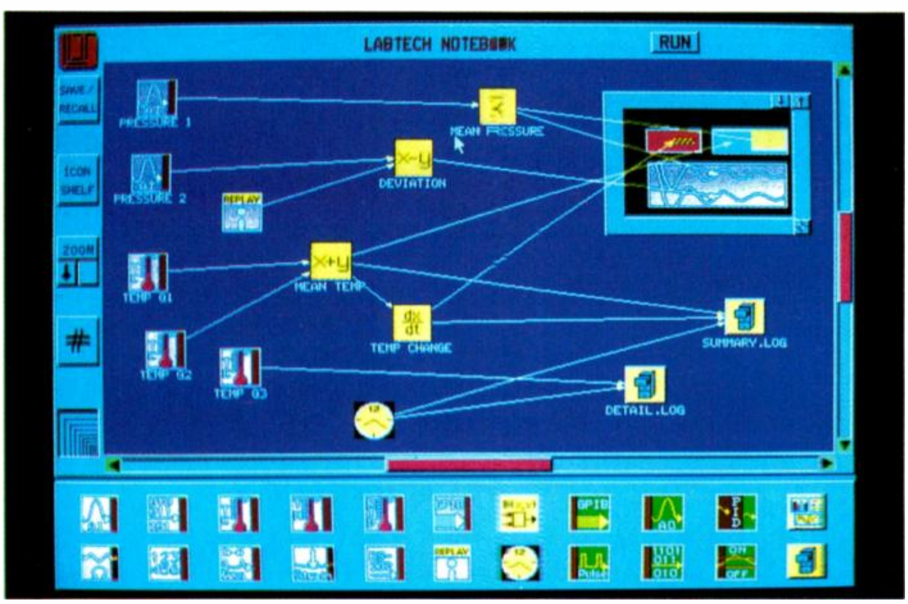
Big disadvantage is that the atmosphere inside a PC is inherently noisy, so resolution of the instrument is a problem. Space is also limited inside the PC, but the external box alternative can get round both these problems.

On price, the PC approach can be anything from 10 to 50% of the cost. For example, a 150 to 250 node digital analyser could easily cost £20,000 but a plug-in card for a PC could cost as little as £2000.

Martin Board from systems design and application specialist Aces, estimates that in general the plug-in card system can be 40 to 50% cheaper than a boxed instrument.

But on top of that: "You could end up with something at about a tenth of the price that works better than a boxed instrument because it is customised to the application," he says.

Similarly, as Nick Challacombe from

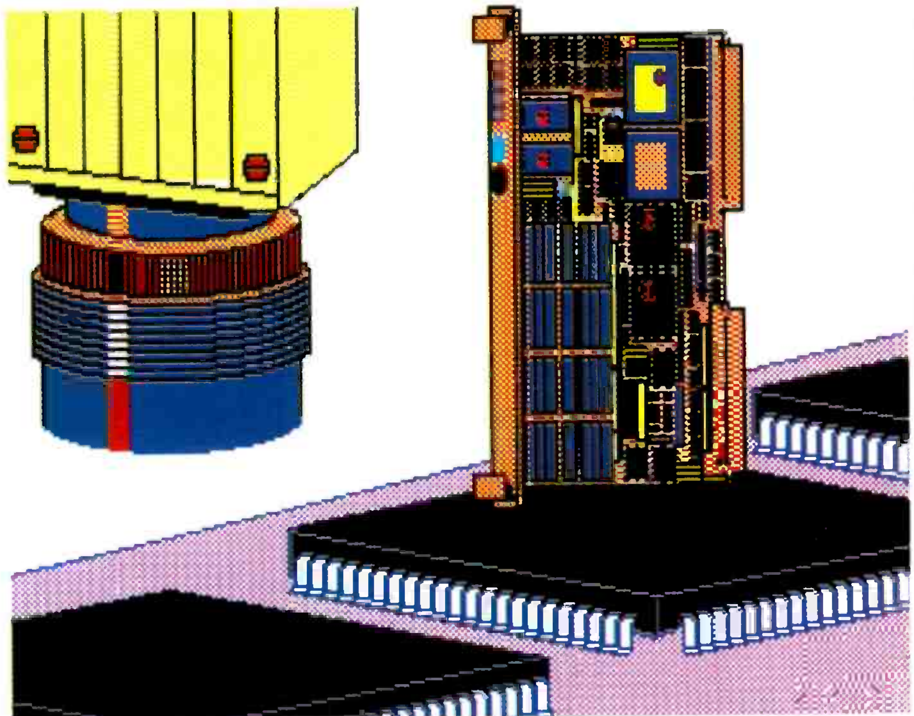


The ability to access the full resources of the PC such as application packages like Labtech Notebook is an important advantage.

Keithley Instruments points out, with a PC you can have a complete eight-channel data acquisition system from about £400. An equivalent eight-channel digital multimeter will be more than £1000.

Undoubtedly a key advantage is cost. Typical cost of a board configuration is around £1000 with software from a few hundred pounds to couple of thousand (you could write your own though this is time consuming). Costs for stand-alone instruments are considerably higher.

Another advantage of the PC is that a dedicated system imposes an architecture on the user whereas a PC system does not have these constraints.



Philips supply a board which can turn a PC into a low cost auto-inspection system using inputs from four cameras. It can be used in manufacturing inspection, for example

Overcoming space restrictions

The restricted input and output space limiting the number of cards that can be fitted can be a serious problem with the PC. Often the situation is made more difficult because PC users are already using some expansion slots for networking or other functions.

One solution is that adopted by Arcom whose boards use a transparent offset address scheme and only take up two or four I/O bytes regardless of how complex the function is.

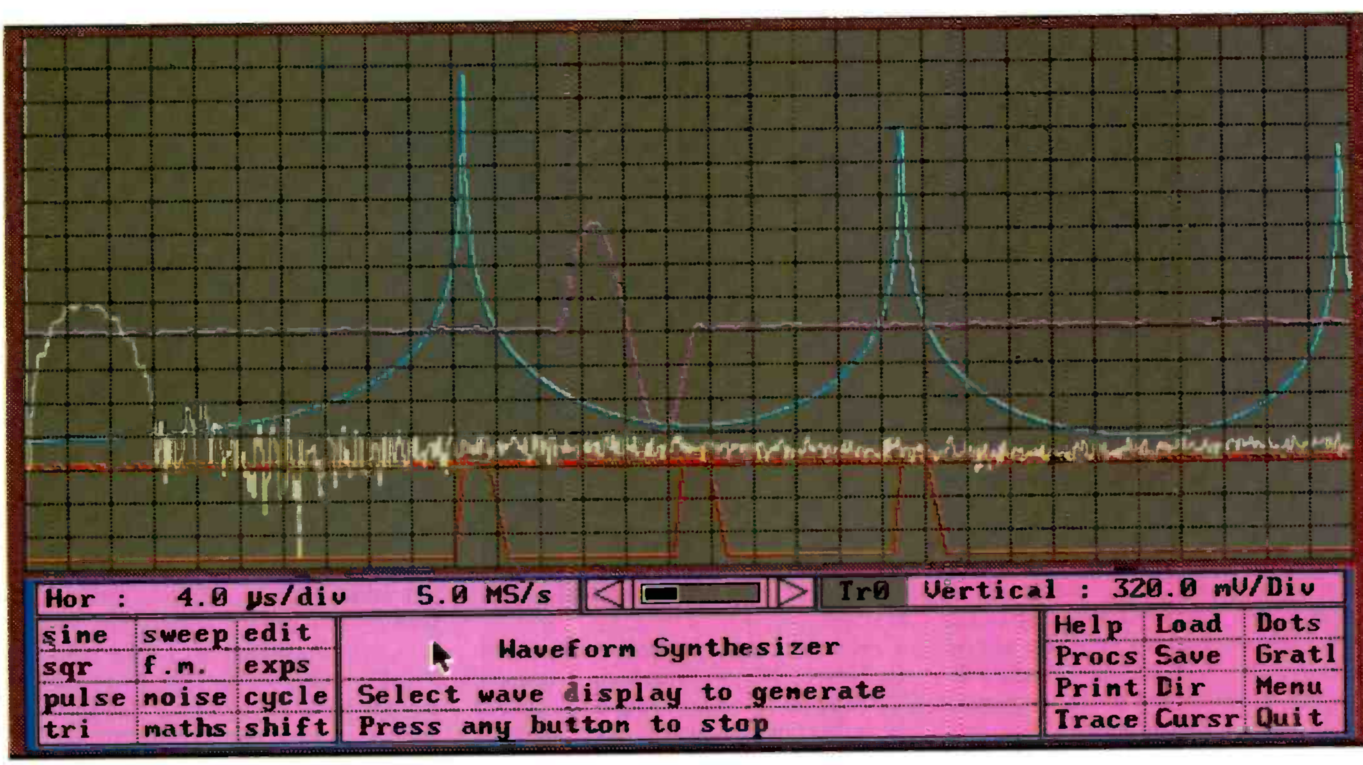
The lowest byte is a pointer and the second is used for 8-bit data transfers. The other two are for 16-bit transfers for boards such as A-to-D converters. Behind the pointer byte is a bank of 256 registers of which 128 provide the requirements of the I/O devices used. The rest are special function registers to simplify configuration, test, diagnostics and general use of the board. The on-board registration system means that from one I/O on a PC you can link to 128 different addresses.

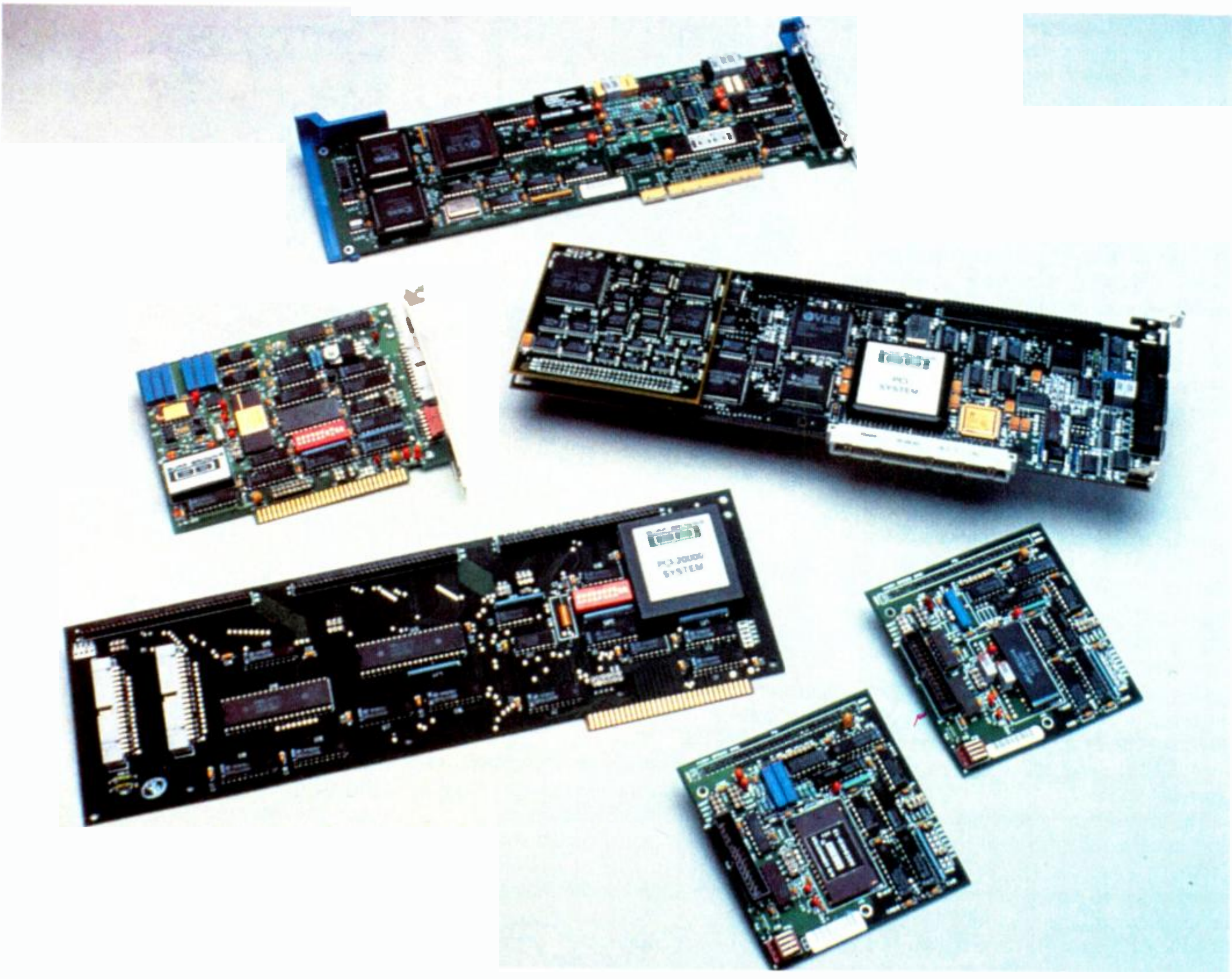
Paul Reeve from Arcom distributor Dean Microsystems says that Arcom products are aimed at the industrial control market where the cheapness and flexibility of the PC and its access to spreadsheets and databases etc is important.

Waveform generators are a popular package for PC boards such as the PC99 from Applied Concepts Ltd, available through Amplicon Liveline.

Modular data acquisition

Another way to obtain the most out of the PC's limited space is used by Burr-Brown in its PCI modular data acquisition system. Burr-Brown's system relies on a family of base boards, called carriers, onto





which various modules can be added. The carrier board plugs directly into the PC bus and provides mounting space for up to three I/O modules that determine the exact functionality of the system.

Modules such as A-to-D and D-to-A convertors and counter/timers communicate with each other via the intelligent instrumentation interface (I3) bus on the carrier. Using the bus each module can send and receive analogue, digital and synchronisation signals between adjacent modules and in some cases between adjacent carriers. The carrier also provides power supply voltages to each module on the bus plus other functions such as digital I/O, a pacer clock and high speed DMA transfers.

The simplest board is the general-purpose carrier which supports up to three I/O modules and provides mounting space, regulated DC power, I3 bus communications and PC bus interfacing, 32 points of fully buffered TTL compatible digital I/O are arranged in 4bytes of 8-bit each and each byte, under software control, can be configured for either input or output use leaving all three module positions free for additional I/O functions.

Plug-in cards can now turn the PC into anything from a digital multimeter to a full vision system — all with an overwhelming cost advantage over conventional equipment.

The multifunction super carrier provides on-board 12-bit A-to-D conversion for as many as 16 single-ended input signals. The analogue input channel can be expanded in 32 channel increments up to 80 channels using analogue expander modules.

The digital section has 16 channels of digital I/O, a programmable burst/rate generator and two general-purpose counters. Two high performance carriers, each with 32 points of fully buffered digital I/O and an 8MHz programmable pacer clock, are for use in timing data acquisition and in DMA transfers of data to and from memory.

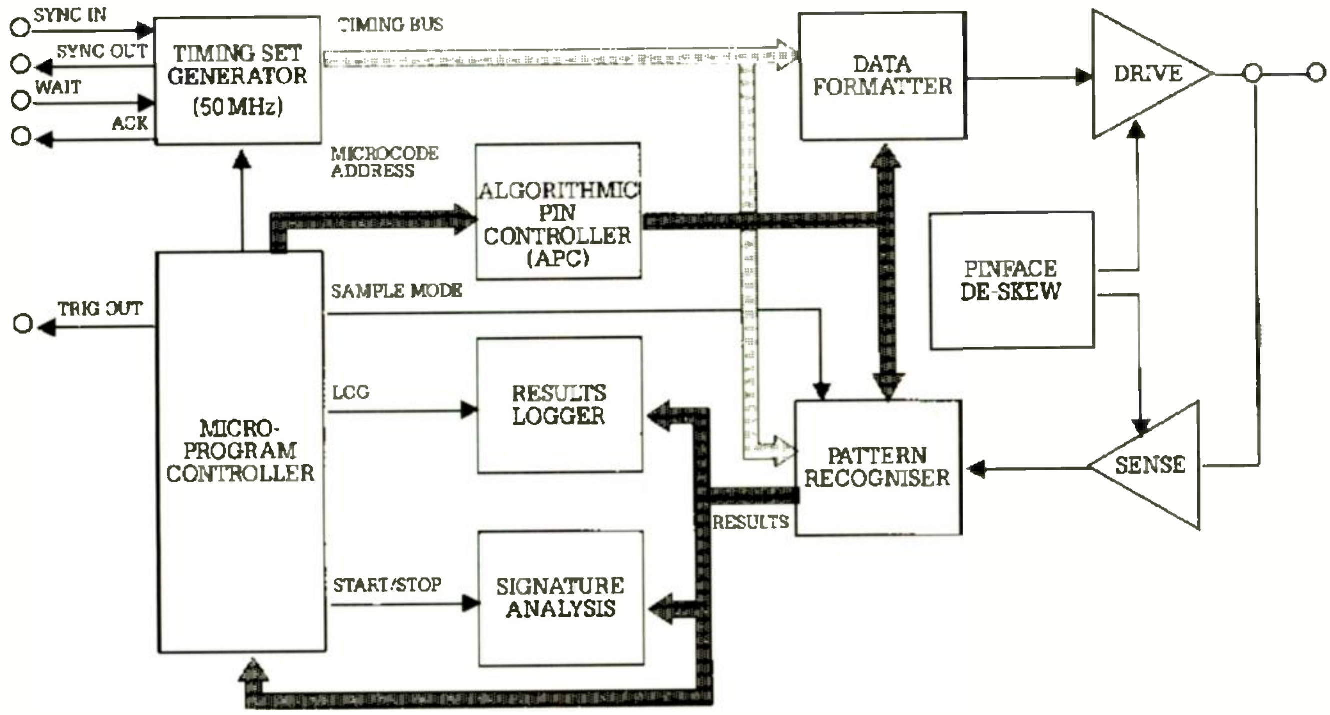
Finally there are the smart carriers with on-board DSP capabilities using the TMS320C25 processor to process data at 20 to 200 times faster than by PC alone.

Familiarity breeds contentment

Applications cover all data acquisition areas: from laboratory research to monitoring industrial processes. It is a small step from monitoring to using the PC to actually control the process based on the readings it is receiving. But there can be problems here. Nigel Wait from Burr-Brown distributor Altek has a warning: "For a simple application the PC is the easiest and cheapest solution but its stability is not good. Cards are long and thin and can move and connectors are open to dust and moisture".

However, a growing role for the PC seems likely. Chris Bower from Diamond Point makes the point that people are familiar with a PC. "We get a lot of enquiries for our PC based stuff because people like to stick with what they know."

Diamond Point sells the Quatech range of PC based data acquisition and industrial control products that provide A-to-D, D-to-A and digital I/O capabilities. One of its recent introductions is the WSB100 waveform synthesiser for use with the PC/AT which can generate analogue signals independent of the host computer.



The output signal is defined by a set of up to 32,768 points and data point generation rate is software-selected from 50ns/point (20MHz maximum) to 107s/point in 25ns intervals. The rate clock can also come from the software-selectable external clock input while external clocks can vary from DC to 20MHz.

Programing can achieve either continuous repetition of the same pattern or output of a programmed number of cycles, from 1-65,536. A delay factor may be programmed to determine the time interval between the end of one cycle and the beginning of the next cycle.

The system can be used as a laboratory tool for reproducing or simulating noise, audio signals and power line signals.

Vision systems

Philips has recently introduced a single board product for PC and VME bus systems. When plugged in, a PC turns into a low cost vision system for high speed recognition, measurement, positioning, quality control and guidance applications. The board can take inputs from up to four cameras, perform real-time recognition and can identify objects from a video camera in only 30ms.

At the heart of the system is the TMS34010 graphic system processor, a video frame buffer and two Febris correlator chips.

Richard Jones from Philips explains its advantages:

Marconi's Midata 511 combinational tester handles analogue, digital and mixed signals, the range configurable by plug-in cards

"Most systems have a frame grabber and then process the image, so they need an expensive processor. Our system can recognise images as they are screened by the camera".

There are two hardware circuits on the Philips card which are programmed to compare shapes stored in the software. Cost of the card is £4000, whereas a dedicated system could cost £8000 or more.

The camera supplies the input signal to an 8-bit A-to-D convertor whose output is connected to a input look-up table having 12-bit input and 8-bit output.

Operation is in one of two modes. In input grey conversion mode, all 8bits of the convertor are connected to the table. The three extra bits are connected for the selection of one out of eight input conversion tables. Tables determine the processing of the video input data after being digitised.

In overlay mode output from the correlator can be stored in one bit-plane which is reserved for overlay data. By selecting a table which converts only 7bits of the convertor, the correlation output can be stored in the overlay bit-plane.

Output from the convertor is also fed into the correlator circuit. With this correlator, real time recognition of objects in the input picture and simple binary operations such as shrink, grow and edge detection are possible. As Jones is keen to make clear, the product is a lot more than just an expensive frame grabber.

Testing digital PCBs

For less than £1000 Aces' Locate-192 PC-based hardware and software package is designed to enable electronics manufacturers and service and repair organisations to test, digitally based PCBs, cables and subassemblies.

Companies can instal the package on any standard PC with a hard disk to automate their test operations at a fraction of the price of a full-blown ATE system.

Each of the 192 test channels is TTL/cmos compatible and can be programmed as an input or output. The channels are brought out to four 50-way on-board connectors and accessed via four ribbon cables attached to the rear of the computer.

The software uses English style commands and includes conditional and unconditional branching, looping, full subroutine capabilities, 100 run-time variables and comprehensive array handling. Test program source files can either be prepared using the package's built-in text editor or a standard commercial wordprocessor. The compiler has error reporting in the text editor to help users debug programs.

After compiling, the optimised code is checked for I/O pin contention before finally saving the object code.

Test software, once proven, can be

introduced into the working environment. The operator is carried through operations via on-screen prompting from the software. Typical operational features include printed test results, on-screen requests highlighted in reverse video, and screen presentation of the last 20 pins tested.

Combined signal testing

A different type of test system is Marconi's Midata 511 combinational tester handling analogue, digital and mixed signals and providing in-circuit and functional test facilities. The range of functions is configurable by plug-in cards and the test frame can accommodate up to 21 instrument and function cards including digital multimeter, universal counter/timer, programmable waveform synthesiser, and dual voltage source.

US firm Strawberry Tree supplies data acquisition and control boards for the PC, available from Adept Scientific, which can use a range of software including the firm's Workbench PC.

For example, at just under £500 the ACjr-12 data acquisition board has eight differential analogue inputs and 12 digital I/O lines. Or at £700-900 the ACPC-12 range of 12-bit resolution data acquisition boards has eight or 16 differential analogue inputs and 16 digital I/O lines.

Two recent products are the ACPC-I/O-40 (£255) and ACPC-I/O-160 (£495) digital interface boards with 40 or 160 digital I/O lines. They are suitable for laboratory or factory use for applications such as detecting contact closures, operating relays, pulse counting, frequency measurement and timing.

Workbench costs an extra £795 and is basically a data acquisition and control program using 14 icons and interconnecting wires to program, measure and control temperature, pressure, flow and other analogue and digital inputs and outputs. It can also act as a control, data logging and display software environment.

A window style interface is used and various graphic symbols or icons represent functions used in data acquisition and control.

These can be selected and wired together on screen to create a symbolic representation of what actually happens in the hardware. Only valid options are presented in the menus because the software reads what boards are installed, their number of channels and configuration.

More 'scope for DMM

The MetraByte range of PC instrument products from Keithley plugs directly into the PC and can be operated in bench or programmed modes.

In bench mode they work just like a standard external instrument but with the computer screen used to display information normally seen on leds, LCDs and calibrated knobs. In programmed mode the outputs are controlled and inputs monitored by a program running in the PC and operating in a similar way to an IEEE488 instrumentation system.

For example the £720 PCIP-DMM 4.5 digit multimeter board uses English language style programming and can handle DC and AC voltage, current and resistance measurements. All the software is included in the price. The display operates in a pop-up mode. When activated, the DMM display takes up one third of the screen allowing three separate instrument displays to be viewed at a time. Operation is by keyboard or mouse.

Or at just over £1000 the PCIP-Scope is a 10MHz two-channel sampling digital oscilloscope with 2ns sampling for repetitive waveforms.

Other boards include waveform generators, voltage references, counter/timers and a 16 channel logic analyser.

£375 spent with Fairchild could buy the PCL860 digital multimeter card. Multichannel measurement for up to 256 channels can be implemented using the on-board 16-bit D/O port to control the external relay multiplexer boards.

DC and AC voltages and resistance can be measured and there are 16 TTL compatible output channels. Software comes in the form of a device driver, loaded into the machine during the system configuration each time the computer is rebooted or turned on.

National Instruments plug-in boards combine analogue, digital and timing inputs and outputs. Many have programmable channel sampling order and conversion modes, separate gain for each channel, and pre-, post- and delayed analogue and digital triggering.

To control them, there are software drivers for programming in C, Basic and Pascal as well as add-on packages for Lotus spreadsheets and application packages such as LabView 2, LabWindows, Labtech Notebook, Parameter Manager, and VisionScope.

So it is now clear that the PC can be turned into anything from a digital multimeter to a full vision system, as well as having its well known ability to control other instruments via the IEEE488 bus.

PC-plus-card instruments are a fraction of the cost of dedicated boxed instruments — and they can often have more functions and are better customised to the particular application.

Editorial survey: use the information card to evalute this article. Item C.

ADDRESSES

Aces Ltd,
St Georges Avenue, Poole, Dorset BH12 4ND. 0202 723373.

Adept Scientific Micro Systems Ltd,
3 Letchworth Business Centre, Avenue One, Letchworth, Herts SG6 2HB. 0462 480055.

Altek Microsystems Ltd,
Lifetrend House, Heyes Lane, Alderley Edge, Cheshire SK9 7LW. 0625 582637.

Arcom Control Systems Ltd,
Unit 8, Clifton Road, Cambridge CB1 4WH. 0223 411200.

Burr-Brown International Ltd,
1 Millfield House, Woodshots Meadow, Croxley Centre, Watford, Herts WD1 8YX. 0923 33837.

Dean Microsystems,
11 Horseshoe Park, Pangbourne, Berks RG8 7JW. 0734 845155.

Diamond Point International (Europe) Ltd,
Unit 9, North Point Business Estate, Enterprise Close, Medway City Estate, Rochester-upon-Medway, Kent ME2 4LY. 0634 722390.

Fairchild Ltd,
Eastpoint, Burgoyne Road, Thornhill, Southampton SO2 6PB. 042121 6527.

Keithley Instruments Ltd,
The Minster, 58 Portman Road, Reading, Berks RG3 1BR. 0734 575666.

Marconi Instruments Ltd,
Longacres, St Albans, Herts AL4 0JN. 0727 36421.

National Instruments UK,
21 Kingfisher Court, Hambridge Road, Newbury, Berks RG14 5SJ. 0635 523545.

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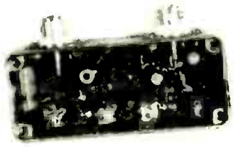
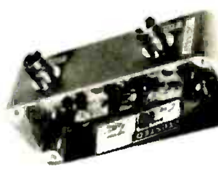

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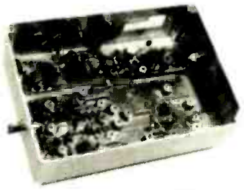
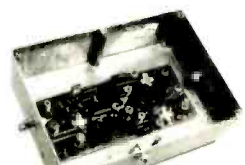

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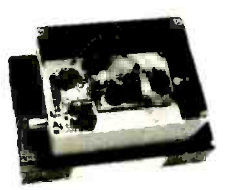
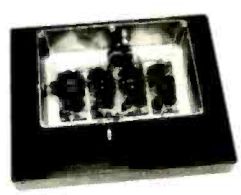

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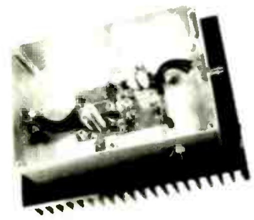
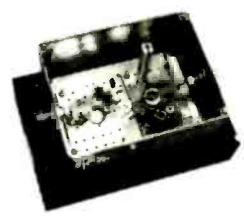

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CIRCLE NO. 141 ON REPLY CARD

DSplay-XL — signally significant software?

Do you really need another DSP package? If you have a DSP32C card then you might well say yes to DSplay-XL says Allen Brown.

Digital signal processing (DSP) has been receiving its fair share of attention from the writers of PC software of late and to add to the plethora of DSP software which runs under MS-dos, Burr-Brown has introduced DSplay-XL.

But what makes DSplay-XL significantly different from other packages is the fact that it uses the PC only as a host platform for performing real-time DSP functions.

To exploit the full features of the package at least one PC expansion card, hosting the much favoured AT&T DSP32 or DSP32C 32-bit floating point digital signal processor, is required. The package can be run without a processor board but operation is limited. Burr-Brown manufactures a number of expansion boards which feature the AT&T chip (the ZPB series) and it is a mark of confidence in the DSP32C that the company should produce a dedicated software package to support it.

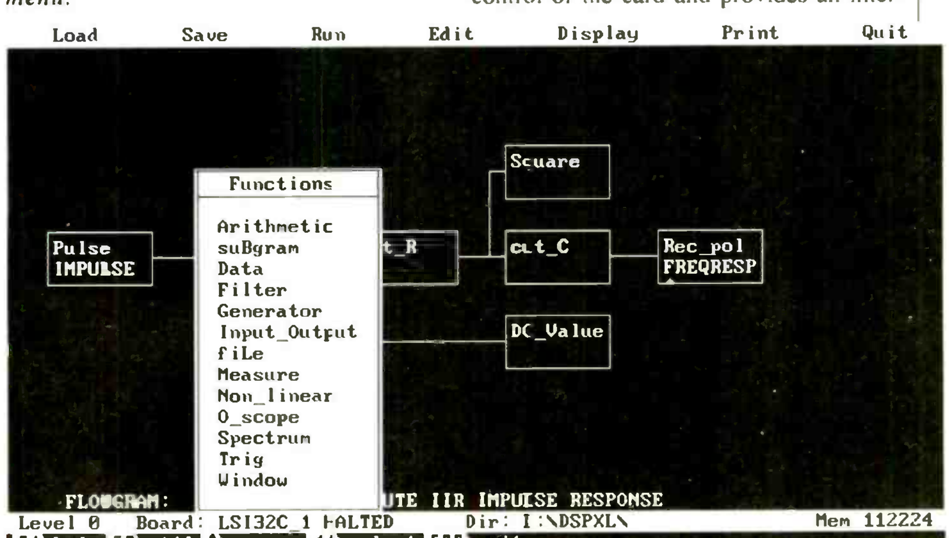
In fact, DSplay-XL can be used to control several DSP320C processor boards running concurrently, either operating on separate tasks or cascaded for a single task. It will also work with the expansion card from Loughborough Sound Images (the LSI DSP32C) hosting the DSP320C.

For this review an LSI DSP32C card was used in a 386-PC with VGA graphics.

Description

The package is basically a development environment enabling the user to generate DSP routines to be down-loaded to the processor expansion card. It also permits control of the card and provides an inter-

Fig. 1. FlowGram showing connected function blocks and the edit pop-up menu.



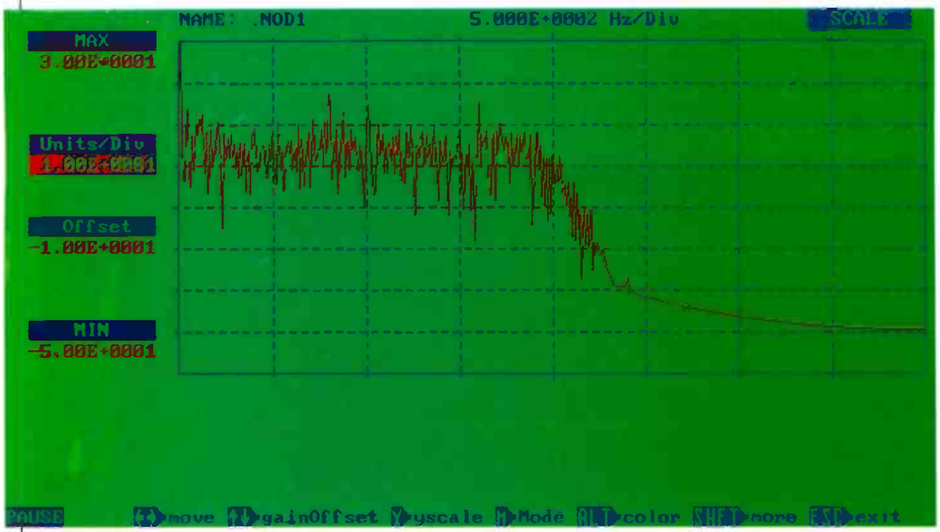


Fig. 8. Spectrum analyser display showing the transfer function of a low pass filter.

impulse response and the transfer function (**Fig. 6.**) is rather colourless but serves its purpose.

Filter coefficients can be stored on a disc file and the designed filter can be called up as a block in a FlowGram. Users who have files derived from the filter design software from Momentum Data Systems Inc will be able to use the FLT to TAB option to convert the files for use with DSplay-XL (is this an acknowledgement of the limitation of DSplay-XL's filter design facility?).

Real-time excellence

The area where DSplay-XL really excels is in its real-time operation.

One of the edit options is O-scope, leading to a menu containing four options for a real time display: a 'scope with one channel, two channels, complex channels or a spectrum analyser.

To display real-time signals a block must first be created for the acquisition of data from the expansion board's A-to-D converter(s). Link this to a scope block and you have an effective oscilloscope or spectrum analyser with control over display settings.

Figure 7 shows the response of the real-time spectrum analyser with the landscape option active giving the waterfall display. However intermediate blocks can be inserted before the display is shown, such as previously designed digital filters.

Figure 8 shows the transfer function, working in real-time, of a low pass filter. By creating an output block the signal out of the digital filter can be fed into one of the expansion board's D-to-A converters to provide a filtered real-time signal. Through the high-level FlowGram design, the user can construct and realise a real-time multi-channel, digital processing system. Alternatively, synthesised signals can be defined using the appropriate blocks in a FlowGram and directed via an output block to the card's D-to-A converter.

Using the PC's graphics as a 'scope or spectrum analyser display can cause problems, since the DSP32C acquires and processes data at a significantly greater rate than the VGA is able to display it. What tends to show on the screen is therefore a snapshot of incoming signals. But the lock option will slow the DSP32C down to match the display rate and allow the user to observe all the processed signal.

When using the real-time facility I did experience difficulties with the trace disappearing and the appearance of the error message: Buffer Read Timed Out. There was no reference in the user's manual to this condition.

User Functions

Despite DSplay-XL's large library of block functions, users will probably want to construct their own function blocks, and a significant part of the package is given over to this option by providing a low level language development environment.

Five features — a text editor, an assembler, an installer, a debug facility and a librarian — are available for this task and to ease the first time user into the system a number of examples are included in the User's Guide.

The debugger is linked to the monitor program ZPB32MON which is a utility allowing examination of the register contents of the DSP32C (**Fig. 9**). When satisfied with performance, a newly created block function can be added to the function library by using the librarian.

These features are fine for users familiar with the assembly language of the DSP32C. But C is now taking on a significant role as a programming language and so it is surprising that no provision has been made to accommodate the AT&T DSP32C C compiler. AT&T have often emphasised the efficiency of their compiler and most software development for the DSP32C will involve a mix of assembly language code and high level code.

The ZPB32MON is not unlike the monitor supplied separately with Loughborough Sound Images's expansion board and the contents of the DSP32C internal registers and a disassembled part of the user code is visible (Fig. 9.). Normal functions of a software monitor are included (single stepping, breakpoints etc.) with the additional capability to display the contents of memory graphically. This is an attractive feature for viewing unprocessed and processed data and will appeal to engineers who like immediate and visual access to signals.

I have mixed feelings about the User's Guide. It comes in a standard three-ring binder with more pages that can be comfortably accommodated. For the first-time-user I feel there is an inadequate number of examples in the early part of the Guide. A lesson that seems to be rarely heeded by manual writers is that engineers often learn through examples.

A sufficient amount of easily accessible information is presented without getting bogged down in detail. But the section on error conditions is feeble and provides no more information than appears on the screen.

Help facility is evoked by the customary F1 key, but on the whole it tends to be rather weak and lacking in information — a slight oversight in the product's design.

To obtain a hard copy of the display the appropriate screen print driver must be installed. Only screen drivers for the IBM Graphics Printer and the HP LaserJet are supplied.

Generally impressive

I am generally impressed with DSplay-XL. It has a gentle learning curve and on no occasion did the package fall over. If you have an expansion card hosting the DSP32C then you should certainly con-

System Requirements

IBM AT/386 or compatible
MS-dos 3.2 (or later)
640K
Hard disc
Graphics EGA or VGA
Optional Expansion card hosting an AT&T DSP32C
Supplier: Loughborough Sound Images, The Tech Centre, Epinal Way, Loughborough, Leics. LE11 0QE. Tel 0509 231843

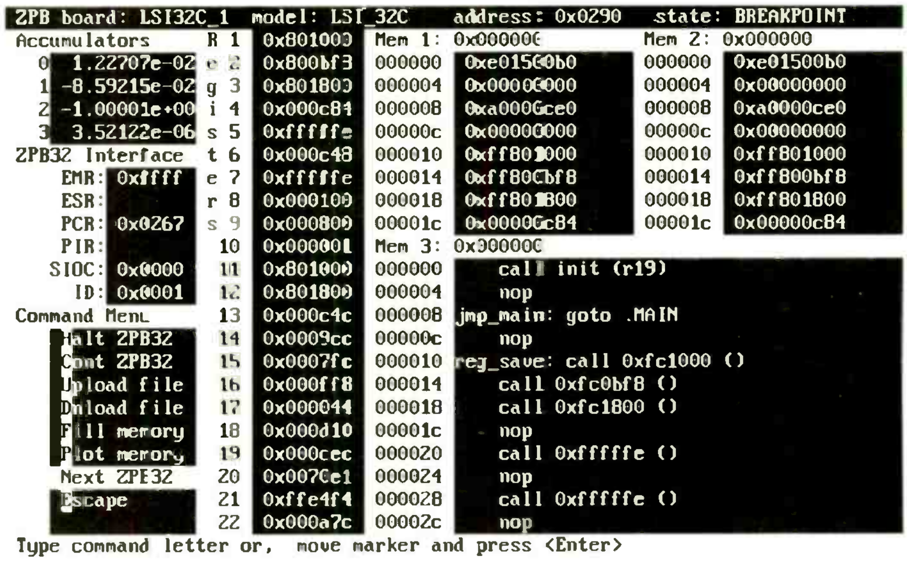
sider acquiring DSplay-XL, forming as it does a comfortable interface between user and processor with a very convenient method of implementing real-time DSP.

