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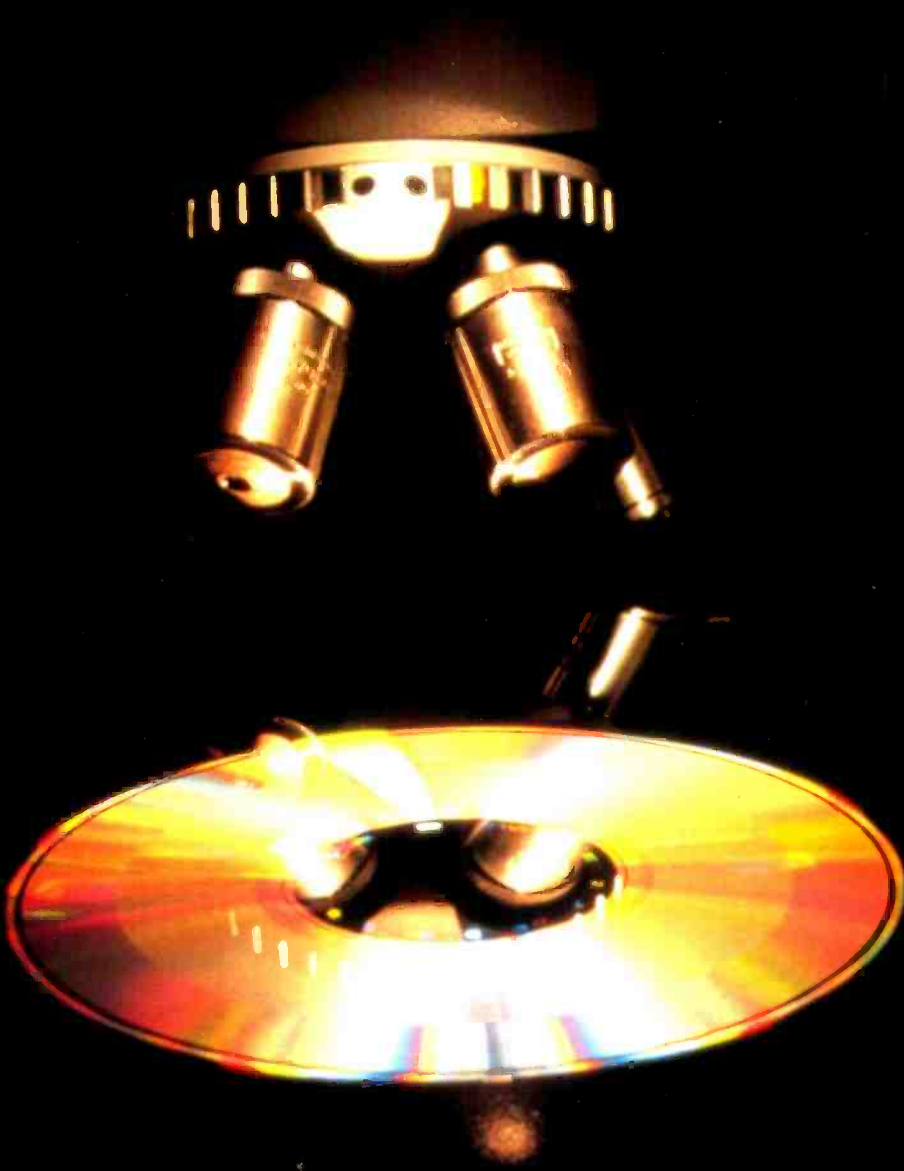

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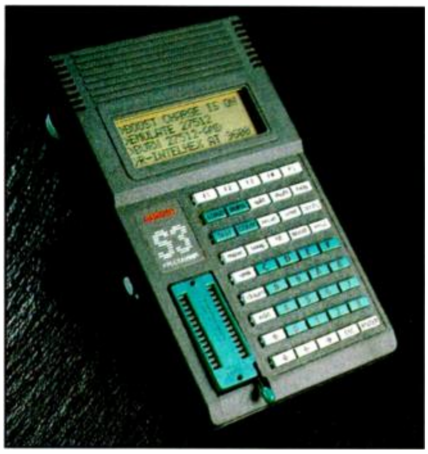

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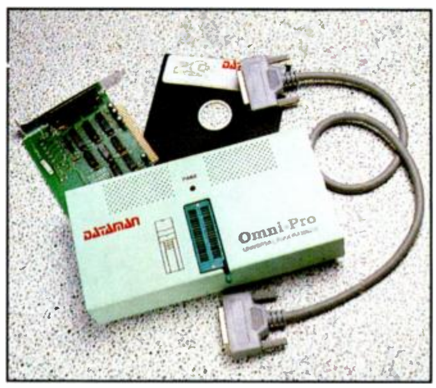

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CONTENTS

FEATURES

REGULARS

In next month's issue. Flux gate magnetometery provides an incredibly sensitive magnetic field measurement method. The simple solid state technology, described both in principle and practical detail by author Richard Noble, is precise enough to form the basis of an electronic compass or measure accurately variations in the Earth's magnetic field due to solar activity.

Men, machines and the human condition

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Readers trying to make sense of *"Design brief: 60W Cuk Converter"* in last month's issue will have had their work cut out. The gremlins which live in the dark places of every computer system went on the rampage and reduced an excellent article to gibberish. PostScript maths setting appeared in place of the diagram scans, some diagrams were truncated while others didn't appear at all. We will be pleased to send out a correct version of the document to anybody who wants one: please see p.629.

All our computing practices are designed to make sure that this sort of thing can never happen, even in the event of equipment failure... yet it did. In this instance, the consequences were upsetting for the author, disappointing for the reader and a general embarrassment for all concerned.

It seems rather ironic that the same issue carried a detailed report on the A320 air crashes of last year, effectively a verdict on the wisdom of using computers in the primary flight control systems of passenger aircraft. Author David Learmount of *Flight International* stated quite properly that computers were not implicated in either incident. Further, rational analysis suggested that the incorporation of electronics into Class 1 systems does not increase the chances of failure above those applicable to purely mechanical alternatives.

It is therefore doubly ironic to report the Lauda Air crash of a Boeing 767, due almost certainly to the failure of its digital engine control system, shortly after we published an official bill of health on fly-by-wire. We are fairly sure that the electronics failed – for whatever reason; the pilot reported that one of two engines had gone into reverse thrust while the aircraft was flying at cruise. The three engine computers, which must each independently agree on the need for an action before it can take place, were specifically programmed to forbid reverse thrust selection except while the aircraft is on the ground and in the landing phase.

It simply couldn't happen... yet it did.

In fairness to Boeing, this type of engine control has been around for 10 years without reports of airborne reverse thrust activation. Yet there remains a sense of unease when we are forced to depend for our lives on anything as capricious as computer software running in hardware prone to alpha strikes, glitches and supply transients.

Electronics hardware on its own is certainly as reliable as the mechanics it replaces or assists. The real problem arises when electronics has to rely on people to write the software to make it work.

Most people will be familiar with computers operating outside aviation and the dull, mechanical stupidity which occasionally results: million pound gas bills, mistaken identities and general systems failure. Computer operators will know the commonplace frustration of a machine which locks up for no apparent reason. The error can be traced to human factors in nearly every case; software bugs, miskeying or corrupted data are part of the human condition. We can't be completely sure of anything which we build.

Aeroplanes don't have Ctrl+Alt+Del keys. Perhaps they should.

Frank Ogden

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REGULARS

UPDATE

Pal TV in EC death pact

A new euro-directive on satellite TV spells death for pal – but by wasting away rather than murder. A recent meeting of euro-telecomms ministers was presented with a set of outline proposals – the Draft Directive followed belatedly three weeks later.

Commissioner Pandolfi's proposals go a long way towards solving the commission's basic dilemma: how to achieve an orderly progress, through D^2mac, towards HDTV, while acknowledging the interests of existing pal audiences and broadcasters.

The solution is an elegant mixture of stick and carrot. D^2mac will be mandatory for new channels from the beginning of 1992. For consumers, it will be an added-value service by providing wide-screen pictures for those sets able to receive them. This includes some 4:3 sets, which have the capacity to "letterbox", as well as the new generation of 16:9 screen models. D^2mac's capacity to broadcast simultaneously in widescreen and 4:3 mode will accommodate the remainder of existing TV sets.

To ensure the creation of an adequate receiver base – and availability of any services to all viewers – all satellite receivers and all TV sets over 22in screen size (from 1993) will have to be fitted with D^2mac decoders. A subsidy fund would encourage existing broadcasters to duplicate some of their channels – especially movies and sport – in widescreen D^2mac. As for pal, existing receivers should be able to receive existing channels for at least five years.

Initial proposals were that pal should be dropped once the percentage of installed receivers with D^2mac reached a certain level (probably 70%). However, Commissioner Pandolfi has already backed off from forcing this point through. No mandatory cut-off for pal is now included.

There has been an initial welcome for the proposals among broadcasters, satellite operators and manufacturers and a cautious confidence that they could form the basis for a Memorandum of Understanding. This would provide a framework for action by the industry, paralleled by a Directive, binding on member states.

For SES-Astra, Koen van Driel described the proposals as "a good compromising job" by Commissioner Pandolfi. "We as a company wholeheartedly support that," he added.

He welcomed the link between D^2mac and 16:9 wide aspect-ratio: "A good consumer benefit", he commented.

The proponents of mac, such as Philips' Peter Groenenboom, seem pleased with progress, and relaxed about the laissez-faire attitude to pal. Groenenboom, chairman of Philips HDTV steering committee, and an implacable opponent of pal has said: "The very best thing is to put an end to pal in the Directive – but life has its complications and you cannot run away from realities."

He praised the efforts of Commissioner Pandolfi in achieving what he called "order" over the last three months. The mac lobby appears to be relying on the inclusion of new satellites as well as new channels in the D^2mac requirement to ensure that pal's life expectancy equals the satellites carrying it. For most Sky channels, and others on Astra 1A, that could mean between 1998 and 2000 before they must switch to D^2mac.]

BSkyB initially maintained a strict no-comment policy on the proposals, possibly covering some intensive behind-the-scenes bargaining over size of any subsidy.

However Rupert Murdoch, in Brussels for publication of the Draft Directive, expressed support for the 16:9 D^2mac and pledged to introduce it as soon as possible.

The proposals were presented to the telecomms ministers of member states who have now entered an intensive period of argument over them. Britain's minister of state for telecommunications, John Redwood, has already declared his opposition not only to the compulsory termination of pal transmissions, now shelved, but also to the compulsory introduction of D^2mac. It would, he said, "impose unnecessary costs on consumers...and depress the market for satellite broadcasts." He also re-opened the subject of digital TV, firmly rejected as too undeveloped by the EC working group. Germany, now with a million pal dish owners of its own, robustly supports the EC line, even including the termination of pal. These differences are of less significance than those already overcome by the once bitterly opposed industry factions. Agreement will have to be reached by the autumn, since the new Directive is due to apply in January 1 1992. Already production plans for D^2mac equipment are well advanced.

Peter Willis

Mine of information: Pitching your tent 200m underground might seem like the perfect solution for campers who hate rain. But ICL have made camp deep in a Cheshire salt mine for the much more serious reason of testing sensitive electromagnetic monitoring of computer systems. They don't have to worry about mosquitoes either.

Service is key to manufacturer survival

In the 1990s, according to a recent report* from the National Economic Development Council, it is service that will distinguish between winners and losers. The key is for manufacturers to form closer links with suppliers and customers which, the report claims, can cut costs by up to 30% and improve competitiveness.

Squeezing suppliers for short-term gain should be scrapped, says the report, as it is far better to build a long term relationship so that in the short and long term both manufacturer and supplier will be winners.

Successful companies and products must now offer more than price, delivery and quality, delivering products that provide the most cost-effective solution to customers over the required operational life".

The procedure starts at the design stage and customers should be involved from the beginning so that design has the customer in mind. Suppliers too need to be committed at this very early stage which means there has to be a degree of openness and trust between manufacturer and supplier. Ideally products should be designed using joint teams.

But the report warns: "You cannot create new relations with all suppliers overnight. Concentrate on the largest suppliers, and those components which are absolutely critical to your success".

This inevitably leads to a reduction in the number of suppliers and avoidance of multiple sources for the same product – though the report acknowledges the dangers here.

Also small and medium sized companies may not be able to put in the initial time, effort training and finance to switch over to a new way of operating. But the report says that all companies can benefit from using at least some of the techniques it covers, and small companies have the added advantage of creativity and flexibility which the report says should be nurtured.

Suggestions are backed by a guide in how to implement the strategies as well as brief examples from large and small companies. Stages include analysing the real cost of manufacture which includes the whole design phase, costs of unreliable deliveries, excessive inventories, poor quality and poor service, and inaccurate invoicing.

Winning together in UK electronics. National Economic Development Council. 071-217 4037.

£9.5m fillip for UK chip research

The DTI and the Science and Engineering Research Council have made £9.5m available to support two innovative research and development programmes in information technology. The programmes are aimed at encouraging greater participation by smaller firms and giving research consumers a bigger say in determining the areas where technological advances are required.

DTI funding for each programme will be worth £4m and the Serc will be making an additional £1.5m available to higher education institutions for collaborative research in design automation.

The Advanced Silicon Technology Programme aims to improve the targeting of silicon chip research by defining requirements that cannot be addressed by current technology, and, by working closely with silicon research groups develop novel solutions. The areas expected to be addressed include: parallel processing; neural networks; high-speed/low-power; "silicon-on-insulator" techniques, and extended functionality.

The VLSI (very large silicon integration) Design Automation Programme should increase productivity and expertise in the design of electronic systems by giving UK systems companies improved tools and techniques for designing high complexity silicon chips.The programme will specifically look at high-level design, novel architectures and niche-area tools.

Both programmes complement the much larger European Esprit and Jessi programmes. These typically involve large (£10m) projects from the mainstream silicon manufacturers and cad tool vendors.

Over 850 air force veterans who played a vital part in development and operational use of radar during World War II gathered in Coventry for their first major reunion in more than 45 years.

The unsung heroes of WWII, many of whom had worked in ground radar stations (known as Air Ministry Experimental Stations) at home and overseas, helped advance radar technology during the grim years. Veterans from Canada, Australia and New Zealand joined their British counterparts at a banquet with their patron, Sir Bernard Lovell, FRS, as guest of honour, and a special service in Coventry Cathedral. Three of the city's hotels held exhibitions of WWII radar equipment, photographs and memorabilia. The reunion was largely the result of persistent efforts of a team of people over several years, led by Harry Jurd, chair of the organising committee, himself a radar operator in the North African and Italian campaigns.

Cuk converter and Labtech notebook

Two articles in the last issue - review of Labtech notebook and the article on the 60W Cuk converter - were victims of a particularly malicious electronic publishing gremlin.

Two text boxes in the Labtech review which should have contained explanatory text instead appeared as mysterious black boxes.

In the Cuk converter article Figs. 1 and 2 were missing and the maths equations were corrupted and appeared in the wrong places.

We sincerely apologise to readers for these annoyances.

Any reader wanting the lost figures and correct maths for Cuk should write to *EW + WW* and we will happily send a copy of the correct, original article.

The text for the two Labtech review boxes is given below.

Dongle disappointment: First disappointment occurred early on when I opened the product box to discover a dongle, that annoying piece of hardware plugging into the parallel port (to protect against copying) and without which the package will not work.

In my case the software only sometimes worked with it.

Software manufacturers do not seem to realise that dongles are very unpopular with users.

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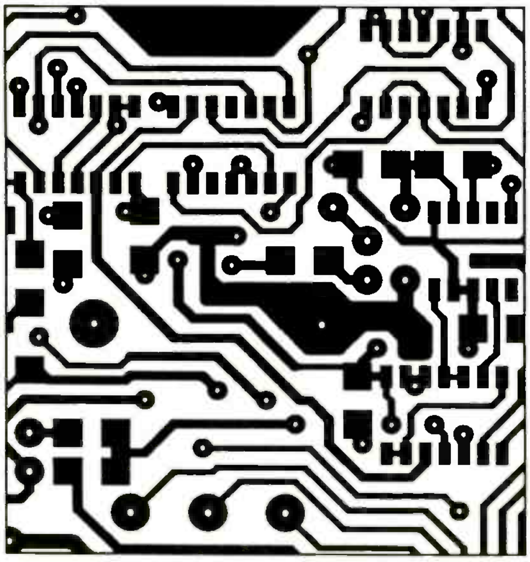

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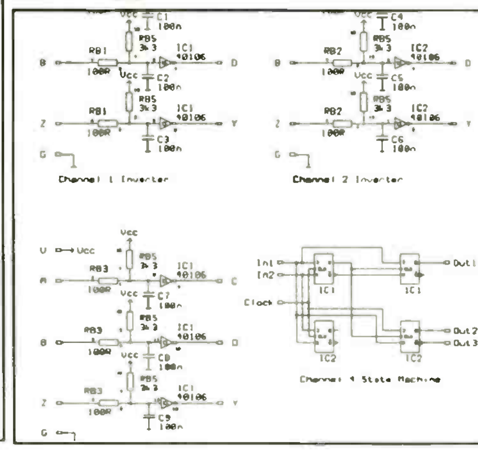

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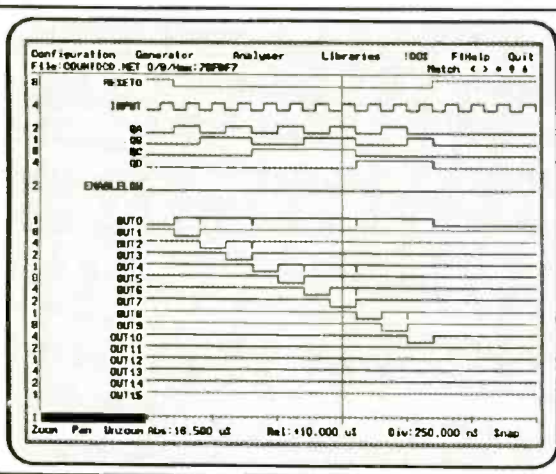

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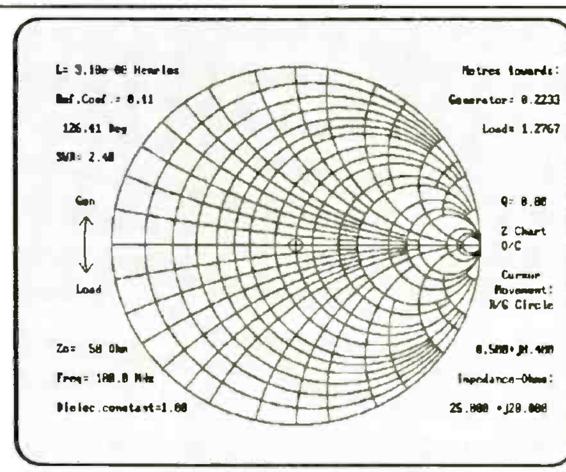

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Optical memories that won't blind you with science

Imagine an optical storage device that can hold up to 10^8 bits of information in a single spot the size of a pinhead. Or goggles that automatically diffuse intense light to protect their wearers from being blinded by lasers.

Such devices and many others are now a step closer to reality following the discovery of the world's first polymer having an optical characteristic previously found only in a few small, expensive crystals.

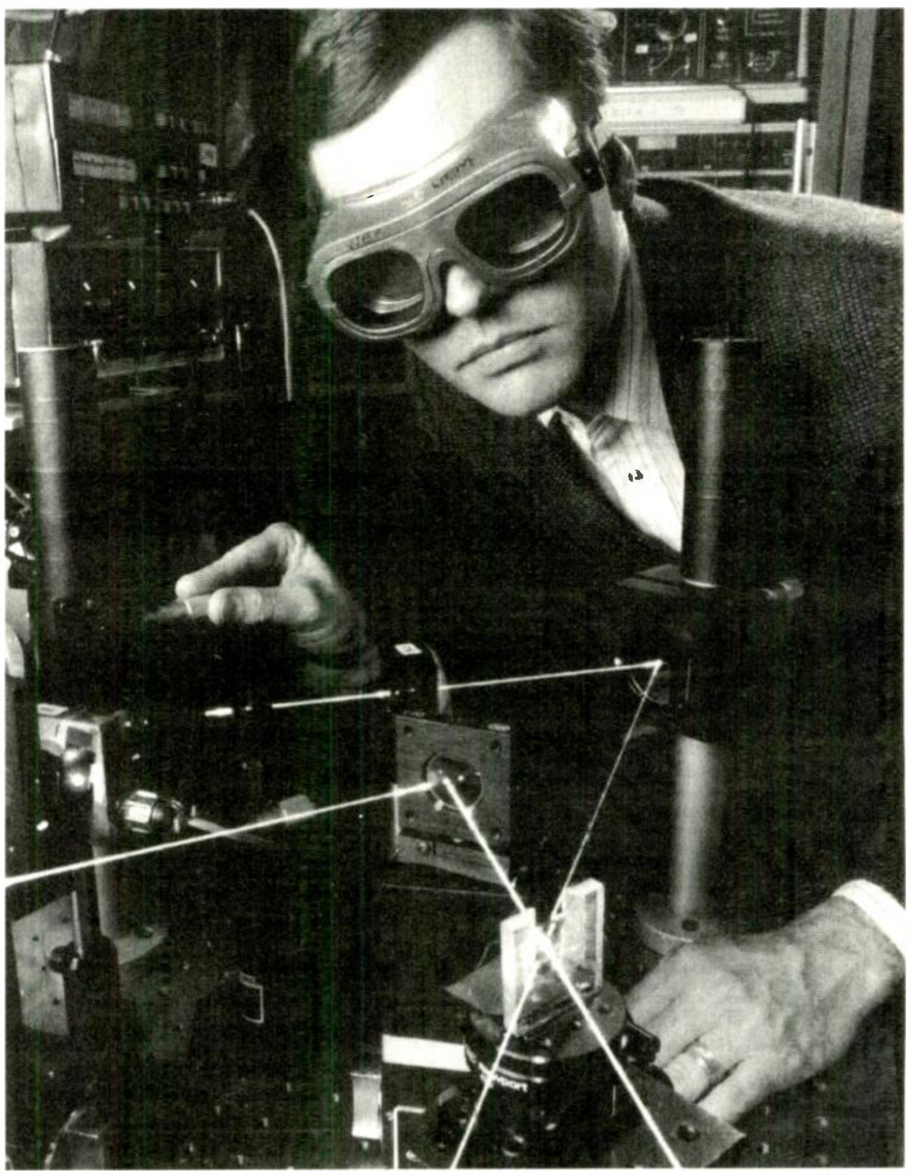
This polymer is the first to exhibit the photorefractive effect, that is, illumination by light causes electrical charges within the material to move, altering its refractive index.

The discovery was made by four scientists at IBM's Almaden Research Centre, San Jose, California - W E Moerner, Stephen Decharme, J Campbell Scott and Robert J Tweig. Since the photorefractive effect was discovered 27 years ago by Bell Laboratories, applications have been limited to laboratory demonstrations in very simple geometries, such as recording simple holograms or making optical filters. This is largely because of the expense of the crystal. Also, the strength of the photorefractive effect in crystals is limited. Although electron donor and acceptor elements are often intentionally added to a crystal to create or enhance its photorefractive effect, a rigid crystal structure will accept only relatively small amounts of doping before it distorts, losing both the required optical quality and the photorefractive effect itself.

However, IBM scientists have suspected for about three years that it might be possible to custom-design organic polymers to be up to 10 times stronger photorefractors than crystals. They also expected that such polymers would still retain the desirable properties of being cheaper and easier to make into usable forms, especially thin films.

The team started with an epoxy polymer (called BisA-NPDA), which has a refractive index that changes when exposed to an electric field. They then added an organic photoconductor material (called DEH) used in copiers and laser printers to serve as the charge transport agent. The resulting polymer mixture exhibited a modest photorefractive effect - a diffraction efficiency of 0.01 to 0.001%. More recently a much stronger photorefractive effect - up to 0.1% diffraction efficiency - has been achieved with a mixture of DEH and another epoxy formulation (called NNDN-NAN).

When two laser beams cross within a photorefractive material, they create a pattern of electrical charge similar to a hologram that changes the optical properties of the very material it is passing through. In some cases, this effect permits one to store 100 complete holograms or images - each containing more than one million bits of information - in a tiny volume, about $3mm^3$. Or, if coated onto



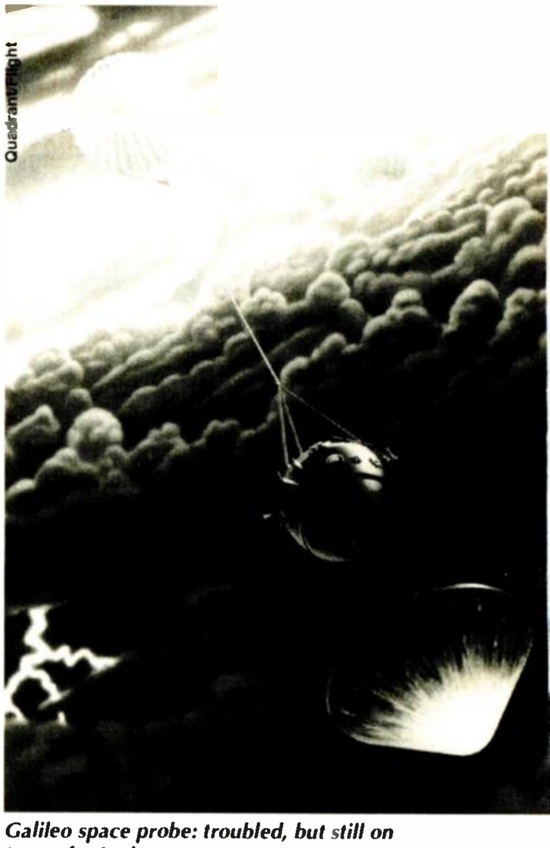
Safe specs: protective coatings on goggles, and high density memories are two applications of photorefractive polymers – materials that change properties in response to light passing through them.

goggles, a photorefractive film could disperse a laser beam so the intense light does not damage the wearer's eyes.

Photorefractive materials can also improve the optical quality of laser imaging and optical communications devices through a property called phase conjugation. Since a photorefractive hologram can contain essentially real-time information about the optical quality of the medium the light passes through (such as turbulent air or an imperfect lens), reflecting a signal off such a hologram back through the medium reverses the effect, compensating for any distortions along the optical path.

The IBM team demonstrated this by projecting an image through a lemonade bottle and using phase conjugation to return the image to its original clarity.

Amazing what modern science can do!



Galileo space probe: troubled, but still on target for Jupiter

Galileo in a jam

Galileo, the $1.3 billion space mission, destined to explore Jupiter in 1995 is in trouble.On April 11 this year, 18 months into the flight, mission controllers at Nasa's Jet Propulsion Laboratory sent a signal commanding Galileo to unfurl its 4.8m high-gain antenna. This fragile, gold-plated umbrella-like structure is the means by which most of the data from Jupiter should be transmitted back to Earth.

Drive motors controlling the antenna whirred into action and the structure began to unfurl. But before it could click fully open, something apparently jammed on one side of it. Subsequently attempts have been made to unfurl this vital antenna, but at the time of writing there hasn't been any success.

Nasa are now pinning their hopes on a technique more commonly employed to free jammed car parts; they're rotating the spacecraft into sunlight so as to warm up the central post. The idea is that differential expansion could free whatever is causing the antenna to jam. If that fails, the high-gain antenna will be moved into darkness to achieve much the same effect as a squirt of freezer aerosol on Earth.

What's more interesting from a radio engineer's point of view is an experiment to try to discover what kind of shape the antenna is in and how far it is extended. Nasa plan to turn on the microwave transmitters and then plot signal strengths and radiation patterns received here on Earth. From this information they hope to discover much more about the precise orientation of the antenna than could ever be gleaned from engineering data transmitted by the two low-gain omni-directional antennas.

Yet another approach to the problem makes use of an identical spare antenna here on Earth. Inside JPL's spacecraft assembly facility at Pasadena, a team are furling and unfurling the fragile umbrella with its gold-plated mesh stretched over graphite ribs. The idea is to try to recreate the fault condition and understand why the antenna in space is misbehaving. As with the spacecraft antenna itself, this backup unit is being thermally cycled, this time to try to *make* it jam.

The only problem with these simulation experiments is that the Galileo high-gain antenna was never designed to be unfurled and re-folded hundreds of times. So the experiments have to be undertaken very carefully indeed.

Nasa project manager Bill O'Neil is confident that if nothing breaks, the antenna will eventually be fully deployed. There are, after all, four years in which to keep trying. But as a final fall-back, there's an even more ingenious idea floating around JPL: that of sending up a repeater spacecraft that would receive the signals from Galileo's damaged antenna and relay them to Earth.

What makes the idea possible is the long route currently being taken by Galileo. In order to reach Jupiter with minimum rocket power, Galileo is making use of planetary gravity to accelerate it on its way. Like a giant slingshot the spacecraft swings around Venus and twice around Earth before winging its way to Jupiter. So if a 'rescue' craft were launched directly to Jupiter it could easily catch up with the beleaguered probe.

Such an expensive solution though won't be necessary for everything Galileo is planning to do. This October, for example, it will be passing the asteroid Gaspra. In the absence of the main antenna, Galileo could record all the data from Gaspra and later play it back slowly Earth via the two small antennas. Even when it reaches Jupiter, a significant part of the mission could still be accomplished in this makeshift fashion.

Australia's alternative national grid

What may prove to be the longest electric circuit in the world has been discovered underneath Australia. A big geomagnetic survey of the whole continent (*Australian Science and Technology Newsletter* Vol 3 no 6) reveals a 6000km current running from Western Australia through the centre where it divides into two branches, one flowing north through Queensland into the Gulf of Carpentaria - the "gap" in the top of Australia .

The path of this natural current, created by the Earth's changing magnetic field, lies about 15km below the surface and is up to 200km wide. It flows through natural mineral deposits and may provide scientists with useful information on what these deposits contain.

Dr Francois Chamalaun of Flinders University in Adelaide, who did the survey, says that such underground currents may eventually provide valuable clues about the formation of oil and gas formation

Maybe they could even explain why kangaroos hop!

What will be lost if the big antenna isn't fixed will be the detailed inspection of Jupiter and its moons.

Properly deployed, the high-gain antenna will be able to transmit about 134kbit/s of data from Jupiter. At the moment the low gain antennas are transmitting about 1.2kbit/s of engineering data, which will reduce to about 10 bit/s when Galileo reaches its destination.

Dead stars tick to lively beat

A massive dead stars circling one another at up to a tenth the speed of light, with one emitting bursts of radio pulses, constitutes the most precise cosmic clock yet discovered. This binary pulsar, code-named PSR 1534+12 will offer an exceptionally accurate tool to study gravitational radiation of the sort described in Einstein's theory of General Relativity. Such radiation has yet to be detected on Earth, though equipment with the necessary sensitivity is currently being developed.

This binary pulsar and a single rapidly spinning pulsar were discovered by Alexander Wolszczan using the huge Arecibo dish in Puerto Rico at an operating frequency of 430MHz. In his report (*Nature* Vol 350 no 6320), Wolszczan tells how the pulsars were revealed by analysing a mass of computer data using the Cornell National Supercomputer Facility. What's special about PSR 1534+12 are the strong, sharp-edged pulses that allow unprecedented measurement accuracy. The period is in fact $0.0379044403665 \pm 4 \times 10^{-13}$s.

The two stars, each the collapsed remnants of gigantic stars once bigger than our Sun, are made up of neutrons squeezed to such extreme densities that one teaspoonful would weigh a thousand million tons on Earth. Because they orbit each other at such an enormous speed, it is calculated that they should lose energy in the form of gravitational radiation. Measurement of how the pulse repetition rate of the radio pulses changes with time should enable astrophysicists to test Einstein's theory with a high degree of precision.

The unique characteristics of the pulsar's radiation and the polarisation of its emission will allow scientists to study another, previously unconfirmed relativistic effect called geodetic precession, the wobble of the star on its spin axis.

As more fast "millisecond" pulsars are discovered, astronomers will hopefully be able to combine the data and rule out measurement errors due to earthbound atomic clocks and irregularities in the Earth's own rotation. The resulting improvements in timing accuracy should then make it possible to detect, unambiguously, the ripples of ancient gravity waves that warp space-time and which change the distance each pulsar pulse has to travel to reach Earth.

Whether it will be here on Earth or 1500 light-years away in space, confirmation of most of Einstein's predictions seems close at hand... relatively speaking.

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

Closet engineers, where are you?

Many times in this journal I've tried, almost in vain it seems, to stimulate research into closet electronics. But judging from the marketplace, sanitary engineers are even less inclined to embrace the silicon age than their automotive counterparts. Could it be, I wonder, a result of that unique British fetish for keeping water and electricity apart - like matter and anti-matter? Or is it some deep-seated (sic) fear of what might happen when things go wrong. The most likely explanation is that electronics engineers, brought up on wholly intelligible and utterly genteel terminology, find the language of plumbing arcanely impenetrable. You don't believe me? Just visit the local plumbers' merchant and ask for a few screws, nipples, female couplings and sex-reversers. You won't even raise a smile.

Whatever the true reason for this technological impasse, the British public are still highly suspicious of having chips in the closet. Even to this day I notice visitors emerging from my own electric WC with a bemused grin on their faces - though to be fair it's not the technological wizardry that provokes their intrigue so much as the 22mm exit pipe.

Worried that my evangelistic enthusiasm for bathroom electronics might be waning, the Editor recently passed me a press release from the Sloan Valve Company of Illinois. Not, as one might imagine, anything to do with upper-crust thermionics, but an organisation after my own heart. R&D engineer Rich Kamysz bemoans that "we have a lot of electronics technology in space but little in public bathrooms". Warming to his theme, Kamysz declares: "Restrooms are the last frontier in electronics." Cool it Rich; when did you ever see Captain Spock go to the toilet?

Enough preamble. Sloan Valve have made a "quantum leap" in faucet technology (look it up in a dictionary) by incorporating a patented bendy printed circuit board into their sensor-operated lavatory faucet. Still puzzled?

Basically, it is a touchless tape that dispenses water when it sense your hands in the washbasin. Infra-red technology avoids the need for taphandles that can spread germs. (Think about it: how do you wash your hands before you turn on a conventional tap?)

Hands-off taps clearly have a great future at this final electronic frontier. But why oh why does the company list amusement parks among potential users?

Public lavatories: the final frontier for electronics?

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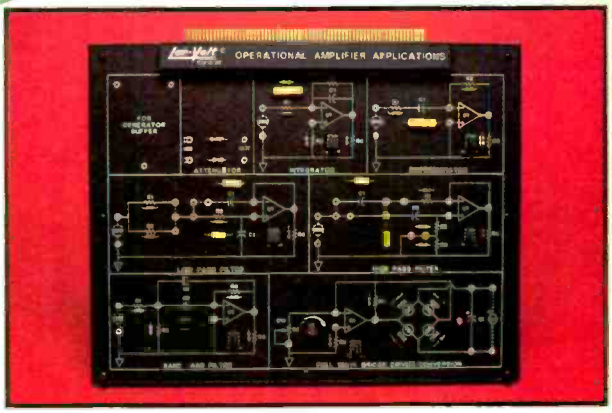

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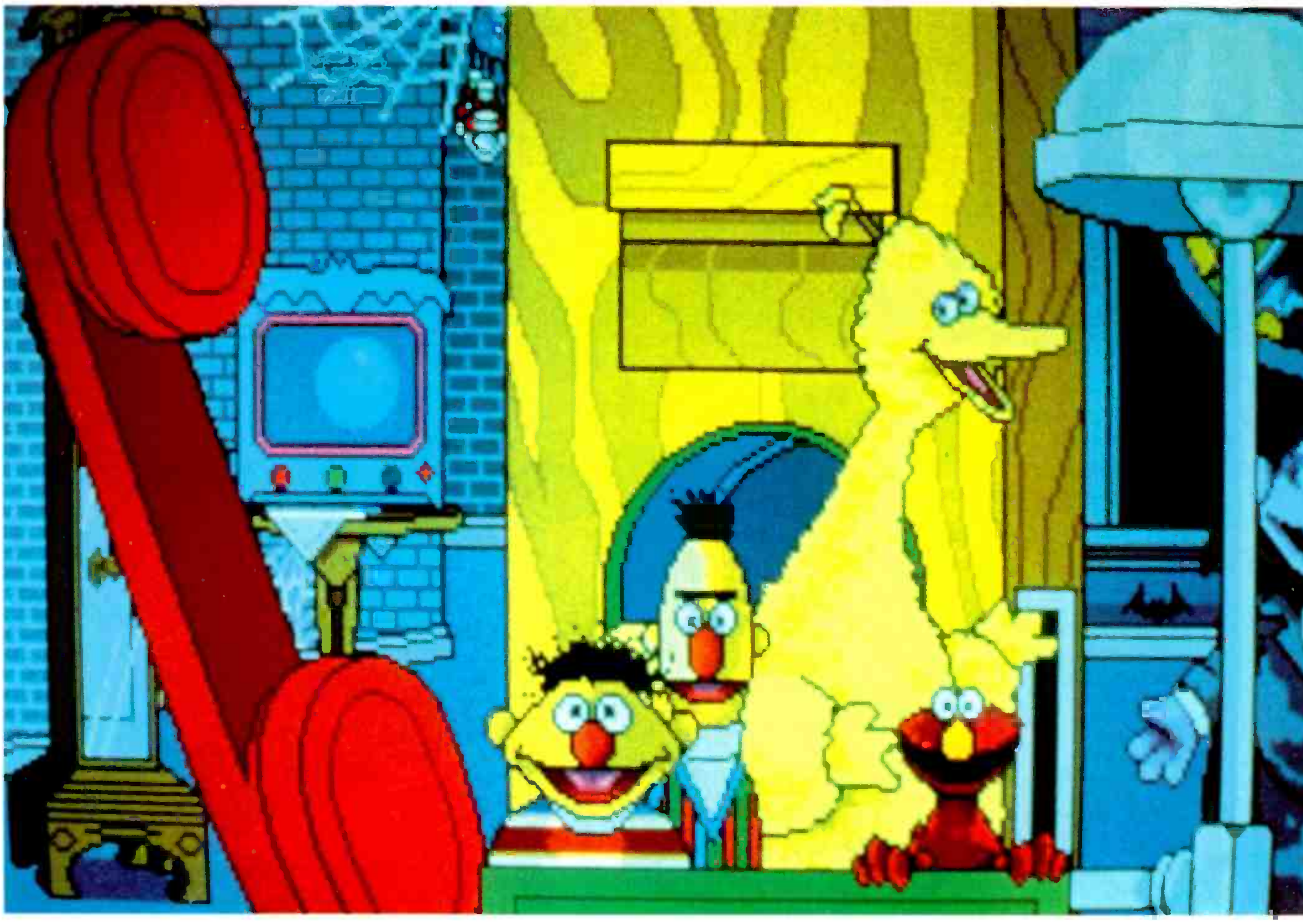


VISION OF THE FUTURE?

"CD-I will be the most significant mass market electronics product since the compact cassette." Thus speaks the Philips marketing department about interactive video technology based on compact disc. But the history of consumer electronics is punctuated with brilliant inventions which failed and indifferent ones which succeeded. Karl Schneider looks behind the corporate optimism.