The only notable reservation I have concerns that of the dos memory. I feel this could be a constraint upon sizeable FlowGrams design and I would expect a future release DSPlay-XL to make use of Extended memory.

References

1.DSP32 and DSP32C Application Software Library Reference Manual. AT&T (Feb 1989).

Editorial survey: use the information card to evaluate this article. Item D.



```
ZPB board: LSI32C_1  model: LSI_32C    address: 0x0290   state: BREAKPOINT
Accumulators        R 1  0x801000  Mem 1: 0x00000C        Mem 2: 0x000000
 0  1.22707e-02     e 2  0x800bf3  000000  0xe0150Cb0      000000  0xe01500b0
 1 -8.59215e-02     g 3  0x801800  000004  0x0000C000      000004  0x00000000
 2 -1.00001e+00     i 4  0x000c84  000008  0xa000Gce0      000008  0xa0000ce0
 3  3.52122e-06     s 5  0xfffffe  00000c  0x0000C000      00000c  0x00000000
ZPB32 Interface     t 6  0x000c48  000010  0xff801000      000010  0xff801000
    EMR: 0xffff     e 7  0xfffffe  000014  0xff80Cbf8      000014  0xff800bf8
    ESR:            r 8  0x000100  000018  0xff801800      000018  0xff801800
    PCR: 0x0267     s 9  0x000800  00001c  0x0000Gc84      00001c  0x00000c84
    PIR:              10 0x000001  Mem 3: 0x00000C
   SIOC: 0x0000       11 0x801000  000000      call init (r19)
     ID: 0x0001       12 0x801800  000004      nop
Command Menu          13 0x000c4c  000008  jmp_main: goto .MAIN
   Halt ZPB32         14 0x0009cc  00000c      nop
   Cont ZPB32         15 0x0007fc  000010  reg_save: call 0xfc1000 ()
   Upload file        16 0x000ff8  000014      call 0xfc0bf8 ()
   Dnload file        17 0x000044  000018      call 0xfc1800 ()
   Fill memory        18 0x000d10  00001c      nop
   Plot memory        19 0x000cec  000020      call 0xfffffe ()
   Next ZPE32         20 0x007Ce1  000024      nop
   Escape             21 0xffe4f4  000028      call 0xfffffe ()
                      22 0x000a7c  00002c      nop
Type command letter or,  move marker and press <Enter>
```

Fig. 9. Screen display of ZPB32MON software monitor showing the register contents of the DSP32C.

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HARMONY IN C

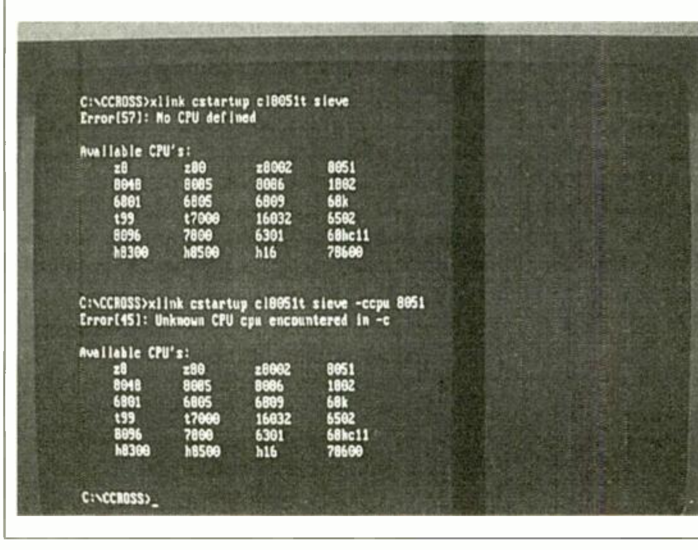
ICC8051 from IAR seems to offer the prospect of the perfect marriage; compilation from everyone's trendiest language, C, to the world's favourite microcontroller, the 8051 and its siblings.

John Moseley confirms that even perfect marriages have their rocky moments

This review describes the latest version of IAR's C cross-compiler for the 8051 family of microcontrollers, described in the brochure as ICC8051 version 4.00. It runs on a PC, accepts standard C and generates highly optimised assembly code for a variety of processors belonging to the Intel 8051 family. Because the user interface and C compiler section of this program is common to all IAR's cross-compilers, much of this review will be relevant to people interested in other processors.

IAR is a Swedish company which has, over the last few years, developed a wide range of software tools for engineers developing embedded systems. It has developed assemblers, linkers, C-compilers and debuggers that produce code for, amongst others, the 8031, 8096, 6801, 68HC11, 68000, 6301 and Z80.

Four 5.25in disks and documentation comprise the package, which includes not just the cross-assembler (ICC8051) but also a relocating macro-assembler, a universal linker/loader (XLINK) and a universal librarian (XLIB). There are also a few miscellaneous support files.



IAR cross-compilers support a number of different processors

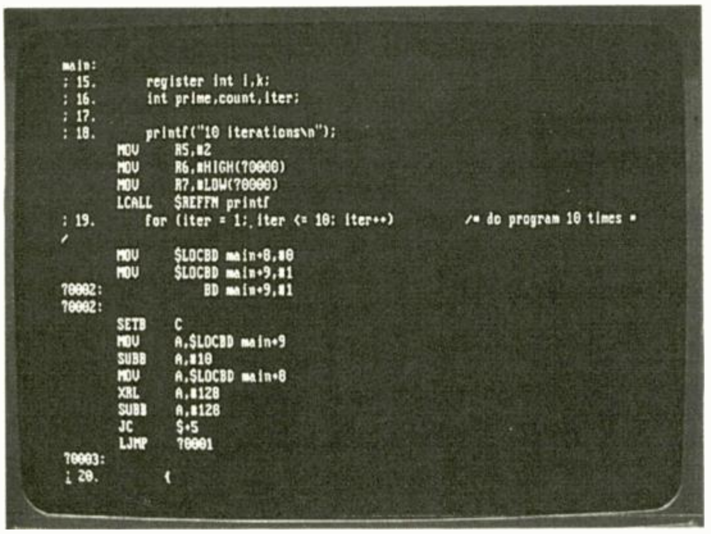
User-hostile?

After copying the disks onto my hard drive, I fired up the program, confident in my ability to muddle through without reading the manual. This was my first mistake. The program is very definitely not intuitively obvious; it is a complex system and, after a few minutes of error messages, I admitted defeat and opened the binder to retire for extended study.

The ICC package is a pure command-line system. You prepare your C program using a text editor (a word-processor or a dedicated programmer's editor like BRIEF). Once you've written the code, you save it in your object file (HELLO.C, say) you leave that program and load the compiler from dos using a cryptic string of parameters. This will typically require a string of gobbledygook like

```
ICC8051 HELLO.C -gA -L -z -x
```

which will compile HELLO, optimising for size and giving full debugging information. If the compilation fails you are thrown out into the cold, harsh light of dos, where you have to read a separate file to find out why, going back to the word-processor to re-type a mis-spelling or change some punctuation. Then you save the file, close the word processor, try to remember the incomprehensible mnemonics for the command line string to trigger the compiler and pray. Sooner or later your program compiles correctly and you can go through the whole jolly loop again, trying to get the program to link and load (separate programs each). Once you've gone through this a few times the program



When the C program is compiled to produce 8051 object code it looks like this (first screen). Original C statements are embedded as comments so it is possible to see, approximately, how each statement is translated into object code.

runs and you can get down to the really hard work of fixing the program logic and solving bugs, whilst staggering between four different programs, all with incompatible commands.

All of this is in tedious monochrome with a text-only display. It is hard work to read, it is an effort to understand what is happening at any given time and it is *very, very*, frustrating. This is definitely not what I expect from a professionally produced piece of software in the 1990s; this user interface belongs to the age of the teletype and not that of the mouse. I think the part that most infuriates me is that this wish list is so easy to fix; none of these things is complicated. I strongly suggest that IAR's people go away and look at Borland's latest offering, Turbo Pascal v 6.0.

Performance

After the crudeness of the front end, I approached the details of the compiler with some trepidation. However, I was very impressed. The program is extremely powerful, very well thought-out and produces some excellent fast and concise code.

This is clearly apparent from the start, when the package offers a choice of six memory models, all offering different code size, data size and speed trade-offs. It is possible to develop code for a single-chip solution ("Tiny", with on-chip rom and ram), for a vast solution with 8Mbyte of bank-switched memory ("Huge"), or for anything in-between. The main differences between them relate to where code is stored (internal/external rom) and where variables are stored.

Which memory model you use obviously depends on the application, but the range should cover most needs. There are some functions such as MALLOC and SCANF

WHY C ?

The benefits of using C on a microcontroller are very definite, very worthwhile and very easy to measure.

Everyone's favourite programming language, C, came out of the closet thirteen years ago. When first described, it was primarily a systems language, used for writing operating systems and compilers (it was initially developed to write UNIX). Since then, it has migrated downwards; not only is it ubiquitous for serious programmers in the PC world, but it is increasingly used to develop efficient programs for microcontrollers and embedded systems.

The major benefit is the comparative ease of writing a large piece of code in a powerful high-level language. Being able to use instructions such as FOR and WHILE loops makes it much faster to develop systems; to a large extent, the developer can concentrate on the task at hand rather than the intricacies of the assembly code. The switch construct, which allows the program flow to select between a number of alternatives, is an elegant way of dealing with different conditions; easy to code and understand.

Embedded systems, particularly those using a standard microcontroller chip, have their own specific needs and expectations, and these need to be considered by any company wanting to release a high-level compiler for these devices. In particular, any program developed for these systems will need to to combine two virtues: it needs to be "memory-stingy", since it is often a requirement that the program fits into on-chip memory; and, for real-time control application, it must be fast. It should also be rugged for vital reliability and allow for the realities of supporting low-level hardware; microcontroller systems are always designed with lots of interrupts and i/o operations, so the compiler must allow for easy, efficient and fluent access to these functions.

A further advantage to using a standard high-level language is the improvement in documentation and support that can be made. It takes a major effort to produce assembly-language code that is even remotely comprehensible to an outsider. In C, it is easily possible for any competent engineer to write clear, easy to understand programs which other people will be able to follow, use and maintain.

C is a very modular language which relies to a great extent on defining functions. The core of the language is tiny and the bulk of what is supplied when you buy a compiler is a range of function libraries. This means that the resulting program can be very compact (it need only include the functions actually used) and also encourages re-usable code; once you've developed a sub-routine to read and filter signals from an A-to-D converter, it can be used time and again. Functions are designed to be written as independent modules, the compiler handling all the messy tasks of relating them to the rest of the program. The same isn't true of assembly- language routines, since a programmer has to know which registers are used for what, which memory areas are reserved, etc., which makes it very difficult to develop "general" assembler routines that can be re-used in different programs.

The (comparative) standardisation of C as a language allows users to port code from one microcontroller to another, so long as suitable compilers exist for both targets. A circuit could be redesigned to use a newer processor and the existing C code should be easily carried across, recompiled and executed on the new device, without needing to re-write the code in its entirety. At least, that's the theory!

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93112A	High speed disc interface for 360 computer	565
98546A	Display compatibility card for use with 200 series s/w or series 300 computers	390
98640A	Analogue input card for series 200/300 computers	400
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7958B	152Mbyte disc drive HPIB interface	1220
79595	304Mbyte disc drive SCSI interface	2650
9144A	1/4" tape drive	850
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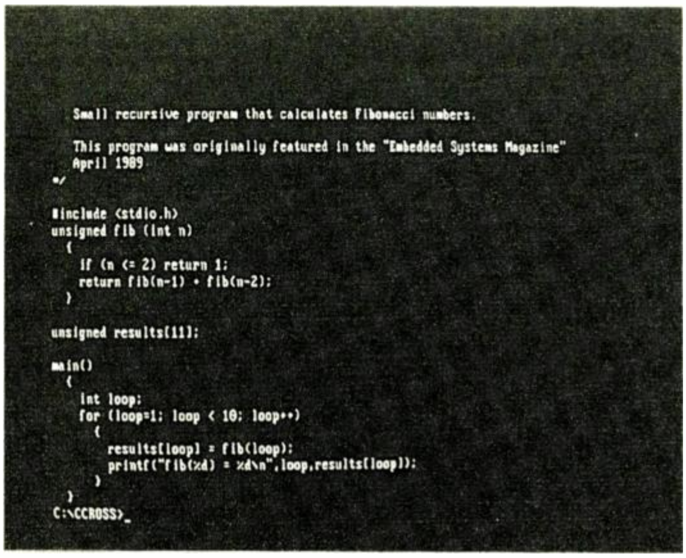

```
  Small recursive program that calculates Fibonacci numbers.

  This program was originally featured in the "Embedded Systems Magazine"
  April 1989
*/

#include <stdio.h>
unsigned fib (int n)
  {
    if (n <= 2) return 1;
    return fib(n-1) + fib(n-2);
  }

unsigned results[11];

main()
  {
    int loop;
    for (loop=1; loop < 10; loop++)
      {
        results[loop] = fib(loop);
        printf("fib(%d) = %d\n",loop,results[loop]);
      }
  }
C:\CCROSS>_
```

Small looped program for deriving a Fibonacci series, in which each number in the series is the sum of the two preceding ones.

It is possible to mix C and assembler, calling an assembly language routine when necessary. This will usually only be needed for time-critical sections of code, such as interrupt handlers or very fast loops (IAR estimates that between 2% and 10% is typical). There are various ways of doing this, including the formal, "correct" method, which involves understanding exactly how the compiler works.

I found the simplest way is a bit of a cheat, but works well and is easy to understand. Start by creating a C-stub; that is a procedure which declares the variables and parameters but which does nothing with them (the equivalent of a no-op). Compile this and get the resulting object code, which you attack with assembler. The top and tail of the object module can then be used, safe in the knowledge that they are compiler-generated and compatible with the rest of the program, as interfaces to the hand-coded meat of your assembler routine. This is a very powerful way of mixing the two languages (if not particularly elegant).

This means that it is possible to create routines in either C or assembler, depending on which is most suitable. The code produced by IAR is so efficient that there is often very little to choose between them, even for time-critical routines. This is particularly true for interrupt handlers, since the code is optimised by only saving the registers required.

In general, the code produce was very concise and efficient. The program does all the obvious things, such as choosing the best type of jump (JMP,AJMP,LJMP) for a situation, moving constant sections of code outside loops. Jumps to jumps and jumps over jumps are eliminated, non-varying calculations are performed at compile-time, not run-time and arithmetic has been optimised. In addition, the developers claim that they spent a lot of effort to produce efficient C code for all the commonest C commands and sequences.

I found that for most of my trivial review programs, the compiled software ran about 10-20% slower than my hand-coded versions. Common sense suggests that there were bottlenecks in these programs, and I could have easily improved on this figure by selectively mixing in a little assembler. It is possible to optimise for speed or size (-s or -z), but I couldn't see any significant differences; in general a short section of code will run quickly too.

To put this 10% in perspective, the largest program I tested was for an 8031-based controller I developed some time ago. This was about 4K of convoluted code, which had taken several months to write and debug. To write a C program for the same task took a few evenings and the result was significantly easier to understand; it ran at almost exactly the same speed as the assembler version; both were comfortably within the system's design specification.

As you'd expect from a standard C implementation, the system supports the full range of variables, including IEEE-format floating- point functions. For people who need floating-point arithmetic in their system, this will probably justify the purchase on its own.

A few miscellaneous points to complete the review. The IAR cross-compiler supports all the common versions of the 8051 microcontroller, with fourteen different options, including the 8031/2, the 8051/2, and confusingly named 321, 521, 252, 515 535, etc. It runs on most development platforms, including the PC, VAX, Sun and Apollo. The same company makes a range of related products, including a sophisticated debugger (C-SPY) and cross-compilers for most standard processors, which are are all compatible and allow you to swap code easily from one to another.

Summary

This is a Land-Rover of a program; it is very powerful, well designed to do a job and it does that job extremely well. However, no-one could describe it as attractive, comfortable or easy to use. The user interface is a pig; it is archaic, unfriendly and irritating.

The compiler does everything that you might expect or require from an Ansi C compiler, and it does it well. The extensions to the language (Bit and SFR data types and IDATA, XDATA memory commands) provide easy access to the special functions of the 8051 series of microcontrollers, while the #PRAGMA directive means they break the Ansi standard in a standard sort of way.

The 8051 code produced is very concise and efficient, and executes at a respectable speed; I estimated it to be about 10% slower than hand-crafted code, and that figure could definitely be improved upon by selectively using assembler. When you consider the dramatic savings in development time that an engineer will find by using C instead of struggling along at the op-code level, this program looks increasingly attractive.

Other than my loathing of the user-interface, I can't find serious fault with this program. If you are working with the 8051 I strongly suggest you have a close look at the ICC51, which could save you a lot of time and grief. If I were developing 8051 applications on a regular basis I'd definitely buy it. But I'd still rather buy version 4.1 with the integrated environment and text editor.

SPECIFICATION

PC, XT, AT or compatible computer, MS-dos 3.xx upwards.
CGA, EGA, VGA or Hercules mono graphics.
Memory 512K minimum, 640K recommended.
Dos extender (Rational Systems DOS/-16M) is included to support 16M ram.
Hard disk required.
Supplier: IAR systems, 9 Spice Court, Ivory Square, Plantation Wharf, York Road, London SW11 3UE. Telephone 071 924 3332.
Price £1195 includes the C cross-compiler, assembler, linker and memory support programs.

IAR have now relased version 4.05 which includes optimisation of floating point maths routines for faster speed and support for new members of the 8051 family including SAB80517/537 version with maths hardware.

Editorial survey: use the information card to evaluate this article. Item E

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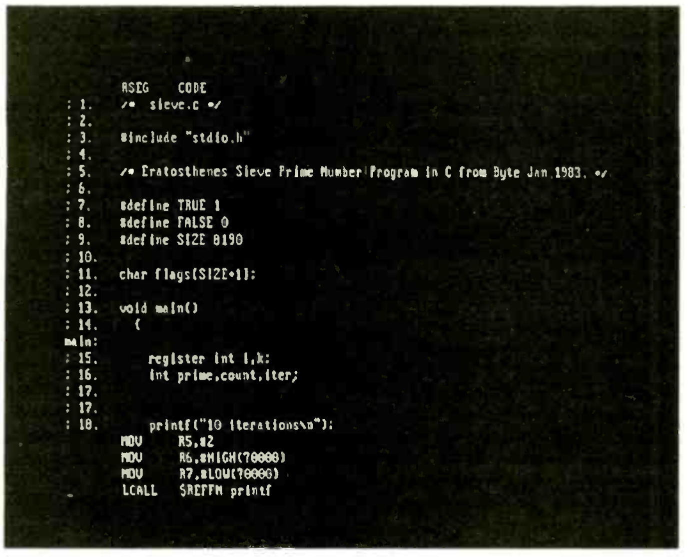
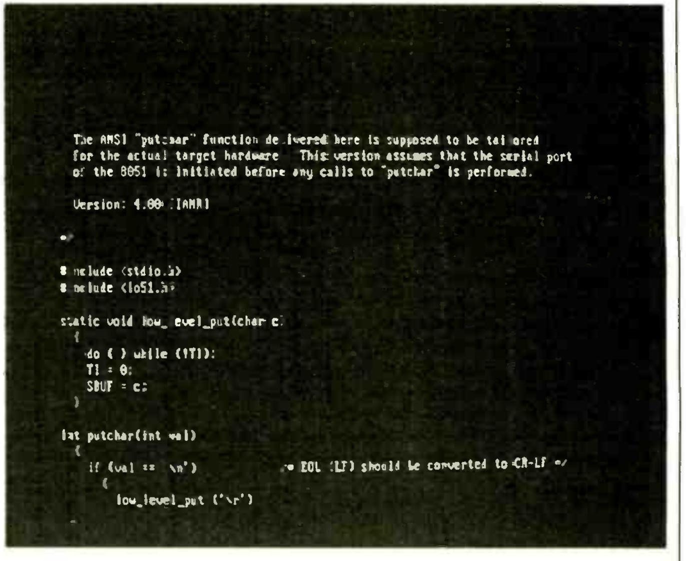


(Above) End of display screen.



Beginning (above right) and end (right) of the process of defining a new C routine ("low_level_put") for low level direct access to the 8051 serial port.

that can't be used in the very smallest models, as they need too much space. PRINTF and SPRINTF can be used, as long the message string is short enough.

In even the trivial examples shown, it makes a difference which memory model is used. I found that as the program became larger the differentials grew; choosing the right model would have a major impact on speed.

In addition to allowing several memory models, ICC supports a number of 8051 features. There are a number of extensions to standard Ansi C, with the addition of Bit and SFR data types and Code, Data, Idata and Xdata memory attributes. These give you the flexibility to put variables wherever you want, regardless of the memory model. For example, you could optimise a large program by putting selected key variables in internal memory, or a look-up table can be placed in rom. Essentially, this is an extension of the standard REGISTER command. Bearing in mind the above point about speed, it is obviously desirable to use the smallest, fastest data types wherever possible and exile non-critical variables to external memory.

These keywords are extensions to Ansi C and are hence non-standard commmands. The #PRAGMA directive allows for the controlled and documented use of such extensions, so no changes to source code would be needed if the program were switched to a different Ansi-standard compiler. In other words, the directive allows both portable code and the use of processor-specific features.

The 8051 is primarily a register/memory-oriented device, in contrast to C's stack-based philosophy; this can pose problems for compilers. Rather than use a software stack for passing parameters, IAR has adopted a static memory system, with parameters and variables put in a fixed location in memory. When they're no longer needed, for example a local variable when leaving its scope, the location can be used by a different parameter, the whole operation being performed transparently by the linker. The advantage of this is that the code is fast and dense, not having the slow stack operations. When the linker does its work, it detects recursive code and saves variables that are still active, so recursion is supported (as required by Ansi). However, re-entrant code is not supported.

The 8051 internal stack is fairly small, so there is a limit on the number of function calls/returns that can be made. Optionally, the system can use space in external memory as a stack, which allows deeper nesting, but with a speed penalty. This may also be required for recursive functions, where the stack can grow very quickly.

In the compiler, IAR has gone to a great deal of effort to use the particular features of the 8051 processor, and I liked what I saw. One of the strong points of the 8051 architecture is its range of Boolean operations and these are fully supported. The data type Bit exists and can be used freely; this is a C-extension and nothing to do with C bit-fields. For example:

```
Bit x, y, z;     /*Define 3 bitwise variables */
x = y & !z;      /*and mess around with them */
z = 0;
if (y)
```

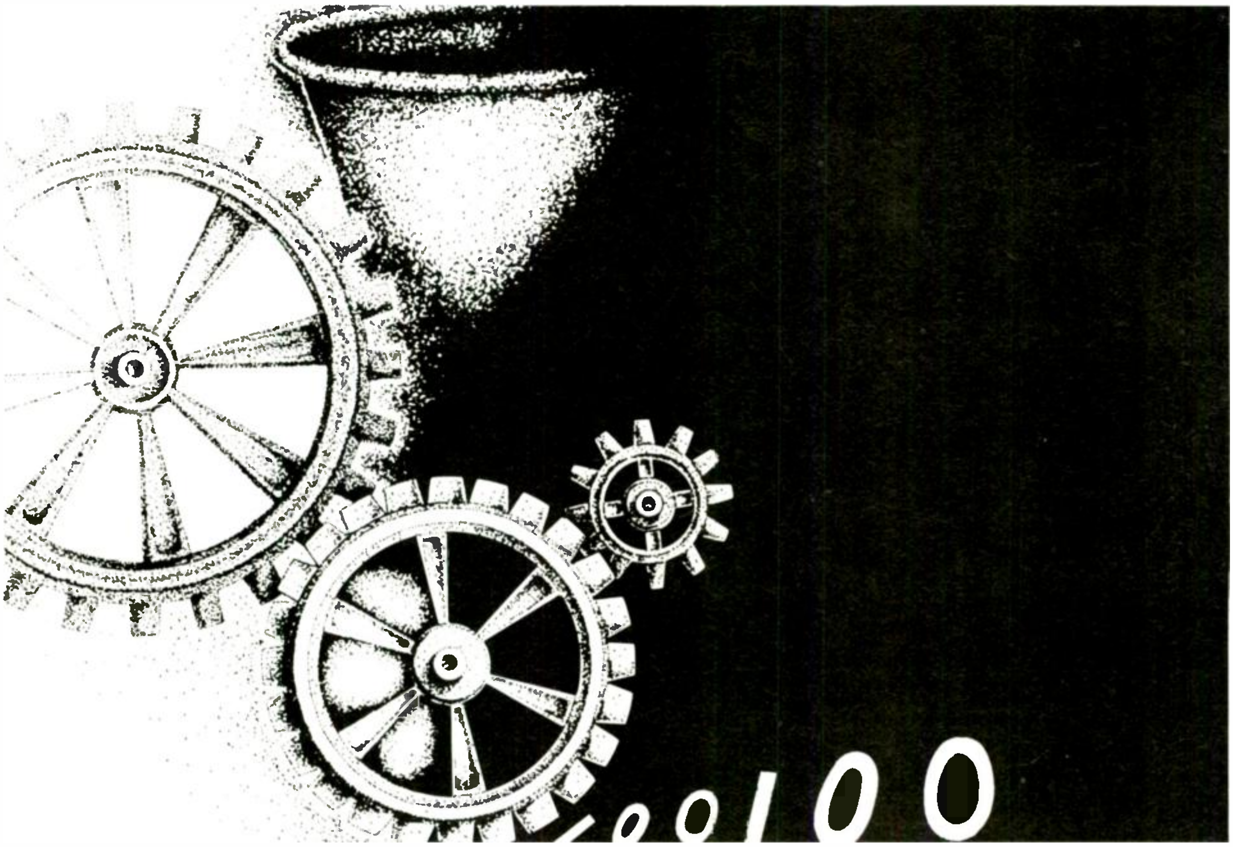
will generate the following 8051 assembler:

```
MOV C,y
ANL C,\z
MOV x,C
CLR z
JNB y,LABEL
```

It is obvious that this an efficient (and fast) implementation of the original code. By using the SFR data type (single byte int) to define absolute addresses, it is possible to create very powerful functions very easily. A set of #INCLUDE files are provided which define the conventional names and addresses of the SFRs for several 8051 families.

Continued on page 394

NEW HIGH PERFORMANCE
8051 C COMPILER



ICC 8051 4.05
high performance

- extremely fast and code efficient
- recursive calls and bank-switching supported
- 8051 C: SFR & BIT variables, CODE, DATA, IDATA & XDATA keywords
- C interrupts, monitor, no_init keywords
- ANSI C and K&R C
- in-line Assembler
- maths unit support

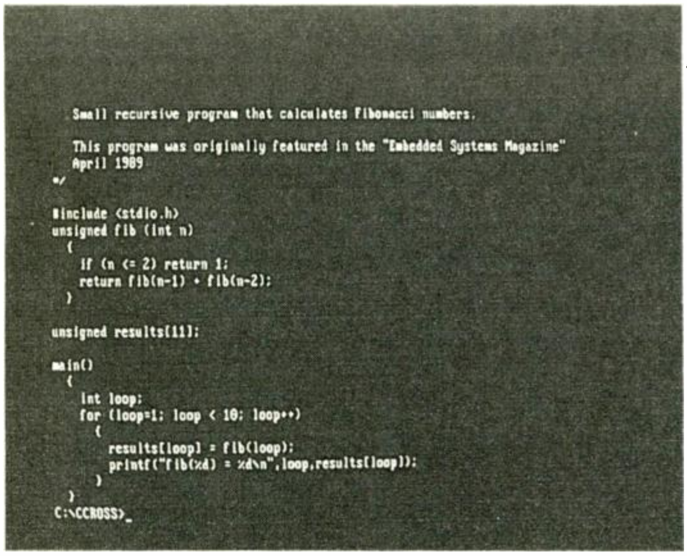
C-SPY 2.15
time saving

- C & Assembler debug
- set/examine variables, registers and memory
- window orientated with on-line help
- simulator & emulator interface
- extended memory support.

IAR SYSTEMS

IAR SYSTEMS 9 Spice Court,
Ivory Square, Plantation Wharf,
York Road, London SW11 3UE
Telephone: 071-924 3334
Fax: 071-924 5341

CIRCLE NO. 104 ON REPLY CARD



```
   Small recursive program that calculates Fibonacci numbers.

   This program was originally featured in the "Imbedded Systems Magazine"
   April 1989
*/

#include <stdio.h>
unsigned fib (int n)
  {
    if (n <= 2) return 1;
    return fib(n-1) + fib(n-2);
  }

unsigned results[11];

main()
  {
    int loop;
    for (loop=1; loop < 10; loop++)
      {
        results[loop] = fib(loop);
        printf("fib(%d) = %d\n",loop,results[loop]);
      }
  }
C:\CCROSS>_
```

Small looped program for deriving a Fibonacci series, in which each number in the series is the sum of the two preceding ones.

It is possible to mix C and assembler, calling an assembly language routine when necessary. This will usually only be needed for time-critical sections of code, such as interrupt handlers or very fast loops (IAR estimates that between 2% and 10% is typical). There are various ways of doing this, including the formal, "correct" method, which involves understanding exactly how the compiler works.

I found the simplest way is a bit of a cheat, but works well and is easy to understand. Start by creating a C-stub; that is a procedure which declares the variables and parameters but which does nothing with them (the equivalent of a no-op). Compile this and get the resulting object code, which you attack with assembler. The top and tail of the object module can then be used, safe in the knowledge that they are compiler-generated and compatible with the rest of the program, as interfaces to the hand-coded meat of your assembler routine. This is a very powerful way of mixing the two languages (if not particularly elegant).

This means that it is possible to create routines in either C or assembler, depending on which is most suitable. The code produced by IAR is so efficient that there is often very little to choose between them, even for time-critical routines. This is particularly true for interrupt handlers, since the code is optimised by only saving the registers required.

In general, the code produce was very concise and efficient. The program does all the obvious things, such as choosing the best type of jump (JMP,AJMP,LJMP) for a situation, moving constant sections of code outside loops. Jumps to jumps and jumps over jumps are eliminated, non-varying calculations are performed at compile-time, not run-time and arithmetic has been optimised. In addition, the developers claim that they spent a lot of effort to produce efficient C code for all the commonest C commands and sequences.

I found that for most of my trivial review programs, the compiled software ran about 10-20% slower than my hand-coded versions. Common sense suggests that there were bottlenecks in these programs, and I could have easily improved on this figure by selectively mixing in a little assembler. It is possible to optimise for speed or size (-s or -z), but I couldn't see any significant differences; in general a short section of code will run quickly too.

To put this 10% in perspective, the largest program I tested was for an 8031-based controller I developed some time ago. This was about 4K of convoluted code, which had taken several months to write and debug. To write a C program for the same task took a few evenings and the result was significantly easier to understand; it ran at almost exactly the same speed as the assembler version; both were comfortably within the system's design specification.

As you'd expect from a standard C implementation, the system supports the full range of variables, including IEEE-format floating- point functions. For people who need floating-point arithmetic in their system, this will probably justify the purchase on its own.

A few miscellaneous points to complete the review. The IAR cross-compiler supports all the common versions of the 8051 microcontroller, with fourteen different options, including the 8031/2, the 8051/2, and confusingly named 321, 521, 252, 515 535, etc. It runs on most development platforms, including the PC, VAX, Sun and Apollo. The same company makes a range of related products, including a sophisticated debugger (C-SPY) and cross-compilers for most standard processors, which are are all compatible and allow you to swap code easily from one to another.

SPECIFICATION

PC, XT, AT or compatible computer, MS-dos 3.xx upwards.
CGA, EGA, VGA or Hercules mono graphics.
Memory 512K minimum, 640K recommended.
Dos extender (Rational Systems DOS/-16M) is included to support 16M ram.
Hard disk required.
Supplier: IAR systems, 9 Spice Court, Ivory Square, Plantation Wharf, York Road, London SW11 3UE. Telephone 071 924 3332.
Price £1195 includes the C cross-compiler, assembler, linker and memory support programs.

IAR have now relased version 4.05 which includes optimisation of floating point maths routines for faster speed and support for new members of the 8051 family including SAB80517/537 version with maths hardware.

Summary

This is a Land-Rover of a program; it is very powerful, well designed to do a job and it does that job extremely well. However, no-one could describe it as attractive, comfortable or easy to use. The user interface is a pig; it is archaic, unfriendly and irritating.

The compiler does everything that you might expect or require from an Ansi C compiler, and it does it well. The extensions to the language (Bit and SFR data types and IDATA, XDATA memory commands) provide easy access to the special functions of the 8051 series of microcontrollers, while the #PRAGMA directive means they break the Ansi standard in a standard sort of way.

The 8051 code produced is very concise and efficient, and executes at a respectable speed; I estimated it to be about 10% slower than hand-crafted code, and that figure could definitely be improved upon by selectively using assembler. When you consider the dramatic savings in development time that an engineer will find by using C instead of struggling along at the op-code level, this program looks increasingly attractive.

Other than my loathing of the user-interface, I can't find serious fault with this program. If you are working with the 8051 I strongly suggest you have a close look at the ICC51, which could save you a lot of time and grief. If I were developing 8051 applications on a regular basis I'd definitely buy it. But I'd still rather buy version 4.1 with the integrated environment and text editor.

Editorial survey: use the information card to evaluate this article. Item E

ACTIVE

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

Sub 1µs conversion. AD671 is claimed to be the fastest monolithic 12-bit A-to-D converter, offering a 500ms maximum conversion time. AD7586 performs a full 12-bit conversion with no missing codes (NMC) in 1µs. Power consumption is 300mW. Both devices are designed for high speed applications. AD671 accepts standard instrumentation-level input signals. Dynamic specifications include a maximum integral non-linearity of ±4 LSB at 500ns and ±2 LSB at 750ns. Analog Devices, 0932 232222.

Fast dual 12-bit cmos. DAC780X 12-bit, four quadrant multiplying cmos D-to-A converters have a high speed digital interface to enable their output currents to settle to 0.01% full scale in 0.8µs. Operation is from a single +5V supply, 11mW. High stability on-chip resistors provide true 12-bit performance over the industrial temperature range of -40°C to +85°C. The devices feature ±1LSB max differential linearity, ±1LSB max gain error, -90dB min crosstalk and full monotonicity — all guaranteed over temperature. Burr-Brown International Ltd, 0923 33837.

500Ms/s 8-bit device. TKAD10C 8-bit A-to-D converter has a conversion rate of 500Ms/s. Input track-and-hold supports bandwidths of 1.2GHz — so two devices can be interleaved for 1Gs/s sample rates — and helps reduce aperture jitter to less than 2ps. Tektronix UK Ltd, 0628 486000.

Discrete active devices

Low resistance mosfet. SMP60N03-10L 30V, 60A power mosfet has an on-resistance of 20MΩ — claimed to be the lowest for any such device in a TO-220 package. It provides more efficient and cooler operation so that fans can be eliminated and in some cases heatsinks can be omitted. The device can carry 10A continuous current with a voltage drop of 0.1V. Barlec Richfield, 0403 50111.

Ge Schottky rectifiers. State-of-art metallisation techniques are used in germanium Schottky rectifiers offering high efficiency at low temperatures. V_F is down in the 0.3 region compared with silicon devices giving 0.5-0.6V. So the GPD G60S series is attractive to designers of low-voltage power supplies — 1.5V, 3V, 5V or 7V for example. Good performance at low temperatures and the inherent efficiency and low heat dissipation of germanium technology means that designers can produce power supplies of simpler design and greater all-round reliability. Germanium Power Devices Corp, 508 475 5982.

Low saturation transistors. 2SD2127 is a 60V, 3A bipolar transistor with an H_{FE} of 500 to 1500 and a saturation voltage of 0.3V. A zener diode between base and collector is included for over-voltage protection. 2SD2092 is a 100V, 3A bipolar transistor with the same H_{FE} and saturation voltage figures as the 2127 device. Toshiba Electronics (UK) Ltd, 0276 694600.

PNP substitutes for Darlingtons. For applications needing low saturation voltage and high gain, a new series of PNP Super E-line transistors offer minimum gains of 300 at 10mA combined with gain hold-up at up to 6A. Saturation voltages down to 0.15V typical with a 1A collector current and 10mA base drive are specified. With collector-emitter voltages of 25V and 200V respectively, the ZTX789A and ZTX796A represent the extremes of the range. Saturation voltage of the 2A-continuous ZTX789 is typically 0.15V at 1A while that of the 0.5A ZTX796 is 0.15V at 200mA. Zetex plc, 061 627 4963.