Next year promises to be the most interesting ever for the consumer electronics industry. In the audio market, Philips and Sony will battle for succession to the old compact cassette - Philips with its digital compact cassette (DCC) and Sony with MiniDisc (MD). In TV, the new 16:9 format wide-screen sets will become familiar items in high street retailers but, at £3500 a time, one suspects not in many sitting rooms.

Consumers themselves know least about the most innovative new product to hit the market in 1992, the interactive CD, or CD-I.

The new audio and TV formats will simply replace consumer goodies which are already a familiar part of most homes. CD-I, however, is something new, enabling people to interact with sound and pictures in a way not previously possible. Its proselytising fans – chiefly Philips and Sony who pioneered the technology – are touting CD-I as the consumer electronics flagship of the 1990s. However, cynics say that the lack of popular software will consign CD-I to the same graveyard as VideoDisc and quadraphonic sound.

CD-I combines CD quality audio with video, text, graphics and animation to create a multi-media "world" through which you can chart your own path. That world could be a sophisticated computer game, a talking, animated encyclopedia, a teach-yourself guitar book or anything else that can fit onto a compact disc. The picture is played through a conventional TV set, with the option of routing sound through a hi-fi.

For example, an early CD-I package used extensively by Philips to show off its potential is *Treasures of the Smithsonian*, which lets you "walk around" the Smithsonian Museum in the US. You can choose any route through the exhibits, stopping to get more information on one that catches your interest or, in some cases, actually playing with the exhibit via a simple two-button and joystick control pad.

CD-I players also double up as conventional CD to play standard music records.

The technology is a combination of conventional CD, desktop computing and digital signal processing techniques. At its heart is

Learning the alphabet can be fun when you have TV's Big Bird and his Sesame Street friends as your teachers. Educational business could be crucial to CD-I success.

the potential 650Mbyte random access storage capacity of a compact disc. This opens up a new world to software developers who, until now, have had to fit their packages within a few megabytes on floppy discs.

Other media, such as video tape, can match the CD storage capacity. But they limit access to a linear journey through the software – like a train, forced to follow the path of the track. CD's random access allows unrelated jumps around a 650Mbyte world at will... at least in theory. In practice, the amount of freedom of movement is limited by the degree of branching written into the software: the more branching allowed, the more difficult and time-consuming (and hence expensive) the package is to write.

The first hardware

CD-I was originally developed by Philips, an extension of its pioneering work on audio CD. The firm published a provisional specification back in 1986. But Philips quickly opened its doors to involve other consumer electronics manufacturers at an early stage, in particular Sony and Matsushita. Standards are all-important in consumer electronics. By pulling the world's three biggest consumer electronics firms into the CD-I fold Philips hope to have put CD-I in an unassailable position as the world's consumer multimedia format.

The first CD-I players will go on sale in the US and Japan this October, followed by a European launch in the Autumn of 1992.

The industry got its first view of fully-working consumer CD-I players in May, just five months before they are due to be in the shops.

Wide variations in the styles of the players reflect the hybrid nature of CD-I, bridging the divide in most sitting rooms between the TV and VCR on the one hand and the hi-fi stack on the other. Philips' player looks just like a VCR, styled to sit comfortably under a TV. Matsushita's offering, branded with the Panasonic name, is packaged to match the company's mini audio systems. Typically, Sony has shot off at a tangent and started off with a portable CD-I player measuring 135x54.5x160mm, with a four inch LCD colour screen.

None of the CD-I players shown so far can provide full-screen, full-motion video (FMV) (see box). The ability to display normal TV quality moving pictures over the whole TV screen is important because it would make it possible to show feature films and pop videos on the CD-I format, as well as widening the possibilities for CD-I-specific software developers.

Originally FMV was supposed to be included in CD-I at its launch. But FMV requires more than 100:1 data compression of the digital video signal before the CD-I player can deliver pictures off a disc fast enough. Developing the complex compression and decompression algorithms and chips turned out to be more difficult than anticipated. So the initial US and Japanese launches will be without FMV. However, the manufacturers maintain they will have FMV ready for the European debut of CD-I. US consumers will be able to upgrade their pre-FMV players with a simple plug-in module, they say.

Software is the key

With or without FMV, everyone agrees that the availability of eye-catching, innovative

MOVING PICTURES FAST

CD-I is due to be extended to include full screen, full motion video (FMV) next year. To do this requires highly sophisticated techniques to reduce the huge amount of data that would otherwise be needed. A single TV picture contains about 1MB of raw information and for FMV, 25 or 30 such frames have to be displayed each second. So compression ratios of several hundred to one have to be achieved to squeeze this data through CD-I's 170kbyte/s pipeline.

The MPEG compression protocol adopted for CD-I uses a combination of three techniques:

Discrete cosine transforms are used to store data in the frequency domain rather than as at signal. When the data is coded in this way, as much high frequency information as possible is thrown away.

Differencing techniques make use of the fact that many individual pixels on a screen do not change between two consecutive frames. So once one frame has been stored, the next frame can be generated by just coding the changes from the first frame.

Motion vectors reduce the amount of data needed when part of a picture is simply moved as a block between one frame and the next – for example when a car is moving across the screen. Once the data to display the car has been stored, the only extra data needed is that required to say how far and in what direction the car has moved between frames.

Philips CD-I player includes bitstream CD audio and photo compatibility

software will be the key factor in deciding the success or failure of CD-I. A CD-I player is merely a black box, a piece of enabling technology. The software will decide the commercial fate.

No one knows this better than Philips. In the early 1970s the company led the way in the development of a home video cassette recorder, only to lose out to the technically-inferior VHS format. The simple truth was that the average video hire shop had shelves full of VHS tapes, a much smaller set of Betamax movies and probably hadn't even heard of Philips' eventual offering – Video 2000.

VideoDisc, Philips' analogue laser disc format for movies, suffered a similar fate. Early forecasts predicted more than five million units a year by 1990; total sales of the players never even reached the 5000 unit mark.

Scarred by these memories, Philips has taken the lead in building a network of deals and joint ventures designed to ensure that there are plenty of titles ready when the players hit the streets.

In the US Philips set up American Interactive Media, a joint venture with its own music subsidiary Polygram. Since 1986 AIM has been developing the new skills needed to write CD-I software, and the company expects to have 50 titles on sale in the US by the end of this year.

In Europe, Philips has just formed Philips Interactive Media Europe, with a mission to have at least 50 CD-I titles ready in each of the six main European languages in time for next year's European launch. Rather than developing software by itself, the new company will scour Europe searching for firms or people with ideas that can be turned into CD-I titles. PIME has been given a blank cheque to fund these projects – another sign of Philips determination not to get caught without software.

Other deals include a joint publishing venture with Robert Maxwell's Maxwell Communications to make travel and language-learning software and a deal between AIM and Nintendo, the world's number one home computer game firm, to produce souped-up CD-I versions of some of Nintendo's most successful games.

In the short term, almost all the CD-I software on the market will come from companies set up on the initiative of hardware manufacturers. But the long term aim is to encourage the development of a strong, independent CD-I publishing industry. To this end Philips has embarked on a programme to make it easier for firms to break into CD-I title production.

Philips has its own CD-I production studio in Dorking which it is using as a facilities house, allowing outside firms access to its equipment and, more importantly, its CD-I software experts. The company is also making available a series of authoring tools for use on Sun, Apple Macintosh and IBM PC computers which turn text, images, sound and control instructions into CD-I code. The most ambitious package, called *MediaMogul*, is designed to enable people with no computing experience to produce complete CD-I titles from scratch.

Unopposed system?

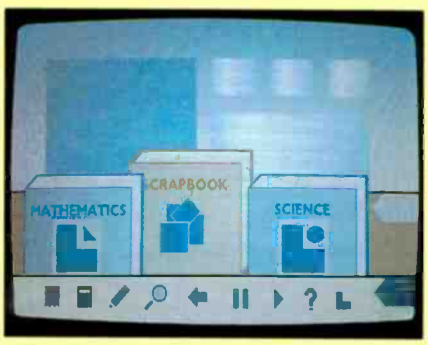
The establishment of CD-I as a standard and the hand-building of a new software industry are particularly crucial because CD-I does not have the market to itself. Commodore, the US games computer maker, has already launched a rival system called CDTV based on its Amiga computer. Like CD-I, the soft-

CD-I IN THE CLASSROOM

This page shows screen images from Spin UK's Education Demonstration Disc. The disc is aimed at pupils aged 11 to 14 taking the Mathematics and Science National Curriculum. The disc encourages children actively to participate in the learning process by allowing them to view audio-visual essays and then test their knowledge using interactive simulations.

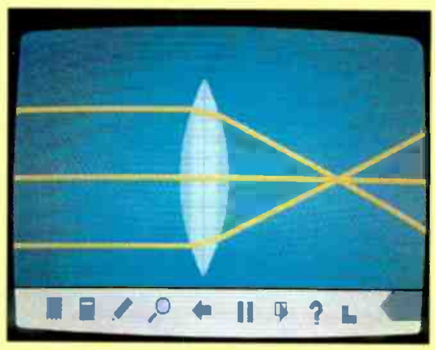
CD-I employs a remote control or a mouse in order to point and click on icons displayed on the screen.

Screen 1 shows the initial screen which represents a classroom. The background contains a blackboard for text on the left and display screens for images on the right. The midground contains a table with three books. The foreground contains a bar with the fol-

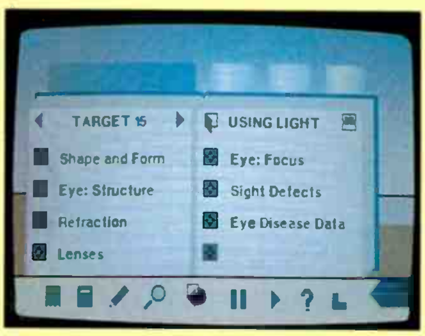


SCREEN 1

SCREEN 3



SCREEN 5



SCREEN 2

SCREEN 4

SCREEN 6

THE SOFT SELL

Until this year there were only two CD-I software titles that anyone had seen working fully – a golf game and the Smithsonian museum guide. But at last new packages are beginning to come off the production line of AIM, the joint venture company set up by Philips and Polygram to develop and commission CD-I software. Other companies will have titles ready before the end of the year.

Children's titles feature strongly in the catalogue of AIM discs ready now. There are two *Sesame Street* packages, which use Muppet characters to teach children about numbers and letters. Children can learn the alphabet with Big Bird in his nest, read a story with Bert and Ernie or play number games with the Count in his castle.

With *Cartoon Jukebox* children can colour in characters in animations based on nursery rhymes, with a separate segment that lets them isolate each instrument and voice in a Dixieland band to see how each part fits into the whole. *Children's Musical Theatre* allows children to compose a song by choosing from a total of 15,000 possible lyric changes, and then watch it being performed in either rock, classical or country style by a group of animated performers.

A far more ambitious title, *Sandy's Circus Adventure*, is an interactive storybook that lets children decide the way the adventure unfolds, by choosing from a selection of possible outcomes at key junctions in the story.

For adults there are serious titles, such a teach-yourself photography course that includes 25 interactive workshops on different photographic techniques using examples from three leading photographers. A novel camera simulator turns the TV screen into a camera viewfinder and lets you take practice shots of a selection of still or moving images, adjusting the field of view and shutter speed to see how they affect the resulting image.

But the main emphasis is on entertainment. *Caesars World of Gambling* features blackjack, slot machines, craps tables and a roulette wheel, with full sound effects but without the financial risk. The programme can keep track of the winnings and losses of up to 12 players, and gives tips on how to improve your game for persistent losers.

By far the most impressive game shown so far is *Escape From Cyber City*, a futuristic action adventure game in which the player has to battle his or her way out of a city full of robots, mutants and other nasties.

Other titles which are in production and are due out this year include a backgammon game, a gardening guide, jigsaw puzzles, atlases, a guide to astrology, an interactive TV game show and a host of new role playing games.

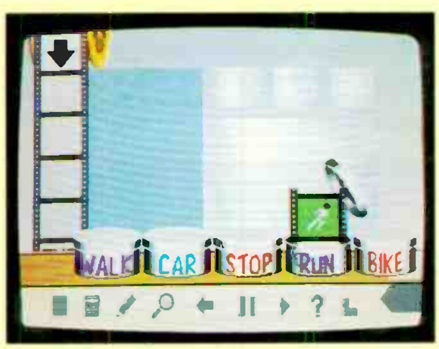
lowing icons: bookmark, calculator, pencil, magnifier, go back, pause, play, help and tutor help.

Science

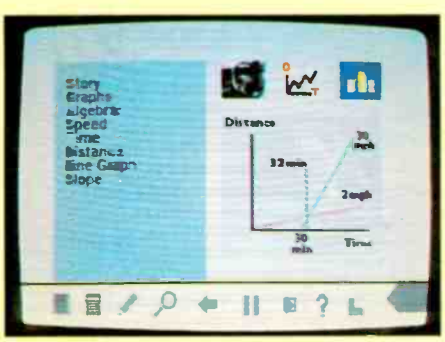
Screen 2 shows the result of clicking on the Science book in order to open it. The screen is a menu allowing access to various sections. Screen 3 shows the result of clicking on the Eye Structure icon; by pressing Play the AV essay starts. Screen 4 shows an image from midway through the essay. As the audio commentary proceeds the images in the video screens change, and keywords are added progressively to the blackboard. The pupil will be able to click on a keyword to receive more information on the topic.

Screen 5 shows an image from the Eye Focus essay; in this section a full screen display is used to allow the illustration of complex images.

SCREEN 7



SCREEN 9



SCREEN 8

SCREEN 10

Mathematics

Screen 6 shows an early shot from an essay explaining the use of distance versus time graphs. The relationship between the two variables is demonstrated by showing a car travelling along a road. In Screen 7 the concept of the graph is introduced in order to relate distance to time as the car travels at a constant speed.

In screen 8, at the end of the essay, two graphs are superimposed in order to predict when the car will overtake a walker.

Screen 9 illustrates the interactive simulation which follows the graphs essay. It shows the pupil opening one of the film cans in order to insert a film clip into the strip on the left. Once the film has been assembled it can then be played with the display showing moving video in the right hand window and a simultaneous animated graph in the left hand window.

Languages

Screen 10 shows a shot from an essay on the electromagnetic spectrum. In this part of the disc the pupil is able instantly to switch between the three languages shown.

INSIDE THE BLACK BOX

CD-I hardware is based around Motorola's 68000 family of microprocessors, controlled by a variant of the Microware OS9 real time operating system. The microprocessor controls data flow around the system and interprets CD-I commands in real time.

Surrounding the microprocessor are four sets of dedicated chips, each handling a different job. CD drive interface and control chips run the CD mechanism, recognising different types of data on the disc and controlling the flow of data from the disc. They separate out control information from the data stream, which is then passed on to two sets of digital signal processing chips, one for audio and one for video. The last set of chips perform I/O, controlling a wide range of possible peripherals including infra-red remote controls, joysticks, keyboards and displays.

At present it takes around 100 separate chips to perform all these tasks: Motorola aims eventually to integrate all these functions onto a single seven millimetre square chip, containing around two million transistors and costing less than ten pounds. In addition, each player has a minimum of 1Mbyte of ram for fast-access memory.

Each compact disc can store about 650Mbyte of information, held in blocks each just over 2Kbyte long. These blocks come in two types. Type one, for control and text data, carries header information to identify the data type, 2048 bytes of data and then some error correction information. The second type, used to carry audio and video information, does without the error correction data to give 2230 bytes for storage. The two types of data can be interleaved at will on a single CD track, so control data, text, audio and video information can all be read from the disc simultaneously.

The main limiting factor for CD-I applications is the rate at which this data can be read from the disc as it rotates at a constant speed: for CD-I this rate is set at 170Kbyte/s. Writing CD-I software is a balancing act, trading off picture quality, sound fidelity and frame rate to fit within the data rate. To make this possible, the CD-I standard includes four methods for picture encoding and three for sound encoding.

Picture encoding methods range from DYUV which can code 16 million different colour tones to show photographic quality pictures, to run-length encoding which can handle just 128 colours and is ideal for simple animation. The four sound encoding techniques give music quality ranging from full CD digital audio to AM radio broadcast quality, suitable for speech. So, for example, full CD quality music can be played while accompanying text is overlayed on a still background.

Alternatively, one could have a slide show of high quality still pictures with a spoken soundtrack in a choice of several languages. A third option would be to show a part-screen TV-quality video sequence with AM broadcast-quality music.

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ware comes on standard five inch compact discs, but coded in a way that is incompatible with CD-I. CDTV will also play standard audio CDs. The hardware went on sale in the US in April and is already in some branches of Dixons in the UK.

Because it is based on older technology, CDTV is inherently more limited and runs incompatible, less sophisticated software. More importantly CDTV is a proprietary system. Commodore is the only company making players. With standards so important in consumer electronics, this could deter customers. It also makes it harder for Commodore to persuade software firms to write for CDTV.

Commodore has now recognised the weakness and is trying to interest other manufacturers in making CDTV players. But so far no deals have been announced.

On the other hand, with the Amiga so well established as the premier games platform, there is a ready-made pool of software writers familiar with the format. And existing Amiga software will run on CDTV, although it comes nowhere near making full use of the hardware potential. Commodore's standard response to critical comparisons with CD-I is that CDTV is in the shops now, whereas CD-I is not.

The game Escape from Cyber City is typical of CD-I's combination of action and interactive decision making.

Intel, the US microprocessor firm, is also believed to be considering a consumer version of its digital video interactive (DVI) format, at present used only for commercial applications.

By the time CD-I is launched in Europe, consumers could find themselves faced with three incompatible interactive multimedia formats to choose from. Some observers see a rerun brewing of the VHS, Betamax, Video 2000 battle fought in the late 1970s.

Is there a mass market at all for consumer multimedia? Certainly with the existing software and at the expected starting price for a player of around £700 few people expect more than a minority of techies to splash out on CD-I in the first year or so. The market after that is in the hands of the software developers. Some say what is needed is a "killer application", a winning CD-I title that is strong enough by itself to persuade punters to buy a player.

The education business could provide a firmer foundation. Interactive video seems a near ideal teaching medium, demanding from the student an intellectual involvement denied to passive video aids. Take a chemistry lesson for example. The branching in a CD-I presentation might depend on student predicting the results of a chemical experiment. Presented images might show the formation of a coloured precipitate if correct, or a clear solute if wrong, etc.

Should the price falls sufficiently, CD-I could take off through its conventional CD capabilities. People looking to buy a CD player may be persuaded to pay a premium to get CD-I thrown in as well, as long as the premium is not too high. ■

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HP 8699B Sweep PI – 0.1-4GHz £750 – HP8690B Mainframe £250.
HP Digital Voltmeter type 3456A – £900.
HP Multimeter type 3478A – £300.
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Racal/Oana digital multimeter type 5001 – £250.
Racal/Dana Interface type 9932 – £150.
Racal/Dana GPIB Interface type 9934A – £100.
Racal/Dana Timer/counter type 9500 (9515 OPT42) – 1250Mc/s – £450.
Racal Frequency standard generators type MA259 – 600Kc/s – 1Mc/s & 5Mc/s – £200.
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Racal/Dana Modulation Meter type 9009 – 8Mc/s – 1.5GHz – £250.
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Adret Signal Generator type 7100A – 300KHz-1.3GHz – £1500.
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Marconi Bridge type TF2700 – £150.
Marconi Attenuator type TF2163S – 1GHz – £250.
Marconi/Saunders Signal Sources type + 6058B – 6070A – 6055B – 6059A – 400 to 18GHzS. P.O.R.
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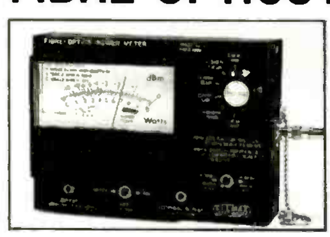

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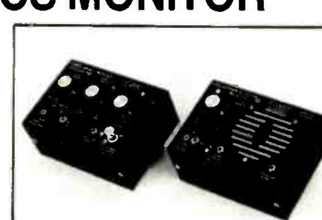

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CIRCLE NO. 130 ON REPLY CARD

Developing situations

The chips are down. Changes in microprocessor development systems have mirrored changes in the microprocessors. But today microprocessors are being designed with on-chip facilities that help the designers of development systems. We have gone full circle. Steve Rogerson traces the events.

Today's microprocessor development system (MDS) is a much different animal from the early 8bit machines, but then again microprocessors themselves have come a long way since then. The whole history of MDS has been driven not by its own dynamic but by the technical changes in microprocessors and the demands of a much more open market.

The original 4bit microprocessors had no dedicated development systems. They didn't need them, they were very simple and slow and had small programs. It was only with the introduction of 8bit devices that the increased complexity meant that some form of MDS was needed. In those days the tool of the trade for digital circuits was the logic analyser.

The early microprocessor manufacturers started to sell their own development systems for their own chips. So if you had an Intel chip, you had to have an Intel development system. They were expensive bulky devices and totally dedicated to one task. And the engineer with two microprocessors from different companies had to have two of the beasts. Large instrumentation companies like Tektronix and Hewlett-Packard also produced some MDS machines.

Tektronix became the leader in these alternatives that were based on Vax type machines. Compiler and assembler software was developed for the Vax and an emulator system would be used for debugging.

The Blue Box

The antiques from the manufacturers were originally paper tape based with information being fed in by teletype machines. The first to switch to floppy disk drives was the Blue Box from Intel, probably the most famous of all the early development systems and typical of most of them.

The Blue Box was really a dedicated form of PC and could have five or more 8in floppy drives piled up on top of it. Later versions had the option of a hard disk drive but the high expense of this limited the take up. It was a Multibus I based product and things like in-circuit emulators took the form of one or two plug-in cards.

The result was a large Blue Box with a big fat cable that plugged into the target system. Software was written using an editor on the system. The user would then have to assemble it and download the program through the emulator. The system was tested in the target. Prom programmers were also dedicated to the Blue Box. They were separate units connected by a socket in the back of the box.

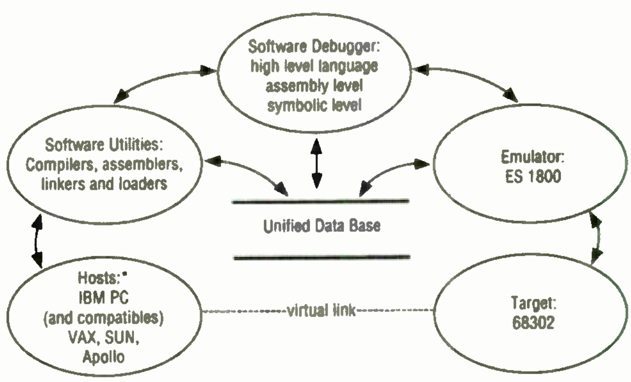
Emulator progress

The next stage was when some companies started making emulators that were independent of the host computer and with the advent of the PC this potential became realised in the early 1980s. This was really the biggest change. It broke the monopoly that the chip manufacturers had in development systems.

Emulators started to take the form of PC plug-in cards. Later products were developed for CAD machines like the Sun workstation. A large number of Blue Boxes ended up in skips.

The first emulators were test instruments for the production and service environment and it took about two years before development facilities such as breakpoints started to appear. A breakpoint is the point where the emulator is programmed to stop the chip working. The trigger can be anything from a variable taking a certain value to more complex things like a loop having been performed a set number of times when a variable is at a certain value. Trace memory lets the user trace the way the microprocessor

Microprocessor development environment, as seen by Applied Microsystems.



has executed the code up to and including the breakpoint.

A number of firms have emerged to service the PC based MDS business. This has led to a major change in attitude by the chip makers.

At first the emulator manufacturer had to wait for silicon to appear before designing the MDS. Today the chip makers approach the emulator firms before they have silicon. For example Motorola gave all the necessary information to build an emulator for the 68020 to Applied Microsystems before the chip was launched. This was obviously an advantage for both companies. It meant Applied Microsystems had its product out early and Motorola could tell its potential customers that it had the development tool ready.

Intel did a similar exercise with the i960, even supplying the bond-out technology, something it once would have guarded jealously (bond-out technology is a way of setting complex and sequential breakpoints on events that occur outside the cache). In fact the chip makers actually go out and encourage people to use their once closely protected tools. This is partly because chip makers no longer want to do it all themselves and partly because having a range of development tools available helps sell the chips.

Software development

Initially the Blue Box ran on Isis, Intel's own operating system, and the forerunner of CP/M. When PCs appeared they were cheaper than the Blue Box so some firms started to produce Isis simulators that let the PC run Isis programs. Such simulators were still widely used as recently as four years ago.

But it was really about 1986 when the PC became the preferred development system and serious programs for development started to appear. Improvements such as colour and windows have boosted this popularity but it is really the software changes that have given the real impetus to development.

As chips moved up to 16bit, the project that needed to be tackled had grown enormously. The size of the address bus had been doubled, and there was a larger amount of code that the microprocessor could access. The speed was increasing. All of which put the MDS companies in a whole new ballgame. For example, if in a system a certain variable takes the value of, say, 10 then this might mean the system has failed. So the easiest way to determine failure is to set that as a breakpoint. You can then stop the chip and see how it did it and trace what happened leading up to the failure. A lot of 8bit machines had no sophisticated debugging facilities. If something went wrong it was literally a matter of looking through the listings to find the problem. But because 16bit chips are so much more complex it is inefficient to do it that way. Using a logic analyser and a monitor is a possibility but an emulator has to combine the facilities of both and be transparent. A monitor interferes because its operation has to be built into the code.

Another task the software has taken on successfully has been improving the user interface and windows has been one of the great steps forward. One window, say, can show the source code in C, another will show variables relevant to the task being performed. And another may have a set of commands. Previously you just saw a load of machine instructions but in the last five years giant strides have been made to improve this interface.

This is illustrated in the cost ratio of an MDS. Ten years ago the software and hardware cost about the same. Now software costs about four times as much as the hardware, and this is only partly due to hardware cost falling - as said the PC was cheaper than the Blue Box. The main reason is that, despite some hardware improvements, much more development effort is in software.

Early systems were command line driven. The user typed in a command and if it was wrong then it would show an appropriate message on screen. Now systems are available that if you start to type a command then all the options are shown along with full syntax and help facilities.

Source level debugging

One of the biggest improvements has been source level debugging. Before this came along users had to debug in hex, so trying to find out what was wrong was difficult. But today most code is written in C and not assembler. With source level debugging you see the full code on screen complete with breakpoints. The user sees the whole high level language line rather than just a line of assembler. There are still some systems without this feature, but it would be an unwise engineer who would buy one.

RANGE WITH NO LIMITS

Many new MDS products have come on to the market in recent times. This account is by no means exhaustive but will give an idea of the range of types of equipment that potential users can get their hands on.

One interesting item is the METAi from Crash Barrier. This consists of an editor, assembler, serial communications and debugger and is for use on a PC. A disassembler and various utilities are supplied as separate programs as is an eprom emulator package. (For more details on METAi, see EW+WW, February 1991.)

Pride of place in the Nohau family goes to a twinned pair of in-circuit emulators - the Emul 51-PC, for 8051 products, and the 68-PC, for 69HC11 chips. Both consist of a board that plugs in the back of the PC. There is also an optional board with extra trace functions and trigger capabilities. The pod is connected to the board by 1.5m of ribbon cable.

This architecture means there are no external boxes or power supplies to clutter the workbench and no serial channel to slow down the emulation process - a 16K object and symbol file can be loaded in 4s.

The user interface has pull-down menus, mouse support and on-line help facilities. Windows give up-to-date information on variables, symbols, registers and memory areas. The 51-PC allows for source-level debugging in C, PL/M or Pascal, and the 68-PC in C or Modula-2. The screen window will show either the source or the assembly code. Breakpoints can be marked directly in the source code window.

The optional trace board makes it possible to record the program flow in real time. Up to 16K source lines can be captured, and a trace filter can be used to trace only selected functions or, say, only interrupt functions.

Also from Nohau, Mutek and MQP is Ecal, an assembly language development system for 4, 8, 16, 32 and 64bit microprocessors. It is a cross-assembler that contains editor, macro assembler, linker, loader and source level debugger.

The Softaid CodeStalker in-circuit emulator for 32bit processors runs in all 386 modes - real, protected and virtual 8086. Zero wait state operation at 33MHz is standard. Breakpoints can be set on C source lines, trace data displayed in the original source, and all debugging performed in the same context as the code was written. A fibre optic link lets programs be downloaded at 250Mbyte/s.

Top of Applied Microsystems range is the EL3200 in-circuit emulator which has recently been upgraded to let it work with Intel's i960 32bit RISC microprocessor. It works on a Sun, PC or Decstation and includes C compiler, assembler, disassembler, and source level debugger. It also supports full symbolic debugging for assembly language.

The firm also has available its EM series emulators for 8bit chips and its ES1800 units for the 8 or 16bit 68302 microcontroller.

Chip maker Intel no longer does its Blue Box but it does have a range of development tools ranging from in-circuit emulators to evaluation boards, including an emulator for the i960. Its breakpoint capabilities include execution address, instruction type, bus read/write /access, and data value. It works on a PC and provides emulation at up to 20MHz (25MHz optional).

The firm also has a range of software debuggers for the i960 which have full symbolic debugging with source level display to allow C or assembly

Nohau's 68-PC ICE for 69HC11 chips offers pull-down menus, mouse support and on-line help facilities.

For some products though you have to work at assembler level. On chips like the 286 and 386 about 95% of MDS work is done with the high level language, but for single chip microprocessors like the 8051 it is more half and half assembler and C. It really depends on the application.

For example, take an 8051 operating an ABS braking system. Here everything has to be done very quickly and C is a bit distant to do that. For processing large amounts of data using the 386 the MDS needs to be quick but not real time.

Basically with a single chip, if you press a button something happens immediately but data processing does not have to be in real time so the simulation to check it also does not have to be real time.

If the user loads the code into a real chip and lets it go, the only way to keep track of what it is doing is in real time. An in-circuit emulator works by taking out the chip and plugging in a pod; the pod replicates the chip exactly and runs the code exactly.

The chip in the pod will be a special bit of silicon with fast memory next to it to capture each clock on the bus so that when you stop it, you can see exactly what is happening and has happened.

This is fairly complex electronically but it does let the user see what is happening in real time and, for many applications, this is what is needed. However if you have a picture processor that does not have to be in real time, you can then run through the program, instruction by instruction. It is not real time but it is cheap. It is really a software model that you can buy on a disk.

Evaluation boards

Another option for users is the evaluation board which contains the processor and a block of memory. The input and output pins from the processor are brought out to connectors on the edge of the board. It allows a user to play with code and test benchmarks to see if the basics of design are right. It suits empirical exercises and it has also found use in colleges for educational purposes.

Evaluation boards are not true development tools but they are cheap and important and some people have taken them a long way. When you run code though them they will not provide the same facilities as an in-circuit emulator. This is because the software is also running other things from the board such as a monitor, so there is a certain amount of intrusiveness.

While changes in development systems have followed changes in silicon, there is now a certain amount of reciprocity. When looking at code the user wants to go somewhere and stop. Hardware in the form of an emulator looks at what has happened. But some of that hardware is now being put on the silicon, for example registers and facilities to let the chip run one instruction at a

code debugging. Breakpoints can be defined symbolically using module names, procedure names and line numbers.

Evaluation boards and educational tools are also available from Flight Electronics including boards for the 68020 and Inmos transputer.

A software analysis workstation from Cadre comprises global trace, local trace, performance measurements and verification tools and works with assembly and high level languages. It will show how code behaves during real-time execution in the target system. It supports 8, 16 and 32bit microprocessors.

Zax sells the ICD and ERX series of emulators covering a range of microprocessors including the Z80, 68000, 80186, 80286, 80386 and 60030. The ICD has 25 and the ERX 70 resident debugger commands. Upgraded versions of the ERX have more than 100 commands.

Development tools from Smart Communications include: the Promulator that will emulate any ROM up to 8Mbit and has the facility to download a 512kbit file in less than 10s; SCMA cross-assembler for 8bit microprocessors; simulators for writing and testing software before the hardware is ready; disassemblers for recreating software, automatically substituting defined label names, and inserting supplied commands; cross-compilers supporting C and Pascal for microprocessors and controllers; in-circuit emulators for the 8051, 68HC11, TMS77C82 and MELPS 740 ranges; and a range of other development tools for the 8051 and MELPS 740.SDE from Dataman is a universal assembly language development system, a PC-based editor, macro-assembler, linker, loader and source level debugger in one system.

Microprocessor source code can be generated in the dual window editor, and then the written code can be assembled, linked and loaded into the target system with a single key press.

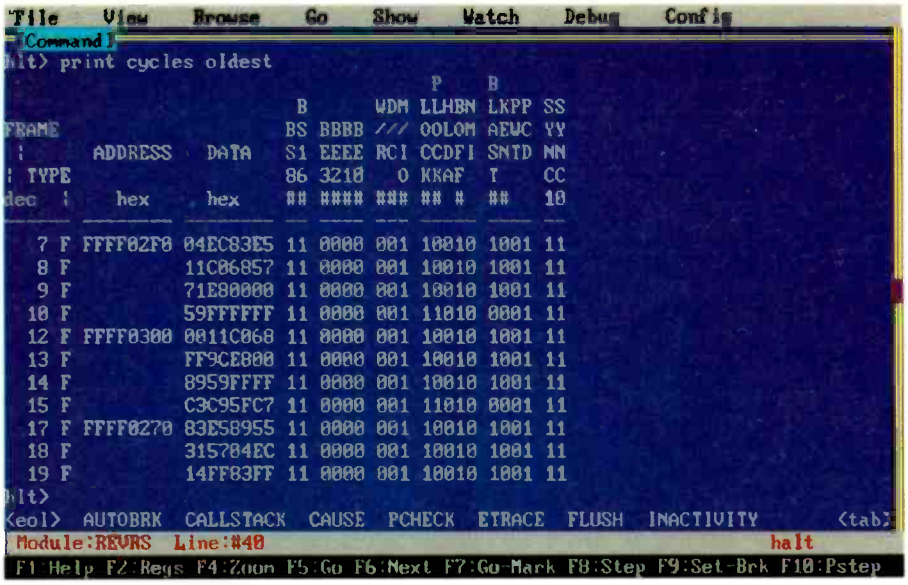
The PC-82 from Citadel can program single chips without using adapters. It can handle PALs, eproms to 4Mbit, proms, 8751s, 8748s, GALs and PEELs. It is for use with a PC and the software includes a screen editor, hex and extended hex to binary conversion programs, two and four-way file splitters, and hardware test programs.

Stag's VSDS software development system contains a dual window editor, serial communications package and source level debugger. Its macro assembler can assemble more than 50 different microprocessors. There is a single universal linker for instruction sets supporting named segments and unrestricted external arithmetic.

NEC has recently introduced a development kit for the V25 single-chip microcomputer that can be used with any PC compatible computer. It comprises an in-circuit emulator, real-time trace board, C compiler, and high-level cross debugger. It allows symbolic debugging of the software and functional evaluation of the target hardware.

One of the leading development systems is Trace 32 from German firm Lauterbach Datentechnik and available from Noral Micrologics. It can be used with a PC or workstation and provides in-circuit emulation, state and timing analysis, chip programming, and simulation functions. Noral also makes and designs its own in-circuit emulator, the SDT-X which supports more than 30 8 to 16bit microprocessors from ten manufacturers.

In-circuit emulators from American Automation support more than 150 microprocessors. High level C debugging is available and trace and performance analysis options are also possible.



Intel's in-circuit emulation of the 486 allows simpler debugging of what would otherwise be an extremely complex task.

time or go to a certain point. There is even information on the chip about where the registers are and how to operate them.

All this is designed in when the chip itself is designed. This means that debuggers are being built that can use these on-chip facilities. Eventually there will be extra interfaces on the chips so that these extra bits can be accessed directly. Now the code has to be modified slightly to allow for them, so they are a bit intrusive.

Getting into the chip itself is essential especially with products like the 486 with large on-chip cache memory; a lot of material is processed without ever coming outside the chip. This process will become much more important and in the future we will see a lot more of the debug facilities being designed into the chips. This is not a luxury.

It will become essential as chip speeds improve. In-circuit emulators of current designs will not be able to handle 100MHz chips and by the year 2000 people are predicting that 250MHz products will be available. At these speeds the cable of the in-circuit emulator will stop it working properly. The time a signal takes to go back and forwards will be too slow. This is even true with fibre optic links which are starting to appear. The only way out is to put much more on the silicon itself.

Buying a system

When buying an MDS there are a number of features you can look for, but it is really a matter of horses for courses: different people have different requirements. For example the level of sophistication needed to design a coffee machine is peanuts compared with that for, say, a missile guidance system. One essential though is that it should have an integrated environment. It is painfully slow to go into editors, linkers and so on, separately. The best systems let the user access other parts from the editor itself.

Source level debugging is also important and the system should be able to single step through the source code and set the breakpoints. Modern emulators for 32bit applications need large amounts of code that need to be downloaded quickly, so beware machines that use serial communications – the best use fibre optic links. ■

Biomation's logic analyser, aimed at top-end risc and cisc applications, uses a high resolution GUI for control. One of the few packages making use of a GUI, Biomation's goal has been to increase productivity through intuitive graphics. In the UK the package is available from Instrumatic.

ADDRESSES

American Automation, Lea View House, Two Rivers Estate, Station Lane, Witney, Oxon OX8 6BH. 0993 778991.

Applied Microsystems Corp., Chiltern Court, High St, Wendover, Aylesbury, Bucks HP22 6EP. 0296 625462.

Cadre, PO Box 1309, Beaverton, OR97075. 0101 800 547 4445.

Citadel Products ltd, 50 High St, Edgware, Middlesex HA8 7EP. 081 951 1848.

Crash Barrier, 18 Oxford St, Wellingborough, Northants NN8 4HY. 0933 224366.

Dataman, Station Road, Maiden Newton, Dorset DT2 0AE. 0300 20719.

Flight Electronics Ltd, Flight House, Ascupart St, Southampton SO1 1LU. 0703 227721.

IAR Systems Ltd, Garden Studios, 11-15 Betterton St, London WC2E 9BP. 071 379 0344.

Instrumatic UK Ltd, First Avenue, Globe Park, Marlow, Bucks SL7 1YA. 0628 476741.

Intel International (UK) Ltd, Pipers Way, Swindon, Wiltshire SN3 1RJ. 0793 696000.

MQP Electronics Ltd, Unit 2, Park Road Centre, Malmesbury, Wiltshire SN16 0BX. 0666 825146.

Lauterbach Datentechnik GmbH, Fichenstraße 27, 8011 Hofolding, Germany. 010 49 8104 9075.

Mutek (MSS) Ltd, Farleigh House, Frome Road, Bradford on Avon, Wiltshire BA15 1LE. 02216 6501.

NEC Electronics (UK) Ltd, Cygnus House, Linford Wood Business Centre, Sunrise Park Way, Linford Wood, Milton Keynes MK14 6NP. 0908 691133.

Nohau UK Ltd, Station Mill, Alresford, Hampshire SO24 9JG. 0962 733140.