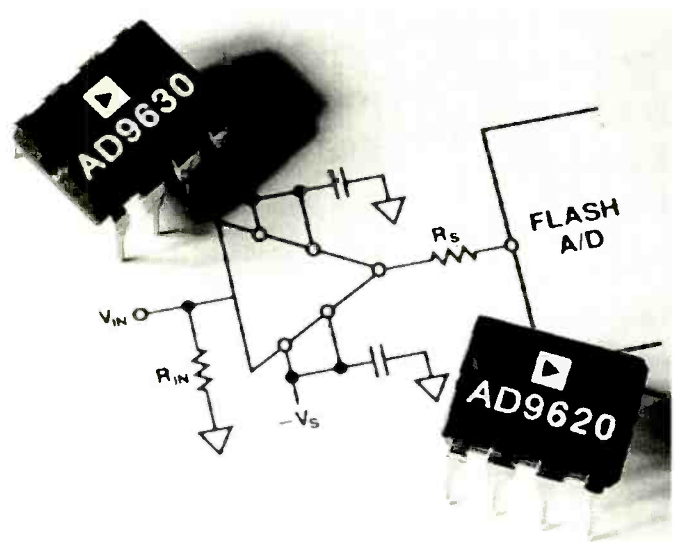
High-performance SOT23 addition. Featuring a current transfer ratio of at least 50 when carrying 300mA, the FMMT555 has an f_T of 100MHz, making it fast enough for video applications. It has an output capacitance of 10pF and a collector-base breakdown rating of 160V. Continuous collector current handling of the 555 is 1A while its peak rating is 2A so the device has numerous uses, including power-amplifier driver stages, medium-power output stages, and relay/solenoid/motor switching. At 100mA collector current and 10mA base current, saturation voltage of the device is 0.3V while base-emitter saturation with the same drive and load is 1V. Capable of dissipating up to 425W. Zetex plc, 061 627 4963.

Digital signal processor

More choice. TMS320C51 and TMS320C16 continue the expansion of TI's fixed point DSP family. Key features of the TMS320C51 include single-cycle multiply/accumulate; zero-overhead looping and context switching; on-chip serial ports and timer; PLU for dynamic bit manipulation; and Jtag. TMS320C16 fixed-point DSP provides an object code compatible performance upgrade path for TMS320C10 and TMS320C15 users, and a low cost alternative to the TMS320C25. It has 8K on-chip roms. $10 per unit (10,000). Texas Instruments, 0234 223252.

Linear integrated circuits

Mixed-signal ICs motor control. Three new mixed-signal ICs are designed for driving the three-phase brushless DC spindle motors used in hard disk drives. A8901SLB and A8902SLB, are designed to drive the low-voltage (5V) hard disk drives used in laptop applications. A8903SLB is tailored to drive the higher voltage (12V) Winchester drives more commonly used with desktop PCs and workstations. They combine back-EMF sensing with power dmos outputs and programmable control logic. Allegro MicroSystems, Inc, 0932 253355.



Transition times of 1.5ns from Analog Devices buffer amplifiers.

Wideband buffer amplifiers. 600MHz AD9620 and 750MHz AD9630 are unit gain wideband buffer amplifiers. At 0.989 V/V (0.994 V/V typical) the AD9620's guaranteed minimum gain accuracy over temperature for 2V pk-pk input swing is claimed to be 29mV/V better than competitive version. The AD9630 has a minimum gain accuracy of 0.983V/V (typically 0.99V/V). The AD9620 and AD9630 respectively slew at 2 200 and 1 200V/µs and guarantee 1.6 and 1.5ns maximum rise and fall time for a 1V step over the operating temperature range. Analog Devices, 0932 232222.

Analogue multipliers for video processing. HA2547 two-quadrant dual analogue multiplier integrates two differential voltage input sections to provide a multiplication function and a current output proportional to the product of the two voltage inputs up to 100MHz. It has a low multiplication error of 1.6%, low noise of 75nV/√Hz and wide signal bandwidth of 100MHz. It also features large input signal ranges of 2V for the control input and 5V. Harris Semiconductor (UK), 0276 686886.

Closed loop buffer amp. Elantec EL2012 high speed bipolar monolithic buffer amplifier provides an output current of 250mA which combines with an 80MHz bandwidth. With a 50Ω load, the device provides a gain accuracy of 0.999. Its output short-circuit current limiting scheme protects the device under both a DC fault condition and AC operation with inductive and capacitive loads. METL, 0844 278781.

High-performance PLL with serial interface. 16-pin MC145170 frequency synthesiser can directly interface with VCOs in the MF, HF, and VHF bands. Architecture allows programming with either bit- or byte-formats. BitGrabber registers eliminate address and steering bits for random access to the three registers. Tuning is accomplished through two byte serial transfer to the 16-bit N register. R counter division range is 5 to 32 767, and direct access to the phase detector input is allowed; N counter is 40 to 65 535. Operating voltage range is 2.5 to 6V, and maximum operating frequency is 160MHz at V_{in} +500mV pk-pk with a 4.5 to 6V supply. $4.17, 500-999. Motorola Inc, 0101 512 928 6880.

Speech recording and playback. NEC's new speed chip, µPD77501 simplifies design of solid-state voice messaging circuits by integrating a dual-tone multi-frequency receiver, an analogue front end, and speech memory management for fixed and re-usable vocabularies on to a single silicon chip. So it has the ability to carry out analogue to ADPCM coding/decoding of acoustic signals simultaneously with the detection of the 16 DTMF tone pairs. The chip is equipped with user programmable sound-level detection threshold for the recording mode. The analogue acoustic signal is sampled at a fixed rate of 6kHz and quantised with a 10-

bit D-to-A converter into a PCM data format. NEC Electronics (UK) Ltd, 0908 691133.

Low-voltage, high-performance. NE/SA5234 matched quad operational amplifier accepts common-mode inputs up to 250mV greater than the supply rails to optimise dynamic range and prevent distortion of input signals in low-voltage systems. It operates to 1.8V and has the capability for input and output rail-to-rail operation. To ensure optimal signal, the output swings to less than 50mV of both rails across the power supply range. Unit gain bandwidth is 2.5MHz and the device consumes only 700µA per amplifier, which improves AC characteristics at low-power. NE5234N $1.56. SA5234N $1.84. Signetics Company, (408) 991 2000.

Memory chips

Fast NVSrams. PNC10C68 and PNC11C68 NVSrams have read/write access times of 25ns and a memory capacity of 64K. They also have address and chip enable access times of 25, 35 and 45ns with a non-volatile eeprom cell incorporated into each static memory cell. The sram can be read and written an unlimited number of times, while independent non-volatile data resides in eeprom. 100 off £16.34. GEC Plessey Semiconductors, 0793 518000.

Largest eeprom. Organised as 256K x 8, the XM28C020 eeprom is comprised of four of Xicor's propriety X28C513 64K x 8 LCCs mounted on a co-fired multilayered ceramic substrate. This allows the module to conform to the Jedec standard 32 pin 600 mil wide pinout and allows a direct upgrade to existing 1Mbit module/monolithic devices. It also offers upgradability to forthcoming Xicor 4Mbit devices. When combined with data polling or toggle bit testing, this effectively provides a 40µs/byte write cycle enabling the module memory array to be written in 10s. Micro Call Ltd, 0844 261939.

Microprocessors and controllers

Low cost microcontroller. TE-180 microcontroller — a high performance, low-cost microcontroller with the Hitachi CPU — is a powerful single board computer with 8K or 32K of user selectable static ram and a 40K option. User applications software is contained within an eprom with an option to expand to 16K. The system includes two RS232 ports, timers, 24 I/O lines, and breadboard area. Options include a system monitor rom, a clock/calendar with battery backup, and a "watchdog" timer feature with user selectable count down and alarm features. Cost is £95 for a device assembled and tested. Aries Electronics (Europe), 0908 260007.

PASSIVE

Silicon carbide varistors. Power Development is offering a full range of equivalents for the silicon carbide varistors previously manufactured by Philips under catalogue numbers 2322 552-555 and 2322-564. They are completely interchangeable with the Philips products sold under the trade name Amperex in the USA, Valvo in Germany and Mullard or Philips in the UK and France. Power Development Ltd, 0293 528888.

Displays

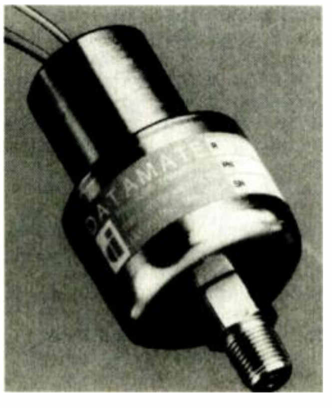
13mm thick LCD graphics displays. Two Seiko Instruments graphics displays, complete with VGA-controller boards have 640 x 480 pixel displays and use RC-film technology with side-mounted cold cathode backlights to produce a good black and white image. Total thickness of either display is under 15mm, making them smaller, lighter and flatter than many others on the market. The G643G (and G642G) weighs 460g-740g with viewing areas of 208 x 153mm (220 x 168mm). Thickness is 14.7mm (G643G 10.6mm). Trident MicroSystems, 0737 765900.

Blue leds. Blue leds using silicon carbide are now available in 3mm and 5mm sizes in diffused, transparent and water clear packages. Wavelength of the leds is 470nm with a forward voltage of 2.7V and reverse voltage of 5V. Typical luminous intensity at 20mA is 14mcd, in transparent and water clear types and 1.0mcd in the diffused package. £7.20 in small quantities; £5.90 in 100 off. Hero Electronics Ltd, 0525 405015.

Instrumentation

Digital voltmeter. DMH-30 digital panel meters are built directly on ceramic using ultra-low profile, surface mount components and thick film, hybrid techniques. 1.20in x 0.8in x 0.2in and fully encapsulated DDIP package. Full differential inputs with bipolar full scale input ranges of ±200mV, ±2V DC, ±20V DC are standard. Very high input impedances of 1000MΩ (1MΩ for 20V model) minimise circuit loading while allowing maximum design flexibility. 5V DC supply. Datel (UK) Ltd, 0256 469085.

Pressure transmitter from Control Transducers for corrosive media.



LCR meter. 7330 automatic LCR meter is intended for volume testing of bandoliered components. Up to 10,000 components/h can be tested and sorted into ten categories. The same instrument is suitable for enhanced in-circuit component measurement in production ATE or loose or bandoliered components can be hand fed using an optional component fixture or special leads or clips. It is robustly protected against capacitors charged up to 10kV and offers a high level of noise immunity even when linked to an electro-mechanical component handler or other equipment in a measuring system. Farnell Instruments, 0937 581961.

PC-based logic analyser. PC/La logic analyser combines the flexibility of a personal workstation with the functionality and performance of a dedicated logic analyser. It consists of a full-size IBM PC-XT form-factor card which can plug into an 8- or 16-bit IBM PC-AT adaptor slot, plus a pod assembly and probe leads. It offers 32 data channels at a 50MHz bandwidth or 16 channels at 100MHz, and is expandable up to 96 channels. Data memory on each channel is 2kbyte in state mode, 4kbyte in timing mode, and 8kbyte at 100MHz. Trigger capabilities include eight levels of trigger states with four-way destination branching. L & M Test Services Ltd, 0280 813707.

Compact signal generator. 2022D is a compact and lightweight 10kHz to 1GHz signal generator now offering extended audio modulation capabilities and a 10-fold increase in maximum FM deviation. Accurate modulation is available at three internal frequencies of 400Hz, 1kHz and 3kHz. Peak FM deviation has been increased to 999kHz, phase modulation up to 9.99 radians peak deviation and AM is available up to 99.5% depth. Wide frequency coverage, +13dBm output power and residual FM noise of only 7Hz RMS. Marconi Instruments, 0727 59292.

Microwave sweeper. Giga-tronics 7200 microwave sweeper is a multi-band synthesised microwave sweeper, available in four frequency ranges: 10MHz-20GHz, 10MHz-26.5GHz, 2GHz-20GHz and 2GHz-26.5GHz. It has digital and analogue power and frequency sweep capability, with resolutions of 0.01dB and 1Hz respectively. The sweep capabilities are enhanced by the addition of eight markers, which allow detailed readings when pin-point evaluation is required. Racal Instruments Ltd, 0734 782158.

Programmable synthesised signal generator. Leader 3216 synthesised signal generator provides continuous-wave, FM or AM signals, including FM stereo, over the frequency range 100kHz-140MHz with a variable output from -20 to +126dBµ. It incorporates a programmable non-volatile 100-point memory for storing settings of frequency, modulation factor and output level. Operation is via front-panel keypad. £1962 + VAT. Thurlby Thandar Ltd, 0480 412451.

Hand-held DMM. TM357 3.5-digit LCD multimeter is a portable service tool housed in a rugged hand-held case; weight is 210g. It provides measurement of alternating and direct voltage over five ranges with a maximum error of 0.5% and a resolution of 100µV; and alternating and direct current over six ranges with a resolution of 0.1µA and maximum input of 10A. Resistance can be measured over six ranges with a resolution of 0.1Ω. Thurlby Thandar, 0480 412451.

Hand-held LCR meter. TC200 provides capacitance measurement over six ranges, inductance measurements over five ranges, and resistance measurements over six ranges with a maximum error of 1%. It has a measurement frequency of 1kHz and a sample time of 0.4s. Dissipation measurement is also provided in a range from 0-19.99. 87mm x 175mm x 31mm. 290g. £95.00 (plus VAT) including probes. Thurlby-Thandar Ltd, 0480 412451.

Literature

High speed VME, PC and multibus boards. *The Bridge to the Real World* brochure gives outline details of Datel's range of analogue I/O boards for bus-based systems, which include Multibus I, VMEbus and PC-AT systems. Details include the number of A-to-D, D-to-A or digital I/O channels, resolution and conversion or settling time. Important features of each board are also listed. Datel, 0256 469085.

Power supplies

Dual output DC/DC converters. LF series DC/DC converters provides up to 500V DC isolation between inputs and outputs. The six single in-line converters in the series are high efficiency 750mW devices, requiring only 0.18in of board space. Units are available with 5V or 12V inputs providing isolated ±5V, ±12V or ±15V outputs. All the 750mW output power can be drawn from one pin, so the LF series is suitable for single output rail applications. No heat sinks or derating is required for operation over the temperature range -25 to +80°C. Amplicon Liveline Ltd, 0273 608331.

Voltage monitor. VM1 voltage monitor provides early warning if a battery or other DC levels drop below a predetermined voltage. In three voltage ranges: 3.5 to 7V DC (6V nom); 7 to 13.8V DC (12V nom); and 18 to 27.5V DC (24V nom), the VM1 has active high and low open collector outputs to indicate when the input voltage has been reached. Collector outputs can drive up to 100mA. It consumes 35mA, resolves to 10mV and operates across the temperature range -10 to 70°C. Amplicon Liveline Ltd, 0273 608331.

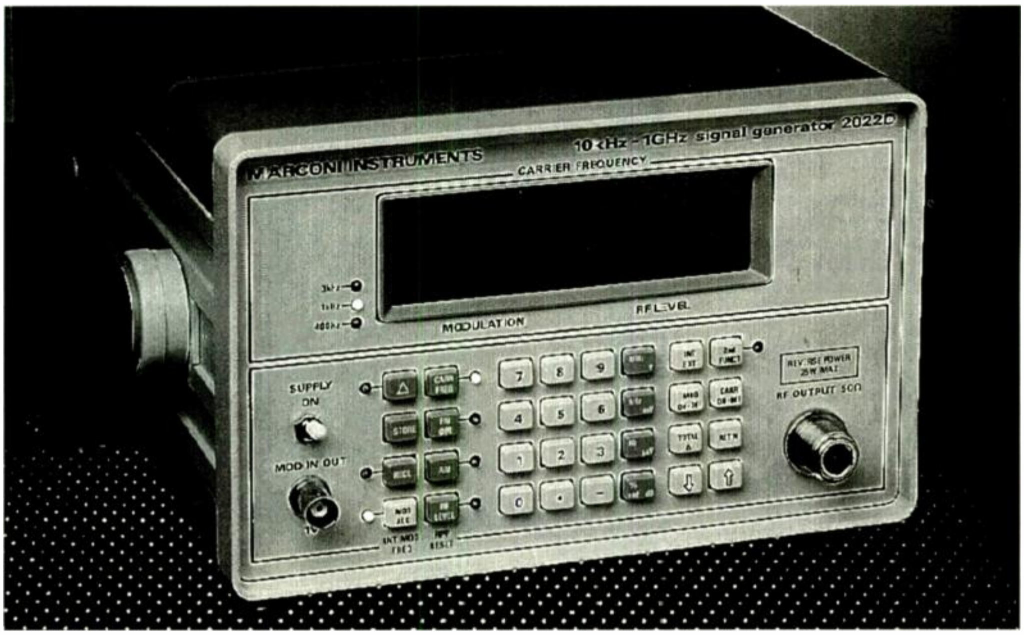
Low power switching regulators. SCI7630 cmos switching regulators provide input voltage step-up and regulation to specified fixed voltage using only an external coil. Maximum drive current is 100mA at 5V from a 1.5V source. In stand-by mode only 3μA is consumed. All devices incorporate precision low-power reference voltage generator internal comparator and inductor driving transistors. 7631 has a built in CR oscillator; 7633 driven by external crystal oscillator; 7635 and 7636, driven by external clock signal. Hero Electronics Ltd, 0525 405015.

Radio communications products

Radio modules for wire-free operation. For general serial data links at up to 200m range, the TXM-418 SAW controlled transmitter module is type approved to MPT1340 and requires 10mA from a 6-12V supply. 10mm x 30mm size and SIL PCB mounting allow it to be used in space conscious applications. Frequency modulation is used and data rates up to 10Kbit/s may be transmitted. The matching 0.5μV sensitive, double conversion superhet receiver module, RXM-418, has both analogue and digital data outputs, a signal strength output, carrier and jam detect outputs. PDS Telemetry Ltd, 081 569 3141.

Switches and relays

Smallest snap-action switch. FU series snap-action switch measures only 7.5mm x 2.5mm x 5mm and weighs 0.2g. It has straight, angled or reverse angled terminals, and is available with a hinge lever, pin plunger or simulated roller lever. Operating spring is stainless steel with gold or silver contacts. AT 0.5A (30V DC) and 20 operations per minute, mechanical life is 20,000. Shock resistance is up to 30g dependent on type. Applications include computer peripherals, video cameras, car stereos or portable electronic equipment. Matsushita Automation Controls 0908 567725.



10kHz-1GHz AM/FM signal generator from Marconi Instruments has extended modulation facilities.

Transducers and sensors

Ultrasonic ceramic microphones. Panasonic's ultrasonic ceramic microphones utilise a piezo ceramic element as a sensor for transmitting and receiving selected ultrasonic frequencies in air. The ultrasonic ceramic microphone has a resonance type vibrator so is highly sensitive, with high sound pressure level. Applications include burglar alarm systems, automatic door openers, flow rate detectors and remote control systems in TVs etc. Alan Butcher Components, 0258 840011.

Pressure transmitter. DataMate, with pressure ranges of 1-32bar and 1% accuracy, the transmitter produces 4-20mA output on two wires. It can be used with corrosive media thanks to its stainless steel entry port and diaphragm and because electrical connections may be made through protective conduit. Excitation voltage is 12-45V DC, operating temperature range of -18 to +100°C.. Control Transducers, 0234 217704.

No iron DC motor. 3042 CR ironless rotor DC motor from Faulhaber can be fitted to planetary gearheads of 23-38mm diameter to give torque outputs of up to 15Nm. Reduction in size means the motor offers the performance of a 35mm diameter by 57mm long motor in a body measuring 30 by 42mm. Nominally rated at 13W, 5000rpm, a life of at least 5000h can be expected at these operating conditions. Stall torque is up to 156mNm with a maximum power of 23W. It incorporates a samarium cobalt motor, twin pre-loaded ball bearings, copper commutator and copper impregnated carbon brushes. Electro Mechanical Systems Ltd 0734 817391.

Vision systems

Low cost teletext decoder. Universal Teletext decoder (Unitext CF70095) has been developed to replace the current generation of single page teletext decoders — incorporates an 11Mips risc processor and automatic flof (fastext) handling on-chip with display graphics to program customised pictures and screen displays. Unitext can decode pages requiring World Standard Teletext (WST) level 1.5. This includes packet 26 processing for overwriting characters in the main teletext display. Without adding any external MPU software, Unitext is able to handle teletext processing for the majority of European languages. Texas Instruments, 0234 223252.

COMPUTER

Computer board level products

Single-board PC-AT. A single-board computer — promising the functionality of PC-AT on a board smaller than a 5.25in disk drive — the SBC-AT incorporates controllers for hard disk, floppy disk and graphics and will run MS-dos or Xenix applications. Up to 4Mbytes of memory, a battery-backed real-time clock and watchdog timer and 80287 co-processor socket are all included. 256K rom/ram disk allows dedicated applications to run on a diskless system. ABA Electronics Ltd, 0264 335025.

STEbus 80386 board. Arcom's "world's first" 80386-based processor board for the STEbus, provides a powerful compute engine for industrial applications. SCIM386SX board combines CPU with memory and I/O capability, to offer a platform for real-time systems that will run PC AT-compatible software, or Unix applications. It costs from £885 with 1Mbyte ram. The all-cmos board is based on the SX version of the 80386 CPU, and is available in 16- or 20MHz selections. Chips and Technologies' SCATSX chipset is used to give compatibility with PC AT computers. Eight surface-mount memory sites allow the board to be supplied with up to 4Mbytes of dynamic ram, extendable up to 16Mbytes using a local expansion facility. Arcom Control Systems Ltd, 0223 411200.

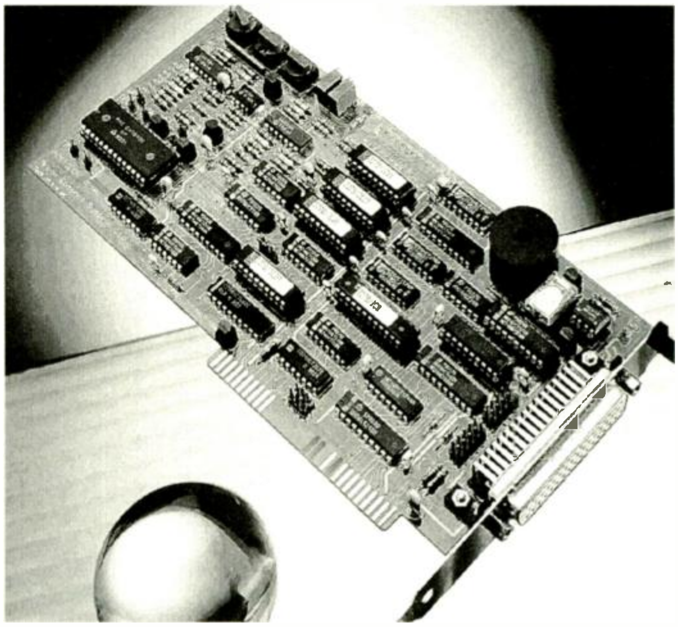
PCbus system integrity monitor. PCsyscon's watchdog can be manually set for variable time-out periods, and can be started under program control. The voltage sensor monitors the three +5, +12 and -12 voltage rails and can be programmed to trip at a wide range of levels, as can the temperature sensor. Two further isolated channels are also available for user-defined connections, to monitor digital power-fail signals, the cooling fans, a control switch, or some other critical system function. Alarms from any of these sources can be programmed to produce a variety of results, such as generating a system interrupt, or activating the on-board relay or the audible buzzer. The board's D-to-A converter can also be programmed to measure a voltage — allowing it to perform background power supply health checks. £165. Arcom Control Systems Ltd, 0223 411200.

DSP and digital audio and communication. DSP56001 processor board takes advantage of multiple Motorola DSP56001 signal processors. Developed for use with the IBM AT and compatibles, the board is for audio and communications systems that use DSP to reduce acoustic echo, compress digitised data, and improve overall sound quality. Two 27MHz 56001 DSP devices share a dual-port ram. The dual 56K board's two processors each have a 74ns instruction cycle and, combined, provide 27Mips. Each processor has access to 32K x 24bits of local memory for zero wait state operation. Loughborough Sound Images Ltd, 0509 231843.

PC performance booster. Number Smasher-860 — based on Intel's i860 64-bit microprocessor can be plugged into a standard ISA slot on any PC-AT 286, 386 or 486 machine. Available in 33 and 44MHz versions, it can perform 80Mflops and is ideally suited for numerically intensive applications. 8Mbytes of high performance memory can be upgraded to 32Mbytes. Two built-in link adaptors, capable of running at 1.5Mbytes/s, enable communication with the host PC, or transputer systems. Package includes an NDP-860 C, Pascal or C++ compiler, running under Interactive Unix, SCO Unix, Xenix or MXdos. £5,000. Microway (Europe) Ltd, 081 540 0614.

Portable GPIB control. GD-GPIB is plug-in module for GRiD system 1500 series laptop computers. A PC with the GD-GPIB can become a cost-effective IEEE-488.2 controller for portable testing applications. It can monitor, control, and communicate with over 4000 instruments. The NAT4882 chip performs the basic IEEE-488 talker, listener, and controller functions as well as all of the controller functions required by the more recent IEEE-488.2 standard. The GD-GPIB sustains data transfer rates of 400Kbytes/s for read and write operations. The GD-GPIB fits in the standard GRiD adapter case for simple, compact integration. National Instruments, 0635 523 545.

Cards for VGA LCD monitors. VGA LCD driver and adapter cards, dedicated to driving the Citizen 640 x 480 pixel VGA LCD panel from any PC-AT bus machine feature a complete kit of parts. As well as the VGA driver card and adapter card (with supply interface and inverter), the kit includes the ultra-thin Citizen CCFL backlit VGA LCD panel together with the necessary connections. An Automap technique automatically maps up to 256 simultaneous colours into as many as 32 shades of grey, giving excellent graphics with colour emulation on an LCD. There is auto-expansion of images to fill the screen. Rugged Displays Ltd, 0734 819521.



First 80386-based board for STEbus, from Arcom.

Computer systems

Laptop industrial data acquisition. Aimed at data acquisition, the GRiDcase 1535DAS is rugged 386-based portable and can be powered from internal batteries. It uses standard (full or half size) expansion cards, two of which can be housed in an external detachable, tray. Fully populated, it can handle 200 channels of analogue I/O, 64 digital lines and 10 counter/timers. The 1535DAS has up to 8Mbyte ram, a 40Mbyte or 100Mbyte hard disk drive and a 10-in VGA display (backlit LCD or plasma). 15lbs with tray fitted. GRiD Computer Systems Ltd, 081 897 6565.

Development and evaluation

Low-cost programming platform. ICE751 is a low cost development and programming platform for the Philips 87C751 microcontroller. It uses a bond-out version of the 87C751 processor connected to a dual port memory emulating on-chip eprom and an emulation cable that can be plugged into users' target boards. RS232 buffered serial port passes data and accepts commands from a host PC. The processor contains 2K bytes of internal eprom, 64bytes of ram, 19 I/O lines, a 16 bit timer, a fixed rate timer, on-chip oscillator and I²C bus interface. There are two modes of operation; download and go, allowing 2K bytes of memory to be used by the 87C751 or debug where 48 bytes of the 2K bytes of memory and 12 bytes of stack space are used by the monitor to enable debug facilities. MicroAmps Ltd, 0483 268999.

Computer peripherals

Industrial VEA monitor. Industrialised version of the NEC-3D multisync colour monitor is housed in a 19-in rack-mounting steel case and protected by an anti-glare safety glass cover. It is designed to withstand rough handling, dust, dirt, water and other rigours of industrial environments. All the common graphics standard supported including MDA, CGA, EGA, VGA and super VGA in up to 1024 x 768 resolution. The basic electronics of the unit remain unaltered to maintain compatibility with most PC/AT and 386 based computer systems. Blue Chip Technology, 0244 520222.

Still video camera. Canon's second Ion still video camera — the RC 260 — handles record, playback and erase functions and can capture images electronically, on 2-in floppy disk. With a film adapter, it can also convert slides or negatives to Ion images. New features include time lapse photography, internal playback; preview facility and wider angle 9.5mm lens. 410g. It can be connected to IBM, Macintosh, Amiga, and Atari computers for applications such as DTP. £499.99. Canon (UK) Ltd, 081 773 3173.

Optical key readers. Rolsecure's infra-red optical key and optical key reader can be integrated into security and monitoring applications, providing a secure means of identifying a specific user. The metal key has over 16 million combinations and the reader head is designed for panel mount applications. System format is an optical key and reader for use with a customer's hardware and software. Interface boards allow connection to the user's system; one allows the reader head to be up to 100m from the user's system; another provides circuitry and software to read an optical key and output its keycode via an RS232 port. Rolsecure Ltd, 0952 680277.

Software

Windows 3.0-based cae. Max+Plus II is an integrated cae system offering hierarchical schematic capture and hardware description language logic entry, logic synthesis and timing simulation for the Classic and Max EPLDs. The enhanced memory management capabilities provided by Windows 3.0 enable Max+Plus II to partition very large logic designs into a set of EPLDs — becoming more important since system-level logic designs of 50,000 or more logic gates are becoming routine. With Max+Plus II, the designer can identify critical timing paths in the source design, and the software then automatically synthesises the design and fits it into multiple EPLDs, ensuring optimum performance and reducing part count. Altera Corporation, 0628 32516.

Windows 3 waveform display. Famos (fast analysis and monitoring of signals) software allows stored waveform data in either binary or ascii file format to be displayed and analysed using Windows 3 protocols. Multiple windows each of up to four waveforms can be displayed simultaneously. Zoom facilities, continuous X and Y interrogation with twin interactive cursors, and wide range of arithmetical and analysis functions are included. Biodata Ltd, 061 834 6688.

Pads-superrouter 3.35. Pads-superrouter 3.35 is the latest release of the popular rip-up and re-try 100% PCB auto-router available on a PC. Enhancements include improved routeing algorithm to give faster routeing times to 100% completion and ability to have infinite SMD pitches on top and bottom layers of the same board, and route correctly to the pad whether it is on grid or not. Tracks exit orthogonally from pads, preventing etch-trapping angles. £2150. Computer Aided Design Services 0767 600774.

Editorial survey: use the information card to evaluate this article. Item F.

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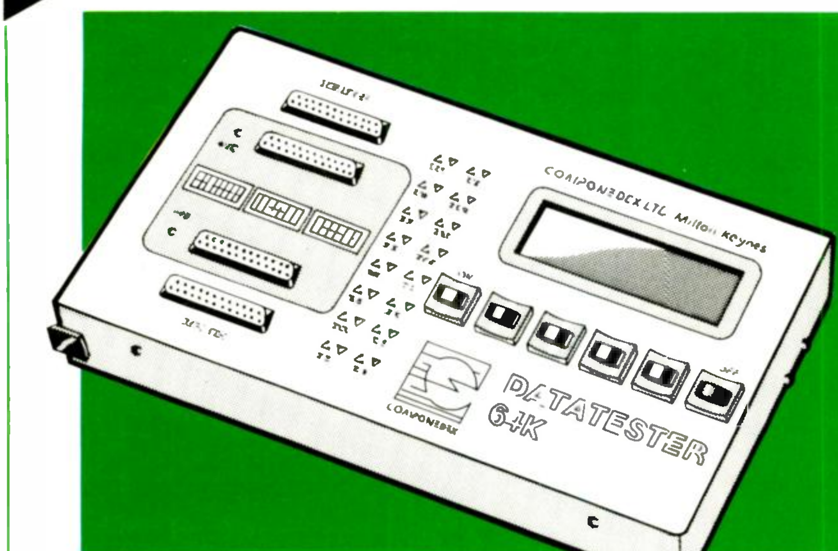

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HP 612A 450 MHZ to 1200 MHZ	£125
HP 651B Test Oscillator	£100
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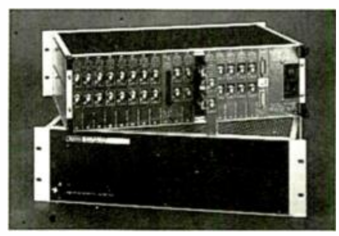

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The 21CF30 is a member of the Series 21 Signal Conditioning Components family Innovative design and constructional features are used to lower manufacturing costs, resulting in units suitable for cost-sensitive applications

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- **FILTER RESPONSE TYPES**

Each 21CF30 card has a fixed response characteristic determined at the factory The card is available in several standard filter responses which are detailed overleaf, see the booklet "Variable Filters - Guide to Responses" for more information The most popular response type is the lowpass 135dB octave, for alias prevention

- **OTHER FEATURES**

The 21CF30 is provided with programmable AC input coupling (-3dB @ 0 1Hz) In addition, a programmable 4mA current source for ICP transducers is fitted, enabling the 21CF30 to offer a complete front end for this style of sensor

The input BNC mounts direct to the circuit board, offering very low input capacitance Standard output is also on BNC, but additional space is provided in the Series 21 frames for a multiway output card which can be used either as an auxiliary monitor or as the main output This is available with a choice of 37way female D or 34way IDC The two output paths are independent, and a fault on one output will not affect the operation of the other Multiway input is not currently available

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CIRCLE NO. 107 ON REPLY CARD

BEYOND THE BLUE HORIZON

With a coastline like Australia's, several hundred conventional radars would be needed for long-range warning. Over-the-horizon radar is probably the only feasible method of coverage, Mike Payne reports.

So far, only the military superpowers — America and Russia — have had the motive, money and technical ability to build operational defence-radar systems using that most difficult of techniques, over-the-horizon detection. Within a few years there will be a third member of the club: Australia.

The Australian government has allocated A$970 million (about £390 million) for the construction of two very long range over-the-horizon radar (OTHR) systems. Together, they will survey the air space and ocean off the northern coast of Australia, detecting and tracking moving targets to a range of several hundred miles offshore. Surveillance for air defence is their main function, but the Australian Ministry of Defence says the performance will be good enough to detect surface vessels and act as a deterrent to drug smugglers and illegal immigrants.

Necessity has forced Australia into the big league. Hundreds of conventional radars would be needed to protect the vast coastline; further, they would not detect low-flying aircraft beyond a few tens of miles away, leaving no time for effective countermeasures in such a sparsely populated country.

Prime contractor to build the OTHR complex will be Telecom Australia; the technical expertise will be mainly native Australian, acquired through 20 years of study and experiment by the Australian government's Defence Science and Technology Organisation.

Britain's GEC-Marconi will make an important contribution through a £120 million sub-contract: Marconi Radar Systems will be overall design authority and Marconi Communication Systems will supply specialised transmitters and receivers.

Marconi companies have worked on OTHR for many years: private-venture work has included experimental systems around the British coast. MoD has funded several project definitions but has never ordered an operational system.

Conventional microwave radar uses wavelengths measured in centimetres and millimetres. Definition of targets and the resolution — the ability to discriminate targets close to each other — can be good, but the beam goes straight to the target and the reflection comes straight back. This limits detection to objects that are in the line of sight; anything over the horizon is out of sight.

OTHR is radar at HF, with wavelengths of typically 20m. Definition and resolution are poor by microwave standards, but at HF, a radio beam has the property that the ionosphere will reflect it, provided the angle of incidence and the frequency are right.

Hence, a beam launched at a low angle can hit the ionosphere after perhaps 1000 miles, be reflected and come to earth again after another 1000 miles, well round the curve of the earth's surface. Targets on the surface at that point generate further reflections, some of which follow a reverse path back towards the radar.

The heading picture shows the 1.75 mile long receiving antenna array serving the Jindalee over-the-horizon radar near Alice Springs in Australia. Its great length is essential for adequate resolution. Digital manipulation of the incoming signals divides the azimuth dimension of the coverage area into several narrower sectors, each of which is examined for target content individually

Below is the transmitting array, some 400 yards long. It is separate from the receive array so that it can transmit continuous wave to get as much energy as possible to the surveillance area. A groundplane of wire mesh in front of the array reflects upwards in the direction of transmission the energy that otherwise would be lost into the ground.

FM RADAR RESOLUTION

Conventional radar uses pulses of RF energy to measure the distance from the transmitter of a reflecting object. Time is measured from the pulse being sent from the transmitting antenna to the reflection being detected by the receiver, usually using the same antenna. Since the velocity of propagation is accurately known, distance to the reflecting object is simple to determine.

Uncertainty arises owing to the finite length of the pulse and the width of the beam of radiation, which is scanned over the area being searched to determine the direction of the target. The length of the pulse sets the limits of certainty in range since, if two targets are separated in space, in the direction of transmission, by less than half the length of the transmitted pulse (1µs equals about 5 miles), their returns merge and the result is only one "paint" on the radar display. Similarly, if the width of the transmitted beam is too large, the same target will be detected at more than one angle of the scanned beam. Minimum area in which targets can be discriminated, set by pulse length and beam width, is called a cell.