Noral Micrologics UK, Logic House, Gate St, Blackburn, Lancs BB1 3AQ. 0254 682092.

Smart Communications, 2 Field End, Arkley, Barnet, Herts EN5 3EZ. 081 441 3890.

Softaid Inc, 8930 Route 108, Columbia, MD21045. 0101 301 964 8455.

Stag Microsystems Ltd, Martinfield, Welwyn Garden City, Herts AL7 1JT. 0707 332148.

Zax Corporation, 2572 White Road, Irvine, CA92714. 0101 714 474 1170.

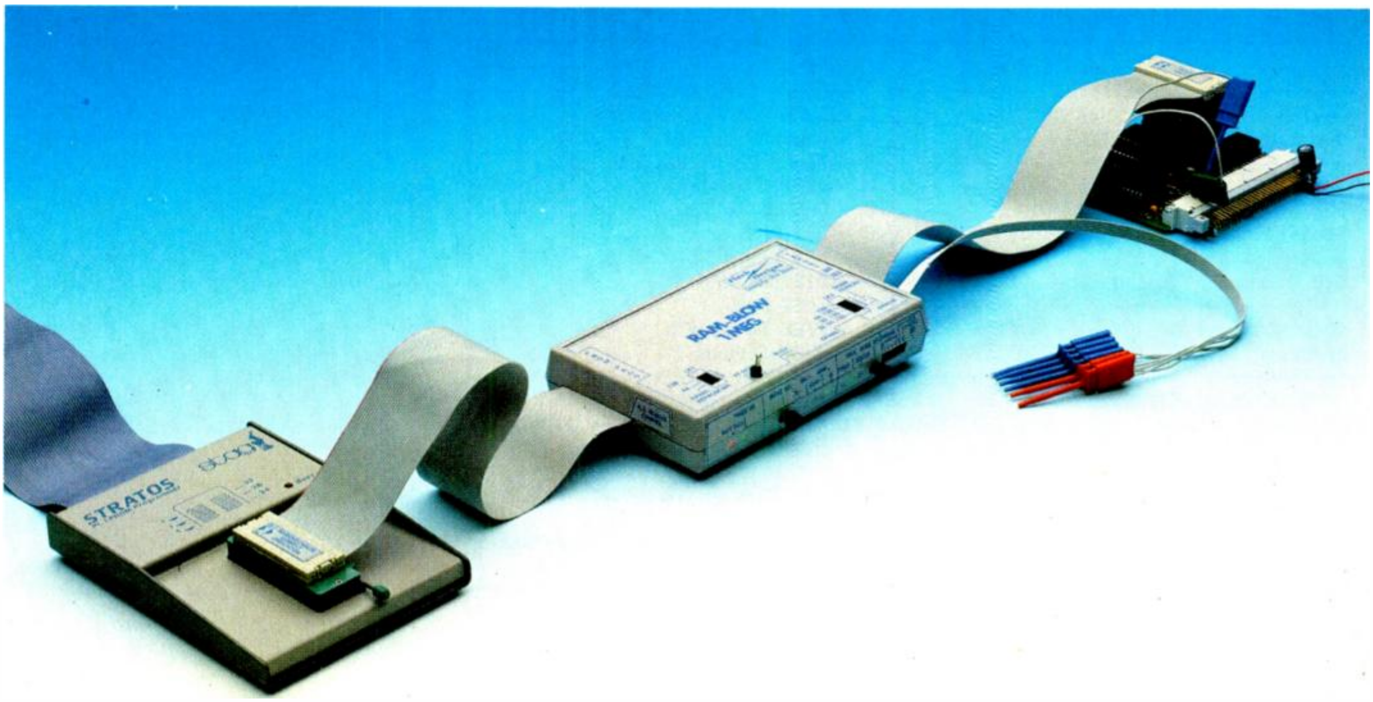


Fig. 1. Cheap ICE: The "promulator" accepts code from a standard eprom blower (left) to run on the target board (right). Flash Designs has added trace facilities to create an ICE-like environment

EMULATING the big boys

Does Flash Designs' novel combination of emulator, hardware breakpoint and history ram provide low cost debugging? It's getting there says John Anderson.

For engineers on a tight budget, the problem of effective debugging of programs on a microprocessor target is a difficult one.

The classical tool is the dedicated in-circuit emulator or ICE, giving a host computer control over all address, data and control lines of the device. At the other end of the hardware/software testing spectrum is debugging with test proms, and these extremes of functionality are also separated by a wide range of costs: an ICE can cost thousands and an eprom only a few pounds.

In the middle ground is a growing number of products based around the idea of an eprom emulator (or "promulator") – a ram which can be rapidly programmed with a quick blow algorithm as if it were a prom, but at the processor acts as if it were an eprom. Development cycle time is improved compared with eprom programming and erasure.

It is into this market that Flash Designs has introduced its Flash Emulator and Turbo Trace, a host prom programmer used as the route to program the promulator ram with additional hardware to provide hardware breakpoints, history ram and trace. These latter functions are only available on expensive ICE products, and should provide the key to finding that most elusive bug.

Flash Emulator and Turbo Trace, in a 90x140x30mm plastic box adorned with various switches and umbilicals, is professionally finished – though ergonomics are seriously impaired by siting the most important displays and operating buttons at the side of the box. Emulator, Turbo Trace, prom programmer and Microsoft Windows 3 can all be included as part of the package.

The manual is a 30 page loose-leaf affair which, though comprehensive, has a rather haphazard layout with no step by step description of the way the product functions.

Further, there is no worked examples for the first time user, necessitating a call to Flash Designs for help. Their assistance was expert and helpful, but as the market grows for this device, a better manual will be required, if only to reduce the number of inane questions which Flash Designs will have to answer, but which should be covered in the manual.

A Stag Stratos PC-based eprom programmer was used as the review system and the PC display screen shown in **Fig. 2** is that of the programmer software.

Target code is prepared and, with the emulator connected to the target rom socket on one hand and the prom programmer on the other, code is down-loaded to the target. On a hardware level, at this point the program is run in the target by automatically releasing the reset line to the processor.

The two hardware breakpoints are entered as the first four bytes in memory using the prom programmer edit memory function. Breakpoints are entered into the hardware by, again, "programming the prom", this time with the emulator in the program rather than emulation mode.

Once breakpoints are hit, the address (16 bits), data (8 bits) and four other lines are recorded in the trace history memory. Trace data may be forward from or up to the breakpoint address and history data may be accessed by the eprom programmer software by "reading the prom" into memory. The result can be reviewed by looking at the ram image using eprom programmer software.

The emulator takes all its power from the target prom socket – typically 395mA total –

```
──────────────────────── S t a g  -  S T R A T O S ──────────────────────
 ──────── Device selected ────────     ──────────── Function Menu ──────────
  Device Type      : 27512-QP           L - LOAD RAM from Device.
  Manufacturer     : INTEL              P - PROGRAM Device.
                                        B - BLANK Check Device.
 ──── Device and Address Limits ────    V - VERIFY Device.
  RAM Start         :    000000         C - CHANGE to new Device.
  Device Start      :    000000         O - OPTIONS.
  Device Stop       :    00FFFF         S - SET Device Limits.
  I/O Format        :Motorola S-Rec     D - DISPLAY RAM.
 ----------------------------------     E - EDIT RAM.
  Address limit of RAM     : 01FFFF     F - FILE Functions.
  Address limit of device : 00FFFF      Q - QUIT Stratos.

     C:\STRATOS\RMTEST.BKP            Line 1    Col 1    Insert    Indent
THIS PROGRAM FLASHES THE L.E.D., IT SHOULD BE RUN FROM SRAM Z.I.F. SOCKET

   1  0000                              org 0h
   2  0000 028040                       jmp 8040h  ;This is in EPROM.
   3
   4  0040                              org 0040h  ; SRAM program memory start
   5  0040 C2D5        test:    clr f0

F1-help F2-save F3-new file F4-import data F5-expand  F10-contract Esc-exit
```

although this can be provided by an external power supply.

Window on the task switch

Using Windows 3 as a software development and ICE environment is potentially attractive. In principle the multitasking Windows allows hot key switches between editor, assembler, compiler, linker, programmer and trace work areas. In theory all could be running concurrently (time sliced).

But at a practical level this is not really a sensible proposition. As indicated earlier, one of the reasons for moving from eprom to dedicated ICE is speed of the development process. Unless a 33MHz 386 or 25MHz 486 machine is being used with several megabytes of memory, the time to task-switch is prohibitive. On a standard AT, task switch times are around 20s!

One further weakness is that the prom programmer software, and for that matter the cross assembler or cross compiler are not written for Windows 3 and so do not offer the ability to have all active windows on screen at the same time.

A good operational compromise is to use a simple terminate and stay resident (TSR) editor, such as Borland SideKick to allow viewing of the assembler listing in a window while the prom programmer software is running. But it must be used with care as activating the hot key during access to the eprom (emulator) could cause damage.

Novel solution

Ram-Blow Emulator and Turbo Trace is a novel combination of emulator, hardware breakpoint and history ram and provides a low cost route to debugging. Data must be transferred via a standard eprom programmer, and it is from here that both the cost advantage, and the user interface weakness stems.

Not surprisingly, eprom programmer software is orientated toward programming eproms, and although quite amazing functionality is provided through the programmer, it can be quite hard work to program and use.

Flash Designs have promised that a PC card will be available soon to provide direct computer control. The move could be a welcome adjunct, improving the user interface and ensuring that this product is not just a flash in the pan. ■

Windows update: Flash Designs has announced that its latest software has Windows compatibility. Resizeable Windows allow control of up to four emulator pods.

```
GOTO  SEARCH  BLOCK  RAM_EDIT  LOGIC  CHECKSUM


Address   00 01 02 03 04 05 06 07  08 09 0A 0B 0C 0D 0E 0F

00000     00 41 D5 F0 FF FF FF FF  00 42 74 F0 FF FF FF FF     .A╒≡      .Bt≡
00010     00 43 00 F0 FF FF FF FF  00 44 90 F0 FF FF FF FF     .C.≡      .DÉ≡
00020     00 45 80 F0 FF FF FF FF  00 46 04 F0 FF FF FF FF     .EÇ≡      .F.≡
00030     00 46 04 F0 FF FF FF FF  00 47 F0 F0 FF FF FF FF     .F.≡      .G≡≡
00040     00 48 04 F0 FF FF FF FF  00 48 04 F0 FF FF FF FF     .H.≡      .H.≡
00050     00 49 90 F0 FF FF FF FF  00 49 90 F0 FF FF FF FF     .IÉ≡      .IÉ≡
00060     00 4A 80 F0 FF FF FF FF  00 4B 05 F0 FF FF FF FF     .JÇ≡      .K.≡
00070     00 4B 05 F0 FF FF FF FF  00 4C F0 F0 FF FF FF FF     .K.≡      .L≡≡
00080     00 4D 04 F0 FF FF FF FF  00 4D 04 F0 FF FF FF FF     .M.≡      .M.≡
00090     00 4E 70 F0 FF FF FF FF  00 4E 70 F0 FF FF FF FF     .Np≡      .Np≡
000A0     00 4F F4 F0 FF FF FF FF  00 4F F4 F0 FF FF FF FF     .O⌠≡      .O⌠≡
000B0     00 50 74 F0 FF FF FF FF  00 44 90 F0 FF FF FF FF     .Pt≡      .DÉ≡
000C0     00 45 80 F0 FF FF FF FF  00 46 04 F0 FF FF FF FF     .EÇ≡      .F.≡
000D0     00 46 04 F0 FF FF FF FF  00 47 F0 F0 FF FF FF FF     .F.≡      .G≡≡
000E0     00 48 04 F0 FF FF FF FF  00 48 04 F0 FF FF FF FF     .H.≡      .H.≡
000F0     00 49 90 F0 FF FF FF FF  00 49 90 F0 FF FF FF FF     .IÉ≡      .IÉ≡

F1 help          F3 toggle hex/ASCII edit          F5 search again
F7 toggle edit/display mode   F9 select feature   F10 return to Main Function Menu
```

Fig.2. How the user views the debugging operation on the PC.

SPECIFICATION

IBM PC, AT based eprom programmer; the unit was reviewed in conjunction with the Stag Stratos eprom programmer system.
Emulates 2764 through 27101 eproms
Access time 100ns
Power required: 70mA from target for emulator/325mA from target for turbo trace.
Power can be supplied from an external power supply.
Algorithms: 50ms, 1ms or quick pulse 100µs to 1µs.
Turbo Trace: 8K bytes fast static ram for trace history.
Trace width 32 bits.
Breakpoints on 16 bits address plus a qualifier bit.
Trace Modes: Trace forward from address (with logic probe=don't care, logic true or write true)
Trace up to address

SUPPLY DETAILS

Several products are in the Flash emulator range. The reviewed product was the top of the range: Ram-Blow 1MByte memory emulator with trace and breakpoint, code number RB1MEG+TR. £698+VAT.
Entry level products start with a 256K emulator priced at £199.
Supplier is Flash Designs Ltd, St Andrews House, PO Box 167, Crawley RH11 9YE. Tel: 0293 551229.

8051 revisited

In line with the theory that small is beautiful, Philips has brought out a cut-down version of the venerable 8051: the compatible 87C751. Richard Marriott reckons that the new chip means big business.

The 87C751 is ideally suited to applications where small space and low cost are crucial. The restriction of 2Kbyte code space and 64byte ram may be too great for some applications. The device has no memory expansion capability, having only 19 I/O lines; the core is in the form of a factory masked rom or reprogrammable eprom. The eprom variety can be either one time programmable (OTP) or quartz windowed erasable.

The programming algorithm for the eprom part is conventional. However, the method used to program the eprom array is not. The 87C751 expects a configuration pattern to be applied on the reset line to force the device into a specific mode: see **Table 1**. A normal reset, high to low, will put the device into a conventional run mode, therefore no special reset logic is required for production. To program and verify the device, the I/O port pins are used as address and data paths. Port P_1 is used as the program and verification data and P_3 is used as the address path. How do you get the 11-bit address of a 2Kbytes eprom into an 8-bit port? Easy, the most significant three bits are multiplexed with the least significant three bits. The multiplexer input is the *ASEL* input on port pin $P_{0.0}$.

Figure 1 shows the pin assignments on the 24-pin skinny DIP. The address lines ($A_0..A_{11}$), the data lines ($D_0..D_8$), *VPP*, *OE-PGM* and *ASEL* refer only to the programming mode. These lines are not normally available. The alternate function for the pins is conventional.

There are architectural differences between the 8051 and the new chip. Apart from the differences in pin number and

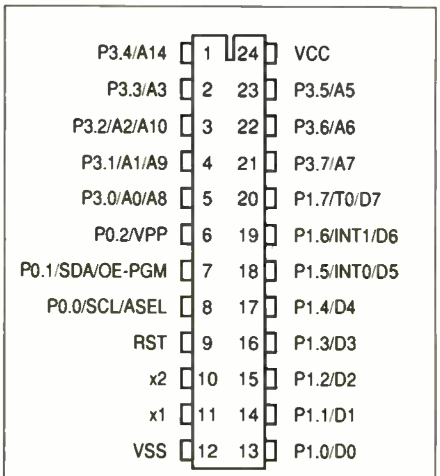


Fig. 1. Pin configuration

Table 1. Program/Verify Modes

Operation	Serial Code
Program user eprom	296H
Verify user eprom	296H
Program encryption array	292H
Verify encryption array	292H
Program security bit 1	29AH
Program security bit 2	298H
Verify security bits	29AH

Table 2. Special function register memory map

SFR address (hex)		Name
80	•	P0
81		SP
82		DPL
83		DPH
87		PCON
88	•	TCON
8A		TL
8B		RTL
8C		TH
8D		RTH
90	•	P1
98	•	I2CON
9A		I2DAT
A8	•	IE
B0	•	P3
D0	•	PSW
D8	•	I2CFG
E0	•	ACC
F8	•	I2STA

Table 3. Interrupt priority

Priority	Name	Service address	Description
Highest	INT0	003	External interrupt 0
	CT0	00B	Counter/timer
	INT1	013	External interrupt 1
	TIMER I	01B	Fixed interval timer
Lowest	I²C	023	I²C serial port

Table 4. Interrupt/enable register modification

Bit	7	6	5	4	3	2	1	0
	EA-	-		EI2	ET1	EX1	ET0	EX0

EA	General enable, when set any individually enabled interrupt will be accepted
EI2	When set enables the IIC serial interrupt
ET1	When set enables the Timer I interrupt
EX1	When set enables the external interrupt 1
ET0	When set enables the counter/timer interrupt
EX0	When set enables external interrupt 0

The EA bit is cleared by reset.

packaging the changes may be summarised as:

- 2Kbytes eprom, 64 bytes ram
- I²C serial port (no UART)
- 19 I/O lines
- No external memory expansion, except via the I²C bus
- One counter/timer operating in mode 2 but extended to16 bits
- Single level interrupt structure
- Fixed interval timer

Because of these differences, the instruction LJMP, LCALL, and MOVX have no meaning. Otherwise the 87C751 is fully code compatible with the 80C51 and operates at up to 16MHz.

Interrupts
The Interrupt Priority (IP) register and the 2-level interrupt system of the 80C51 are eliminated. Simultaneous interrupt conditions are resolved by a single level, fixed priority as shown in **Table 3**. The interrupt enable register (IE) is modified as shown in **Table 4.**

Special Function Registers (SFR)
Special function registers are on-chip memory locations with special functions within the 751 device. The special function area of the 80C51 is from 80h to ffh but not all of the addresses are occupied. Unoccupied addresses are not implemented on the chip. Read accesses to these addresses will in general return random data, and write accesses will have no effect. The SFR map for the 87C751 is shown in **Table 2.** The SFRs that are bit addressable are marked with an asterix.

Table 5. TCON controls for the counter/timer.

7	6	5	4	3	2	1	0
GATE	C/T	TF	TR	IE0	IT0	IE1	IT1

GATE	1	Timer/counter is enabled only when INT_0 pin is high, and TR is 1
	0	Timer/counter is enabled when *TR* is 1.
C/T	1	Counter operation from T_0 pin.
	0	Timer operation from internal clock/
TF	1	Set on overflow of *TH*.
	0	Cleared when processor vectors to interrupt routine, by reset, and by writing 0.
TR	1	Timer/counter enabled.
	0	Timer/counter disabled.
IE0	1	Edge detected on INT_0.
IT0	1	INT_1 is edge triggered.
	0	INT_1 is level sensitive

Counter/timer subsystem
The 87C751 has one timer/counter. Its operation is similar to mode 2 operation of the 80C51, extended to 16 bits. The controls for the counter/timer are centralised in a single register called TCON (**Table 5**.).

These flags are functionally identical to the corresponding 80C51 flags, except that there is only one timer and they are combined into one register.

A second timer, called TIMER I is available. In I²C applications this timer is dedicated to time generation and bus monitoring. In non-I²C applications it is available for use as a fixed time base. It provides a period of 1024 machine cycles when used for this purpose.

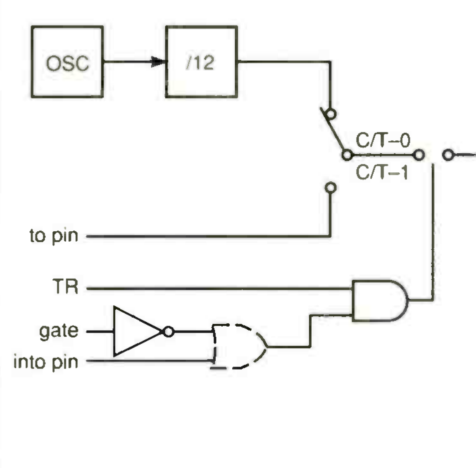


Fig. 2. 87C751 converter/timer

I²C serial comms subsystem
The 87C751 I²C subsystem is a single bit hardware interface and uses two physical I/O port pins, namely Serial CLock (*SCL*) and Serial DAta (*SDA*). It includes more than just the absolutely minimum hardware in an effort to simplify the software overhead.