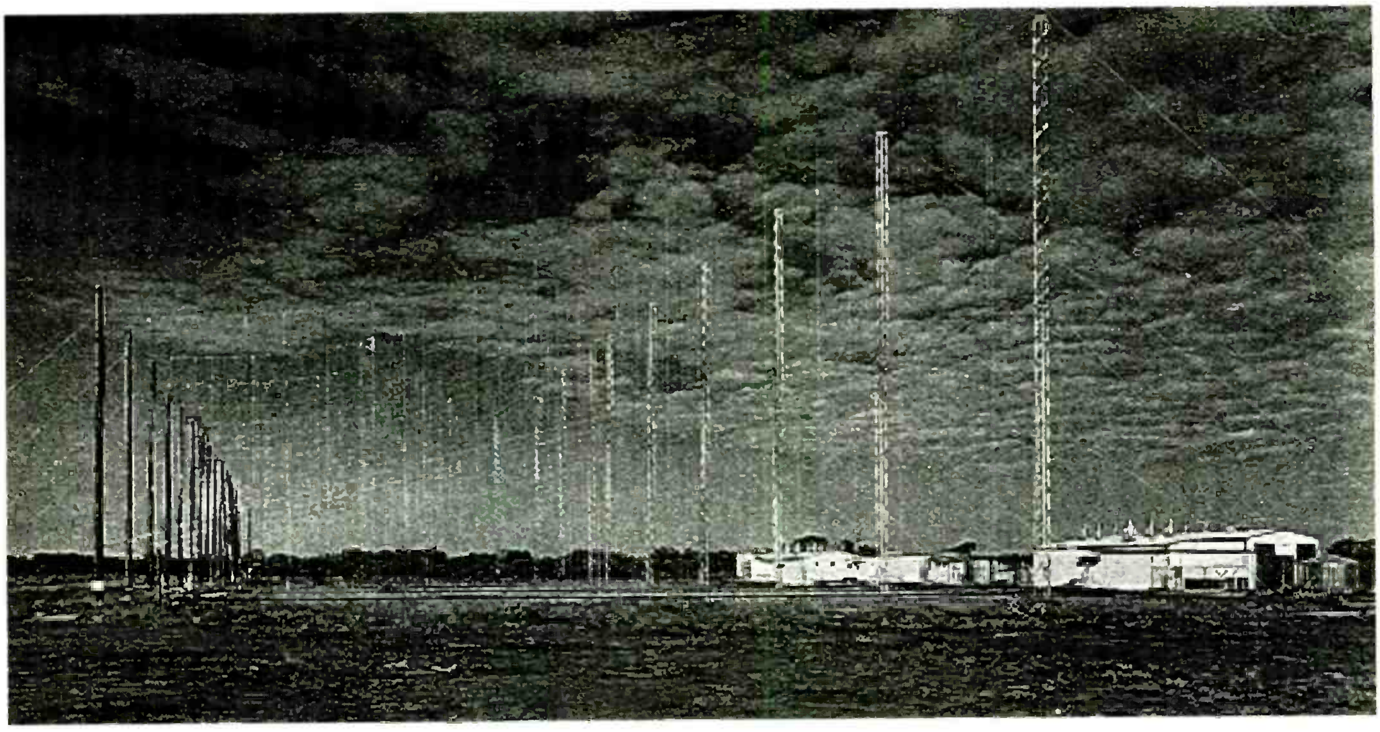
In the continuous-wave radar used in Jindalee, there is no pulse with which to measure time and, therefore, range. In this case, range is measured by frequency modulating the transmission. When a target is "illuminated" by the beam at a given instantaneous frequency, the echo returns at that frequency, but by that time the frequency of transmission has changed. Range is therefore determined by measuring the time between transmission at the given frequency and reception of the return at that same frequency. In the same way that pulse width sets the range resolution in a pulsed radar, the length of time that the frequency in an FM radar stays unchanged sets the size of the cell in the range dimension. If the frequency were to be held constant for 50µs, cell size would be about 10 miles. Cell size in azimuth is set by the beam width; in the case of Jindalee, beam width is 0.5°, so the width of the wave front at a distance of 1200 miles is 1200 tan 0.5, or about 10 miles.

P.D.

Problems at HF

The principle is simple, but implementation is fraught with difficulty. Constant changes in the ionosphere affect its powers of reflection: its altitude is not constant, the effective reflecting layer is not always at the same level within it and it is not always parallel to the earth's surface. Further, the ionosphere's reflection efficiency varies between day and night and with the seasons and is affected by sunspot activity and wind at high altitudes. These variables affect the range and bearing from the transmitter of the ground area illuminated.

As for the radar, the returns from wanted targets are very weak indeed and are swamped by clutter returns from unwanted targets and by galactic, atmospheric and man-made noise. The beam width



may be well controlled at transmission, but inevitably its width at the target is enormous. Great ingenuity is needed to find the position of detected targets within the vast ground coverage area.

Another problem is that outside interests must be accommodated. Frequencies in the HF band are widely used for radio communication and radar must avoid these channels, those with higher priority and adjacent channels. This can rule out a lot of channel space.

Very large antenna arrays are needed, since adequate resolution demands that the aperture is many times the wavelength — in the case of the receiving array at least 100 times the wavelength. Worse still, separate transmitting and receiving arrays are required because the only way to get sufficient power onto the targets over such a long distance is to transmit continuous wave. All this means that large, well separated sites must be found.

Changeable ionosphere

Australia set out to solve these problems in the early 1970s, being helped considerably by the Americans, who lent equipment and offered advice to help the Australians avoid blind alleys.

Their first task was to establish the characteristics of the ionosphere over Australia. That done, and the ionosphere deemed suitable for the job in hand, in the late 1970s a fixed-beam radar of limited capability was built near Alice Springs in the centre of Australia to investigate the practical feasibility of HF. It was called Jindalee (an aboriginal word meaning "bare bones") and looked north-west at aircraft in the civil air lanes between Singapore and Australia.

Between 1979 and 1985, Jindalee Stage A was expanded into Stage B, which approximated a simple, scanning operational radar. Its purpose was to see whether OTHR would provide information of genuine value in the defence of Australia. The trial proved positive and the experience was used to define the further development necessary to produce the optimum operational radar. This is what Telecom Australia and GEC-Marconi will build.

Stage B has proved the general lines on which the inherent problems of OTHR will be solved in operational radars. Obviously, the ionosphere cannot be changed to solve the problems it poses, but it can be probed continuously and enough learned of its instantaneous nature to allow for its effects on radar propagation.

In this, the Australians have been helped by work done by makers of HF communications equipment and users to improve the reliability of HF communication. The Falklands war demonstrated the hard way that satellite communication alone is not sufficient for a hundred per cent reliable contact 24 hours a day.

To monitor the ionosphere, the whole segment of interest in the HF band is scanned continuously by probe signals, characteristics of the signals received at various sites enabling a real-time picture of ionospheric behaviour to be built up.

At any time, certain frequencies emerge as optimum for radar use. Some will be eliminated because they are permanently forbidden (distress frequencies, Flying Doctor frequencies, etc.) or are guard bands around forbidden frequencies. Probing will have shown that some are carrying communications traffic and, by convention, cannot be used for radar until they have been quiet for 30 minutes. What is left is available.

This is not as bad as it sounds. Channel usage, ionospheric behaviour and general noise have a tendency to follow regular behaviour patterns with time. Schedules have been built up through the years which will guide radar operation and in some ways influence radar design to take advantage of the cyclical nature of the contrary forces.

With regard to siting, the transmitting array must be placed so that the beam will be reflected and return to earth to cover the ground areas of interest; the receiving antenna is normally close by. This means that arrays covering coastal sea areas have to be a long way inland and this factor, together with accessibility, led to the choice of Alice Springs for the experimental installations. The transmitter is about 100 miles north-east of the town and the receiver about 25 miles north-west. Separation is about 60 miles, which is enough to be sure the receiving array does not pick up energy directly from the transmitter.

Jindalee in practice

Operational systems will need to take in much more of the Australian coastline. One radar will be near Laverton in the south-west of the country, and the other near Longreach in the north-east. The operations centre will be between the two, in South Australia.

The intended configuration of the operational systems has not been disclosed. Stage B Jindalee, on which they will be

Continued over page

THE WOODPECKER THAT ECHOED AROUND THE WORLD

Over-the-horizon radar has earned itself a very bad reputation among other HF radio users through its potential to cause world-wide interference.

In the early 1970s the Russians built a massive OTHR located about 100 miles east of Moscow for ballistic missile early warning. Using a highly directional phased transmitting array several miles long, the station radiated 100μs pulses with an estimated peak power of 20MW at a PRF of 10Hz. The operating frequency varied from 5 to 20MHz depending on time of day.

Unlike modern HF radars which rely more on computerised signal processing and frequency agile sources than the brute force of the Russian system, the Russian "woodpecker," so called because of its remorseless staccato chirp when heard over the air, could wipe out reception of other HF services in a band up to 100kHz wide. The sheer impulse power could cause receiver blocking several thousand miles away even when detuned from the woodpecker operating frequencies.

The Russians compounded the interference caused by their search for incoming ballistic missiles by operating the system 24 hours/day. Neither did they respect international frequency planning. Woodpecker mostly used amateur radio frequency allocations although it often strayed into marine and fixed service frequency allocations.

The US also built OTHR stations, but used technology to reduce the interference caused to other HF users. With stations located in New England on the East Coast and Alaska looking west, the radars use a PRF of about 50Hz and an order of magnitude less power than their Russian counterpart. Slower rise and fall times on the transmitted pulses reduce band splatter to around 10kHz.

The US early warning systems shift frequency every few seconds reducing the potential for sustained interference. However, this quality has as much to do with the avoidance of potential enemy jamming as good neighbourliness. The USAF Command and Control Centre at Cheyenne Mountain, Colorado continually calibrates its BMEWS using commercial transatlantic and transpacific aircraft movements. **F.O.**

HF radar and spectrum abuse

There is nothing new about the use of the HF band (3-30MHz) for radar, but its recent growth is viewed by many users of this crowded band as something close to spectrum abuse, even though such installations offer unique and probably irresistible attractions for military and some civilian applications.

They not only add relatively broad transmissions (even with CW FM modes) which result in yet more overcrowding to frequencies not yet allocated to radar, but also present potential environmental and health hazards. This is not to deny that the Australian Jindalee installation, for example, is operated responsibly and with consideration to other users of HF, but the insoluble problem with long-range back-scatter and bistatic radars is their need to follow the maximum usable frequency as it traverses the spectrum.

From the first experiments in the UK on about 6MHz in 1935, the UK "Chain Home" was initially planned to use frequencies of the order of 11MHz, thought likely to produce maximum returns from aircraft, and finally implemented between 20 and 30MHz with RF pulses of 350kW, later upped to 750kW. Centimetric and millimetric radar came later.

HF radar came back to Orfordness in the mid-1960s, when RCA built what ultimately proved an unsuccessful over-the-horizon HF radar. But before it was aborted, there were many complaints from North Sea trawlermen of sparks being drawn from their rigging — just one indication of the problems that surround these massive, megawatt installations.

The appearance in the 1970s of the Russian "Woodpecker" HF pulse radars brought chaos to the HF bands for a time (see separate box) — a problem that lessened but did not disappear with improved pulse shape that stayed within somewhat narrower channels.

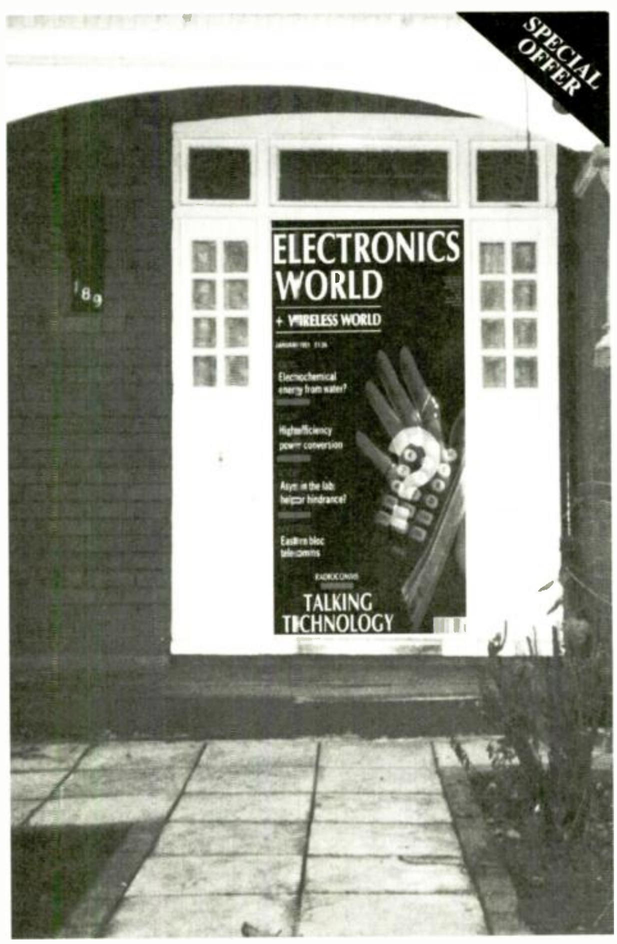
By the end of the 1980s, work on long-range (3000km) radars had been joined by medium-range sky-wave and ground-wave radars for the detection of ships, low-flying aircraft and sea-state radars, fortunately needing less power.

While the supposed "zapping" of America by the Russian OTH radars had no basis in substance, there could be problems for those living close to the installations; there is also concern, possibly justified, that such radars add to the ionospheric heating already brought about by the high-power HF broadcast stations.

High-power HF radars have been built in a number of countries. CNET France has its major Valensole back-scatter installation at Lannion and did not endear itself to radio amateurs when it was revealed at a 1988 conference that one of the frequencies used was 14,147kHz, right in the middle of the exclusive world-wide amateur band.

It is not surprising that many people view the return of radar to HF with misgivings.

Pat Hawker



based, has a transmitting array rather less than one-quarter mile long and a receiving array 1.75 miles long. Each consists of numerous individual transmitters or receivers in line, connected electronically for integrated operation. The receiving array has to be long to achieve a narrow beam width for a reasonable target resolution in azimuth — about 0.5° — at the wavelengths used, which are around 20m.

A phased-array transmitting antenna steers the beam through the scan angle. It moves in steps in both azimuth and range, pausing for several seconds at each step to flood the coverage area. Because the wavefront travels such a long way to get to the volume of air space in which it will seek targets, expanding all the way, it is very large by the time it arrives. After 1,200 miles it is 10 miles wide.

Azimuth precision is improved by using the long receive array to divide the azimuth dimension of the coverage area into several narrow angle sectors, each of which is examined individually for evidence that targets are present. Division is done by digital manipulation of the signals arriving at the array elements. The width of a narrow receive "beam"sets the azimuth dimension of a radar cell. However, because transmission is continuous, there is no pulse duration as in conventional radar to set the size of a cell in the range dimension. Nor can the range of cells be measured using pulse out-and-return times. Instead, the transmitted beam is frequency modulated in steps during the dwell period. The duration of a modulation sets the cell range dimension and the time interval between transmission at a particular frequency and returns (if any) at that frequency sets the range to the cell being examined.

Detecting and recognising radar returns from wanted targets in the overwhelming mass of received noise and clutter is done by sophisticated digital signal processing. Recent advances in this field, made possible in turn by advances in semiconductor technology which have made number-crunching computers available at economic prices, are vital to practicable OTHR systems.

While the radar beam dwells on a coverage area, the gross return — wanted targets, clutter and noise — from each cell is sampled for long enough for the content that is phase coherent with the transmitted beam to accumulate and build up above the noise, which does not accumulate because it is not phase coherent. This reveals the presence of a target or targets, wanted or unwanted.

Because the purpose of the radar is to detect moving targets (mainly aircraft, but also larger, steel-hulled ships), wanted targets can be distinguished from the bulk of unwanted targets (which will be stationary) by using digital Fourier transforms to detect the Doppler shift. Targets are confirmed as aircraft or ships by tracking from cell to cell; unwanted moving targets, such as meteors, do not generate persisting tracks and are easily eliminated.

As with all engineering systems, Jindalee's great advantage of exceptional range — minimum about 500 miles, maximum about 1500 miles — has to be paid for by disadvantages in other respects.

Wide tolerances have to be allowed on displayed target positions because it is impossible to be sure that all ionospheric effects have been taken fully into account. Tolerance on range measurement can be 20 miles, range resolution similar.

Continued on page 413

All at c

Imagine, Alvin and Brian are sitting together on a park bench in the dark listening to the Archers on their Walkmans. For an instant, Alvin shines his torch due south. At exactly the same time, Brian shines his torch due north. A short time later, the north-going and south-going wavefronts have moved away from them by equal distances. Therefore, they are midway between the two wavefronts.

Brian lives due north so, after bidding goodnight to his friend, he strolls directly home and goes to bed. While he is walking home, the north wavefront moves away in front of him at constant speed c. Likewise, the south-going wavefront moves away behind him at constant speed c. Therefore, as he lies in bed enjoying sweet dreams, he is still midway between the two wavefronts. Alvin, however, has dozed off on the bench and so stays where he is. The two wavefronts move away from him, also at constant speed c, due north and south, so he therefore is also equidistant between them.

The problem is, Alvin and Brian are no longer in the same place. Well, this is a problem isn't it?

C.W.Piggott
St Albans
Hertfordshire

There are many simple electronic proofs that c is a constant to the source or a target but is not a limit. In WWII we had a moving target indicator (MTI) radar on my ship that could tell us distance, speed and heading of 20 or more targets. The radar pulse from the magnetron was always the same frequency.

Chemists know quite well the precise frequencies absorbed and radiated by most elements. How do astronomers get blue and red shifts from stars? They must add or subtract radial velocity between the source and observer. This same effect is present with 21cm spin/flip radiation from hydrogen clouds. We now use a light year to give the distance electromagnetic radiation (light) travels in a year. At the same time astronomers know light from a blue-shifted quasar travels much further toward the earth in a light year than light from a red quasar.

Police will soon be proving this many times daily with their new laser speed-traps. A good laser operates on only one coherent frequency (a laser is an excellent clock) out of the 320 trillion electromagnetic frequencies in the spectrum of white light. From a car closing at 55mile/h, the laser gets back a higher frequency than it transmits. How? The reflected signal from a car travels 55mile/h faster than c or the speed of light in air. Most distant quasars have a radial motion towards or away from the earth much faster than any car will travel.

Whenever we get up-Doppler, it is because an electromagnetic signal of a given frequency comes to our receivers or detectors faster than c. Does all radiation travel at c and get the velocity of the source or target?

You can beam a laser through a vacuum, air, water, glass, etc. and also reflect, refract or disperse the beam, but this never changes the frequency detected from the laser.

John H. Ecklin
Alexandria, VA
USA

Hardware v software

I would like to apologise to readers who had difficulty following some of the arguments in the article "Removing the Bottleneck" (*EW+WW*, February 1991, pp139-142). I guess I didn't make some points clearly enough in the article that I submitted to the editors because it appears that, in the process of shortening the article to fit between the more profitable advertisements, some key arguments were lost and some were so changed that they suggested the opposite to what I had intended. I would like to clarify here three of the more important points.

Firstly, the article reads "An active switch will cause the output wire to mirror whatever is happening on the input wire". In fact the output is the *opposite* of the input. The switch works in the same way as a bipolar n-p-n transistor with input wire tied to base, emitter to ground, collector to output wire and the wires pulled to the positive rail. So when the input is "passive", that is at positive voltage in the above, then the switch emits an "active impulse" — it pulls the output to the dominant ground state. When the input is "active" (at ground) then the output is "passive" (effectively disconnected) and can float high or be pulled to ground by another switch. The above mechanism is essentially the same as that used in the logic families RTL, DTL, TTL, ECL, IIL, BTL and NMOS.

Secondly, the text of the article suggests that only 1% of a typical von Neumann computer does any computing. The correct figure is closer to 0.1%. Counting the number of wires and switches in "typical" computers results in figures of roughly 99% memory and 1% processor. But looking more closely at the processor reveals that most of it, namely the I/O latches, the registers, the microcode store, etc., is just another layer of memory, albeit the fastest. It is only the ALU and similar circuits that do the actual computing (add, sub, and, or, cmp, test, etc.). The ALU accounts for only a tenth or so of the processor, hence an overall efficiency of 0.1%.

Lastly, the impulse matrix described in the text would use conservative 1980s 3-micron cmos technology and yield a speed index of 10^{16} impulses per second. The figures in the last column of Table 1 are for a similarly sized 1990s impulse matrix using 1 micron BiMOS technology, which would consequently be one thousand times as fast.

Archie Medes
Dee Why
Australia

Electronic cameras exposed

Information on camera autofocus mechanisms is hard to find, so this article (March 1991, pp.191-195) would be of great interest to many amateur photographers. However, it left me wondering if one part of it was entirely accurate.

I have a Konica AA-35 half-frame camera with a 24mm f4 lens which seems to have sufficient depth of field to cover for any errors inherent in its two-stage autofocus system. The distance between centres of the two IR windows is 17mm.

George Cole states "When the shutter is pressed, a beam is sent from the camera and reflected from the subject into the receiver, the time taken for the camera to detect the beam indicating the subject distance".

Taking a subject-to-camera distance of, say, 1.5m, this time would be

$t = \text{dist/vel} = 2 \times 1.5/3 \times 10^8$
$= 10\text{ns}.$

Is it likely that such a response time could be achieved? Is it not more likely that the system just measures the *quantity* of infrared radiation received, with the assumption of an average reflectance of, say, 18% ?

D. L. Smith
Daventry
Northamptonshire

Turning a deaf ear

Far be it for me to accuse John Greenbank of naivety, but to suggest that the preference of hi-fi dealers and, ultimately, their influenced customers in their choice of amplifier A over amplifier B is in anyway due to technical merit — oh, come, come now. For a number of years, hi-fi products have been consumer durables and subject to all the hype that one expects in the marketing process. The reviewers and "experienced" dealer staff to whom he attributes such doubtful integrity are 100% a component part of that machinery, and nowhere will you ever get complete evaluation subjectivity — except, perhaps, in *Which* magazine. The techniques which the hi-fi business has adopted with such enthusiasm are in no way different to the puerile, women-debasing adverts on TV for soap powder.

The whole issue could be resolved quite easily, if those in the subjectivist camp are prepared to accept the challenge. If amplifier A is really that much superior to amplifier B, then subject all concerned to a carefully controlled, double-blind A-B listening test and analyse the results in a proper scientific manner. I, for one, am more than ready to accept the outcome. But no — it won't be accepted, will it? The goalposts are not movable and there is too much to lose.

Reg. Williamson
Kidsgrove
Staffordshire

John Greenbank, in his March letter about subjective audio equipment testing, says "truth of the kind being sought is not discovered by assertion and counter-assertion". I fully agree with this, which is why my letter in the December 1990 issue (p.1044) had much to say about the actual results of various carefully organised listening tests — such results largely speak for themselves.

However, it seems to me that a fairly extreme example of assertion is John's statement that dealers *unanimously* prefer a well known power amplifier to the Quad current-dumping one. He cannot possibly know whether this statement is true, for neither he nor anyone else is in a position to find out the views of all dealers. Even if a substantial number of dealers do prefer some "well known amplifier" that is at present fashionable in audiophile circles, the true reason may be that the product is very expensive and hence gives more profit per sale. These dealers are probably the same ones that try to persuade the customer to spend hundreds of pounds on special cables which confer no sonic benefit whatever — not the sort of dealers that Quad would choose for the sale of its products.

John has been willing to damn Quad in print, but I am left wondering why he didn't feel magnanimous enough to mention at the same time the make of the preferred amplifier!

Peter J. Baxandall
Malvern
Worcestershire

New test for audio amplifiers

The pages of your journal have long rung with the clash of pens on subjective versus quantitative measurement of audio equipment. No matter how often this topic is debated, the same conclusions are always inevitable.

If two amplifiers measure identically, but sound different, then unquestionably we are not measuring the right things. As DSP techniques advance, it follows that in time it will become possible to compare audio reproduction in the laboratory by measuring everything. Conversely, no sensible person would consider purchasing a bottle of vintage wine on the basis of a gas chromatograph analysis of its contents. Music, like good wine, is a sensory experience; its enjoyment cannot be measured. The "Golden Ears" brigade have lowered the subjective review to ludicrous depths, and the vocabulary of hi-fi is now identical to that of wine-tasting, and equally meaningless applied to either.

It is possible to become formally qualified as a wine-taster. A Master of Wine takes many years to achieve his (or her) high status. Because of the subjective/quantitative dichotomy, it is not possible to attain a formal qualification in audio auditioning. An electronics engineer offers no more to music than a chemist can to wine.

Classical musicians, unfortunately, listen "in their heads", and can be satisfied by a wind-up gramophone with a sock stuffed up the horn as their domestic sound source. Pop musicians need constant levels above the pain threshold to hear anything. What is needed is a subjective test which prospective purchasers can perform for themselves with a minimum of procedure, but with controlled repeatability.

Any traveller will have first-hand experience of the Distant Piano Effect. As you sign the register in an unfamiliar hotel you can hear, faintly, piano music playing somewhere in the same building. Even with ears ringing after hours of long-haul jumboing, and listening through maybe five intervening sets of swing doors, it is immediately discernible whether the piano is real, played by an actual person, or that it is piped, canned or some other draught keg music. It is even possible to tell the make of piano and how recently it was last tuned or dropped. No hi-fi can yet achieve the same emotional subtleties and nuances.

This common effect can therefore provide the basis of a true, "double-blind" listening test. The immediate advantage is that it can be provided to visitors at any current hi-fi show venue. Far better, surely, to lounge at the hotel bar listening to live versus recorded performances happening several floors below, than to cram sweating into hundreds of exhibitors' cells only suitable for demonstrating in-bath audio? Few exhibition hotels offer domestic living-rooms, but most possess a reasonable Steinway or Yamaha. All sell wine.

Thus hi-fi can be subjected to a simple subjective test which evaluates directly the emotional experience coefficient in real versus reproduced music, while simultaneously allowing a control cross-reference to other senses. My own experiments indicate that audio designers still have a lot of ground to cover. Californians, in particular, make much better wine than loudspeakers.

Why discuss complicated, esoteric audio testing when a simple "real or simulated" judgement can offer the layman self-evaluation?

T.W.Woodford
South Carlton
Lincolnshire

Women and mathematics

I feel that I must reply to Charles Small's letter in your March issue on the ability of women at mathematics. Since IQ tests were used in the 1930s to "prove" the mental inferiority of ethnic minorities, I think people should be wary of using similar tests to "prove" that women cannot do maths. There may be a tendency for boys to be better at maths (just as there is for girls to be better at languages) but it is a tendency only and must not be used to stop women from studying maths and science.

I also feel that he has underestimated the effect of social conditioning. A study by Dr Lloyd[1] has shown that, even at age 4 or 5, girls are often stopped from playing with Lego and other constructional toys by their male classmates, who feel these toys are for them. This may seem trivial, but many engineers and scientists will admit that their interest in science started at an early age with such toys. Interestingly, the proportion of girls from girls' schools that study maths and science is greater than the proportion of girls at mixed schools who study such subjects. This is hard to explain in terms of the natural ability of girls at maths, but can be seen as evidence of pressure for girls to conform to a female stereotype in the mixed schools.

My final point is that I am disappointed by Mr Small's letter because, as a woman engineer, I do not like the implication that I am in some way abnormal or unfeminine. Hopefully in the future, the place of women in science and engineering will be so assured that this will be a non-issue.

Katrina Joss
Swindon
Wiltshire

Reference

1. Lloyd B., Rules of the gender game, *New Scientist*, no 1693 p.60, December 2, 1989.

RDS in theory

I was interested to read the letter from T.G. Parrott in the February 1991 issue. As a technical consultant and reviewer for *FFWD* magazine, I have carried out comparative tests on most of the current RDS-capable Band II mobile receivers using both calibrated trials routes and a computer-controlled test rig. I agree that only a very few RDS receivers currently perform at all well, and those that do are European-sourced; those of Japanese origin all have more or less poor implementations of RDS. The limitations appear to be due to a combination of software which is nowhere near subtle enough, and hardware embodying an AF switching strategy which is some way from the best choice for European (and especially UK) conditions.

What is perhaps worse is that no manufacturer has yet seen fit to produce an implementation of the very important EON (Extended Other Networks) facility. It can be done quite easily (conversion of a commercial receiver took me approximately two days) and greatly increases the usefulness of RDS: it seems odd that manufacturers fight shy of incorporating it.

I suspect that none of the Japanese majors has truly understood what RDS is about and how to make it work properly, and no doubt not having an indigenous network to play with does not help. From my own work, I have come to the conclusion that field trials over known routes are much more useful for RDS development than any amount of laboratory work.

J.H. Nelson
Shrewsbury
Shropshire

ELFin signals

I was interested in the letter from Mr Pickworth in *EW + WW*, February 1991 because I have had a lot of experience looking for interference. Mr Pickworth, who lives in Surrey, gave his position as 110km from Droitwich and 45km from Rugby. I have had some experience of navigation on land, sea and air, so I plotted his position on my aeronautical chart which shows radio masts. I found he lives about 15km east of Kettering or Corby, which is a long way from Surrey. Also the oscilloscope pictures had no time scale, so I did not write to you.

Now in March, Mr Pickworth has moved to Market Harborough, which is 22km and 48km from Rugby and Droitwich. Also he has told us that the PRF is 50, which is what I should expect.

In the last 30 years electronics has become very small but also very large. The power control systems for very large electric motors and furnaces are now electronic. Thyristors are capable of handling thousands of amps and thousands of volts. They cause trouble for the power supply people, who make and want to sell complete sine waves, but the furnace designer only wants to buy the back half of the sine wave.

This switching generates 50Hz PRF damped oscillations which Mr Pickworth has found. I cannot visualise Mr Pickworths circuit; he appears to use a horizontal antenna on the ground between two earth rods in wet clay — then he calls it elevated. He also refers to a common earth. Common to what?

The size of the signals from GBR and R4 surprises me. The receiving antenna is horizontal but both transmissions are vertically polarised; the relative size may be a function of the measuring equipment. The tuned circuit is tuned by a capacitor box. Capacitance for GBR is 150 times that for R4 and the Q is unknown, so the dynamic impedance at 198kHz is 100 or 200 times larger and we should expect a larger output even though the transmitter is further away. GBR is only 22km away, is very powerful and has a huge array supported by 820ft masts.

I suggest Mr Pickworth removes all mains equipment; I have always used the microvoltmeter made by Levell Electronics for this work. Then sound out the farmer, his bull and his dog; if all three are friendly, move the experiment into a large field away from all overhead and underground cables, water troughs or any other man made devices.

Then let us know the results and include a circuit diagram with lengths of wire, positions, etc.

Michael Samain
Salford

Singing the blues

The need for absolute pitch in humans (Research Notes, March 1991) may have an origin based on the need to comprehend language. In Thai and possibly other languages, the tone of a word decides its meaning. There are five tones, normal, falling, high, low and rising. Most words are monosyllables comprising a consonant vowel combination. The tone of the vowel can provide up to five totally different meanings.

There may be few problems in distinguishing rising and falling tones without a well developed sense of pitch, but only context will enable the tone deaf to distinguish words using the other tones. The inherited characteristic to develop absolute pitch could have evolved for survival in Thailand and other countries with tonal languages.

Guy Selby-Lowndes
Billingshurst
West Sussex

Savage science

A very brief note to say how refreshing and heartening it was to read the "Flights of Conscience" editorial in the March 1991 issue. A unique chance to apply sanctions in order to get rid of Saddam Hussein's murderous regime was abandoned — politically we may yet pay heavily for that. Our fascination with the "murderous technology" seems also to paralyse our feelings for the thousands of fellow human beings torn apart by these weapons. You rightly point out the hypocrisy which has been prevalent in this war. Western politicians would like us to turn a blind eye to their failings — I hope you will continue to ask awkward questions. You have an important platform from which to do that.

Shirley Tanley
Bow Street
Dyfed

Stopping the drift

In your article by John Linsley Hood, I was interested in the reference to early VHF tuners. I too built a tuner based on the design by S.W.Amos and G.G. Johnstone (*WW* April/May,1955). Frequency drift was a real problem, so perhaps older readers might be interested in the complete answer to this snag.

The design used the then-popular magic-eye tuning indicator; not liking this item, I used a centre-reading moving-coil meter for a tuning indicator.

In parallel with the meter is another meter movement with the dial removed; in its place is a piece of Bakelite with a small piece of sheet copper attached. The meter has a flat needle which, together with the copper sheet, forms a very small capacitor and, when connected to the oscillator tuning section, controls its wanderings caused by thermal changes. The AFC meter is 1-0-1mA, the tuning meter 5-0-5mA and the tuning meter moves hardly at all when AFC is working.

This tuner is in daily use feeding a Mullard amplifier built at the same time; total replacements to date — four valves.

R. Scholey
Grimsby
South Humberside

Crossed-field antenna

I sometimes wonder whether the CFA has suffered from "the Giraffe effect" — someone seeing a giraffe with its long neck for the first time is supposed to have said "I simply don't believe it." We are so accustomed to the idea that an effective radiator should have a size comparable with the wavelength that anything else is automatically disbelieved.

The CFA can be justified by Poynting's theorem that the integral of **ExH** over a closed surface is equal to the rate of change of stored field energy within the enclosed volume. He also showed that the power flow in an electric circuit can be measured *either* as the product of current times voltage in the conductors *or* in terms of the integral of **ExH** where **E** and **H** are the electric and magnetic fields associated with the current in the circuit.

So now describe a surface which is closed around the CFA except that it is penetrated by the feeder which provides an **ExH** proportional to the flow of power *into* the system: since field energy is not going to accumulate indefinitely in the enclosed space, there must be a corresponding flow of **ExH** outward through some other part of the closed surface, i.e. the CFA must radiate. To validate this argument the CFA must have resistive input impedance, so that there is an inward flow of real power through the feeder; but this has been established by measurements in the UK as well as in Egypt.

The theoretical confusion has arisen from a mis-interpretation of one of Maxwell's equations for the propagation of a plane wave in a continuous medium which is usually presented in the form

$$- \times H = \partial D / \partial t + J$$

where J is the current *density*. It is tempting to say that J times the area of cross-section of an antenna wire is equal to the antenna current i_a and therefore - **H** is proportional to i_a.

But this is entirely fallacious. Each term in the differential equation refers to conditions at a particular point in space, and the same point for all of them, so the current in a more or less distant antenna wire is irrelevant to the propagating wave. This is illustrated by the calculation of skin effect in a metal or of the penetration of radio waves into sea water with J being the density of eddy current at the depth in the medium which is under consideration. Maxwell's equations for the propagation of an electromagnetic wave in a continuous medium, which is usually assumed to be non-conducting so that J=0, have no relevance to boundary conditions such as must occur at the boundary between an antenna and the surrounding medium.

Thinking about the CFA has clarified another problem. When presenting to students the standard way of finding the radiated field from a resonant half-wave dipole I was always troubled about the complexity of vector algebra involved, but now the reason is apparent: the H field is strongest at the centre and the E field at the ends of the dipole and they are out of phase. So it is only because H in the radiated field depends on the E field, not on the current in the wire, that one gets the distinction between the "near field", produced mainly by the current in the wire, and the "distant field" or radiated field which derives from the electric field between the ends of the dipole.

D.A.Bell
Walkington
Beverley
Yorkshire

Editorial survey: use the information card to evaluate this article. Item H

FM RADIO: PLAYING A BETTER TUNE

In the last part of his series, John Linsley Hood describes the evolution of stereo broadcasting and the influence of higher-quality sound on requirements for studio-transmitter links. He also examines frequency synthesis in local oscillators and RDS

Historically, the BBC has shown a continuing interest in the possibility of transmitting stereo radio signals since before 1957 and broadcast experimental programmes on a fortnightly basis from 1958, one channel being transmitted on VHF FM and the other using a standard medium-wave AM broadcast transmitter.

Meanwhile, the search for a stereo broadcast system which could be employed with existing VHF FM transmissions was being pursued with enthusiasm in the USA and a number of alternatives had been proposed. Six of these possible competing methods were tested by the Federal Communications Commission in the USA in 1961. The final choice was for an amalgamation of pilot-tone systems proposed by Zenith and GE, now defined as CCIR recommendation 450/1970, and broadcasting in the USA, using this system, was authorised by the FCC in June 1961. (See the *WW* editorial comment of the same date).

System requirements

The basic need was for a method of transmission on a single carrier of a stereo signal, having a +0-3dB audio bandwidth of 40Hz-15kHz, which would be received by an existing monophonic receiver as a normal L+R mono signal, but as a stereo signal by a receiver equipped with a decoder. It should not significantly degrade the existing FM transmissions received by normal mono FM sets.

In the Zenith/GE pilot-tone system[1], this was accomplished by the method shown in **Fig. 1**. The existing L+R signal was broadcast to a maximum modulation level of 90% of the permitted 75kHz deviation, together with a L-R signal, which was transmitted as a double sideband AM signal, with an equivalent 45% peak modulation level. The transmission was centred on a suppressed 38kHz sub-carrier which could be regenerated from a continuously present 19kHz pilot tone, broadcast at a 10% modulation level.

This composite signal had the equivalent modulation depth of the existing 40Hz-15kHz mono transmission, where 100% was equivalent to a modulation of 75kHz.

Stereo decoding methods

In principle, all that is needed to receive the stereo signal is to use the 19kHz pilot tone to generate a suitable-amplitude 38kHz carrier waveform, from which the double-sideband L-R supersonic signal, which occupies the 23-53kHz part of the audio spectrum, can be resolved into the required L-R audio output. The L+R and L-R signals can then be converted into the left and right audio channels by the simple matrix system, also referred to as a frequency-division multiplex decoder, shown in **Fig. 2**.

A practical decoder of this type was shown by Browne[2], and illustrated in **Fig. 3**, in which both the 38kHz carrier regeneration and the matrix addition were accomplished simultaneously.

Unfortunately, this simple circuit does not offer reverse compatibility in which a mono signal can be received in the absence of the stereo pilot tone. This drawback could be removed by the simple expedient of making V_2 self-oscillatory, although this would slightly degrade the mono s/n ratio.

This method of stereo signal decoding was the major technique used during the 1960s, and formed the basis for the bulk of the stereo decoder ICs designed during this period, such as the Motorola MC1304, MC1305 and MC1307 and similar devices from the other major semiconductor manufacturers.

A survey of the various possible techniques for decoding the Zenith/GE pilot-tone stereo signal was made by *Wireless World* in September 1966, (pp. 445-448), shortly before the BBC began making test transmissions using this system. This survey drew attention to the possibility of using a simple 38kHz channel-switching (time-multiplex) system, of the kind shown in **Fig. 4**, as an effective method of decoding the composite signal. There were some inherent problems in this technique, as discussed later.

A channel-switching decoder, using the circuit shown in **Fig. 5**, was described by Waddington[3] in 1967. He used a pair of silicon planar transistors in a shunt-mode chopper circuit, driven by a 38kHz signal derived from the 19kHz pilot tone by way of a frequency multiplier and phase-splitter circuit.

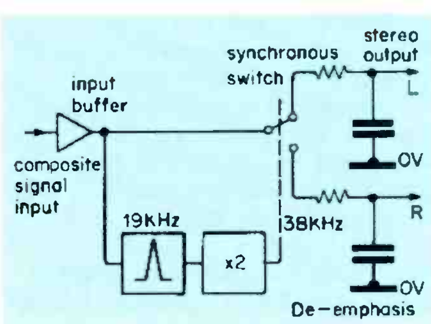
Although Waddington's circuit provided automatic (stereo-mono) reverse compatibility, several difficulties still remained with the 38kHz switching technique, of which the most immediately obvious was a 6dB fall in mean signal level when a stereo signal was received, due to the chopping action of the switching circuit.

A further problem was that the correct matrix addition of the L+R and L-R components of the composite signal in the time-multiplex mode would only be obtained if the reconstructed 38kHz switching signal had the correct phase relationship to the other modulation components. This was critically dependent on the adjustment of the tuned circuits in the frequency multiplier chain; if these were incorrectly tuned, the stereo separation would be greatly impaired.

Both of these problems were solved by the very elegant phase-locked-loop stereo decoder shown in **Fig.6**, described by Portus and Haywood[4]. The PLL circuit regenerated an accurate 38kHz square wave, locked in phase to the 19kHz pilot tone, so that the maximum practicable stereo separation could be ensured without the need for very accurate alignment of a tuned-circuit frequency-multiplier chain.

Equality of gain between mono and stereo operation and true reverse compatibility was automatically ensured by the

Fig. 4. Basic channel-switching, time-division multiplex decoder, switching at 38kHz.



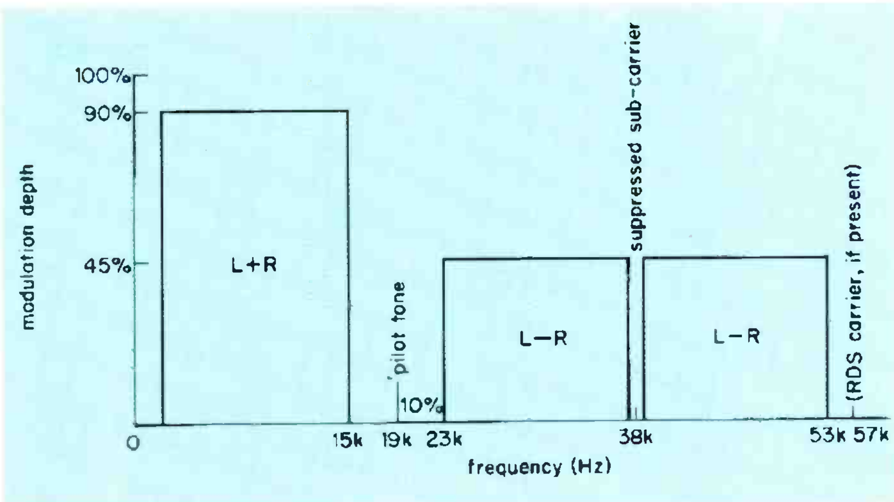


Fig. 1. Zenith-GE composite stereo modulation characteristic, producing compatibility with existing mono receivers.

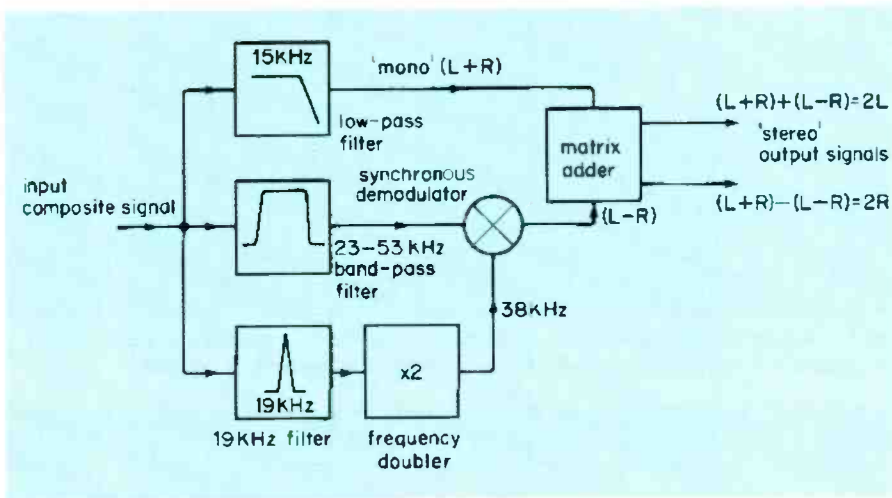


Fig. 2. Stereo decoder using frequency-division multiplex system. Channel separation was critically dependent on tuned-circuit alignment.

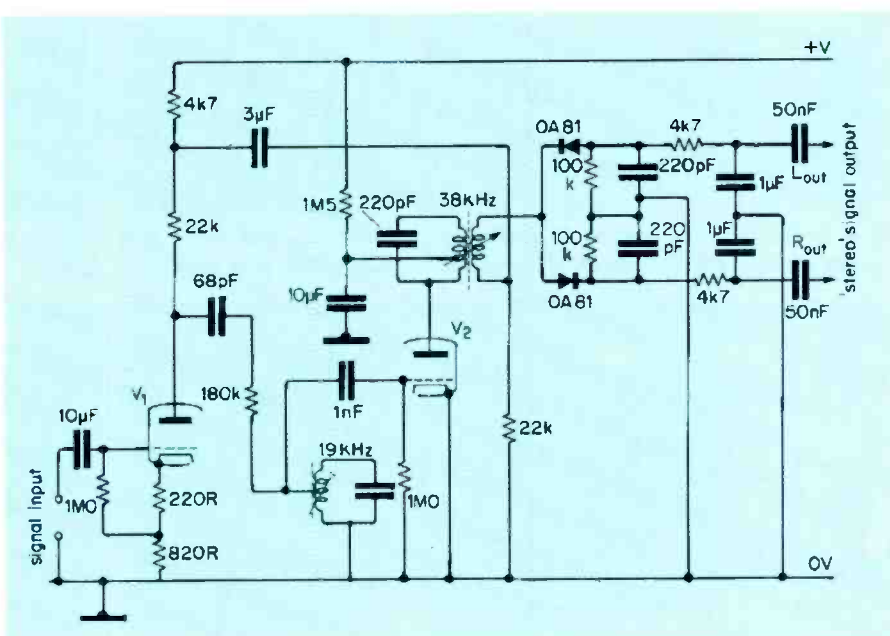


Fig. 3. Practical decoder of the Fig.2 type from 1962, in which carrier regeneration and matrixing were simultaneous. Mono was not received without pilot tone.

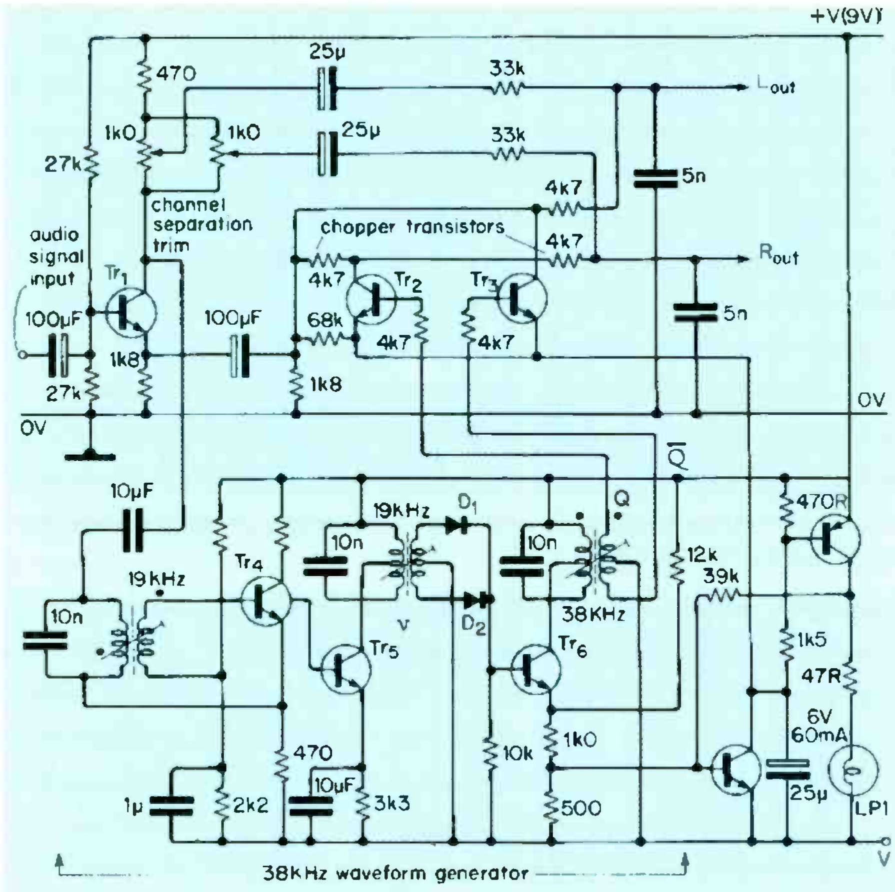


Fig. 5. Channel-switching decoder by Damer Waddington, published in 1967, which was compatible with mono signals. Phase of switching signal was critical.

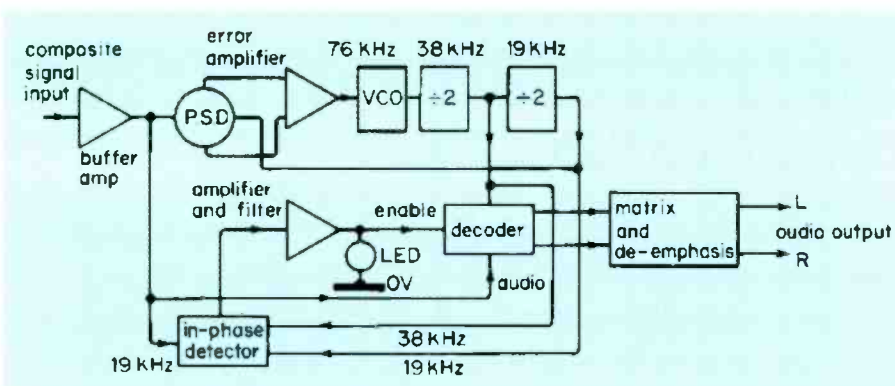
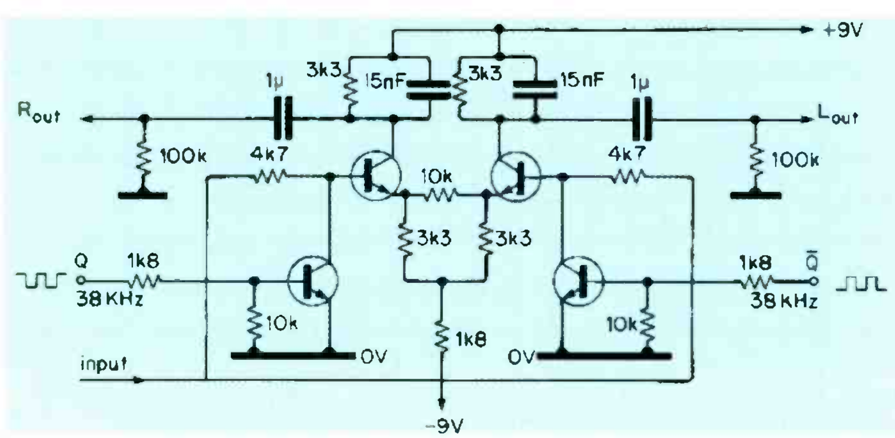


Fig. 6. Portus and Hayward phase-locked-loop decoder of 1970, which overcame both phasing problem and inequality of stereo/mono gain, suffered by circuit of Fig. 5.



use of the long-tailed pair switching circuit, shown in **Fig. 7**. A major tribute to the technical superiority and innovative quality of this design was paid by the semiconductor manufacturers, who promptly copied the design philosophy and introduced monolithic ICs, starting with the CA3090 in 1971[6] and, as a more exact replica, in the MC1310, LM1310, CA1310 and so on in 1972[6].

Channel separation and distortion specifications for BBC and IBA transmitters, and for various decoder systems, fed from an ideal signal input, were quoted by Brook[7,8].

Although some minor improvements have been made in the circuitry used in this IC system, it is undoubtedly true that the majority of contemporary stereo FM tuners use the 1310 type of decoder. Its only drawback is that the 38kHz square-wave switching waveform, which is rich in odd-order harmonics, will also demodulate wide-band noise or adjacent-channel signal components based on its 3rd and 5th harmonic frequencies if they are present in its input signal; this may degrade the overall stereo s/n ratio.

The problem of the unwanted demodulation of signals near the third harmonics of both the 19kHz pilot tone and the regenerated 38kHz sub-carrier has been addressed in the LM4500A. The basic PLL oscillator operates at 228kHz and the 19kHz and 38kHz waveforms derived from this by way of a three-stage Johnson counter are free of any second or third harmonics, or their multiples. Sansui, in its TU-D99X receiver, uses a Walsh function generator to synthesise a pseudo-sinusoidal 38kHz demodulator waveform to reduce harmonic-related interference from ultrasonic and adjacent-channel signals. An explanation of this technique is given by Thomas[9].

Typical channel separation levels in excess of 45dB are claimed for most of the commercial PLL decoder ICs — a performance which could only be obtained using the frequency-multiplex systems of the type shown in Fig. 2 if their tuned circuits were very carefully aligned.

However, it should also be remembered that for this order of channel separation to be obtained in practice, with any of these decoder types, it is necessary that the relative amplitude and phase of the L+R and L-R modulation components should be correct in the input signal. This requirement places considerable demands on the gain and phase characteristics of the audio stages preceding the decoder.

Fig. 7. Long-tailed pair used in Portus and Hayward design was responsible for elimination of gain inequality.

PCM distribution

From the inception of the BBC broadcasting service it had been customary for the BBC to rely on high-quality telephone-line links to carry the programme signals from the studio to the transmitter; in these early days, the transmitter was likely to be fairly close to the studios and a close relationship had grown between the BBC and the GPO for the maintenance of this service.

However, the bandwidth of even these high-quality links was only some 50Hz-10kHz and the proposed audio bandwidth of 40Hz - 15kHz for the new FM service could not be guaranteed, particularly for lines serving some of the projected, more remote transmitter locations. Moreover, with the new stereo broadcasting service, precise time coherence between the L and R signal channels would be essential, since any relative time delays would alter the apparent stereo image position.

The BBC decided to make use of the existing 6.5MHz-bandwidth television transmission network and to encode the audio signals in digital form. This approach was similar to that subsequently adopted by Philips in their Compact Disc recording system, but at a 13-bit rather than 16-bit resolution level, and with a 32kHz sampling rate instead of 44.1kHz.

This sampling rate imposed an absolute upper limit of 16kHz on the audio pass-band so, to allow a practicable low-pass filter slope, the broadcast signal bandwidth was amended to 40Hz-14.5kHz (0.2dB). The BBC 13-channel PCM encoding system is shown schematically in **Fig. 8**.

The way this works can be explained most easily by considering the path of a single signal channel, in which the signal first passes through a 15kHz low-pass filter with a very high attenuation rate, followed by the HF pre-emphasis network — 50μs in the UK and Europe.

Effective low-pass input filtering is essential in any digital encoding system because the presence of any signal components at a frequency above half the 32kHz sampling rate would create problems of aliasing, in that signals above 16kHz would be reproduced identically to those at the same frequency interval below 16kHz.

An intrinsic characteristic of the PCM system is that, after the final digital-to-analogue decoding process, the recovered waveform has a staircase-type structure in which the relative size of each individual step is determined by the sample resolution. To reduce the extent of this granularity distortion, which becomes more significant as the amplitude of the encoded signal becomes smaller, the overall input signal level to the encoder should be as high as possible.

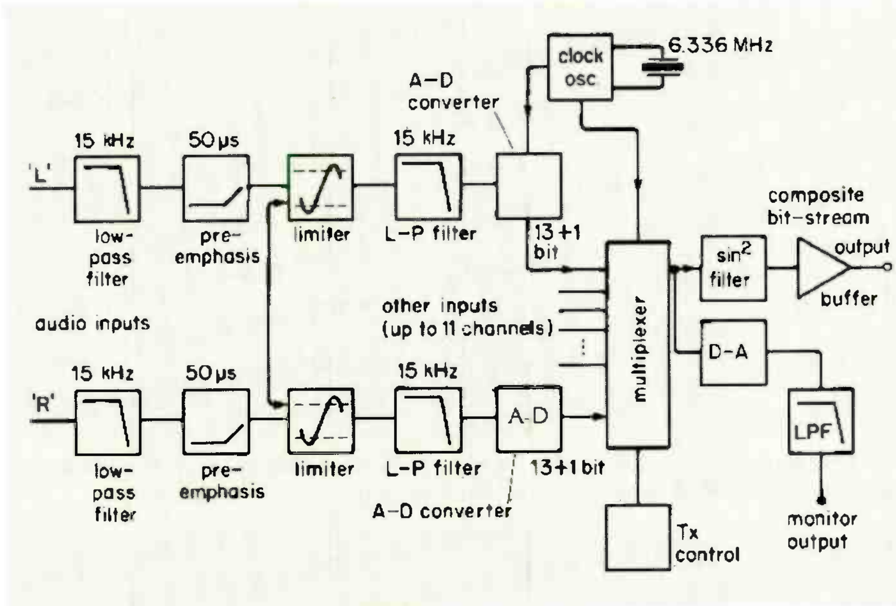


Fig. 8. BBC 13-channel pulse-code modulation system for programme distribution.

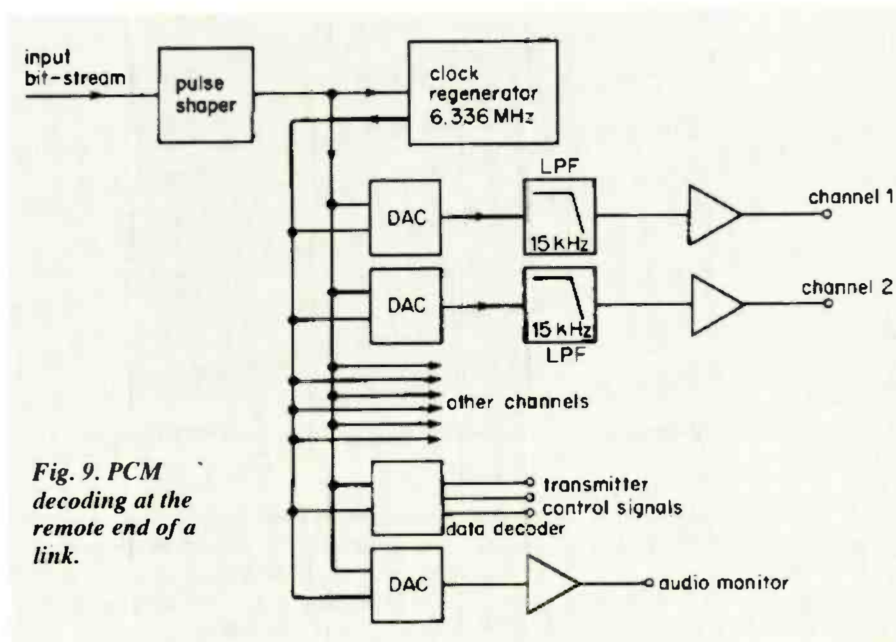


Fig. 9. PCM decoding at the remote end of a link.

On the other hand, it is essential that this A-to-D encoder should not be overloaded, and also that the signal should not be subjected to hard clipping, since both of these would produce audibly unpleasant effects. The BBC therefore use delay-line type limiter circuits, in which the signal is delayed for long enough for an appropriate and gradual reduction in gain level to be applied. These limiters are arranged to have an absolute maximum output level of 2dB above the nominal peak programme level.

An ingenious feature of these limiters is that their actions are linked, so that if the peak output level is exceeded in one half of a stereo channel, the other channel is also limited to prevent any sudden shift in the position of the stereo image.

Since the action of peak limiting can itself introduce harmonic components, the signal encounters a further 15kHz low-pass filter before passing to the A-to-D encoder. A clocked, double-ramp-type converter transforms the amplitude and bandwidth-limited signal into a digitally encoded pulse train which is fed, along with the bit streams from up to twelve other channels, to a time-domain multiplexing circuit.

The output pulses from this are fed through a sine-squared filter, which greatly reduces harmonics beyond the second, giving a final output of a rounded-off pulse of 158ns duration at 158ns intervals. Since there is little harmonic output above the second, there is a negligible energy

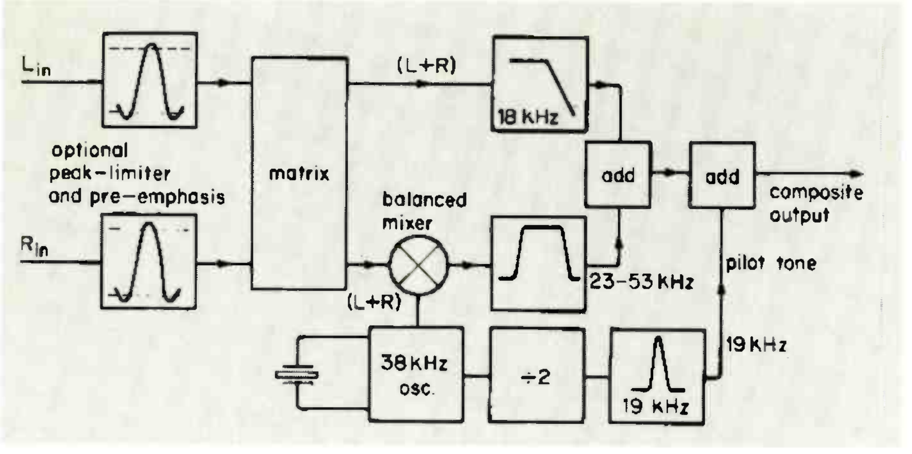


Fig. 10. Zenith-GE encoding system, one of which is required for each programme at each transmitter. 40dB carrier suppression is obtained.

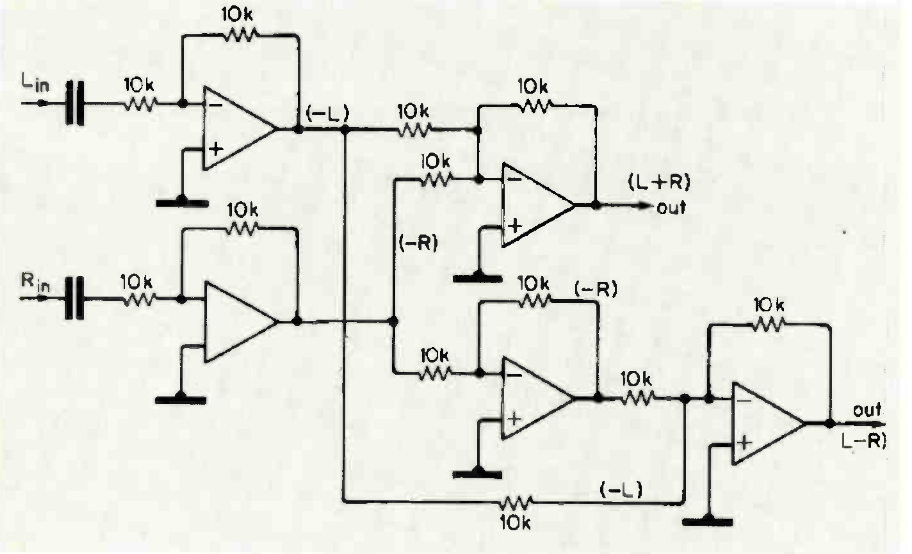


Fig. 11. Matrix circuit used in arrangement of Fig.10 to generate L+R and L-R signals.

content above 6.33MHz, which allows the composite signal to be carried by a 625-line TV channel.

As in the Philips Compact Disc system, a parity bit is added to each preceding 13-bit word. This provides a check on the accuracy of encoding of the preceding five most significant digits, so that if an error is detected, the faulty word can be rejected, and the preceding 13-bit word substituted.

If the error persists, the signal output is muted until a correctly encoded signal is again received. This technique gives a high degree of immunity to noise and transmission-line errors.

With a 32kHz sampling rate, the 6.336MHz channel bandwidth allows a group of 198 bits in each sample period. This contains 13 multiplexed 14-bit channels (182 bits) and 16 spare bits. Of these, 11 are used to control the multiplexing matrix and four are employed to carry transmitter remote-control instructions.

Decoding system. At the receiving end, the incoming bit stream is cleaned up, decoded using the circuit layout sketched in **Fig. 9**, and fed to the stereo encoding system, described below.

Stereo encoding systems. The technique employed in the Zenith/GE stereo encoding system is shown in **Fig. 10**. In this, the input left and right stereo channels are passed through a matrix circuit, such as that shown in **Fig. 11**, to generate a pair of L+R and L-R signals. In principle, an encoder of this type is required for each programme channel at each transmitter location.

The L+R (mono) signal, occupying the 40Hz-15kHz part of the audio spectrum, is then filtered and added to the double-sideband L-R modulated output of a balanced mixer, fed from a 38kHz crystal controlled oscillator, which gives rise to the 23-53kHz part of the modulation spectrum. If the mixer is accurately balanced, the 38kHz carrier component will be largely absent from the mixer output — 40dB suppression is typical.

Signal from the 38kHz quartz oscillator is then divided in frequency by two, filtered and phase corrected to provide the required sinusoidal 19kHz pilot tone, which is then added to the signal to allow the suppressed 38kHz carrier waveform to be regenerated within the decoder circuit.

Additional carrier signals

In the USA, supplementary sideband components have been added to the FM stereo signal for some years. They are called SCA (Subsidiary Communication Authorisation) or Storecast, and consist of signals transmitted as a 10% level double-sideband modulation based on a 67kHz sub-carrier. These signals are usually relatively low-quality continuous broadcasts intended to provide background music for restaurants and supermarkets; stereo FM receivers designed for use in the USA need care in decoder design to prevent inadvertently demodulated SCA signals from interfering with the wanted programme.

In Europe, an additional low-level, (3% modulation) HF signal is now added as a carrier for Radio Data System (RDS) broadcasts, which provide time, station identification and programme and road traffic information. This is transmitted as a phase-shift keyed, 7.5kHz bandwidth modulation of a 57kHz sub-carrier, initially locked in quadrature to the pilot-tone third harmonic to avoid interference with other 57kHz sub-carrier modulation.

Data is transmitted in 16-bit words at 1187.5bit/s and allows a variety of supplementary data to be broadcast. A full explanation of this system and its potential has been given by Shute[10], and commercial RDS decoders are now available as DIY add-on components for existing FM receivers. They usually require effective screening to avoid interference with the audio output signals.

Frequency synthesiser systems

Domestic users of FM receivers demand some means of accurate, preset, push-button station selection. This required accurate and stable tuning mechanisms — better, probably, than could be obtained from the existing Varicap-diode voltage-controlled tuning systems — and has encouraged the development of relatively low-cost, IC-based frequency-synthesiser techniques, using variations of the method outlined in **Fig.12**.

In its simplest form, the outputs of both the local oscillator X in the receiver frequency changer (which is voltage controlled because of the varicap tuning sys-

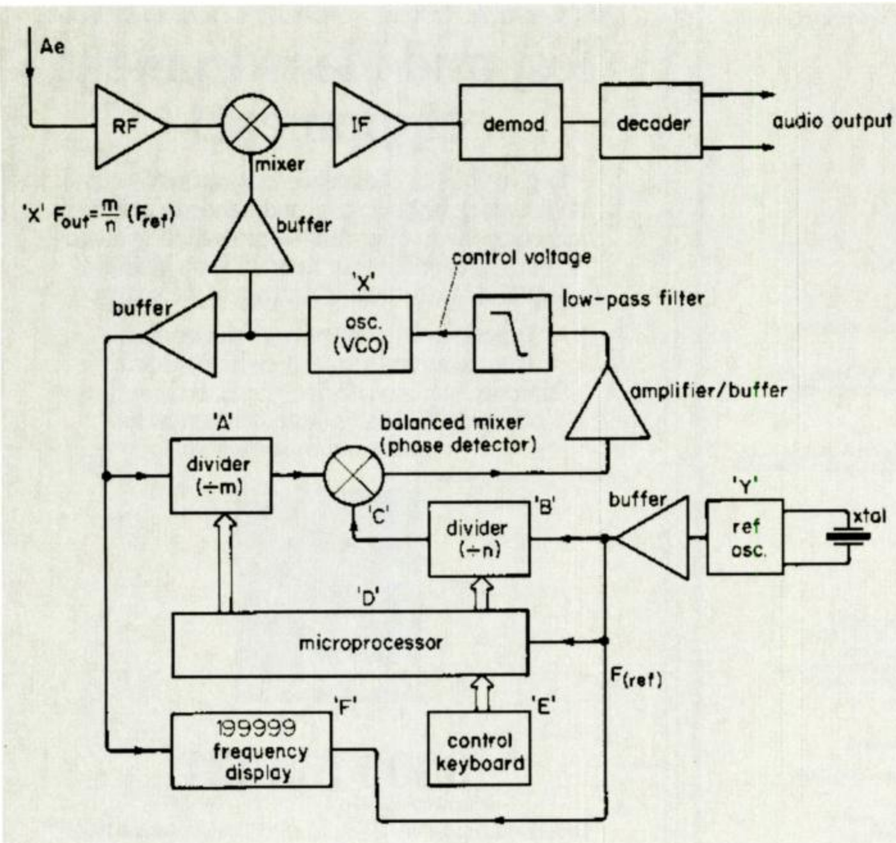


Fig. 12. Phase-locked-loop frequency synthesiser provides simple and accurate tuning for domestic users.

tem) and a highly stable, quartz crystal controlled oscillator Y are fed through a pair of frequency dividers A and B to a phase detector C. The output from this, after amplification and filtering, is then used to control the frequency of the local oscillator in a phase-locked loop, so that the output frequency is precisely held to mF_{ref}/n.

Precise values of the division ratios m and n are controlled by a microprocessor D, in response to the input commands from a push button station selector E; the tuned frequency is also displayed by a frequency counter system F. It is common practice for all the function blocks A-F to be combined in a single IC.

Requirements of the frequency dividers are simplified somewhat by the fact that, by international agreement, the operating frequencies of all VHF FM transmitters within the 88-108MHz band are held to exact multiples of 100kHz.

The elaboration of the receiver system will depend on its price bracket, but it is fairly common for current models to offer switched options for tuner selectivity, and also for stereo/mono blend to optimise both selectivity and signal-to-noise ratio. Receivers also incorporate a battery back-up system for preserving the microprocessor memory, so that the tuning data for a given channel can be stored during switch-off.

With the growing availability of RDS information, it is practicable for details of both the station selected and the programme being received, to be displayed on an information panel.

It is also feasible for the tuner to select automatically either the type of programme material required — speech, drama, pop or classical music — or the transmitter giving the best signal strength for that programme. This will be of particular value to car radio users travelling through the reception areas of local transmitters.

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Editorial survey: use the information card to evaluate this article. Item I.

BEYOND THE BLUE HORIZON

Continued from page 404

Azimuth accuracy and resolution suffer for the same reason and, in addition, imprecision increases with range as the beam widens. In poor conditons tolerances can be several tens of miles.

At a typical 20m, the wavelength is bigger than the largest dimension of the smallest aircraft, so that the radar cannot show the shape of a target except possibly the very largest.

In practice, imprecision does not matter at the very long distances involved; modern fighters have airborne radars with ranges of 100 miles and need to be directed only to the general area of a threat.

Over-water radar diffraction

This work has also involved a different type of OTHR. If the transmitted beam is directed, not at the ionosphere but very low over the sea, it interacts with the sea surface in a way that bends the path of the beam to follow the sea surface; the same interaction affects returns from targets near to the surface, so long-range, low-level, over-water radar is possible.

The continuous interaction attenuates the power of transmission and reflections more than happens with ionospheric-reflection OTHR, but detection ranges of several hundred miles are possible. Marconi companies have built a demonstration system on the south-east coast of England that consistently detects aircraft flying at low level underneath any likely radar beam. It uses 250μs pulses, not continuous transmission, but this is solely so that transmitting and receiving arrays can be on the same site to avoid having to find two sites on the crowded south-east coast.

Frequencies used are between 4MHz and 8MHz and the beam is steerable electronically through 90°; there are six receiving beams, which overlap. A target appears in more than one and signal amplitudes are compared to compute the bearing. Range/azimuth radar cells are typically 10 miles square and Doppler processing fixes the radial velocity of an aircraft to within a few knots.

Amplitude of sea clutter is enormous and the six receivers have dynamic ranges of 100dB to cope with the clutter at one end of the scale and the minute amplitude of wanted signals at the other. For each cell, data from more than eight thousand pulse returns is collected and integrated over typically 16 seconds to build up target signals present.

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Tektronix 491 spectrum analyser – 10Mc/s–40GHz – £1000 + manual.
Tektronix 491 spectrum analyser – 1.5GHz–40GHz – as new – £1200 + manual.
Tektronix DC508A – 1.3GHz counter + TM500 mainframe – P.O.R.
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Tektronix mainframes – 7603 – 7623A – 7633 – 7704A – 7844 – 7904 – TM501 – TM503 – TM506 – P.O.R.
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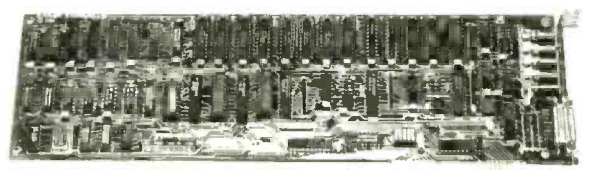

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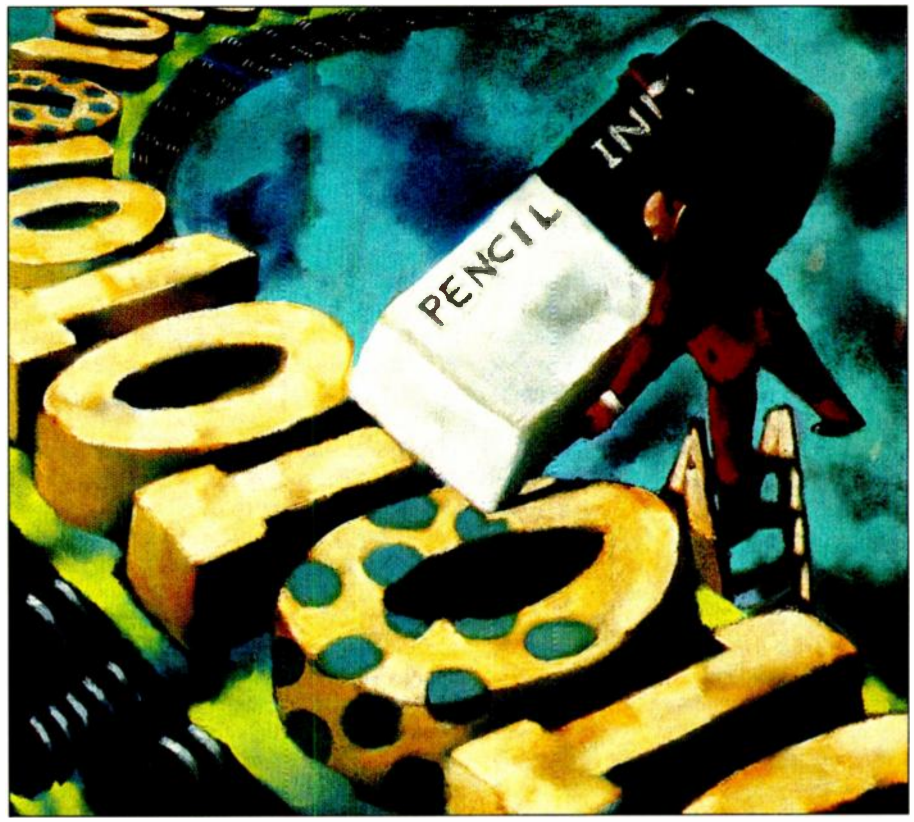

FEC, CRCS AND ERROR CORRECTION

Error detection in digital data communication is well known. But to correct errors without asking for re-transmission has an aura of magic about it. David Bacon reveals the trick

With computers routinely pushing zillions of bits around without a single error, digital methods can seem infallible. In many cases, however, and particularly in data communications, it is not economic to build-in the noise immunity enjoyed by computers. Some form of error recovery then become essential.

An important and fascinating class of error protection is known as forward error correction, or FEC for short, which has the ability not only to detect errors, but to correct them, and to do so without requesting any re-transmission of the original data.

FEC coding is based on completely way-out mathematics and has a reputation for being incomprehensible, at least to normal people! This reputation is undeserved; although the theory may be pretty opaque, FEC coding is quite straightforward to implement, in either hardware or software. In this article, I will try to give an insight into how FEC methods work, with the minimum of mathematics and enough details to put FEC coding into use.

Hamming space

First, a look at the useful concept of Hamming space. Most engineers know that the Hamming distance between two binary words (of the same length) is the number of corresponding bits which are different. Hamming space is simply the space in which Hamming distances exist. Thus the binary values 10011011 and 10111010 are separated by 2 in Hamming space, since they differ in two bits.