In particular, hardware for stretching *SCL* is included, and the time that *SCL* is stretched is bounded by hardware to prevent bus hang up in case of faulty software or certain kinds of faulty hardware. The I²C subsystem consists of four SFRs: *I2CON*, *I2DAT*, *I2CFG* and *I2STA*. Prices for one off quantities range from £8 to £12.

An application note, AN422, can be obtained from Philips Components or its distributors. This note describes in detail the bus operation and programming. Alternatively, a copy of the I²C master and slave software on diskette can be obtained from Micro Amps.

Tools
A low cost in-circuit emulator for the 87C751 which handles both program development and programming of the devices is available. This, plus a fully operational I²C master and slave driver together with associated software is also available from Micro Amps Ltd on 0483 268999. ■

pc engineering

Has the Smith chart met its Match?

As a Smith chart program Z Match II offers plenty, but you have to go a long way to beat a sharp pencil and an eraser says Ian White.

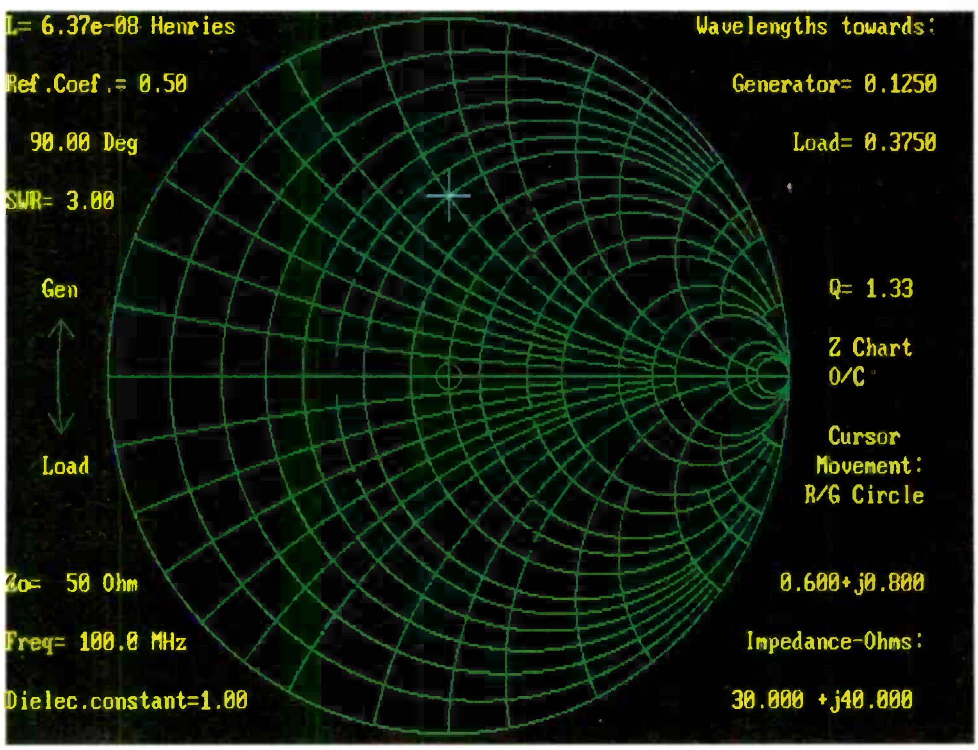
Given the right software, modern PCs with high-resolution graphics displays have the potential to combine both the numerical accuracy of the digital computer and the intuitive "feel" of a Smith chart on the screen.

What the user wants from a Smith-chart program is everything that the paper chart could give (and I do mean *everything*), plus some genuinely useful enhancements that only the computer can provide.

Enhanced numerical accuracy can almost be taken for granted, but more useful than precision is the ability to deal with the fuzzy parameter values encountered in real-life RF engineering.

The problem for the software engineer is to provide all of this through an input inter-

Fig. 1. Smith chart display by Z-Match II, showing the cursor at an impedance of (30+j40)Ω.



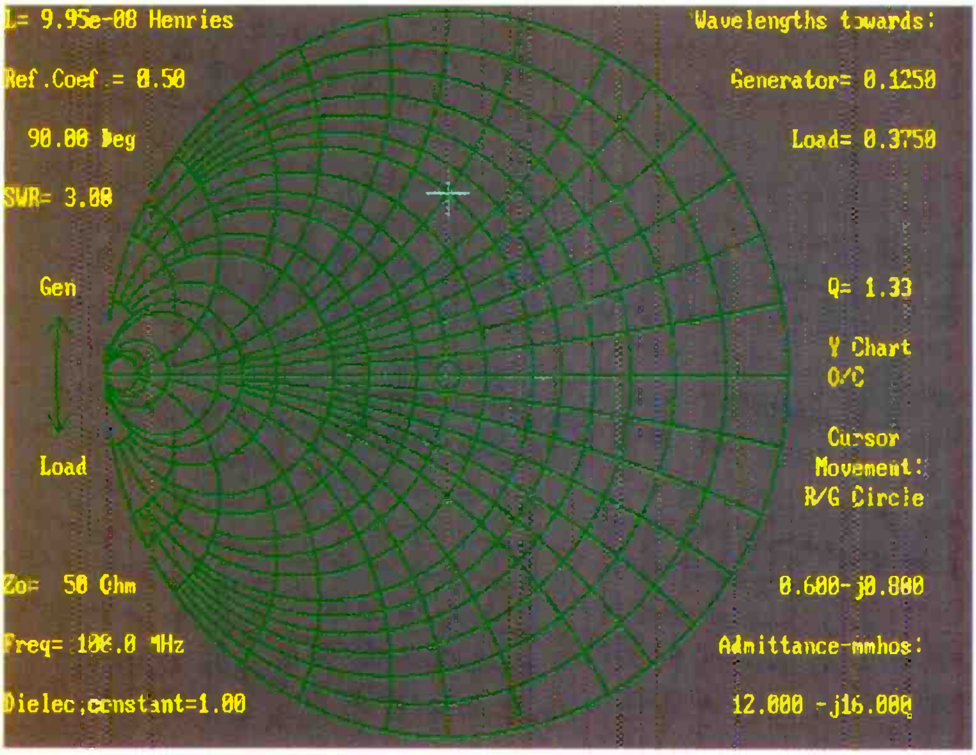


Fig. 2. Admittance-chart dual of Fig. 1. The cursor is at the same position while the chart has been inverted behind it. Note the changed numerical information around the display.

face consisting of a keyboard and a mouse.

It is with these criteria in mind that I opened the Z-Match II package from Number One Systems, well-known for their Analyser nodal analysis program and Easy-PC printed circuit and schematic drawing package.

On the screen

Z-Match II begins with a display of the familiar Smith chart surrounded by numerical and text information. **Figure 1** shows the crosshair cursor positioned at normalised co-ordinates of (0.60+j0.80), which in a 50Ω system corresponds to (30+j40)Ω. Normalised and absolute impedances both appear at the bottom right-hand corner of the display, and the absolute result can be re-normalised by changing the system impedance Z_0 (bottom left). The normalisation menu can also change the frequency and the velocity factor of any transmission line. A "velocity factor" greater than unity is interpreted to mean the dielectric constant of the line instead, and the velocity factor is calculated from ($1/\sqrt{e}$).

Given these "environment" parameters, Z-Match II can then display the series inductance or capacitance associated with the reactive term, the standing wave ratio (SWR) and the reflection coefficient (magnitude and phase angle).

A constant-SWR circle is just a key-press away. Also displayed are wavelengths from the plotted point towards the generator and towards the load, which are required for transmission-line calculations; on a printed chart these would be measured on a scale around the periphery.

As an alternative to wavelengths the display can easily be changed to metres, according to the frequency and velocity factor supplied.

The cursor can be moved around the chart in a variety of ways. Straightforward X-Y movement takes the cursor quickly to your starting point. A change of mode will then move the cursor around circles of constant resistance/conductance, reactance/susceptance or SWR, the same as one would draw using a pencil and compasses. The main keys for cursor movement are the block labelled 1-9 on the PC's numeric keypad, allowing the cursor to be driven one-handed.

One delight of a computerised Smith chart such as Z-Match II is that all the numerical displays follow the movement of the cursor. On a 16MHz 80386SX machine with a coprocessor there is no noticeable time-lag.

Even more convenient is the facility to switch from impedance to admittance chart with a single key-press. On a printed chart this requires the plotted point to be mirror-imaged through the centre of the chart, and all the scale calibrations need to be changed to their reciprocals.

In Z-Match II the cursor stays still and the whole chart is mirror-imaged from left to right (**Fig. 2.**). The impedance values change automatically to admittances, and the corresponding inductance or capacitance value (top left) changes from the series to the equivalent parallel form. Series-to-parallel impedance transformations are thus simplified to a single key-press.

Computer enhancements

A computerised Smith chart can automate many operations that would be tedious on a paper chart, and can also provide facilities unique to itself.

Automated operations include calculation of the length and characteristic impedance of a transmission-line transformer to match the impedance at the cursor point to the system impedance (Z_0+j0), if such a match is possible. Z-Match II also takes account of transmission-line loss in one simple operation, and can read files of impedances calculated by the Analyser II program and plot them on the chart for further analysis.

The real showpiece of Z-Match II is the facility to design small-signal RF amplifiers

ANATOMY OF A REVOLUTION

RF engineering calculations are either very simple or absurdly complicated. Back in the days of the slide-rule, calculations involving reactive impedances and transmission lines were complex in every sense of the word, and experimentation was often the quickest route to a practical solution. Philip Smith changed all that.

By plotting impedances of the form (R+jX) on his own ingenious set of axes, Smith managed to simplify almost every impedance calculation into a series of geometrical constructions using a ruler and compasses.

The Smith chart was a revolution: suddenly all manner of RF engineering problems became soluble in numerical terms, and the test of a true RF engineer was how well he knew his way around a Smith chart.

More than that, the Smith chart was – and still is – a visual aid to engineering intuition. Doodling on the chart can quickly lead towards the right solution for the problem at hand. "Starting from here, if I add some series... er... capacitance that'll take me around to ...there. And then I could match that impedance more easily by...".

Equally, a few freehand pencil lines can quickly show when the best option is to rub everything out and think again!

The Smith chart suffered a setback when computers and programmable calculators came along, with their promise of accurate numerical results without the aid of a really sharp pencil.

But ten-digit precision is of little value in the real world of RF engineering where device characteristics are often ill-defined and subject to variations.

The other major shortcoming of purely numerical methods is that the peephole of a one-line numeric display gives no view of a problem as a whole.

from a set of device S-parameters. This normally requires tedious calculations involving matrices of complex numbers, followed by a session with the Smith chart to design the networks to match the required input and output impedances to the system Z_0. With Z-Match II the calculation is virtually instantaneous and the required values of Z_{in} and Z_{out} for maximum power transfer are ready-plotted on the chart (**Fig. 3**): match these to Z_0 and the design is complete.

Also plotted in Fig. 3 are the contours on which the output impedance should lie in order to obtain gains of 12dB and 14dB.

On a Smith chart these are circles (like almost everything else) and Z-Match II plots them easily on request. If an amplifier is only conditionally stable, yet more circles are automatically plotted to show which input and output impedances will result in instability.

Although the S-parameter analysis can only be done for one frequency at a time, the speed of the program makes it quite simple to check a design for stability over a wide range of frequencies. The only hold-up is the time required to type in the new S-parameters, so it would have been useful to provide an interface to device data files which are distributed by many semiconductor manufacturers in an industry-standard format.

User interface

So how does Z-Match II perform against our list of criteria?

Well, we have a representation of the Smith chart with some very useful computer enhancements; but does Z-match II do everything that its paper predecessor could? Sadly, it doesn't – the user interface lets it down.

Since reaction to a user interface can be highly individual I asked other Smith chart users to try Z-Match II. But reactions of occasional and expert users were the same as my own. Criticisms centred on two areas: the lack of an adequate "pencil-and-paper" simulation and the inconsistency between the control menus and the short-cut function keys.

One of the great advantages of the paper Smith chart is that the pencil lines leave a trail to remind you how the present position was arrived at. Z-Match II just moves its cursor, leaving nothing behind but your own fading memory.

Likewise the paper-and-pencil chart comes with an absolutely essential feature called an eraser; but Z-Match II has no progressive UNDO facility to provide a route back to the way you came in. Also, although a single keystroke will draw a constant-SWR circle, for example, you are then stuck with it; a second keystroke won't take it away again.

Another essential feature which is only half-implemented in Z-Match II is the facility to mark the current point with a cross before moving away from it. You can leave several such markers; but you cannot jump quickly and accurately back to them, and they all disappear when you flip between impedance and admittance charts.The keyboard is not a natural metaphor for a pencil, though the mouse can be, as many successful cad packages have demonstrated. But even the latest version of Z-Match II can use the mouse only to drag the cursor in the X-Y directions.

Taken together, all these shortcomings suggest that the designers of Z-Match II have missed an essential point about the Smith chart: it is not just a calculating engine – it is also meant for drawing on.

Z-Match II has a good menu system, accessed by pressing F10. The available options appear at the top of the screen, each with its short Help message that changes as the highlight is moved along.

Selecting an option will either produce a sub-menu or take the desired action.

Once you know your way around, the faster alternative is to use the short-cut function keys F1-F10 with Shift and Ctrl. But these keys are organised in a way that bears no relationship to the menu structure. Quite clearly the function keys came first and just grew with the prototype program, while the more logical menu structure was added later.

One final problem was an incompatibility with the VGA adaptor and/or the mouse driver of the Amstrad PC2286. Although not necessarily the fault of Number One Systems, failure to check that software works with a current Amstrad PC is a surprising omission.

Not the answer

At the high end of the RF design software market there are several extremely powerful circuit analysis programs such as Touchstone and Super-Compact which use the Smith chart for input and output. Yet there is also a market for lower-cost PC software which provides a handy implementation of the original Smith chart, with improved numerical accuracy and graphics displays. Z-Match II could have filled that niche, but unfortunately it shows all the classic symptoms of software that was developed to satisfy its own programmers.

Some people may like Z-Match II, marvelling that a PC can model a Smith chart; but that isn't quite the point. It is still not too late for Number One Systems to ask practising RF engineers what they *really* want in a low-cost PC Smith chart, and then write a Z-Match III to satisfy the true needs of the market. ■

SYSTEM REQUIREMENTS

IBM PC compatible
384K free ram
CGA/EGA/VGA/MCGA, preferably colour (reviewed on colour VGA). Maths coprocessor will be used if available.

SUPPLIER DETAILS

Z-Match II from Number One Systems Ltd, Harding Way, Sommersham Road, St Ives, Huntingdon, Cambs PE17 4WR. Tel: 0480 61778.
£195.00+VAT

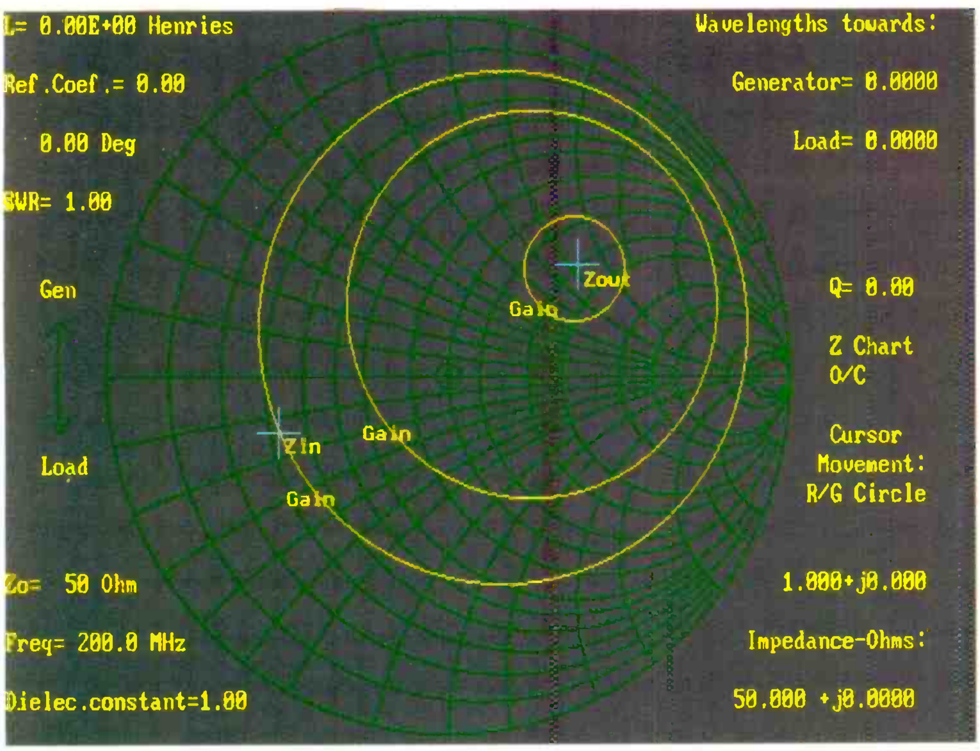


Fig. 3. Z-Match II has analysed a small-signal amplifier from the device S-parameters, and has plotted the input and output impedances required to achieve the maximum available gain. Also plotted are constant-gain circles for 12dB and 14dB.

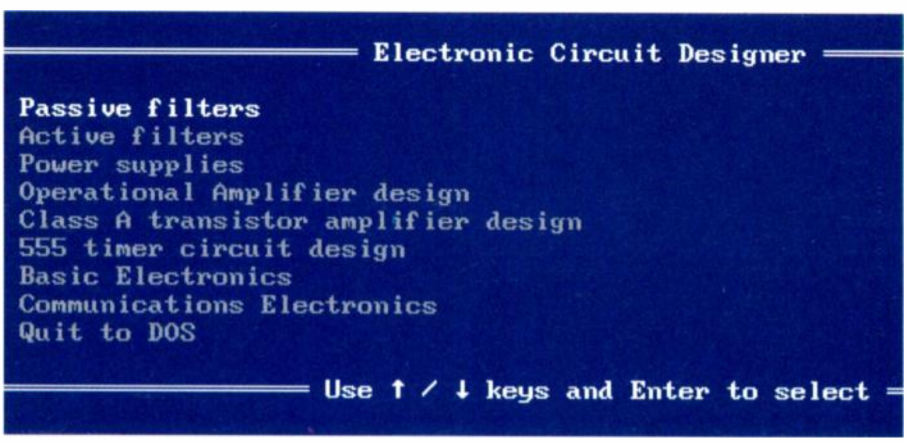
Circuit design improved by second thoughts?