The simple parity bit illustrates the principle of Hamming space. **Figure 1** shows the complete Hamming space diagram for a 2-bit value protected by an even parity bit, which is chosen such that there is an even number of 1s in every 3-bit word. The Hamming space diagram shows all eight possible words, of which half are valid (an even number of 1s) and the other half are invalid. You can quickly see, by inspection, that no two valid words are adjacent. Every valid word is separated by a Hamming distance of 2 from every other valid word. This immediately shows how the parity bit can be used to detect a single-bit error. Every word is transmitted with the overall even parity. If, in transmission, one bit gets changed, this moves the word a Hamming distance of 1, so the word can only become one of the invalid values.

At the receiving end, each word needs to be tested simply to see whether it is valid or not. This can be done by indexing into a hardware or software look-up

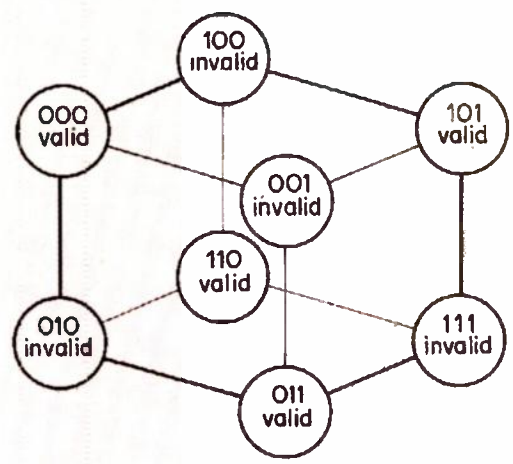

Fig. 1. Complete Hamming space diagram for 3-bit even parity

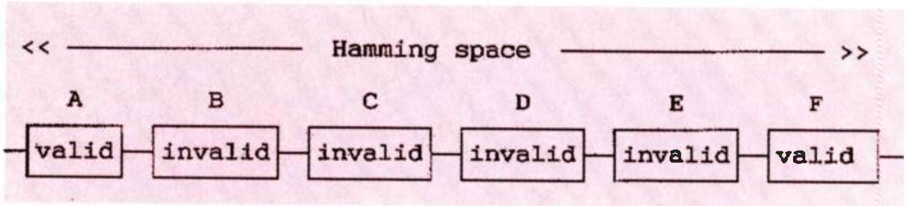

Fig. 2. A Hamming separation of 5

table, which is much faster than counting 1s. However, with the simple parity bit, errors can only be detected, not corrected because although it can be established that an incoming word is invalid, there is nothing to indicate which valid word was transmitted.

Correcting errors

Now suppose there was a way of adding several bits to the information to be sent, such that the valid words are all separated by Hamming distances larger than 1. Since there are now several times the number of invalid words than valid words, the valid words should be distributed uniformly within the available Hamming space such that their minimum spacing is as large as theoretically possible. Consider a tiny fragment of such a Hamming space diagram, as shown in **Fig. 2**. Here, two valid words, A and F, are Hamming 5 apart. If an incoming word arrives in the form of C, the most probable interpretation is that it started as A, and suffered two bit-errors in transmission. Thus, it should be corrected to A. A word arriving as D or E would be corrected to F.

If the Hamming separation between valid words throughout the entire diagram is nowhere less than 5, you can correct up to two errors in each word. This is the basis of FEC. The only problem is how to compute the additional bits needed to distribute valid words evenly throughout Hamming space. But first, some essential terminology.

Coming to terms

A very common situation, for example a 7-bit Ascii character protected by, say, an even parity bit, can be described in FEC terminology as "even-parity (8,7)". This gives the following information: "Each transmitted word, consisting of data plus protection, has 8 bits, of which seven bits are the data and the rest protection. Protection bits are computed by even parity."

The complete 8-bit word is called the codeword, the 7-bit block of data being the message; the remainder, in this case just 1 bit, is the suffix. The description before the brackets indicates how the suffix is computed. In this case, it is by even parity.

Even-parity (8,7) can only detect a single-bit error in each 8-bit codeword. It cannot correct errors, so it isn't an FEC code. In contrast, there is a real and very powerful FEC code called Golay (23,12), in which the data to be transmitted must be split up into 12-bit messages. An 11-bit suffix is then added to each 12-bit message to make a 23-bit codeword. The complete set of valid codewords has the remarkable property that their minimum Hamming distance is 7. If you mentally expand Fig. 2, you will see that this allows correction of up to three errors in each codeword.

Computing the suffix

In a datacomms specification using Golay (23,12), the error protection is likely to be defined something like this:

> "Error protection is provided by Golay (23,12) coding having a generator polynomial G(x) given by
>
> $$G(x) = x^{11}+x^{10}+x^6+x^5\ x^4+x^2+x^0$$
>
> The suffix F(x) is computed such that $x^{11}.M(x) + F(x)$ is a multiple of G(x), where M(x) is the message polynomial."

This is the kind of thing which can be confusing if met unexpectedly. In fact, the computation is not particularly difficult. Since "Golay (23,12)" means that data will be transmitted in codewords of 23 bits, of which 12 bits consists of the actual message, an 11-bit suffix must be added. (In practice an extra dummy bit is usually thrown in to make the codeword up to the more convenient size of 24 bits, or 3 bytes, but ignore this.)

The next thing is the value of the generator polynomial G(x), in which the use of "x" may need explanation. It is often retained because the original maths allows arithmetic to any base. In a binary world, x = 2, and thus G(x) is the binary value

110001110101

or the 12-bit value C75 in hex.

Message bits are always transmitted first, followed by the suffix. So, considering first the message, here are the 12 bits written in transmission order:

a b c d e f g h i j k l

The "a" is transmitted first and, in datacomms, it is normal for data to be transmitted in increasing order of significance, so that "a" will be the least-significant bit of the actual data.

However, in the maths used to calculate the suffix, bits written in transmission order are taken in the normal sense of most-significant on the left. So, while computing the suffix, treat the message purely as a string of bits. Ignore meaning, and treat "a" as most-significant.

To add the suffix, make space at the least-significant end of the codeword. Provisionally, do this by adding 11 zeros, so the prototype codeword, now the correct length but not yet the correct value, in transmission order, looks like:

a b c d e f g h i j k l 0 0 0 0 0 0 0 0 0 0 0

Adding 11 zeros at the least-significant end of a binary number is equivalent to multiplying it by 2^{11}.

This is the origin of the term $x^{11}.M(x)$ above: it is simply clearing space for the suffix.

Now, to compute the actual suffix, the 23-bit prototype codeword as above must be divided by the generator polynomial G(x). The remainder, when this division is completed, is the suffix, and is used in place of the 11 zeros.

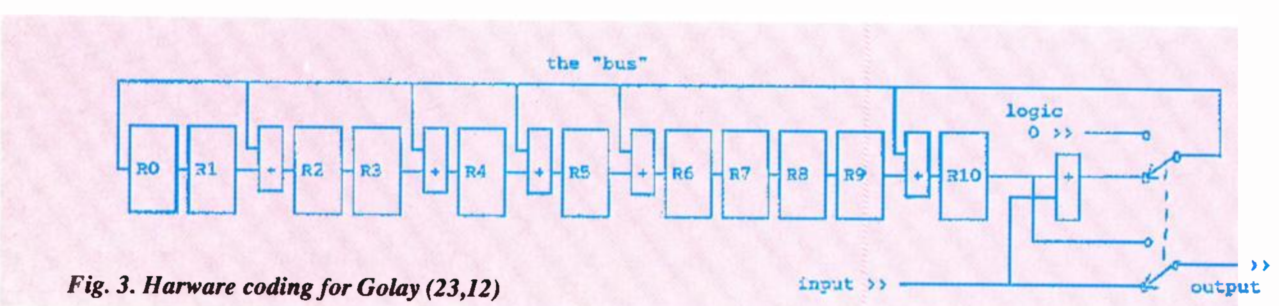

Fig. 3. Harware coding for Golay (23,12)

INTERFACING WITH C

by

HOWARD HUTCHINGS

C HERE!

If you have followed our series on the use of the C programming language, then you will recognise its value to the practising engineer.

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To complement the published series, Howard Hutchings has written additional chapters on D-to-A and A-to-D conversion, waveform synthesis and audio special effects, including echo and reverberation. An appendix provides a "getting started" introduction to the running of the many programs scattered throughout the book.

This is a practical guide to real-time programming, the programs provided having been tested and proved. It is a distillation of the teaching of computer-assisted engineering at Humberside Polytechnic, at which Dr Hutchings is a senior lecturer.

Source code listings for the programs described in the book are available on disk.

Modulo-2 arithmetic

The only thing you need to know, which is sometimes explained and sometimes assumed, is that division must be according to the rules of modulo-2 arithmetic. Since division can be accomplished by repetitive subtraction, we only need to define modulo-2 subtraction.

Modulo-2 works on the principle that there are only two numbers in the Universe, namely 0 and +1 (not even -1). Thus there are only four possible subtraction sums, which are:

0 - 0 = 0
0 - 1 = 1
1 - 0 = 1
1 - 1 = 0

Digital hardware engineers will recognise this as the exclusive-Or function. It is also the same as modulo-2 addition, represented by the "+" symbol in circuit diagrams to follow.

Back to school — long division

To calculate a sample Golay (23,12) codeword, assume that the data to be sent is the current year, 1991, expressed as a 12-bit binary number. Written with the most-significant bit on the left, this is 011111000111 transmitted, in normal datacomms practice, least-significant bit first. So because, in FEC maths, the first bit transmitted is the most significant bit, write the prototype codeword with the bits in reverse order and followed by 11 zeros:

11100011111000000000000

```
11100011111000000000000
110001110101
------------
 100100101100
 110001110101
 ------------
  101010110010
  110001110101
  ------------
   110110001110
   110001110101
   ------------
      111111011000
      110001110101
      ------------
        111010110100
        110001110101
        ------------
          101100000100
          110001110101
          ------------
remainder  11101110001
           ===========
```

Now divide this by 110001110101. Using the modulo-2 rules, this can be done by the old-fashioned school method of long division. Unlike 10-base arithmetic, in each column position the number being subtracted can either be subtracted once, or not at all. This depends purely on whether the most-significant bit of the previous subtraction is 1 or 0, respectively. Thus, after each subtraction, ignore leading zeros and just move the generator polynomial along to the next position, starting with a 1, pulling down enough digits to cover it.

Replacing the last 11 zeroes by the remainder now gives the correct suffix, and hence the valid Golay (23,12) codeword to transmit the decimal number 1991 is

11100011111011101110001

To confirm that this is a multiple of the generator polynomial, you should be able to divide it by 110001110101 and get a zero remainder.

Software implementation

The above division process can easily be done in software. Because in a real situation there will be many messages to code but only one generator polynomial, it is easier to bit-reverse the generator, which only has to be done once, and to process each message with the first bit to be transmitted in the least-significant position. This means swapping the above scheme left-to-right. The kernel of the task can be written in C as shown in the software Golay (23,12) coding:

```
int i;                              /* loop counter         */
unsigned long buf;                  /* working buffer       */
unsigned long poly = 0xae3;         /* bit-reversed         */
                                    /*   generator poly     */
buf = message;                      /* load message word    */
              /* note: higher bits = 0 where suffix will go */

for (i = 0; i < 12; i++)         /* do 12 times:            */
{  if (buf & 1)                     /* if leading bit = 1   */
      buf ^= poly;                  /*   subtract poly      */
   buf >>= 1;                       /* shift word for next  */
}
                                    /* (if required)        */
                                    /* assemble complete    */
buf = (buf << 12) | message;        /*   codeword           */
```

Figure 4. Software Golay (23,12) coding.

Rather than shifting the generator polynomial along the word, shift the word through the buffer so that, at the end of the For-loop, only the suffix is left in the buffer. If the complete codeword is needed, it can be re-assembled by shifting the suffix 12 places to the left, and Or-ing the message back into its original position.

The complete 23-bit codeword will now, of course, be an exact multiple of the generator polynomial, as required by the above sample of a typical specification.

It is this mathematical process, by means one can just view as magic if it seems too much like hard work, which arranges the valid Golay (23,12) codewords nicely spread out in Hamming space, with a minimum separation of 7.

Hardware implementation

For real-time datacomms you normally need to generate FEC codewords in hardware, using shift-registers and Ex-Or gates in a circuit which implements the long division process. In **Fig. 3** there are eleven shift registers R0 to R10 and six Ex-Or gates, indicated by "+". Dataflow is left-to-right through all of these. The ganged double-pole, double-throw switch represents gating. Starting with R0-R10 all cleared to zero and the ganged switches as drawn, the twelve message bits are applied in transmission order to the input and the registers and transmission hardware are clocked for each (twelve clocks). Then the ganged switches are moved to the other position, and a further eleven clocks will output the suffix and simultaneously clear the registers for the next codeword. Thus codewords can be generated continuously.

How does it do it? First, note that the positions of the Ex-Or gates coincides with the 1s in the generator polynomial, written with the least-significant digit on the left, except for the first 1. It might be worth mentioning here that generator polynomials always start and end with a 1.

Second, when the signal on the "bus" is a 1, clocking theregisters will do a modulo-2 subtraction of the generator plus a shift of the result one place to the right. When the bus signal is zero, only the shift occurs.

Third, the bus value comes from the Ex-Or gate on the extreme right, which performs a modulo-2 subtraction between each message bit in transmission order, that is decreasing significance, and the most significant bit of the result of any preceding subtraction and shift.

With this under your belt, and remembering the bit-reversal, it is not too difficult to see that Fig. 3 implements a modified form of the modulo-2 division (see box), in which each message bit is dealt with by itself, as illustrated in **Fig. 4**. It wouldn't work in 10-base arithmetic, but it produces the same result (as shown in the box) where there are no carries between columns.

Fig.4. Calculation using the "hardware

```
prototype codeword   11100011111000000000000
                     =======================

  message bit  0     1
  generator          110001110101
  subtract & shift   ------------
                      100011101010
  message bit  1      1
  just shift          ------------
                       000111010100
  message bit  2       1
  generator            110001110101
  subtract & shift     ------------
                        101101000010
  message bit  3        0
  generator             110001110101
  subtract & shift      ------------
                         111001101110
  message bit  4         0
  generator              110001110101
  subtract & shift       ------------
                          010000110110
  message bit  5          0
  just shift              ------------
                           100001101100
  message bit  6           1
  just shift               ------------
                            000011011000
  message bit  7            1
  generator                 110001110101
  subtract & shift          ------------
                             100101011010
  message bit  8             1
  just shift                 ------------
                              001010110100
  message bit  9              1
  generator                   110001110101
  subtract & shift            ------------
                               110110000010
  message bit 10               1
  just shift                   ------------
                                101100000100
  message bit 11                0
  generator                     110001110101
  subtract & shift              ------------
  remainder                      11101110001
                                 ===========
hence:
valid codeword       11100011111011101110001
```

Detecting and correcting errors without knowing the right answer depends on a special data coding. The Golay system multiplies a dataword and codeword at the transmission end, followed by a reciprocal factorisation on reception. The rigid pattern thus imprinted on the transmission stream can be sorted into predictable slots, even in the presence of errors.

The calculation is repeated in Fig. 4, using the method followed by the hardware, with each stage identified. The decision whether to subtract and shift, or just shift, depends only on the most-significant bit at each stage, as controlled by the right-most Ex-Or gate in Fig. 3. If you care to draw up a table of all register contents for each clock pulse in Fig. 3, you will find that they contain the remainder at each stage.

Decoding

There are various ways in which an FEC codeword can be error-corrected in software. A very simple "brute-force" method would be to generate a look-up table for every possible codeword, all 223 of them, for Golay (23,12). Although there are several refinements to this sort of approach, none has the elegance of the most widely used technique, the so-called "syndrome" method. Like the coding procedure, this relies on the remarkable features of modulo-2 maths, and can be readily implemented in either software or hardware.

Look first at the basic maths of the syndrome method. To make this less cumbersome, we will forsake the Golay (23,12) example for the time being, and turn to a much smaller code. This has (7,4) structure, and the generator polynomial is binary 1011.

Figure 5 shows two modulo-2 division calculations. The first takes the message 1000 and computes the suffix 101. The second takes the codeword 1000101 but with the third bit errored so it is 1010101, and performs a division to see if the remainder is zero.

It isn't: the remainder after dividing the incoming codeword by the generator polynomial is 110, indicating at least one errored bit. The syndrome procedure is now as follows. The division continues, with additional bits being supplied at the least-significant end of the word. These additional bits must be 0s when they cor-

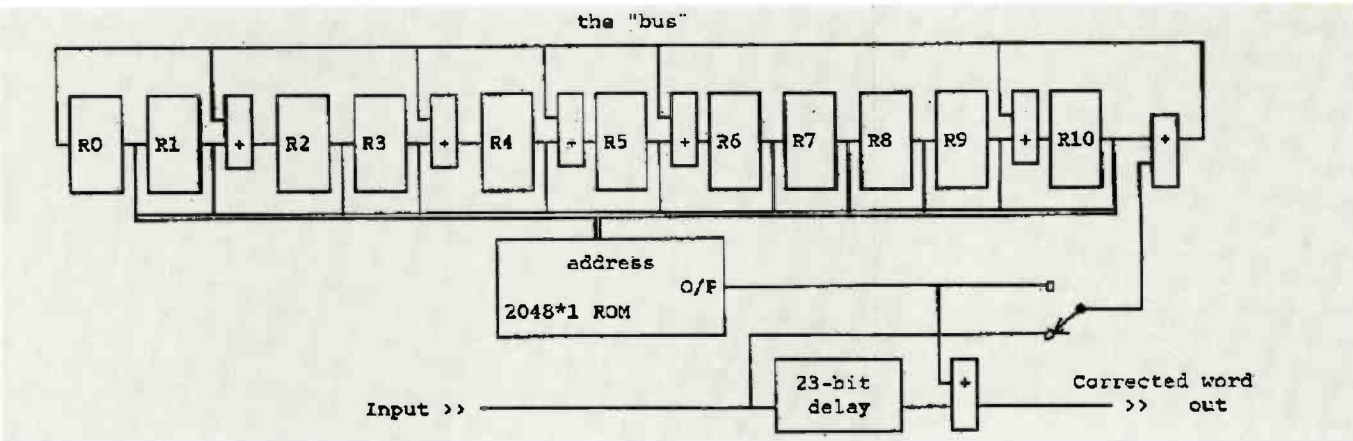


Fig 6. Arrangement of Fig.3 modified to decode and correct Golay (23,12) words.

respond to non-errored bits in the codeword, and 1s when corresponding to errored bits. In this example, since the third bit is errored and the rest are good, add two 0s and then a 1. The 1 reduces

```
Message - 1000
prototype codeword - 1000000
divide by 1011       1011
                     ----
                      1100
                      1011
                      ----
                       1110
                       1011
                       ----
remainder = suffix =    101
                        ===

Valid codeword      = 1000101
Errored codeword    = 1010101
divide by 1011        1011
                      ----
                        1101
                        1011
                        ----
Non-zero remainder      110 0010000
so continue with        101 1
additional bits         --- -
indicating position      11 10
of errors                10 11
                         -- --
                          1 011
                          1 011
                          - ---
Zero remainder after      0 000
last or only error        = ===
```

Fig.5. Two division sums, the second with the third bit in error. Is the remainder zero?

the remainder to zero and the example need not be taken any further.

Now the remarkable property of the maths at this point is that the remainders at each stage of the second division process map without ambiguity to the positions of the original errors. For instance, the last error in the word, wherever it comes, will always leave a remainder of 101. This is the first three bits of the generator: the last 1 is supplied, and thus the remainder goes to zero. If there are two consecutive errored bits, anywhere in the codeword, the penultimate remainder will be 010, and the last 101 as before. All remainders which require a 1 to be supplied, and which thus indicate an errored bit, are a unique function of the errored bit's position and the error pattern relative to the last errored bit in the codeword.

It is thus possible to supply the additional 0s and 1s for the repeat division from a look-up table or rom, and this can be "programmed" by running software which generates a test codeword with every possible combination of 2- and 3-errored bit patterns, relative to the last bit of the codeword, plus the one-error case.

Figure 6 shows how Fig. 3 can be modified to decode and error-correct Golay (23,12) codewords. The array of shift-registers and Ex-Or gates, which performs the modulo-2 division, is exactly as before. The 11 address lines of the 2048 by 1-bit rom are driven by the register outputs. Note that if you are using this hardware division system, the rom must be programmed with the remainders which appear in the bit-by-bit method illustrated in Fig. 4. This can be simulated in software just as easily as the "bit-parallel" division shown in Fig 5 (and the box).

In operation, the registers must be cleared to all zeros and the input codeword applied bit-by-bit, in transmission order, with the gating switch as drawn. The registers and the 23-bit delay register are clocked 23 times to put the complete codeword through the first division process. If the codeword contains errors the registers will now hold a non-zero value.

In practice, the second division would be run even for a zero remainder, since this is easier than omitting it. Thus after the complete codeword has been clocked through the registers, the switch is moved to its other position, and the system is clocked 23 more times. During this second process, the register contents will select 0s and 1s as required, according to the error pattern. The same bits are used to correct the original codeword, delayed by 23-clock periods.

Since it takes 46 clocks to correct a 23-bit codeword, the system needs to be duplicated to correct continuous codewords. With a little extra gating, the rom and 23-bit delay can be shared between both halves of such a system, but the rest would have to be doubled-up.

Can we draw any conclusions?

Well, for improved completeness a few comments can be made:

— There is a great deal more to FEC methods than the very short treatment given here.

— The FEC suffix is sometimes called a cyclic redundancy check, or CRC.

— A suffix computed from a generator polynomial can also be used for very efficient error detection, without correction. In these cases the message is much longer than the suffix, or even of indeterminate length.

— With a computer and a lot of time, you can go searching for efficient generator polynomials yourself. Choose a generator, and codeword and message sizes, compute the suffices for all possible messages, and find the smallest Hamming separation between valid codewords. You'll be lucky to be the first to find a useful code, but who knows?

Apart from that, in my opinion FEC codes are great fun. I also find it fascinating to think that the underlying maths is, and always has been, part of the Universe, waiting to be discovered and put to use. At least, that's what I think. Some would say that it didn't exist until someone first thought about it. Either way, I have enormous respect for those who did.

Editorial survey: use the information card to evaluate this article. Item

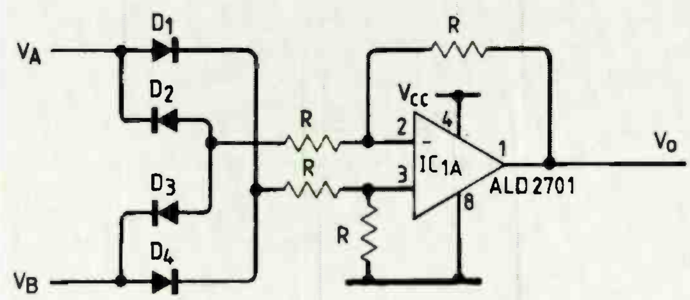
Absolute-value differencer

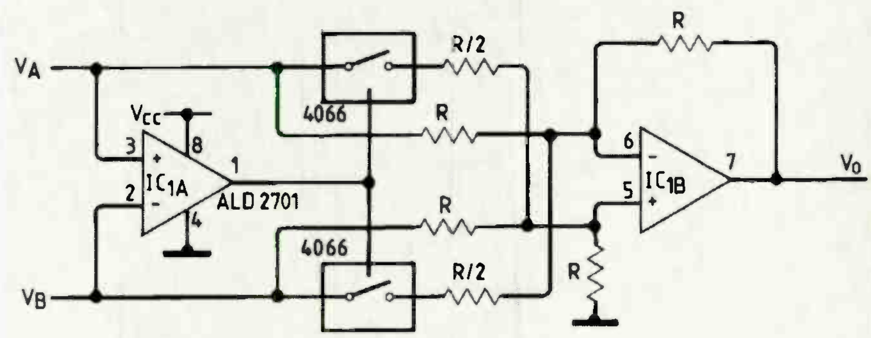
Using a single battery supply, the outputs of these circuits are (V_a-V_b) or (V_b-V_a), whichever gives a positive answer, which is the magnitude or absolute value of (V_a-V_b).

In the simple version (top), the more positive input, selected by D_1 and D_4 — a "highest wins" gate — to the non-inverting input. Diodes D_2 and D_3, which form a "lowest wins" gate, select the smallest input and feed it to the inverting input. The output is therefore the larger of V_a or V_b minus the smaller of V_a or V_b.

One disadvantage of the Fig.1 circuit is the forward voltage drop of the diodes. An improvement is the lower circuit, in which the diode gates are replaced by analogue switches controlled by an ALD2701 op-amp comparator, which has a good common-mode input voltage range and output swing and is therefore very suitable for battery-powered circuits. If a fast op-amp or a dedicated comparator IC were used in this position, a degree of hysteresis would be needed to avoid oscillation at the switching point.

M. Neal
London SW15





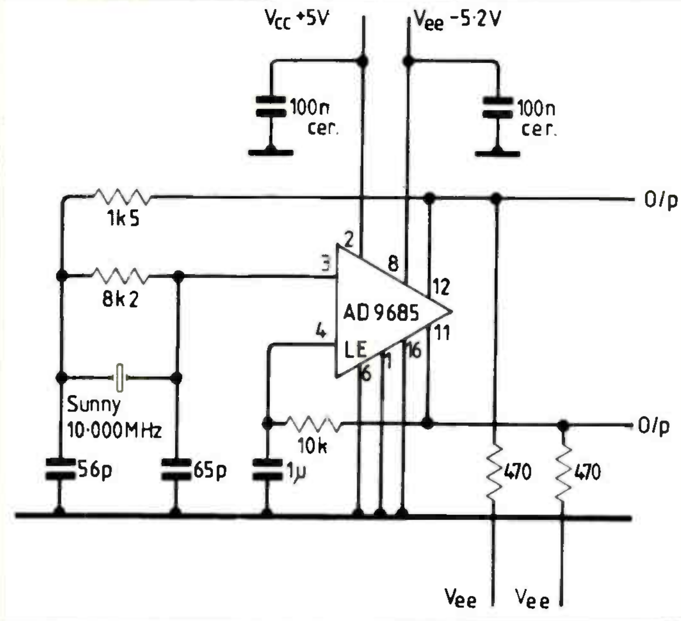
High-frequency digital oscillator

Needing a high-frequency digital crystal oscillator for use in a frequency synthesiser, I decided to save a few components by using a comparator as the oscillator to produce a square wave directly, instead of using a sine-wave oscillator and squaring the output with the comparator.

The circuit is similar to other oscllators of this type using one inverting gate, but not many gates can match the speed of the AD9685, which I used to produce ECL levels; for TTL levels, I would suggest the AD9686. A 10MHz waveform is obtained reliably, but I see no reason why much higher frequencies should not be obtained, perhaps with component value changes. Pay particular attention to the loading of the crystal. Using the 9685 gives the facility to drive a 50Ω load if the output is properly terminated.

Since the 9685 will oscillate at over 500MHz, a large, low-inductance ground plane is needed, as are short lead lengths and decoupling capacitors close to the supply pins. Analog Devices advise against the use of IC sockets.

Phil Denniss
Department of Plasma Physics
University of Sydney
Australia



40W voltage doubler

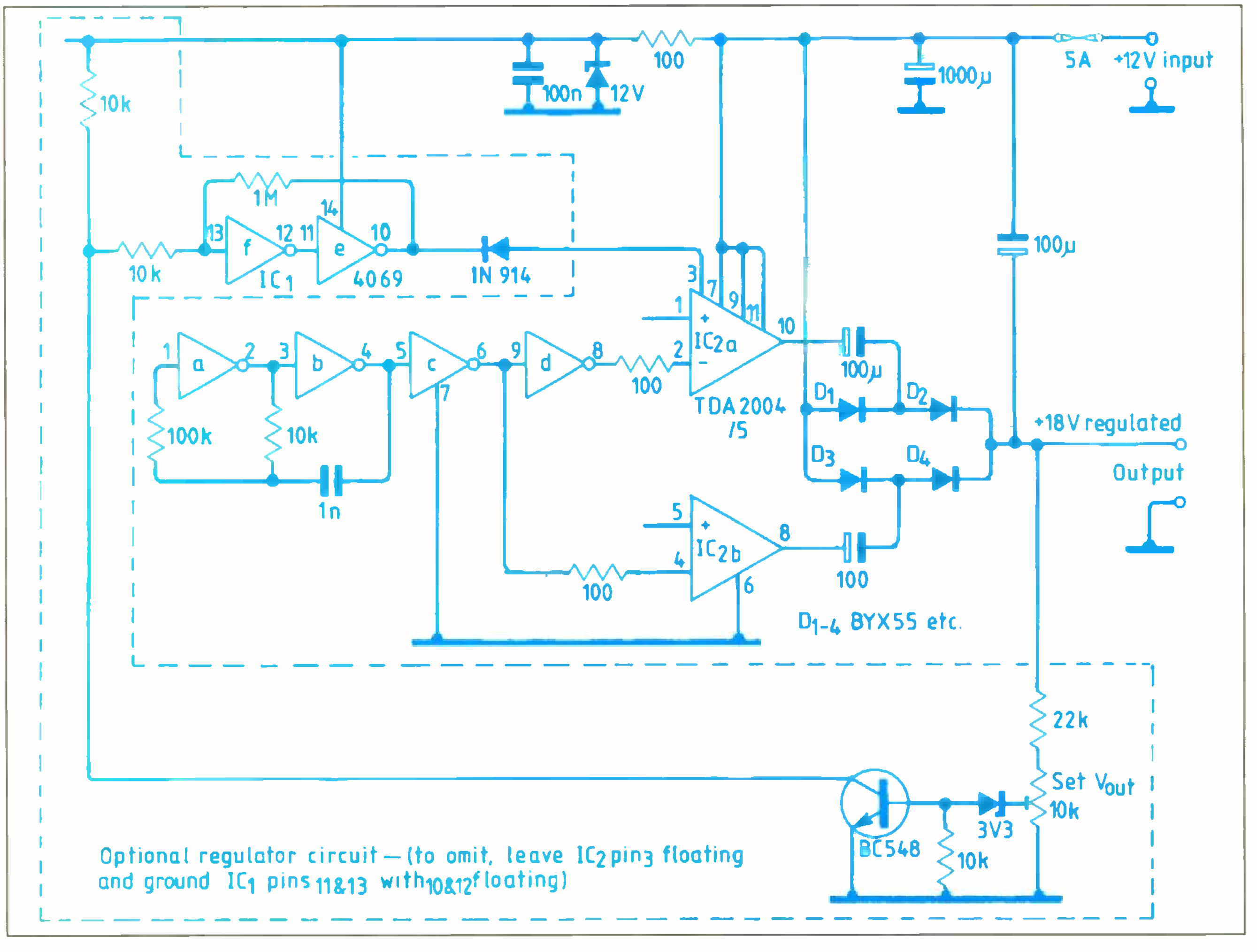
A cheap audio power IC, the TDA 2004/5, will serve to make a regulated voltage doubler giving up to 4A at 20V from a 12V car battery. The original circuit was designed to power a car radio amplifier, which needs an 18V, 4A(pk) regulated supply.

With a few extra components, the IC is used as a switching H bridge that includes thermal and overvoltage shutdown and current limiting. Since the transition times are 200ns when the IC is driven by more than 10V, switching rates of up to 300kHz can be used. In this circuit, the frequency is 35kHz; standard 85°C electrolytics give 2A continuous in an ambient temperature of 50°C or less. For higher temperatures, use 105°C, low-ESR capacitors.

Efficiency is 80% for loads of 500mA to 1.5A; Schottky diodes could be used for higher efficiencies, but are expensive.

The output voltage stays within 0.1V from no load to 2A and ripple is about 0.1Vpk-pk; no-load current is only 10mA. Thermal shutdown occurs after a few seconds when the output is loaded to 4A on a 13.5V supply.

Ian Hegglun
Manawatu Polytechnic
New Zealand



On-board transistor tester

This instrument will test transistors without removing them from the printed board. A 555 multivibrator oscillates at a frequency of 1kHz, its output being taken to a 7474 D-type flip-flop connected as a toggle, which produces complementary square waves (Q and /Q) at 500Hz. Diodes D_5 and D_6 are red and green leds in the same package. Base drive for the transistor under test comes from the mid-point of the Q and /Q potential divider.

With no transistor connected, the bicolour led appears amber, since both leds switch on and off at 500kHz. If a good p-n-p transistor is connected, it is on when Q is low and /Q is high, since its base/emitter is forward-biased; in this condition, neither led lights since a low Q reverse-biases D_5 and the voltage across D_6 is equal to $V_{CE(on)}$ which, for a good transistor is 0.1V. During the next pulse, Q becomes high and /Q low and a good transistor at the terminals will be off; in this condition, D_6 is off because it is reverse-biased and D_5 is on. The opposite effect applies if a good n-p-n transistor is connected.

A good transistor has a collector/emitter voltage of around 0.1V and a silicon diode drops about 0.6V. Each of the two loops formed by $D_{1,2}$ and $D_{3,4}$

Continued on page 425

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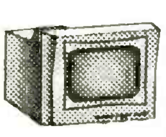

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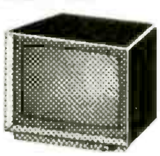

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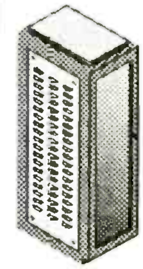

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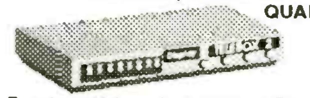

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between pins 5 and 6 of the flip-flop has one collector/emitter drop and two diode drops to impress on the leds which, at 0.1+1.2 = 1.3V, is insufficient to turn on one of the leds which stays off if the transistor is good and on if the device has one shorted junction to make it behave like a diode; in this case the voltage drop is 1.2 + 0.6 = 1.8V.

Therefore, one led lights if the transistor is good (both p-n-p and n-p-n); both leds are off for a transistor with shorted C/E junction; and both are on if the transistor is bad. Diodes $D_{1,2,3,4}$ prevent false indications of normality when a transistor with a B/C short or a B/E short is connected.

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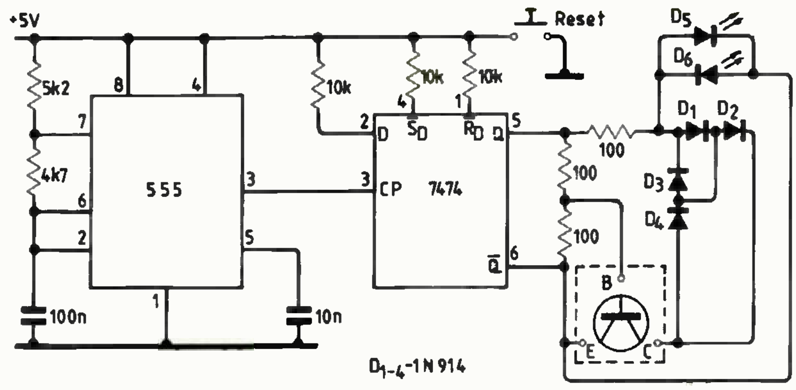
Centre for Development of Telematics
Bangalore
India

state	D_5	D_6
open C/E	flicker	flicker
short C/E	off	off
good p-n-p	on	off
good n-p-n	off	on



Single-phase to three-phase converter

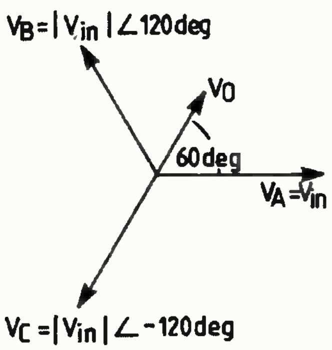
This is a method of deriving a three-phase sine-wave reference using a frequency tracking phase-shift network.

In the diagram, the analogue multiplier IC_1, with R and C, forms a voltage-controlled transfer-function generator, of which the transfer function is

$$(V_o/V_{in})(s) = (V_{CM}RCs)/(10+V_{CM}RCs) \quad (1)$$

where V_{CM} is the multiplier control voltage.

The input signal V_{IN} is half-wave rectified by IC_2 and the multiplier output V_O is half-wave rectified by IC_3 after being amplified by a factor of 2 in IC_3. Integrator IC_4 forms a low-pass filter and high-gain comparator for these two rectified signals, its output being the control voltage V_{CN} of the multiplier. This feedback loop maintains the magnitude of the transfer function at 0.5 and, under this condition, the phase of the transfer function is exactly 60°.



The phasor diagram shows how the other two phases are derived from the output of the transfer-function generator. If $V_A = V_{IN}$ is the reference phase, V_O has half the amplitude of V_A and leads it by 60°. In conjunction with the transfer-function generator, IC_6 forms an all-pass network which doubles the phase lead of V_O while restoring the amplitude to that of V_A to form the second phase V_B. The third phase V_C is formed by inverting V_O and amplifying it by 2 in instrumentation amplifier IC_5.

Input to the circuit must be sinusoidal with no DC offset, although input amplitude is not important. Operation is from 5Hz to 100Hz, distortion is less than 2%, phase error is better than 0.75degrees and the input should be between 1V and 5V.