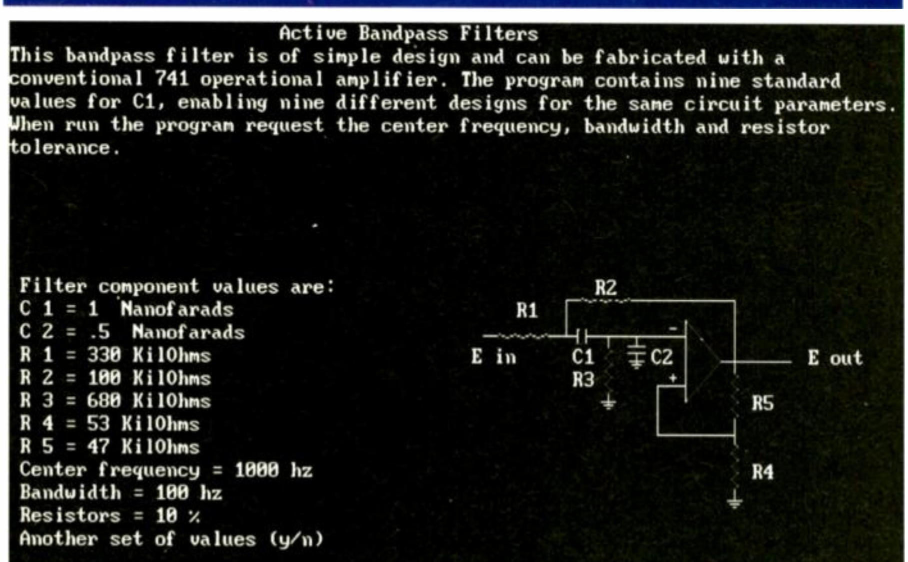
ECD, a bargain basement circuit component calculator has been given a much-needed facelift since it was last reviewed. Has it improved? Mike Tooley compares notes.

I first reviewed this particular software package (available as "shareware") in the May 1990 *EW + WW* (Electronic Circuit Designer, pp. 422-424).

Since that review, many readers throughout the world have become interested in the program and are now putting it to good use in a variety of applications – from attenuator design to VSWR calculation, from decibel conversion to microstrip design.

Now, as a result of user comments, ECDesigner has been greatly enhanced.





Arguably the most significant change (and the one which caused me most soul-searching in the original review) was that the software would not operate as a stand-alone executable file. Instead, it required the services of the crude and somewhat outdated GWbasic interpreter.

To overcome this flaw, Version 3.4 is supplied in a compiled format, using Microsoft's excellent Quickbasic 4.5, and includes support for EGA/VGA graphics. The program now offers more options, several useful additional facilities and, for good measure, the overall structure of the program has been greatly improved with a more logical arrangement of menus and sub-menus.

Reason for registering

Electronic Circuit Designer is largely self-documenting, but Diatom supply a "User's Guide" to registered users, and this document has been much revised for the better

The guide now comprises a very neatly presented 31-page manual with the necessary formulas, circuitry and background information required to make use of the individual programs. It is one of the best I have ever seen supplied to complement a "shareware" product and speaks highly of Diatom's commitment to supporting the product - and is yet another good reason to register the software.

Options

As before, the package can be used with many different types of circuits – passive and active filters, operational amplifiers, power supplies, timer circuits etc – with the user simply selecting the circuit from the main menu (using up and down arrow keys) and then, in most cases, making further selections from a sub-menu.

Overall structure of the package has been modified to provide more logical distribution of main-menu and sub-menu options:

Electronic Circuit Designer's opening screen (top) presents the main categories of circuit handled by the program. Selection leads to a number of sub-menus. (Bottom) Final screen in the active bandpass filter option.

the only main-menu option that does not have its own sub-menu is that associated with class-A amplifier design.

Sixteen main-menu options in the previous version of the program have been reduced to just ten: passive filters (15 sub-menu options); active filters (9 options); power supplies (6); operational amplifier design (5); class-A transistor amplifier design* (no sub-menu); 555 timer circuit design (3); basic electronics (19); communications electronics (12); attenuator pads* (14), and quit to dos. (Options marked * are only accessible to registered users)

New features include star-delta and delta-star conversions and the new main-menu option"communications electronics" groups together topics such as RF inductors, VSWR, transmission lines, Gaussian noise bandwidth, dB conversion, stripline and microstrip design.

Readers should refer to the previous review for details of the function of each of the major sub-programs.

A useful attribute of the software is that the ESCAPE key permits return to the main menu from anywhere in the program.

Registered versions of the software are supplied with a batch file (ECD.BAT) containing the password giving full access to the program's facilities. Without this file, users are unable to make use of the class-A amplifier design and attenuator design sub-programs though other facilities are unaffected.

The disk supplied to registered users now contains only two files, ECD34.EXE and ECD.BAT (but note that the executable program file amounts to a massive 320656 bytes!).

During initialisation of the program, the user is presented with a copyright screen and a menu that allows selection of the video graphics mode (either text, CGA, or EGA/VGA).

System requirements

Electronic Circuit Designer is supplied on either 3.5 or 5.25-in disks and should run on almost any IBM PC or compatible system. As before, I successfully installed the package on a number of systems including a standard AT-compatible machine (DSC Turbo), an Amstrad PPC-512, an Olivetti M-24, and an Atari-ST with a Condor/Beta Systems Supercharger. In all cases, the software was installed and operated without hitch.

Supplier details

Version 3.4 package (with printed manual) costs $25 plus $7 for surface mail or $15 for air mail postage to the U.K. Diatom Software is at PO Box 262, Northfield, Ohio 44067, USA. Telephone USA (216) 468 2230.

Operating software purely in text mode means on-screen circuit graphics are not available. But this is no real problem *provided the user has a copy of the excellent manual supplied.*

Impressive improvements

I was very impressed by the original package and, with a few minor reservations, I concluded that it would certainly "earn its keep". But this latest version is undoubtedly an improvement on the original software.

It is easier to use, offers more options than before, and has several minor imperfections removed. Users will find it very difficult to fault the package which must now be considered to be a real bargain at $25.

Electronic Circuit Designer will undoubtedly repay this modest investment many times over ■

HIGH POWER AMPLIFIER For your car, it has 150 watts output. Frequency response 20HZ to 20 KHZ and a signal to noise ratio better than 60db. Has builtin short circuit protection and adjustable input level to suit youe existing car stereo, so needs no pre-amp. Works into speakers ref 30P7 described below. A real bargain at only £57.00 Order ref 57P1.

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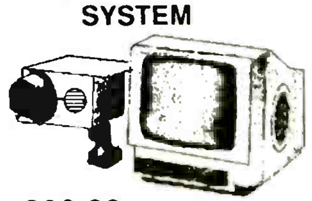

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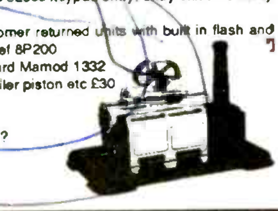

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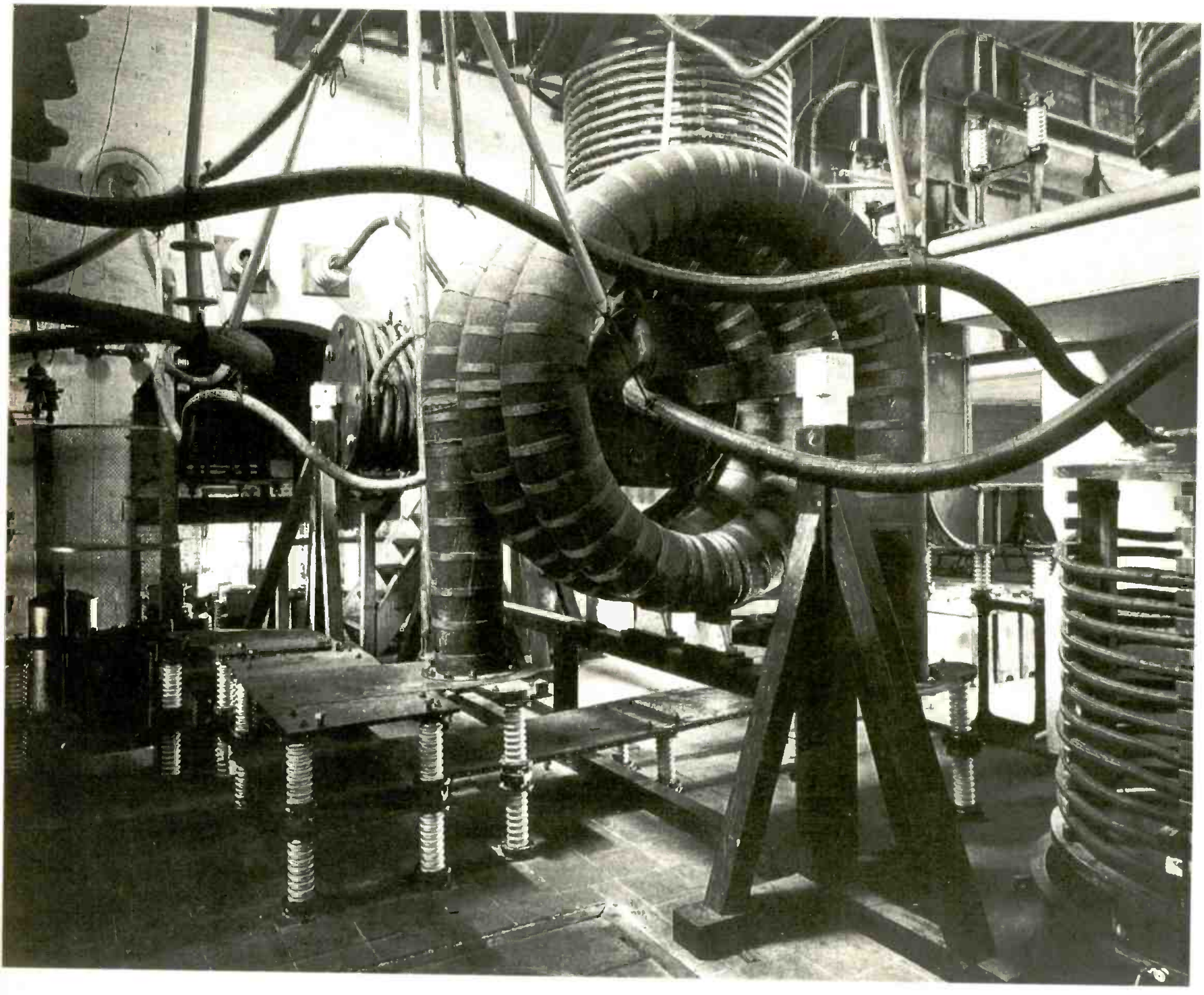


END OF THE BEGINNING

The period up to the start of the first world war saw the "spark era" drawing to a close and the beginning of the amateur radio movement, brought forth largely by the news of the Titanic catastrophe in 1912 and serviced by articles in the journal on building transmitters and receivers, in one case at least using a motorbike ignition coil for the transmitter

The Marconigraph changed its name to *The Wireless World* in 1913, as a result of continuing strife between the journal and the Postmaster-General. The Imperial wireless proposal intended to keep the Empire in touch with itself was under way and the PMG was under fire for not throwing the contract open to tender, this journal naturally being on the side of Marconi, since it was the company's house journal. Marconi was eventually awarded the contract, but to get it had been forced to either prevent the editor of the day from rocking the boat or divest itself of its house journal. Lord Iliffe bought it and changed the name.

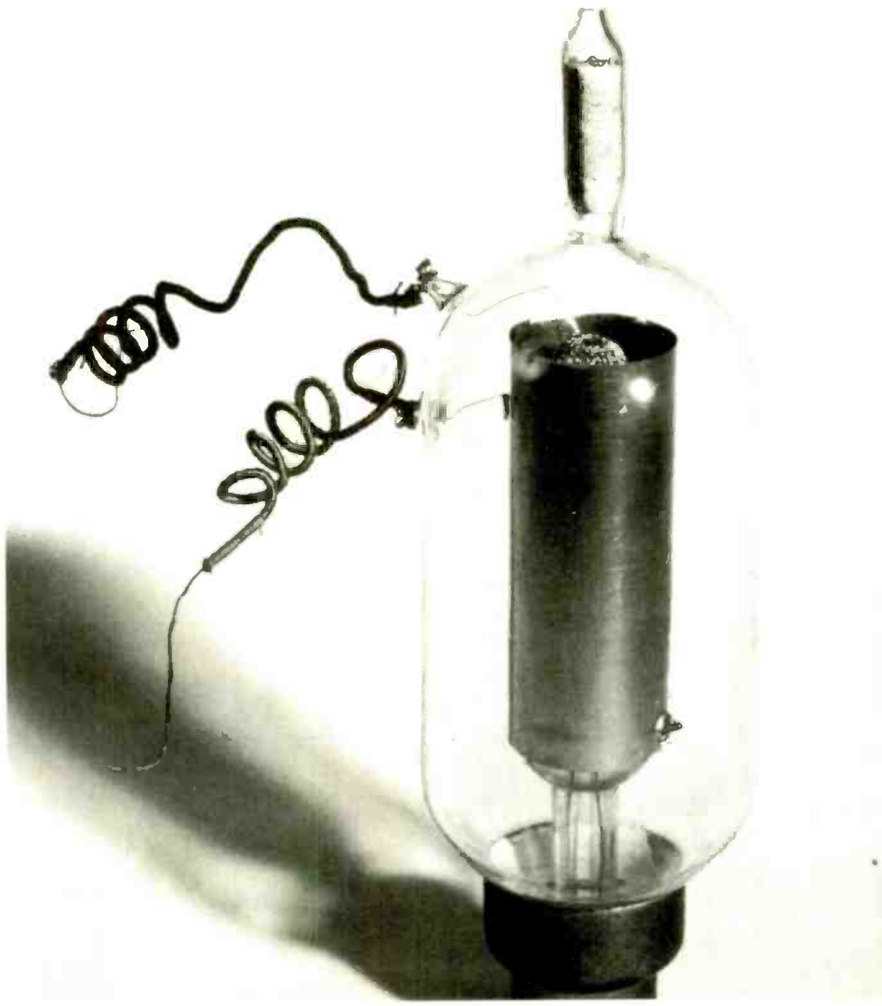
Figure 1 shows the primary winding of one of the aerial coupling transformers (jiggers) of the 300kW transatlantic synchronous AC transmitter at Caernarvon,

Fig. 1. Primary side of the aerial coupling transformer in the Marconi Caernarvon station. Such transformers were called "jiggers", for some reason no-one now seems to remember. A movable secondary winding, mounted on a wooden carrier, slides into the massive primary circuit for adjustable coupling.

opened in 1914. This was a spark transmitter, but produced fairly continuous waves by timing discharges so that they overlapped.

1914 saw the introduction of what *WW* considered to be "the most momentous

Capt. H.J Round's soft triode of 1914, developed with Marconi's. The cathode was a Wehnelt oxide-coated type; the grid a fine mesh around the filament; and the anode a concentric cylinder. The protuberance on top is a wad of asbestos, intended to emit gas and prevent the tube becoming hard. Heat had to be applied to the wad externally.



advance so far described in our pages": the triode valve developed by H.J.Round and Marconi's. Lee de Forest had come up with his triode design several years earlier, but had not exploited it. Indeed, Marconi's asserted that it was an infringement of Fleming's work on diodes, but had to confess that Marconi's had also been guilty of an infringement. This meant that both Marconi's and de Forest were banned from making triodes by American courts. The Round-Marconi triode enabled development of the equipment shown, which was a wireless telephony set by Marconi's which was said to have a range of up to 45 miles and drew about 12mA from a 500V dry battery.

During the war, *WW* was prevented from printing anything about valves and, indeed, anything much about anything. Progress on the amateur side forged ahead during this period, but only in the USA, since all amateur licences had been confiscated here in 1914. ■

Marconi's "practical standard set for wireless telephony", a combined transmitter/receiver using the Round-Marconi triode amplifying valve with 500V on the anode.

No time for games

I was interested to read your Comment (*EW + WW*, June 1991) on stand-alone computers. It may well be that your failure to mention the most versatile of them all, the Atari ST and STE ranges may be due to the simple fact that you have had no experience with them.

It is unfortunate that the Atari has this image of being a games machine, but this is totally unjustified.

After my retirement in 1985, with absolutely no experience of computers, I spent a long time looking around for one to use, primarily as a word processor. The blatant user-unfriendliness of MS-dos soon became apparent and was more than off-putting.

But the Atari ST, then just appearing, was clearly head and shoulders above everything else with its wimps and Gem interface.

The rawest tyro, and that included me then, could get into using one within a few hours. Such features as windows, now belatedly and expensively available on IBMs, were inherent in the Atari's OS and built-in to a rom. No longer did the OS have to reside on disk, as with dos.

I took to it like a duck to water.

In addition to its WP versatility, graphics are a doddle and the machine will emulate practically every other OS going. I regularly use it with dos proramme such as Analyser II and I can emulate CP/M and even the Z80.

At Keele, we have dozens of them, since they are ideal for the educational environment; and in the music department, where digital music technology is big, they are used exclusively – they come already equipped with a midi interface.

Now that I use all types of computers, with a variety of OS, there is no doubt in my mind, that the Atari ST and STE ranges are the most versatile of them all.

There is an enormous variety of moderately priced software, often costing a fraction of dos equivalents plus an equally large collection of free software, which includes the WP used to write this letter.

It has always irritated the Atari ST user that the company itself does not seem to have the same faith in its product. Interestingly, I believe that in Germany the Atari actually outsells the IBM and its clones as a stand-alone computer, and all the best software comes from there.

Reg Williamson
Staffordshire

Amiga offering

I must respond to your your remark ("Comment" *EW + WW*, June 1991) that "Until Windows 3... the only machine with a built-in intuitive user interface was the Macintosh".

The Commodore Amiga series has offered a well-designed wimp interface since its introduction six years ago.

Furthermore, unlike the Mac it has true multi-tasking, and a command-line as well as a mouse interface; there are many jobs for which the mouse is not appropriate, and the Mac can be a very frustrating machine to use.

One end of the larger Amiga models (2000, 3500) has a standard PC bus, so that by adding an XT or AT board one can have an Amiga and a PC in the same case, with easy file transfer. A Mac card has also been shown in prototype form and is expected to be available this Autumn while Unix is already available – if you must have it – as is Ethernet.

Of course like any multi-tasking machine, it needs plenty of memory (say 4Mbyte) to work happily, and a good multi-scanning monitor is essential.

Given these characteristics, the Amiga is hard to beat for image analysis, video digitising, graphic design and DTP, and presentation/multimedia.

The only snag is that there is as yet little electronic design software in native Amiga format, though there are good general cad programs.

I believe the Archemedes also has a wimp interface, but this is a rare machine and I have not used one.

Don Cox
Cleveland

Looking at the future...

In John de Rivaz's letter on Benjamin Franklin (*EW + WW* April 1991) he states that unless readers interested in alternative physics can come up with a mechanical time machine, Franklin's dream of time travel remains unfulfilled.

Why a mechanical time machine? The assumption that if time machines are ever achieved, they will be mechanical, may be somewhat questionable.

Time, the fourth dimension as it is sometimes called due to mathematical extrapolation, is to me an interesting subject.

I wonder how many other *EW + WW* readers share this interest?

Experiments with very accurate atomic clocks flown for some length of time in passenger aircraft do show that time is affected by travel at speed, by a very small amount, as predicted by Einstein.

But does the direction of travel relative to the earth's spin for example affect the results?

Do many short journeys, on a shuttle flight that has travelled the same distance in a week but between two nearby cities, give the same results as a long-haul jet flying intercontinental at the same average speed?

What about round trips and rotating machines? Does high speed circular motion also slow down time?

Perhaps the assumption that time machines will be mechanical is not surprising when one follows the above train of thought. A mental picture of a gigantic gyroscope-like machine with rotating magnets, cogs, wheels and motors comes to mind.

However, in my view, the discovery in 1911 of the phenomenon of superconductivity, may eventually lead to a practical time machine. Room temperature superconductors (RTS) look extremely likely to be achineved in the next few years – already materials which superconduct at 240 degrees K have been demonstrated. When perfected, inevitably someone will make a Faraday cage with the material, able perfectly to isolate the space inside from the electromagnetic continuum opuside. Anyone inside would be "electromagnetically decoupled".

Could then high velocity electromagnetic fields be set up rotating on the inside surface of the Faraday cage, mimicking circular motion, and hence slow down time?

Science fiction perhaps, but wouldn't such a machine be useful. Keeping food fresh for months without freezing, looking after the family pet when on holiday, the uses are limitless.