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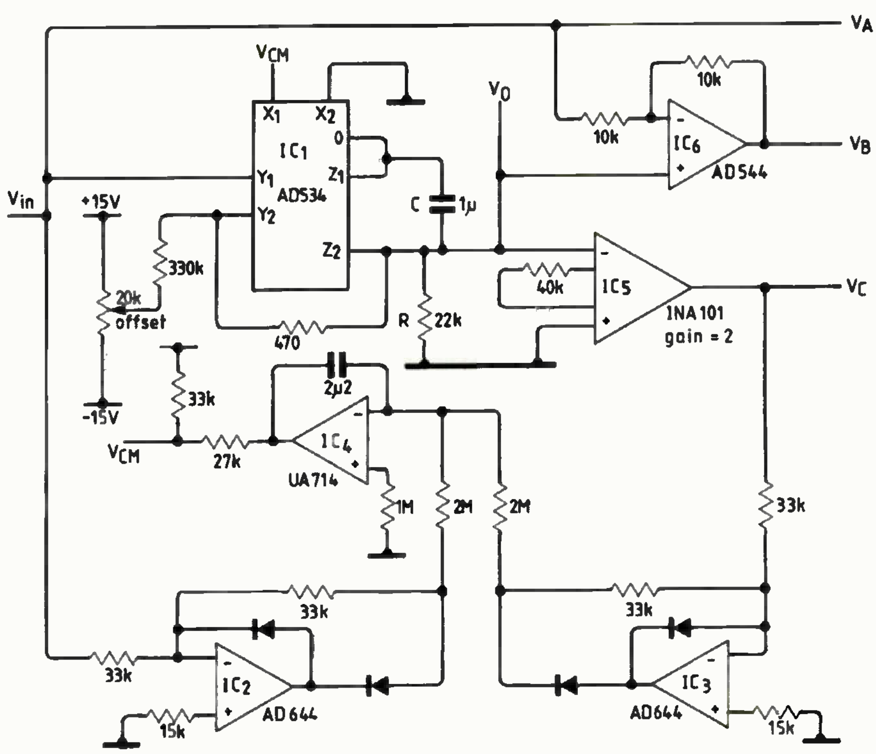
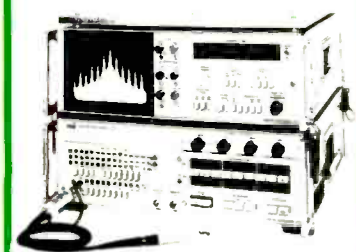
Indian Institute of Technology
Madras

Editorial survey. Use the information card to evaluate this article. Item K.





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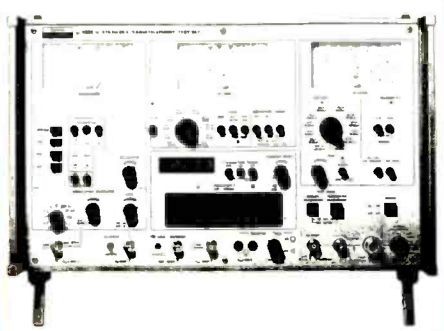

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CIRCLE NO. 143 ON REPLY CARD

Better video switch chips?

Video routeing places special demands in semiconductor switches. Siliconix has produced a special device for the job.

In discussions concerning picture-tube performance and transmission standards for high-definition television, it is important also to consider the means of switching and routeing auxiliary signals from various external equipment. Even now, the consumer is presented with a large selection of possible information and entertainment sources (video recorders, laservision players, home computers), all competing for the same display medium.

It is with the need for a flexible interface to external equipment in mind that this device has been developed.

DG894

The device is a monolithic, wide-band switch, capable of switching analogue or digital signals of up to 100MHz; it comprises fourteen switches, as shown in **Fig.1**. For convenience, these are labelled for RGB plus fast blanking signals, together with luma (Y) and chroma (C), which is the S-VHS signal input. However, these could be other video or wide-band or even audio signals as convenient. It comes in a 28-pin DIL package as standard and is intended for operation over the -40°C to 85°C temperature range.

Signal capability

Signal-handling capability is 4V pk-pk; for single-supply 12V operation, this allows an input of 0V to 4V. By using dual supplies of +12V and -5V, the input signal range may be shifted, allowing input voltages between -2V and +2V to be applied. This is how the device has been characterised, but these supplies would allow a signal swing of between -5V and +4V, if desired. Crosstalk is -70dB at 5MHz.

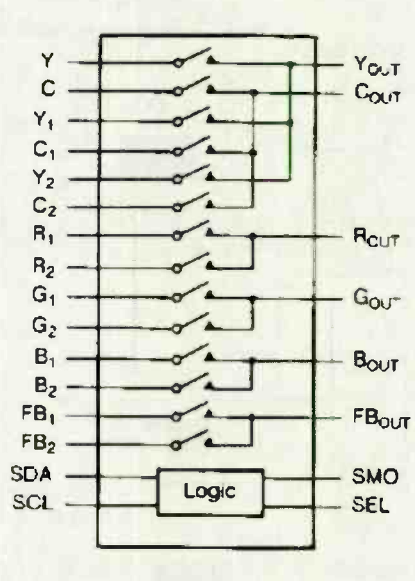
Switch configuration

The switches are fully bilateral, allowing signal transmission in either direction when closed, with an $R_{DS(ON)}$ of less than 100Ω.

Switch control may be either direct by parallel DC addressing, or serial via the Philips I²C bus, as appropriate. The Philips two-wire (data and clock) bus structure has been widely adopted for television and two addresses have been allocated for use with DG894.

As can be seen from the truth table of **Fig. 2**, with Serial Mode (SMO) selection pin at logic 0, the address to which DG894 responds will be determined by the logic state of the SEL (SELect) pin. This allows two of these devices to be used simultaneously on any I²C bus system, while retaining independent control. Two further addresses have been allocated by Philips, so that a second version of the device, with different metal-mask, could allow simultaneous operation of four of these switch arrays, if desired.

The truth table also shows the eight selections possible by DC address control where the I²C bus is not implemented. Note that in this mode the SEL pin dou-



TRUTH TABLE

SMO	SEL	SDA	SCL	FUNCTION
0	X	I²C Bus Operation		
1	0	0	0	All Switches OFF
1	0	0	1	Y.C
1	0	1	0	Y1.C1
1	0	1	1	Y2.C2
1	1	0	0	SCART1
1	1	0	1	SCART2
1	1	1	0	SCART1.Y1.C1
1	1	1	1	SCART.Y2.C2

X = Don't care

Fig.2. Truth table. With SMO at 0, DG894 responds to address set by SEL pin.

Fig.1. Arrangement of switches in the DG894.

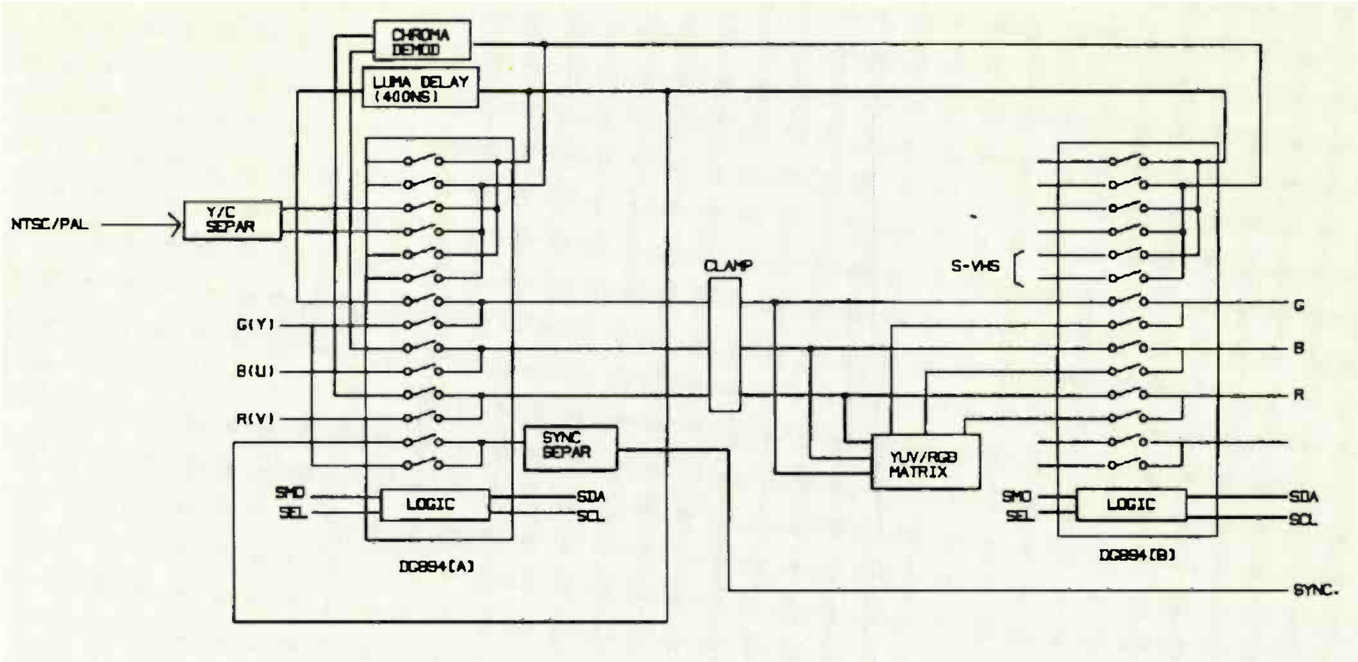


Fig.3. DG894 used as multi-standard converter, switching a number of input formats to RGB plus sync output to the receiver.

bles as one of the address lines, so minimising the pin count.

It should also be pointed out that the number of switch-state selections is only limited to eight by the number of address lines available; in the I²C bus control mode, further combinations such as Y,C plus Scart1; Y1,C1 plus Scart2 are possible).

Applications

The chip can obviously be used singly, for example, to switch between two Scart connections and/or three S-VHS connections.

Alternatively, **Fig.3** shows an application which uses two DG894 plus some standard circuit blocks to switch a variety of input standards to a common RGB plus sync output.

Process

The device is fabricated using Siliconix's d/cmos process, allowing optimisation for high-frequency signals, while maintaining low on-resistance and low capacitance. On-chip cmos circuitry provides the necessary level shifting, logic interface and latching functions to ease system design.

INPUT	DG894[A]				DG894 [B]			
	SMO	SEL	SDA	SCL	SMO	SEL	SDA	SCL
PAL/NTSC	1	1	1	0	1	1	0	1
S-VHS	1	1	0	0	1	1	1	1
RGB	1	1	0	1	1	1	0	0
YUV	1	1	0	1	1	1	0	1

Should even higher bandwidths and/or lower crosstalk be required, this is possible by the construction of T switches, together with the necessary control logic, on chip. **Figure 4** shows a cross section of an n-channel device made with the d/cmos process, incorporating dmos and pmos transistors. The fabrication of the T switch is shown; the short channel feature of the

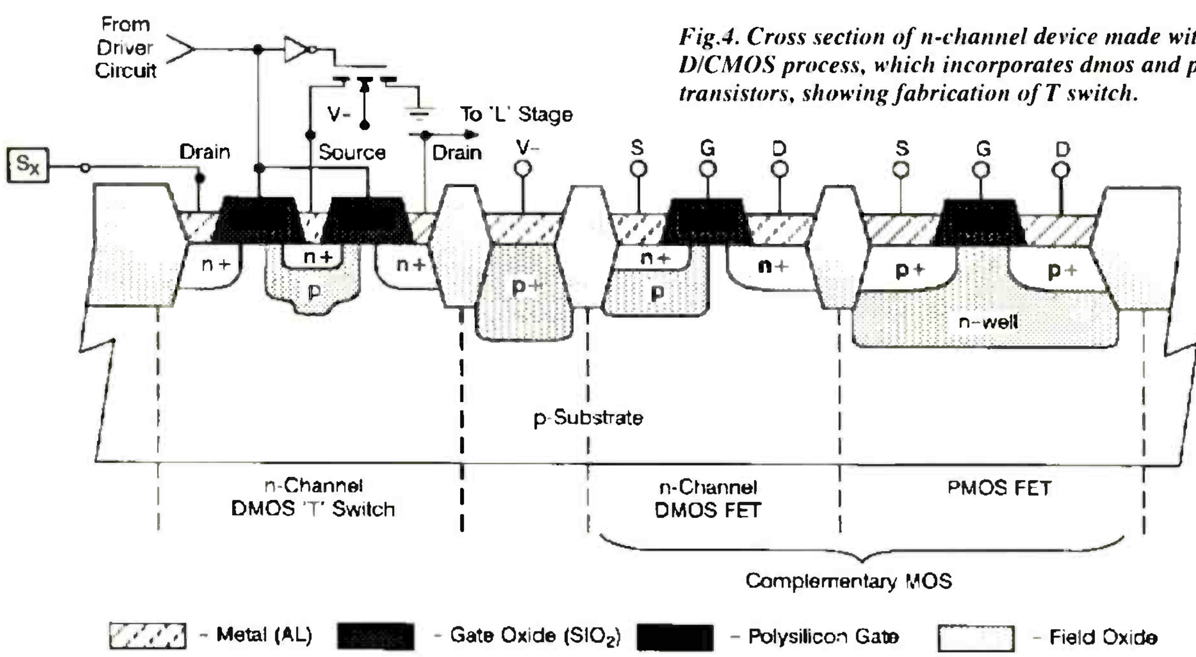


Fig.4. Cross section of n-channel device made with the D/CMOS process, which incorporates dmos and pmos transistors, showing fabrication of T switch.

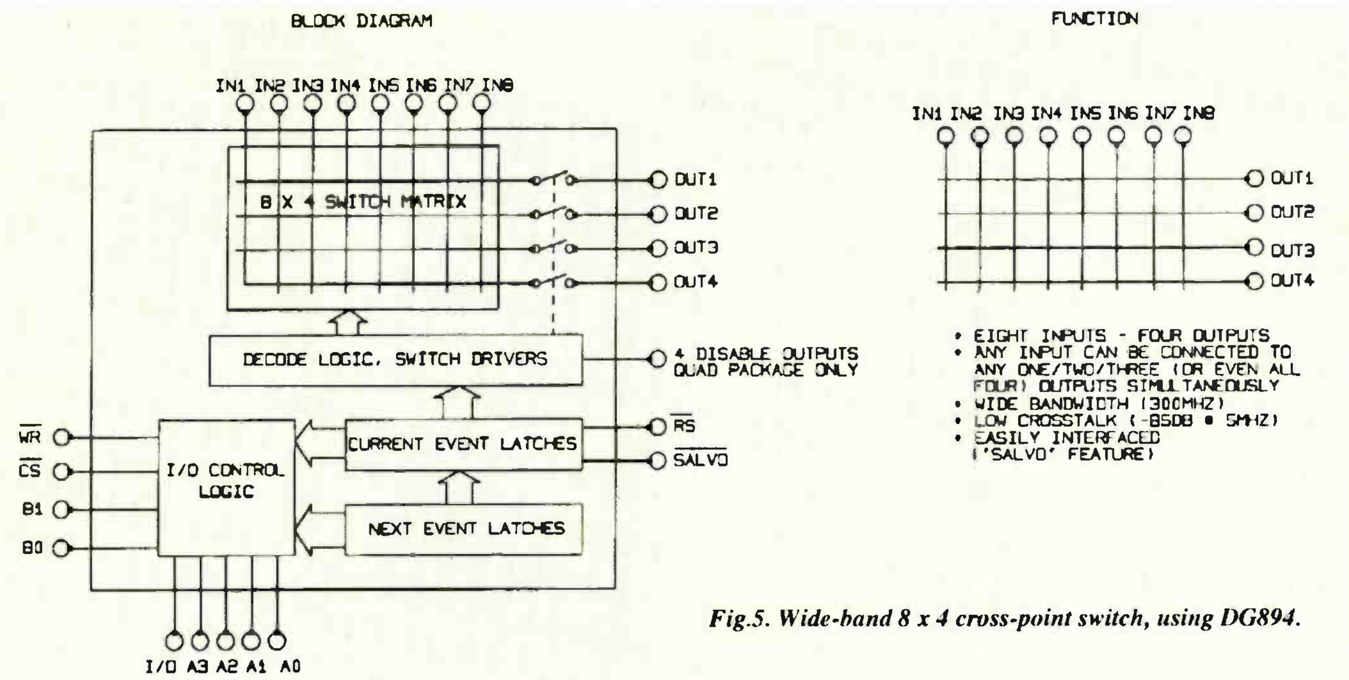


Fig.5. Wide-band 8 x 4 cross-point switch, using DG894.

dmos devices offers 8 to 10 times less channel capacitance than a conventional lateral nmos transistor for a given $R_{DS(ON)}$.

The p-n junctions would become forward biased if input signals were more negative than the p substrate; for this reason, the negative supply is necessary for signals which swing below ground.

An example of the crosspoint technique is shown in **Fig. 5**, which is an 8 x 4 crosspoint which utilises the T switch method to provide 300MHz bandwidth, with -85dB crosstalk at 5MHz.

Siliconix, Weir House, Overbridge Square, Hambridge Lane, Newbury, Berks. R914 5UX. Tel: 0635 30905.

Editorial survey: use the information card to evaluate this article. Item L.

DSP3210 brings music and movement to PCs

Will DSP chips such as AT&T's DSP3210 bring animation and stereo sound to the PC? Allen Brown takes a look — and listen.

"Multi-media" is the combination of image, sound and communications and 1991 will be its year — at least according to Microsoft. But turning the concept into reality on the PC is a difficult task, even with the much heralded Intel 80486 32-bit microprocessor.

However many multi-media tasks lend themselves to the techniques found in digital signal processing (DSP), including document image processing, graphics animation, image compression, speech generation, speech recognition, processing sound quality and high speed data comms. So multi-media tasks could be performed on a dedicated processor, acting as a slave to the PC's central processing unit (CPU).

DSP for multi-media

AT&T, having recognised the future market for multi-media PC workstations, has recently released its DSP3210 which builds on the DSP32C 32-bit floating point digital signal processor to satisfy multi-media needs.

One of its appealing features is the 32-bit bus master interface allowing the DSP3210 to be linked with processors from either Intel or Motorola. To meet multi-media real-time requirements it has its own operating system, VCOS, which supports multitasking, multiprocessing (several DSP3210s) and allows the DSP3210 to use the PC's memory.

Initially the DSP3210(s) would appear as an enhanced processor on expansion boards which host either the extended industry standard architecture (eisa) or IBM micro channel architecture (MCA) interface bus.

In the first instance multi-media operation would be transferred to the enhanced processor board by the system CPU and run as a closely coupled peripheral.

A reasonable assumption is that most multi-media applications will be coded in C — reflected by AT&T providing an optimised C compiler for the DSP3210. With this objective in mind, VCOS comes with its own multi-media function library for sound and graphics processing.

The first releases of the DSP3210 have a context latency of 80ns, making the device eminently suitable for real-time applications.

The 32-bit bus master on the DSP3210 allows the device to make efficient use of the PC's own memory; it can access the system dram without the intervention of the CPU by using a memory request and acknowledgement protocol.

In principle it can execute code from dram but for real-time processing, data and program instructions can be imported directly into the DSP3210's internal ram from the PC's (slow) dram.

DSP3210 advantages

There are three areas of the multi-media concept where the DSP3210 scores well.

Graphics processing is inherently intensive from a computational point of view. Manipulating 3-D images requires standard functions such as matrix multiplication, and the DSP3210 is well suited to performing this type of operation especially since it has support for z-buffering via the clip-test register in its DAU.

Algorithms for image animation will also prove to be compute-demanding since differential and translation calculations are involved. For image storage and retrieval, a variety of compute intensive compression algorithms is needed.

Efficient data throughput is vital to give the ability to process information quickly. The DSP3210 with its DMA and SIO facil:ties can engage in rapid access to mass storage devices or through comms links to remote data storage sites.

Sound processing whether speech recognition or synthesis, may use many signal processing algorithms. Although speech recognition is proving to be particularly difficult to implement, speech synthesis is showing more promise.

Editorial survey: use information card to evalutae this article. Item N.

Closer look at the DSP3210

The CAU contains a 32-bit arithmetic logic unit, a barrel shifter and a rich complement of 32-bit registers which are supported by 32-bit buses.

The DAU on the other hand has 40-bit accumulators for single extended precision arithmetic and a 32-bit floating point multiplier and adder (mac). This is able to operate in a single machine cycle to perform a floating point mac — an essential feature for fast signal processing.

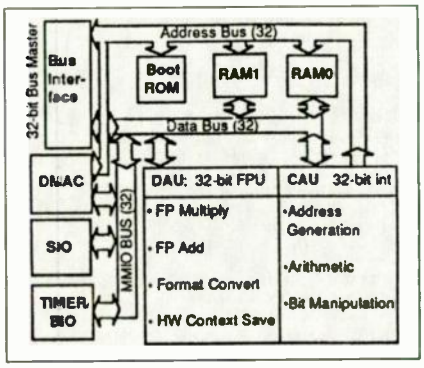
It is also able to convert its floating point numbers into IEEE-754 floating point format or a variety of other formats including A-law and mu-law for comms applications.

Other functional elements include a serial I/O (SIO) unit which supports multiprocessor interfacing and comms links, a direct memory access controller (dmac) with two 32-bit buffered channels operating with the SIO unit and a timer.

The times are used for interval measurement, event counting, waveform generation and is needed for real-time interrupts. To make the DSP3210 appear more like a general purpose microprocessor.

All interrupts and error conditions are treated as prioritised exceptions, handled through a relocatable vector table containing start addresses of service routines for the exceptions.

Block diagram of the DSP3210



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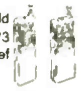

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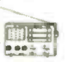

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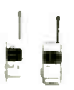

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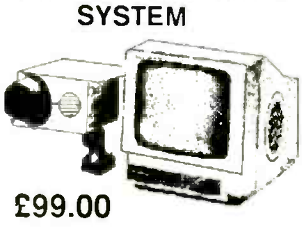

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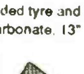

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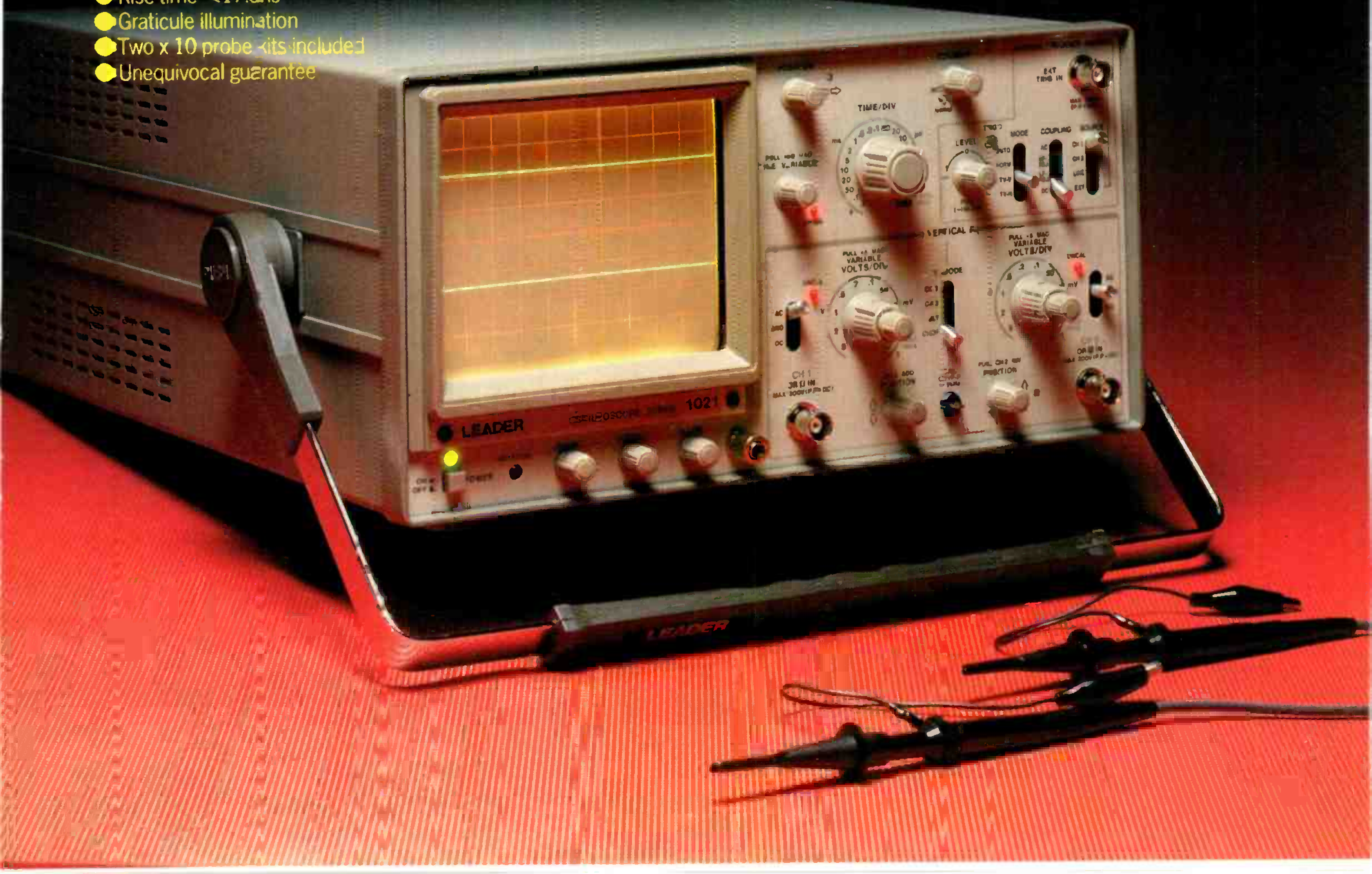


LEADER
1021

Defining progress to HDTV broadcasting

Geoff Lewis takes a North American view of the latest manoeuvres in the battle to establish an HDTV standard.

Zenith's "spectrum compatible" high definition television (SC-HDTV) system (left) provides twice the horizontal resolution and twice the vertical resolution of conventional NTSC images.

At the end of 1987 there were two major contenders for the world HDTV standard — Japan and Europe — plus some 23 North American proposals. North America would only countenance NTSC-compatible systems because of the huge investment in NTSC by viewers, programme originators and transmitting authorities. Additional information needed to extend services to high definition was to have been provided via an augmentation channel.

But by the end of March 1990, the Federal Communications Commission (FCC) had decided that this was wasteful of frequency spectrum and so it proposed the alternative of simulcast: a station could transmit HDTV in parallel with its normal NTSC service using an alternative 6MHz channel for the new service.

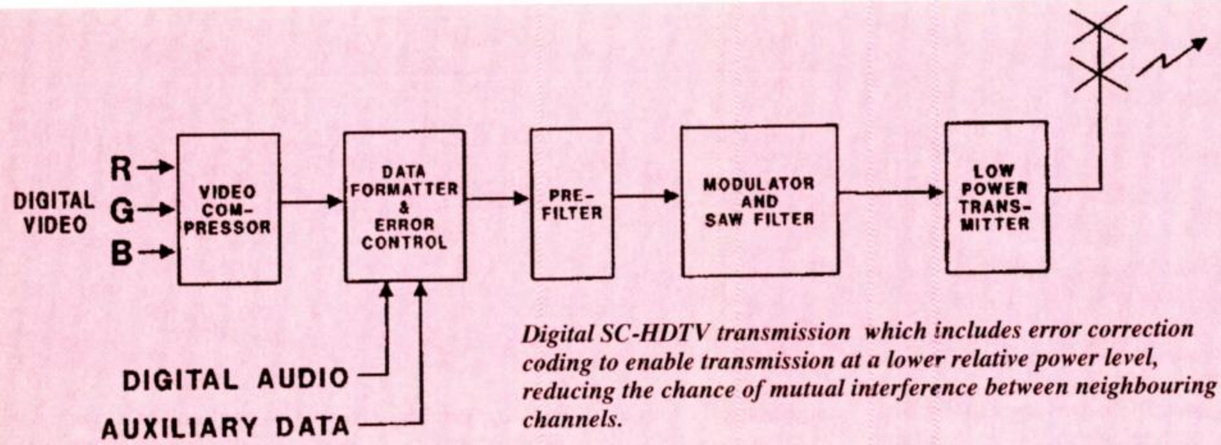
NTSC-compatibility no longer seemed to be a constraint, but where was the necessary spectrum to provide these additional transmissions?

On cable and broadcast, channels can only be reused if mutual interchannel interference can be avoided, thus giving rise to the term "taboo" channels.

Interference is primarily from the power distribution within each channel spectrum, power being particularly high at carrier frequencies due to sync pulse modulation. So if the power could be more evenly distributed throughout each channel, interference should not arise and the taboo channels could be used for a high definition service.

Again, this implied a further non-compatible change to the TV signal, but allowed a high definition service to be started without disenfranchising the present NTSC users. In the future, the current NTSC channels would no longer be needed and so could be released.

The FCC further stipulated that firm



Digital SC-HDTV transmission which includes error correction coding to enable transmission at a lower relative power level, reducing the chance of mutual interference between neighbouring channels.

proposals by each contesting organisation had to be lodged by a deadline, resulting in six proposals being presented by end of June 1990. These included analogue, analogue/digital and purely digital systems.

During this period a tight schedule of demanding test procedures was drawn up. All competing systems were to be demonstrated under normal working conditions, with specified test signals and software so that an objective and subjective decision could be reached by June 1993 on the best proposal. This would allow the FCC to present a firm proposition for the preferred system to the 1994 Plenary session of the CCIR, ensuring that there would now almost certainly be three alternatives for the world standard title.

The six contenders include a channel compatible system from the Massachusetts Institute of Technology (MIT), a spectrum compatible system from Zenith Corporation, the narrow muse system from NHK Japan, an advanced compatible TV system from a consortium formed by Sarnoff Labs, Thomson, Philips and NBC (ARTC), the Digicipher HDTV system from General Instruments Corporation and super-NTSC from Faroudja Labs. This was the situation as late as November 1990.

SC-HDTV

Spectrum compatible high definition television (SC-HDTV), the original proposal from Zenith Electronics Corporation adopts a new scanning standard to achieve high definition images. A line scan rate of 787.5 lines per frame with 59.94 frames per second gives a line frequency of 47.203kHz — three times that of NTSC.

Aspect ratio is 16:9 as internationally agreed. With 720 active lines per frame and 1280 active pixels per line, sequential or progressive scan yields a vertical resolution equal to that of a 1050 lines interlaced image.

Complex analogue and digital processing squeezes the video signal into two 3MHz baseband components. These amplitude-modulate quadrature versions of a single carrier using double sideband suppressed carrier techniques so the transmission occupies a single 6MHz channel. The carrier is thus positioned in the centre of the transmission bandwidth and since there are no carriers or sub-carriers being transmitted, the spectral power has a more even distribution.

Possibility of interference with other channels can be minimised through off-set carrier techniques. Analogue signal compression is used to reduce the peak transmitted power and the complementary expansion in the receiver improves the signal to noise ratio.

The video signal source is typically RGB format with up to 37MHz bandwidth, matrixed to provide luminance and two colour difference components. Luminance is filtered to remove the DC and low frequency components which are digitised, time compressed and multiplexed with digital audio, data, and control information for transmission during the vertical blanking interval.

High frequencies of the luminance signal and the two colour difference components are time compressed and multiplexed together for transmission in analogue form. The complex transmission signal carries vertical and horizontal sync pulses, but at an amplitude not exceeding the average video level. Conventional NTSC techniques are used up to the second detector stage so that a standard receiver with suitable changes of scanning speeds can be used for display. A few VLSI circuits (asics) should perform all the necessary complementary processing, time expansion and filtering to restore the video signal to its RGB format.

During December 1990 it became apparent that the above proposal was just a place marker. Zeneth Electronics and American Telephone and Telegraph Corporations had spent the previous 18 months in extensive cooperative research to produce an all-digital solution. Since Faroudja Labs has withdrawn because its system was not Taboo-channel friendly, this must now leave the two analogue/digital proposals as outsiders.

Technical details of the Zenith-AT&T proposal is still a little sparse but testing is due to start in the SC-HDTV time-slot (October 1991). The basic image format is retained but the coding which allows the digital HD signal to be contained within a 6MHz bandwidth is completely new. This has been achieved by combined efforts in video compression technology, algorithms, motion compensation and filtering — all of which take the properties of human vision in to consideration. The high speed digital signal processors (DSPs) which can operate at speeds as high as 4bn operations per second are being provided by AT&T Microelectronics. Since the system is digital and includes error correction coding, it can be transmitted at a lower relative power level, so that it will not introduce mutual interference between neighbouring analogue channels.

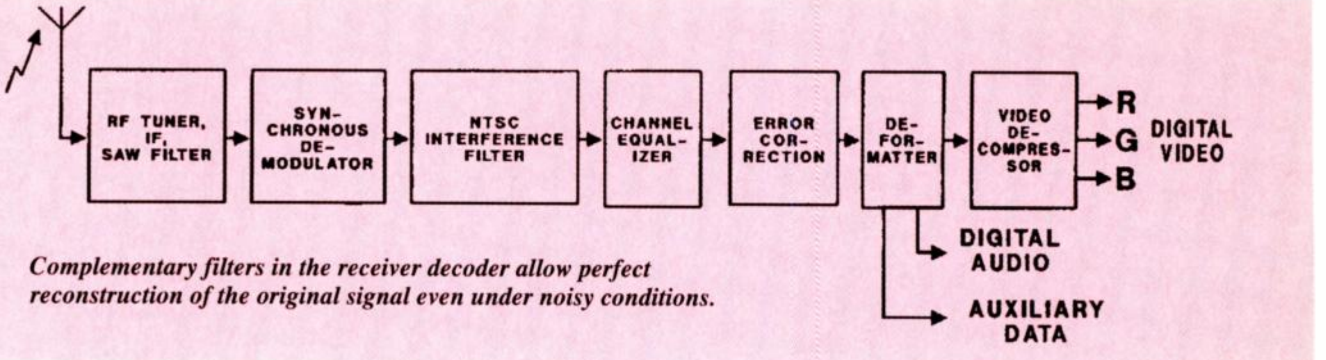
The image signal is analysed on a frame by frame basis[1] for compression and motion compensation so it is very likely that the discrete cosine transform (DCT) is employed in the coding process.

Although not specifically mentioned, it is most probable that the digital filtering will be of the recently developed quadrature mirror filter (QMF)[2] type allowing for frequency fold-over and aliasing to occur in the coding chain.

By using complementary filters in the receiver decoder, these artifacts become self-cancelling and allow perfect reconstruction of the original signal even under noisy conditions. Furthermore the three-dimensional filter needed for TV image processing can be produced simply by cascading one dimensional filters.

Digicipher HDTV

Digicipher HDTV system, General Instruments Corporation, is a completely



Complementary filters in the receiver decoder allow perfect reconstruction of the original signal even under noisy conditions.

digital system. If it performs to expectations, the technology should last well into the next century (one of the main requirements of any HDTV concept). The system — described as VHF/UHF-, cable-, satellite- and VCR-friendly — includes ghost cancelling, encryption and controlled access with CD quality sound plus a teletext/data service.

The modulated carrier frequency can safely be transmitted on any taboo 6MHz channel without problems.

The final carrier is 16-QAM digitally modulated (each symbol represents 4 bits), with a symbol rate of 4.86MHz. Highly complex signal processing in the transmitter and receiver is expected to be performed using asics.

Scanning parameters include 1050 lines at 2:1 interlace, with 59.94Hz field rate and 16:9 aspect ratio. A luminance and chrominance bandwidth of 22 and 5.5MHz respectively provides for a vertical resolution of better than 660 lines. High definition video input can be provided in either RGB or YUV format. Luminance and colour difference components are then sampled at 51.8MHz and multiplexed into a single data stream. Forward error correction (FEC) bits are added to give a performance better than one uncorrected error in 24h.

Bit rate compression is achieved through a complex DCT which makes use of the redundancy within a television image. The image area is divided into blocks, superblocks and macroblocks of pixels and the amplitude of each element is replaced by a DCT coefficient. These are further processed in a differencing technique and then coded using a variable run length code, to reduce the number of bits needed to define an image.

Incidentally, it is likely that a similar technique will find its way into HD-mac in Europe.

Telletra of Italy has been involved with a data compression codec developed within the Eureka program for various applications, which also uses a DCT algorithm in a similar way. Motion processing information is coded into the bit stream and frame synchronisation is provided by the inclusion of a unique 24-bit data pattern with line sync being derived by a counter.

The ARTC system previously known as advanced compatible television (ACTV) together with narrow muse and super-NTSC have previously been described[3].

Where next?

Trying to predict three years progress in the television industry is almost impossible, but a gambler should weigh up the following parameters before placing a bet.

Muse has been around for some time but is a proven technology from the 1970s. Although the muse-to-NTSC convertor has now been reduced to VCR size, artifacts produced when displaying horizontal or diagonal motion are unacceptable.

A muse-to-pal version has been demonstrated, but the problems are even more intractable due to the eight field pal sequence. The all digital systems are state-of-the-art technology, as yet unproven, but are probably more compatible with ideas of the 21st century.

The smart money would now seem to favour the digital system that provides the highest image resolution achievable. At present the Zeneth system with its 1575 lines at 30 frames per second, is probably the digital outsider.

HDB-mac

B-mac (multiplexed analogue components) systems have been selling into the medical, education, training, off-course betting and racing services, and financial institutions, in many places around the world.

Judging by press statements, HDB-mac is set to follow suit particularly in video-conference applications. Due to its 10.5MHz bandwidth, it is not being promoted as a North American standard for HDTV.

In essence the system consists of a modified standard B-mac encoder with extended bandwidth filters to cater for the high definition input signals and a pre-processor stage. Horizontal and vertical filtering produces spectrum folding at 7MHz and the encoder then compresses this and adds the other signal components to provide a combined bandwidth of 10.5MHz.

At the receiver, a standard B-mac decoder removes the folded component, selects the central 4:3 aspect ratio section and converts the high definition signal into a standard NTSC signal.

The HDB-mac decoder processes the same signal but at 16:9 aspect ratio, with 525 line sequential scanning at 59.94Hz field rate using a field store convertor. The system provides vertical and horizontal resolutions of 480 and 950 lines respectively — somewhat below that normally accepted as HDTV.

Are we ready for HDTV?

Does all this activity bring high definition images any closer to realisation?

HDTV only makes sense when viewed on large brightly-illuminated screens and so is unlikely to find a place in an average sized home using a cathode ray tube to provide the display.

Generally it is agreed that development of a flat plate-type solid state display is some ten years away. If this is so, the driving force in the HDTV market is unlikely to be the domestic viewer. More likely the technology will be influenced by other applications.

The computer industry wants improved definition images but seems not to be prepared to spend its own money on developing the necessary CRTs. With this in mind, why is there the urgency to define a single world HDTV television standard?

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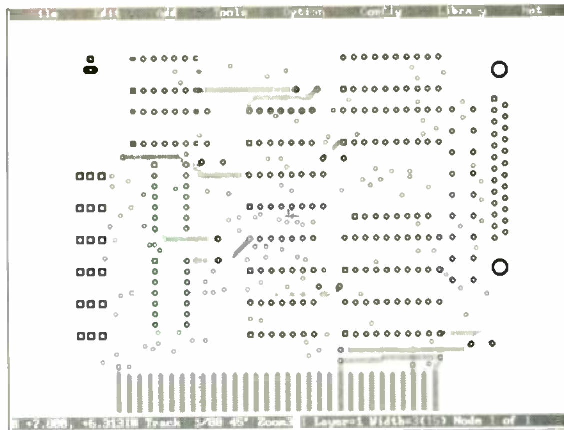
2. Quadrature mirror filter banks. Vaidyanathan PP. IEEE (USA). *ASSP*. vol 4 pp.4-19, July 1987.
3. Standard HDTV, Geoff Lewis, *EW + WW*, Jan 1990 pp.54.

Editorial survey. Use the information card to evaluate this article. Item M.

Take the Sensible Route!

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



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BoardMaker V2.23 is still a remarkable £295.00 and includes 3 months FREE software updates and full telephone technical support.

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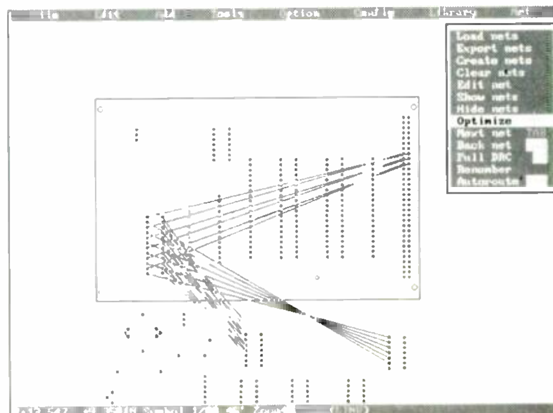
BoardRouter is priced at £295.00, which includes 3 months free software updates and full telephone technical support. As a special introductory offer, BoardMaker and BoardRouter can be bought together for only £495.00.



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

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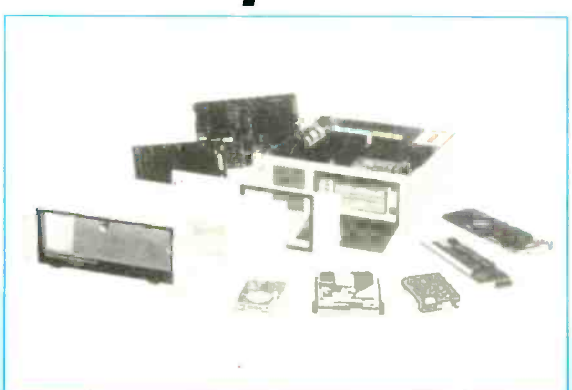

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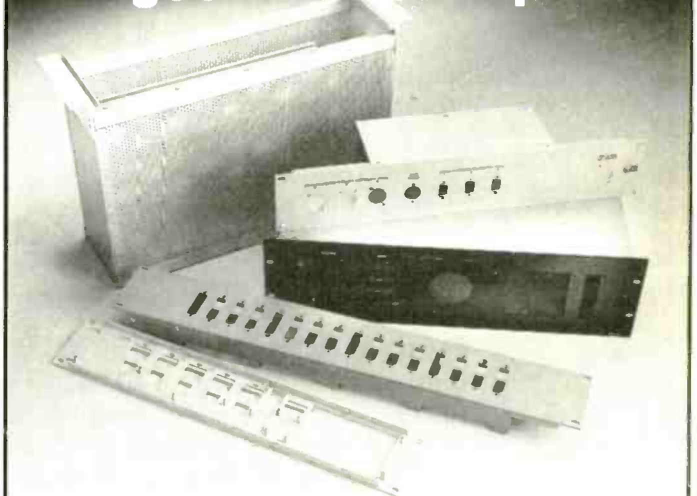

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Avalanche transistor for fast power pulses

Transistors operating in avalanche mode exhibit extremely fast switching and provide much higher current than that obtainable from conventional devices. It has long been known that fast, high-power pulse generators could be designed using these transistors, but suitable devices have not been obtainable. Zetex, however, now produce the ZTX415, which will produce a 10ns pulse at 60A.

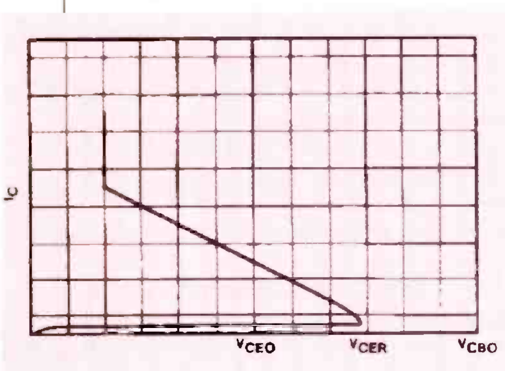

Fig.1. Negative-impedance slope in secondary-breakdown region

Figure 1 shows the characteristic of an avalanche transistor, which exhibits a negative region called secondary breakdown, in which controlled switching of very high currents at high speeds is possible. Output pulse capability is limited by primary breakdown B_{VCBO}, on-state voltage and mean dissipation.

Avalanche current I_{USB}, passed in the secondary breakdown region, depends on

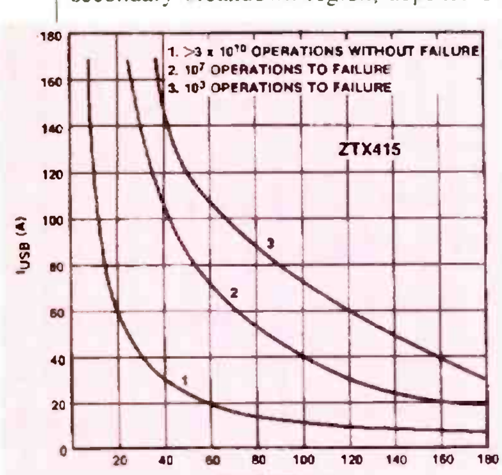

Fig.2. Avalanche current v pulse width

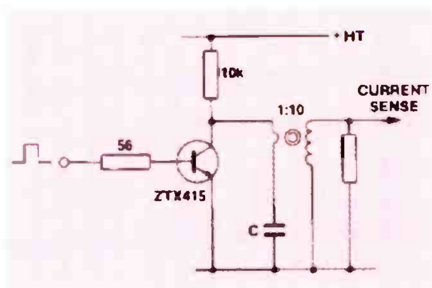

Fig.3. Circuit producing curves of Fig. 2.

the supply to the device and its "on" state characteristic. Figure 2 shows peak current plotted against pulse width for a sine-squared type of pulse; pulses of more than 60A reduce life span, but there is still the provision for about 1000 40ns pulses at 140A, at worst. A single-capacitor load arrangement was used to derive the Fig. 2 curves, as shown in Fig.3.

For a V_C of 250V, avalanche current temperature dependence is slight, varying from 36A at 0°C to about 32A at 180°C.

Static voltage characteristics largely dictate the circuit techniques to be used and the usable range. For a high-voltage pulse, the transistor must have a high B_{VCES} and, to produce a device with a minimum of 260V, high-voltage technology is used, which makes it possible to obtain high-current pulses with little external circuitry.

Below a minimum voltage, the device switches in a non-avalanche mode. This "starting voltage" depends on the external circuit: for a simple, single-capacitor arrangement, starting voltage varies as in Fig.4, which shows this voltage as a function of capacitance for different drive currents. A somewhat lower starting voltage

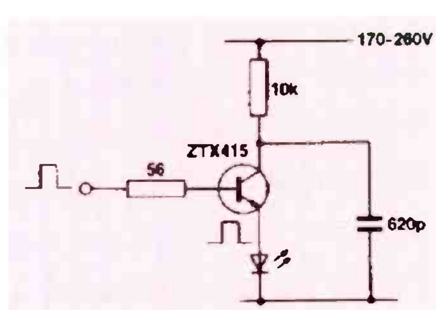

Fig. 6a.Variation of Fig. 5, using one capacitor for a 7ns sine pulse.

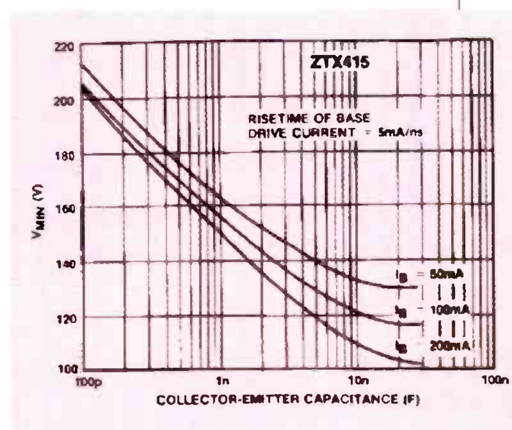

Fig.4. Voltage varying with capacitance.

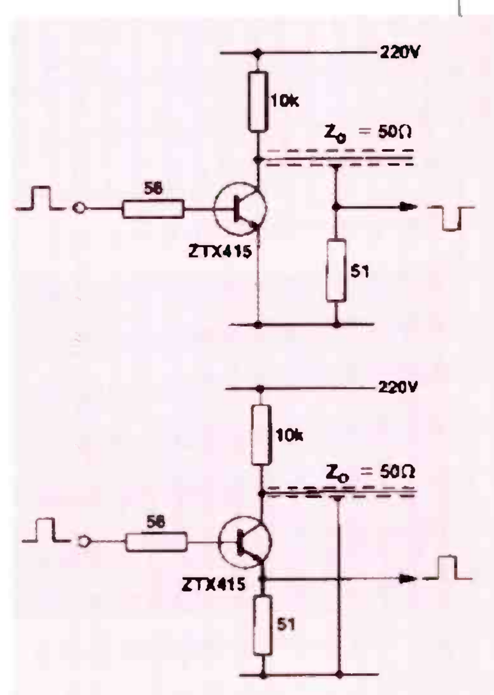

Fig. 5. Two arrangements of delay-line pulse generator.

can be obtained by using a base drive with a faster rise time.

Figure 5 shows a typical application — a pulse generator, in two configurations, which uses the reflection from an open-circuit delay line; the width of the rectangular output pulse depends on the length and impedance of the line. A similar circuit, shown in Fig.6a, uses a single capacitor to produce the 7ns sine pulse of tens

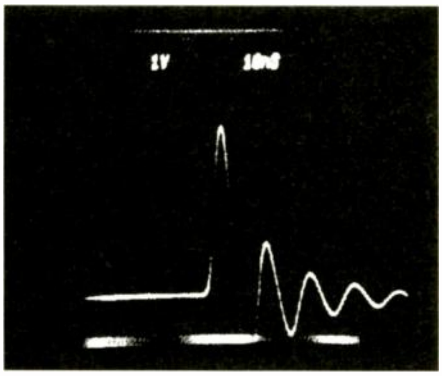

Fig. 6b. Pulse from circuit of Fig. 6a.

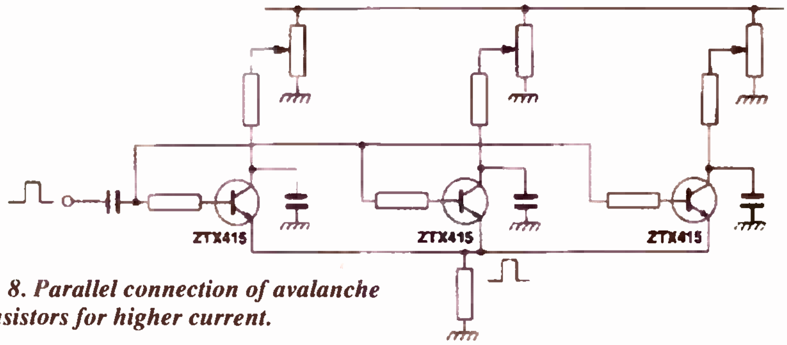

Fig. 8. Parallel connection of avalanche transistors for higher current.

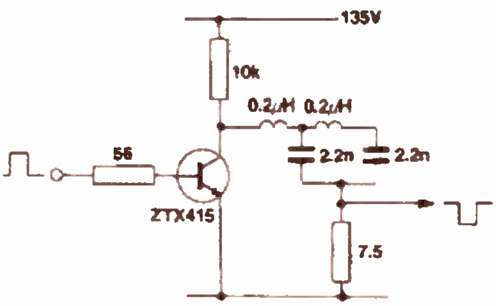

Fig. 7a. Further variation of pulse generator to give 80ns pulse.

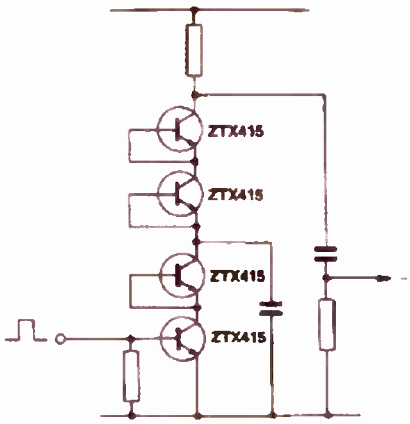

Fig. 9. Series stack for high-voltage pulses

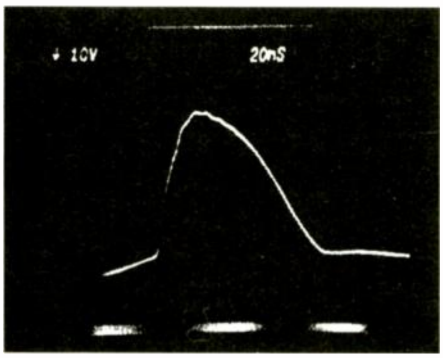

Fig. 7b. Pulse output from Fig. 7a.

of amps, as in **Fig.6b**. Pulse-forming networks added to the basic circuit will provide specific shapes; **Fig.7a** shows two LC sections used to produce an 80ns pulse, as in **Fig.7b**.

Parallel and series connection of the ZTX415 to produce higher currents or voltages is possible, as seen in **Figs 8** and **9**, the stack of devices in Fig.9 needing an additional capacitor on the lower devices to ensure avalanche.

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Instrumentation amplifier

OPA2107 from Burr-Brown is a dual, twin-fet operational amplifier, intended for use in analogue circuitry needing precision, low-noise performance and can be used as an upgrade for designs currently using bifet amplifiers. In the new device, the difet dielectrically isolated process is used to maintain very low bias currents, without compromising input offset voltage, drift and noise. Quiescent current is less than 2.5mA/amplifier Circuits are unity-gain stable, with good phase margin.

A precision instrumentation amplifier, shown in the diagram, uses the INA106 as an output difference amplifier to extend the input common-mode range to ±10V from the ±5V of a unity-gain difference amplifier. Here, the output voltage is

$E_0 = [10(1+2R_F/R_G)(E_2-E_1)]$

$= 1000(E_2-E_1)$.

Leakage current between closely packed pins, as in the SO-8 surface-mount package, can be a problem, which is reduced by thorough cleaning of the board. A further reduction is gained by the use of guard tracks to encircle high-impedance nodes with a low-impedance connection at the same potential — on all layers of a multi-level board.

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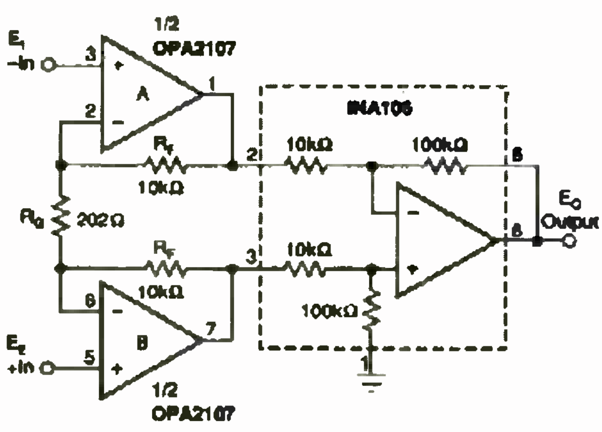

High power-factor preregulator

Power factor is the ratio of real power in watts to apparent power in volt-amps. When current is sinusoidal and in phase with the voltage, power factor is unity; if current is out of phase, less power is transmitted to the load, but the out-of-phase current plus that needed by the load must still be carried, the wiring and circuit breakers thereby being heavier and costlier than necessary.

With the huge number of computers and other equipment using line rectifiers and capacitor-input filters, the simple expedient used when the current is sinusoidal of placing capacitance across the equipment to bring the phase back into line is defeated by the non-sinusoidal current waveform.

For use with this type of equipment, Unitrode have the UC3854, which contains all the active devices needed to obtain power factors close to unity and further to make a preregulator capable of working from any power outlet in the world, regardless of voltage or frequency.

Two main sections of the circuit are the control circuit using the UC3854 and the power section. The power section is a boost converter, in which the inductor operates in the continuous mode. Duty cycle depends on the input/output voltage ratio and input current has a low switching-frequency ripple so that line noise is low. Output voltage is higher than the peak of the highest expected line voltage.

For control, the UC3854 sends PWM gate-drive pulses from pin 16 to the power mosfet, the duty cycle of the signal being controlled by four inputs to the device. Input V_{sens} controls output direct voltage; I_{AC} affects line-voltage waveform; I_{sens}/ and Mult out control line current; and V_{RMS} the RMS line voltage. Additional controls set start-up delay and the duration of soft-start.

To force the current to follow the voltage, a sample of power-line voltage is fed to pin 6, I_{AC}, where it is multiplied by the output of the voltage amplifier in the internal multiplier to generate a reference signal for the current control loop. The current-control loop has a very wide bandwidth to enable line current to follow line voltage closely.

Line feedforward keeps input power constant with varying input voltage. The multiplier divides line current by the square of the RMS value of line voltage; its output is a current that increases with current at pin 6 and voltage at pin 7, decreasing with the square of the voltage at pin

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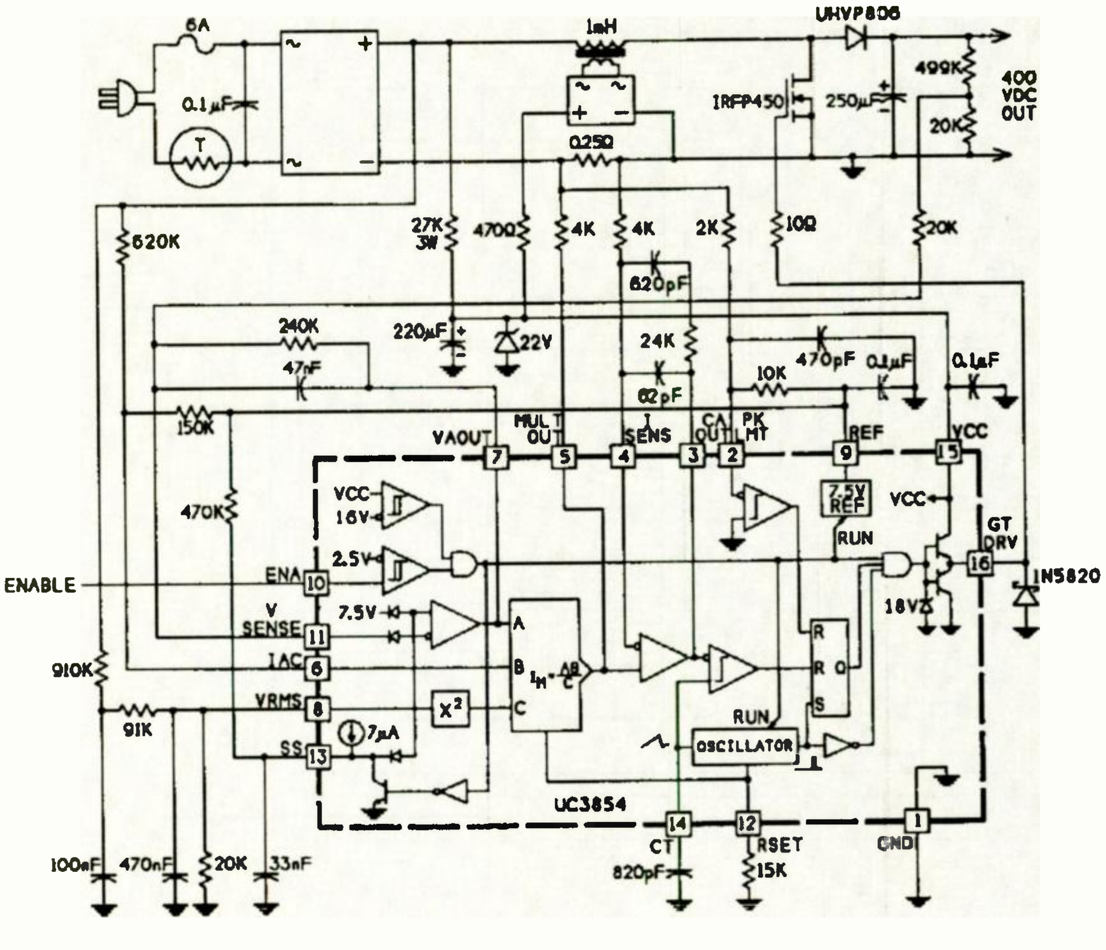

Low-voltage, narrow-band FM receiver

Motorola's MC3367 is intended for narrow-band audio and data communications up to 75MHz in circumstances that need low power consumption; a V_{CC} down to 1.1V is permissible.

Input RF is converted to 455kHz IF, filtered by a ceramic filter, amplified and taken to a conventional quadrature demodulator; modulation bandwidth is 3 to 5kHz. There are buffers for audio or data amplification, active filtering, on-board voltage regulation, a programmable low-battery detector and disable circuitry.

MC3367 can be used as a high-performance FM IF for low-power, dual-conversion receivers, but is also usable as a stand-alone, single-conversion, narrow-band receiver at frequencies up to 75MHz, when image-frequency interference is not a problem. In this case, an RF preamplifier will be needed to overcome preselector losses.

The oscillator is a crystal-controlled Colpitts type, with parallel-resonant resonators for fundamental-mode crystals and third-overtone crystals for higher frequencies; two 455kHz ceramic filters are used for best channel and sensitivity response, but can be replaced by 100nF coupling capacitors with some performance degradation.

Data buffering provides a voltage gain of about 3.2 and needs about 250mV of external bias; a single-pole RC filter on the buffer input supplies the bias and some post-detector filtering. This and the audio buffer (which must be AC-coupled) can be used to allow simultaneous audio and very low-speed data reception, or to receive audio only and provide a noise-triggered squelch. Application note MC3367 gives full practical details of the circuit.

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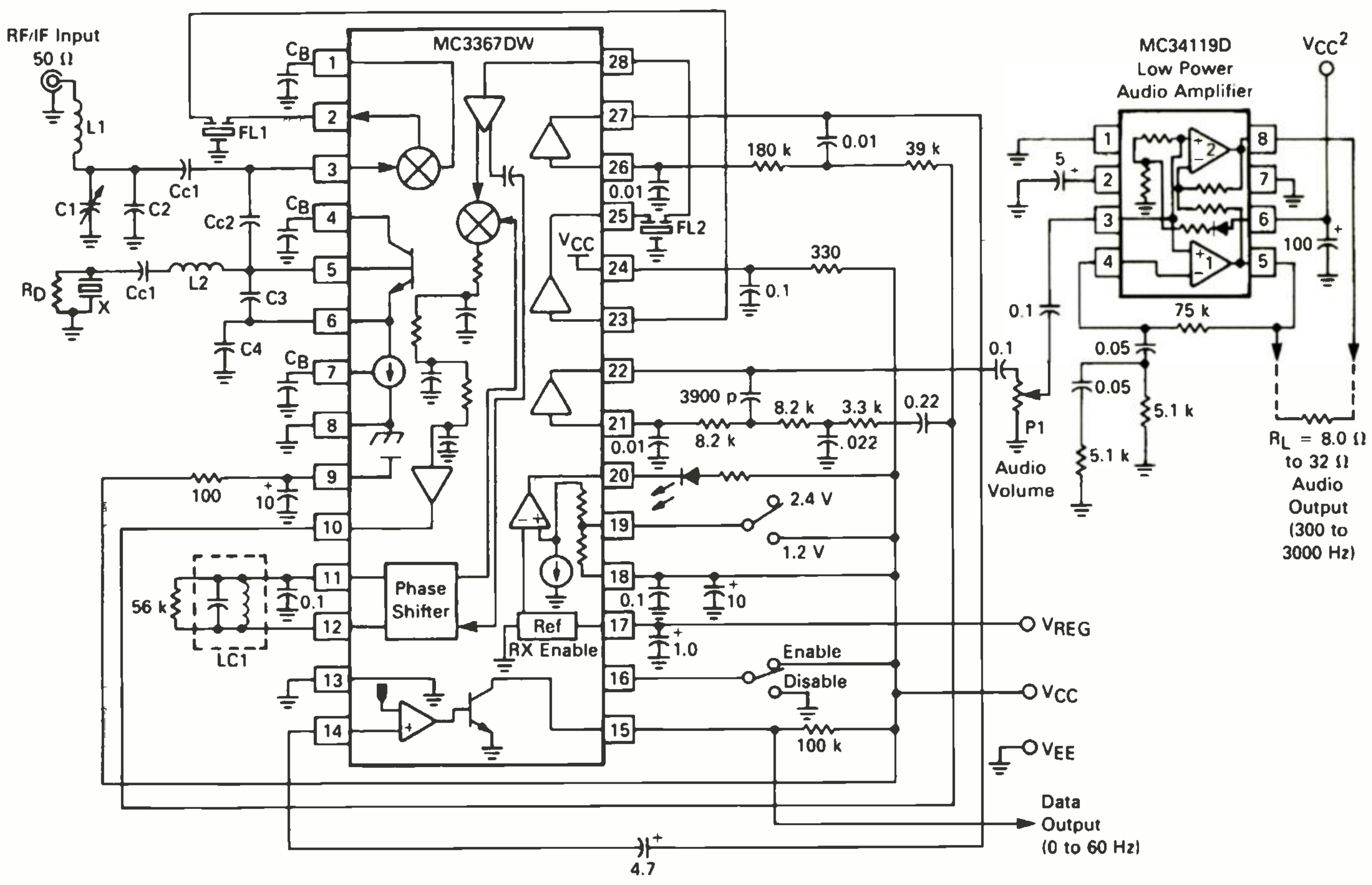


Picture clears for CCD full-facility cameras

For more than 20 years Plumbicon/lead-oxide-vidicon camera pick-up tubes and close relatives such as the Saticon have dominated the high-quality broadcast scene. But it now seems likely that the present generation of tubed cameras will be the last, with the solid-state CCD-sensor camera taking up the challenge not only for portable, lightweight electronic-news-gathering (ENG) cameras but also, most recently, for full facility studio and major outside broadcast events.

Broadcasters agree that CCD cameras are now routinely producing pictures of a quality equivalent to that of the best pick-up tube cameras when carefully set up by experienced staff — a quality which in practice cannot be maintained on a day-to-day basis.

But this does not mean that CCD cameras cannot be further improved; in some respects their introduction has put the clock back rather than forward. There are still, as John Wardle (BBC Head of Technical Investigations and Evaluation) stressed at an IEE Colloquium "Recent Advances in Broadcast Television Cameras: Optics, Sensors and Processing", quite severe problems of sensor blemish and reliability, streaking, reflections, flare, camera ergonomics, including poor weight distribution and the need for strain-free viewfinders and hoods.

CCD sensors also set more difficult requirements in limiting the effects of chromatic aberrations and specification of the zoom lenses; new glass materials are helping.

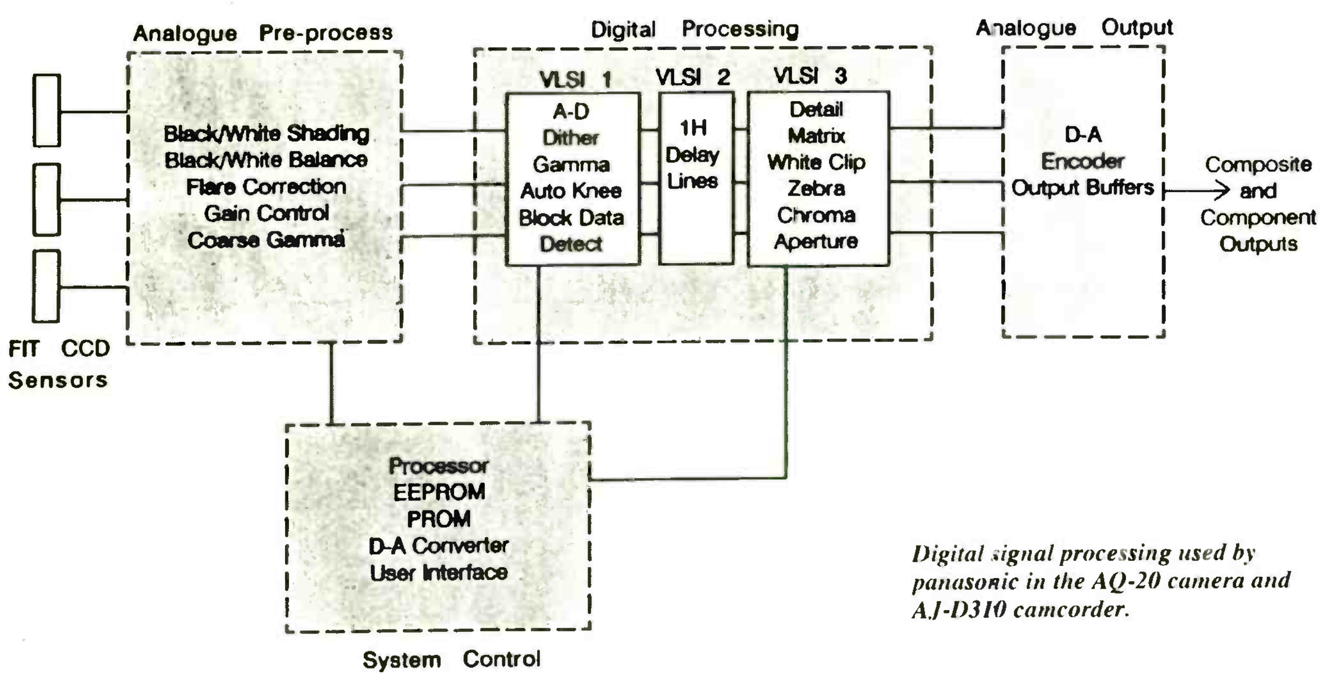
Of the three main types of CCD arrays, interline-transfer (IT) sensors continue to suffer from vertical smear produced by very strong highlights and are used primarily in ENG and for other less critical cameras.

Frame-interline-transfer (FIT) chips overcome this problem at the expense of larger total chip area and complexity. They are significantly more costly, though their performance under working conditions far exceeds the average performance level of tube cameras.

Frame-transfer (FT) cameras use a mechanical shutter to eliminate vertical smear and are featured by one manufacturer. The BBC has decided that only FIT or FT cameras offer high enough overall quality for studio or OB use.

Broadcasters agree that CCD cameras are now routinely producing pictures of a quality equivalent to that of the best pick-up tube cameras.

Initially, the problem that delayed introduction of CCD sensors throughout the 1970s was primarily that of achieving a sufficiently high packing density in the chip to provide adequate resolution with a reasonable yield. The number of horizontal pixels, under 100 in 1972 and about 250 in 1980, rose to about 500 by 1986 and currently is about 750-800, representing some 440,000 to 480,000 total pixels, all ideally active and providing identical performance characteristics. A Sony proto-



Digital signal processing used by panasonic in the AQ-20 camera and AJ-D310 camcorder.

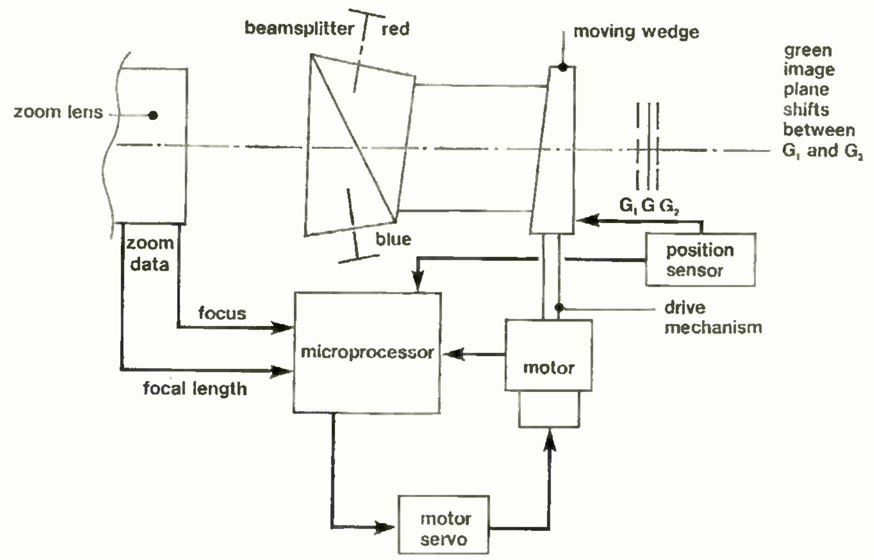
type 16:9 aspect-ratio, DTV FIT CCD camera has 1920 horizontal pixels and 1036 vertical pixels (over two million pixels) but this requires an extremely large chip with consequently a much reduced yield.

The BBC has found that "it is practically impossible to purchase CCD sensors without any defects and particularly even with no defects in the central zone" (specified for tubes). It has also been found that, despite claims for infinite life without replacement, CCD sensors tend to develop extra blemishes quite quickly. John Wardle says: "BBC experience so far is not good, with several cameras failing due to increased blemishes over a three or four month period, and others during the acceptance period".

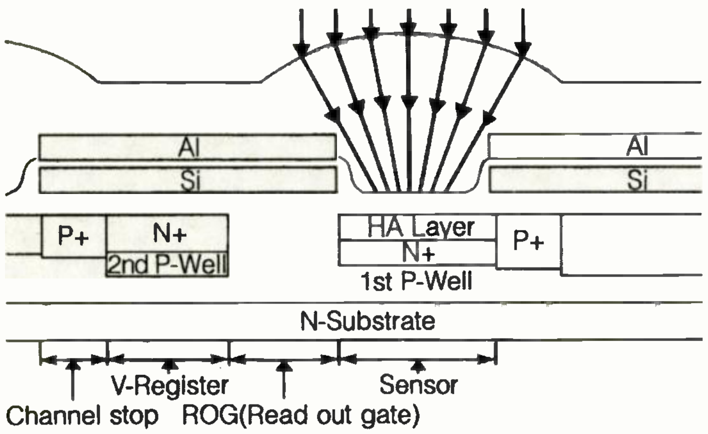
On camera ergonomics, he suggested that more of the weight of a camera plus zoom should be towards the back; adding that the early-1970s EMI-2001 camera, if fitted with CCD sensors, "would still be the choice of many cameramen".

The morning session was devoted to camera optics, an arcane subject for many electronics engineers. Jacques Angenieux described his patented "intelligent' lens and prism with microprocessor control that can deliver an image virtually free of longitudinal chromatic aberration, which has become more important with the emergence of CCD sensors.

Several speakers emphasised the importance of the modulation transfer function (MTF) of lenses involving complex acceptance tests; the need for in-service checks to measure MTF degradation; the need for optical manufacturers to provide more information on and specifications of their products. An EBU technical document "Specifications for film and television lenses" is due to be published shortly, resulting from some eight years work by an EBU specialist group on lenses. Improved optics will be needed for DTV although the demanding requirements for these are already met for film-making. A high-quality zoom can cost up to £50,000 more than the camera.



Intelligent dynamic prism developed by Angenieux to eliminate longitudinal chromatic aberration.



Sony's microlens array of the Hyper had CCD doubles sensitivity, providing equivalent of an extra f-stop.

Ian Sheldon (Sony Broadcast) explained how the new Hyper-had sensor offers double the sensitivity of the had (Hole Accumulated Diode) sensor introduced about a year ago. This is achieved by having an on-chip microlens array that serves to concentrate the light onto the photosensitive areas of the array without introducing any performance disadvantages to the basic had sensor, although adding to fabrication difficulties. The had sensor has a heavily-doped P-type region only two or three molecules thick at the surface to trap random electrons generated there. This reduces dark current and dark noise; also, since there is no need for a polysilicon electrode, it provides much higher sensitivity.

Steve Owen (Panasonic Broadcast Europe) made a strong case for more digital signal processing within the camera head. Panasonic believes that future cameras and virtually all broadcast technology will be digital.

Digital signal processing was first introduced about one year ago in the lightweight AQ-20 camera in conjunction with an analogue CCD sensor. Similar processing is used in the AJ-D310 digital camera/recorder, shown at IBC-90, with 480,000-pixel FIT sensors.

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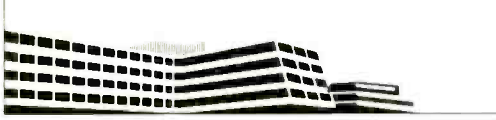

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