Slowing time down means that inside the cage travel is effectively forwards in time with respect to the outside.

Devising a machine to go backwards in time seems to me to be much more difficult, in fact impossible.

Hugh Pincherie
Barnet
Herts

...and the past

Do you know of anyone who would like a copy of Volume 1 No 1 of the *Journal of the Institute of Wireless Technology*, dated October 1926?

I recently offered to donate it to the library of the Institution of Electronic and Radio Engineers (now merged with the IEE), but it was of no interest to them.

It seems a pity to consign it to the waste bin.

R Phillips
22 The Fairway
Wembley
Middlesex
HA0 3LJ

CFA questions

Opponents of crossed field antennas suggest that some other part of the system is radiating. Could not an experiement be done where a small transmitter is placed at the centre of the structure eliminating the feed wires altogether?

It is also claimed that the structure produces waves much smaller than conventional plane-wave theory. How are experimenters getting on with testing *this* observation?

David Gibson
Leeds

HDTV flare-up

As one who has worked for some years in the television development laboratory of one of Denmark's largest electronics companies, I too was able to welcome the introduction of the "flat" square

picture tube. The present day discussion revolves around HDTV and the exaggerated geometry of the 16:9 format.

Anyone who has seen such a pictures tube will surely agree with me that the most reasonable name for such a monster is the "squat flare" picture box.

Stephen Theobald
Vrist
Denmark

Power line plea

In *EW + WW* February 1990 a very interesting and informative topic on non-ionising radiation, with the heading "Killing Fields" was discussed and references given to case studies.

We, as a local area outside the municipality of Port Elizabeth, are facing the same consequences mentioned, because the municipalaity want to erect two 132kV overhead power lines through our area passing 3m from boundaries and 23m from houses.

So far we have managed to delay erecting these lines, but we need as much information as possible regarding the negative health effects caused by electromagnetic fields emmitted from these lines.

We have to defend our case in court and any additional references willbe most welcome.

Any technical information will be useful because it can be interpreted by us.

A Friend
Theescombe Local Area Association
c/o PO Box 10707
Linton Grange
6015
Port Elizabeth
Republic of South Africa

Diary note?

EW + WW does not have a diary listing trade shows, exhibitions or specialist colloquiums. I understand that this omission is because these are so well advertised in the "freebee" trade sponsored technical press. Yet I for one would appreciate a diary column of what is going on.

In 1989, I used to receive *Electronics Weekly*, not to mention others such as *Electronics Times*, *Microwave Journal*, *Electronic Product Design* and *New Electronics*. I've made two moves of job and residence since then and now receive no freebies. There must be many others, consultants and the like, who move either willingly or through redundncy from firm to firm.

When a move takes place it takes many months to be re-instated on the controlled circulation lists.

Nor are you likely to be accepted unless the personal profile you are asked to fill in suggests you can generate large numbers of purchase orders from the address to which the magazine is to be mailed.

I've also found that some large employers refuse to distribute freebies in their internal mail and consign the lot to the skip.

So I for one would welcome a subscription journal that contained a trade diary column.

What do others think?

WH Powell
Warwickshire

Chaotic antenna design

I read with interest your recent article on "Chaos in Electronics" by Jim Lesurf (*EW + WW*, June 1991 pp467-472). I am involved in similar work at the University of York although we are more interested in non-linear loads to antennas.

It occurs to me that your readers might be interested in information concerning the modelling of currents in arbritary (3-D) antenna designs.This has traditionally been done in the frequency domain. But recent advances in computer power, and development of suitable time domain integral equation methods, has meant that currents can be modelled in the time domain, allowing non-linear as well as linear loads to be attached at any point on the antenna design .

In more general terms, this allows the user to define a 3-D or 2-D antenna consisting of any number of straight wire segments (ie a wire grid) subject to a few limitations.

This grid of wires can then be illuminated with a chosen electric field and the currents at each wire segment at a given time can then be calculated, giving I(r,t), the current as a function of postion and time. The grid of wires can model dipoles, dipole arrays, loops, arbritary 3-D shapes, etc.

All coupling between wires is included in the calculations.

I(r,t) can be used to calculate the radiated field, the radar cross section, or other parameter. It is also possible to calculate the impulse response Y_{in} of any given antenna design using this method.

Once I(r,t) and Y_{in} have been calculated it is possible to assertain the effects of linear and non-linear loads (ie. diodes!) which can be attached at any point in the antenna, using a Norton equivalent type model.

Note that it is impossible to calculate the effects of non-linear loads using the frequency domain model.

To give a typical example of the use of this type of system, imagine a simple dipole antenna. The technique can be used to calculate the I at any number of points along the antenna length, for a time t. This can be done for a range of t so that if we have a central impulse V at time t=0, the current or voltage pulse can be seen travelling along the dipole arms, reflecting off the ends and moving back towards the centre.

We can then model the effects of any combination of diodes, resistors, capacitors and inductors attached at various points on the antenna and "see" directly the effects on the current pulses.

A suite of programs in C has been developed which can be run either on an IBM PC – although a minimum of 286/386 performance is needed – or on Unix workstations, such as Sun Sparc 1/2.

It is beneficial for us to reach a wider audience with this technique and it would be useful if I was able to sell some of the software I have developed to interested parties.

Ian R Frost
University of York
Electronics Departmen

Light conversation

I agree with Frank La Tella's opinion (*EW + WW* "Letters" June 1991) that "Nobody ever said (Einstein included) that Special Relativity is intuitive or that it makes sense...". But his statement that "Light does not obey the Newtonian principle of addition of velocities..." requires some clarification.

The speed of light as measured at its source, is c as predicted by Maxwell's equations of e-m theory. But to measure the velocity of light from the source, observers must take into account their own velocity, relative to the source. The following example explains why.

Suppose a transmitter radiates a signal of frequency F. Velocity of the wavefront, as measured at the source, will be c. The wavelength will be λ where:

$F.\lambda=c$

If a mobile receiver approaches the transmitter at a speed V, its receiver intercepts the approaching wavefront at a speed $(c+V)$. The frequency and wavelength of the received signal will be f and β, where frequency

$f=F.(c+V)/c$

and wavelength

$\beta=\lambda.c/(c+V)$

which is not inconsistant either with Newton's Law, with Maxwell's e-m theory or with common sense.

An observer who measured the speed of the wavefront would measure $(c+V)$.

To determine the value of c the observer's own velocity would also have to be measured (V) with respect to the source.

John Ferguson
Camberly

Electronics SOS

I enjoyed reading the article on electronic yacht navigation by Steve Rogerson in April *EW + WW* ("On the right Track", pp 311-312).

However it did contain some half truths and missed some points.

It is not true that Loran does not cover most of the British Isles. Loran receivers of suitable quality can give good results around the UK. The generally low-quality equipment offered to yachters may not cope south of Scotland but the transmissions are there – and they are likely to be there for the foreseeable future as it is inconceivable that Europe would allow itself to become dependent on GPS which is totally under US government control.

But a wider problem is raised by use of this sort of equipment. Yachters are becoming increasingly reliant on electronic navigation and neglecting basic skills such as dead reckoning. This would not matter if the electronic navigation aids on sale were all reliable.

Sadly they are not. In particular yacht electronics is often very vulnerable to disruption from interference or power supply problems. Inevitably gimmicks such as enormous numbers of "waypoints" or glossy advertising sell equipment more effectively than rugged design – especially to a leisure market unable to judge quality in the way that professional users can.

Unfortunately the EC directive on electromagnetic compatibility is likely to be postponed as it would have forced manufacturers to raise their standards. As matters stand I fear there may be an increasing number of "Decca assisted" strandings and mayday calls in the coming years.

Mike Brettle
Potton Marine Equipment
Bedfordshire

Short circuit

In the diagram for Mr Barker's "Switching oscillator" (*EW + WW*, Circuit Ideas June 1991), the + and – inputs for A_2 are reversed.

Michael Covington
University of Georgia
USA

THE HYDROGEN ECONOMY

Everyone recognises the need to move away from fossil fuels. Electrolytic decomposition of water using energy from alternative sources produces hydrogen. Is this the basis for a new energy economy? Report by James Kloeppel of the Georgia Institute of Technology, and Steve Rogerson.

Easy to produce and non-polluting, hydrogen could be the ideal fuel for the future. As a gas, it could be piped to homes and businesses for heating and cooking purposes, or converted into electricity by fuel cells. As a cryogenic liquid, hydrogen could launch rockets or fly aircraft. Or locked as a solid in metal hydride storage canisters, it could propel cars and lorries. And all with virtually no impact on the environment.

Bill Livesay, an energy specialist from Georgia Tech, reckons that by shifting from an economy based on fossil fuels to one dependent upon clean-burning hydrogen gas, cities could once again be free of smog, acid rain, oil spills, and global warming. But this utopia is not ours simply for the asking. He warns: "We have some serious work to do."

Mercede-Benz's active research programme is aiming to develop a car that operates from a hydrogen energy source.

A lesson not learned

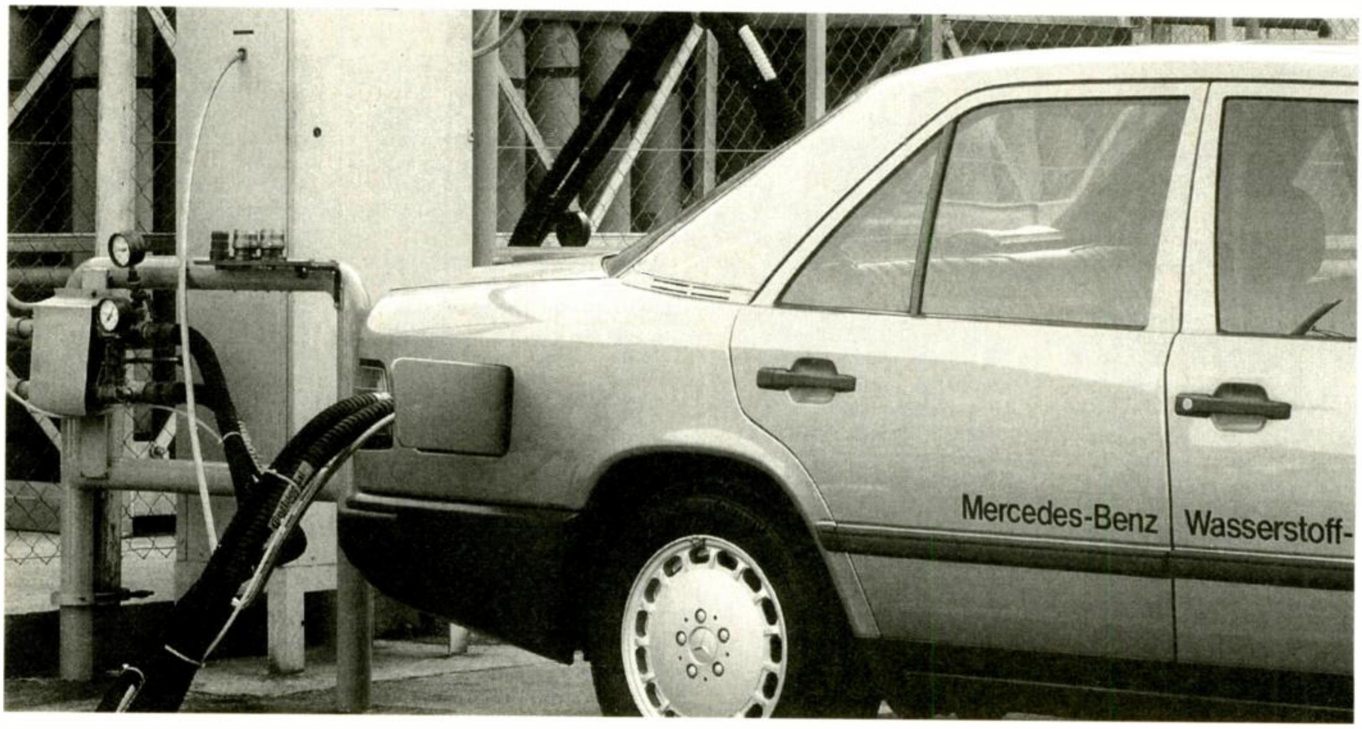
The oil crises of the 1970s sparked a number of significant advances in energy conservation and the development of alternative fuels. In the US, encouraged by government to reduce dependence on overseas oil, many responded by lowering thermostats, installing storm windows, adding insulation and weather stripping, and by driving less. Car manufacturers introduced new models with dramatically improved fuel efficiency, while handsome tax benefits promoted the use of other fuels, such as solar energy, to heat homes and businesses. The US successfully tightened its belt and, for awhile, the government broadened its vision.

What happened next was a classic example of supply and demand. As cars became more fuel-efficient and people learned to conserve energy at home and work, the demand for oil fell. With decreasing demand, oil supplies again rose and the cost of a barrel of crude dropped near its former level.

Unfortunately, as the world oil markets once again stabilised, the movement towards greater efficiency and renewable energy sources stalled. In fact many people, believing the energy problem had been solved altogether, reverted to old habits.

Today, in the wake of spiralling petrol prices and renewed concern over maintaining an unbroken supply of crude oil, spurred by the recent war in the Gulf, a painful reminder has been brought home. The world's supply of oil is indeed limited, and people can neither afford to waste this fuel nor wait to develop other sources of energy. World stores of energy are being depleted at an alarming rate.

Livesay maintains that over half the US supply of oil and natural gas has already been consumed. The remaining deposits, at



For many the thought of using hydrogen as a fuel conjures up visions of the fiery crash of the Hindenburg, a hydrogen filled zeppelin that burst into flames while landing in New Jersey in 1937. Tragically 36 passengers and crew members lost their lives in the accident raising serious questions about safety.

As a car fuel hydrogen may prove much safer than petrol. Because hydrogen is so buoyant, when leaks or spills do occur, the gas will disperse rapidly into the atmosphere, unless of course it leaks into the passenger compartment of the car when any spark could spell diaster. Petrol on the hand evaporates slowly and the heavier than air hydrocarbons in the vapour tend to accumulate until an ignitable mixture develops.

In the case of the Hindenburg, the terrible fire that burned for more than an hour was fed by diesel fuel and debris from the wrecked airship. The hydrogen had been consumed within a minute of the accident.

In a car crash, hydrogen may prove far less flammable than petrol. A few years ago, the Billings Energy Research Corporation fired armour piercing incendiary shells into two tanks, one filled with petrol and one with fully charged metal hydride. The hydride tank slowly burned through a puncture in its side. The petrol tank exploded.

SR

HULTON PICTURE LIBRARY

current levels of consumption, are projected to last a mere 30 years with world supplies running out 20 years after that. "Currently, the US has no national strategy to deal with this impending disaster" he says.

Energy in water

In a way, hydrogen already fuels much of the planet. The chlorophyll found in green plants uses sunlight to split water absorbed by the roots into hydrogen and oxygen. Oxygen, a waste product in this case, is released to the atmosphere. But the hydrogen is retained and combined with carbon dioxide to form simple carbohydrates, the beginnings of an elaborate energy chain.

The electrolytic cracking of water was first demonstrated in the early 1800s, but nearly a century passed before the process went into commercial production. Even then, electrolysis plants were used to generate oxygen, not hydrogen. The liberated hydrogen was usually treated as a mere by-product with little practical use. Today, the electrolysis of water is still used primarily as a source of high-grade oxygen for medical and industrial applications, and to replenish oxygen supplies on submarines.

Solar cells have long been plagued by problems associated with the storage and transmission of the energy they produce. In addition, variables such as time of day, season, and local weather conditions can cause major fluctuations in the amount of energy being received, and converted, at any given place and time. Hydrogen, produced by electrolysis from solar energy, can be readily stored until needed. And the long distance transmission of hydrogen gas through pipelines should be more efficient than the transmission of electricity down power lines.

Livesay believes a time will come when giant solar panels efficiently convert sunlight into electricity. The electricity, in turn, would power huge electrolysis plants to mass-produce hydrogen. The gas would be distributed as a portable, storable fuel. But the real beauty of using hydrogen as a fuel, he says, "is that it can be made from water, a cheap and abundant raw material. And when burned, it turns back into water, resulting in a cyclic process which is environmentally sound."

The missing link

For global use as an alternative fuel, hydrogen still has a major drawback, the lack of sufficient fuel storage for vehicle propulsion.

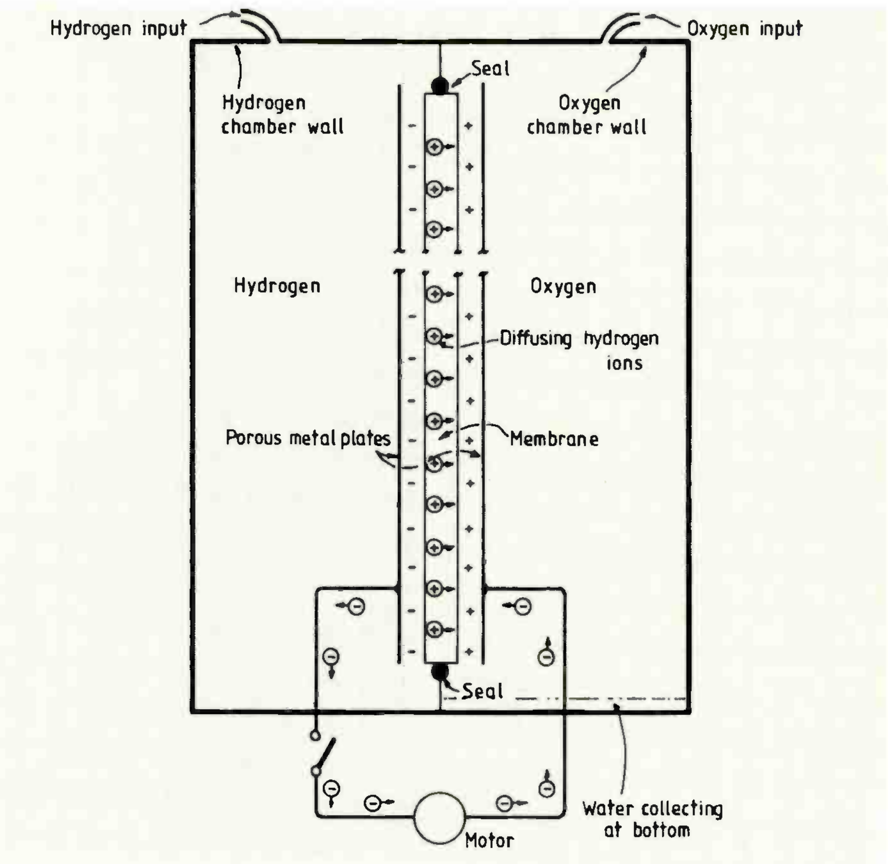
Hydrogen can be stored conveniently only as a compressed gas or as a cryogenic liquid, neither of which is particularly suited for the average car. Cylinders of compressed hydrogen are extremely heavy and contain relatively small amounts of fuel, yielding poor travelling range and needing frequent refills. Liquid hydrogen, though packing more power per pound than compressed gas, is much more difficult to handle.

To prevent rapid boil-off, liquid hydrogen must be kept at -252.8°C. Special cryogenic flasks are required, and these flasks are difficult to fill and properly maintain. Although liquid hydrogen is useful for launching rockets or flying large aircraft where trained technicians handle the complex fuelling operation, it probably never will become practical as a fuel for ground transportation.

One potential solution for vehicular fuel storage involves the use of metal hydrides, specially formulated alloys that soak up hydrogen much like a sponge absorbs water. Metal-hydride storage canisters can absorb pressurised hydrogen gas and then release it as needed following the application of heat which would normally be supplied by the hot engine exhaust. Some of these materials, like iron-titanium, lanthanum-nickel, and special magnesium alloys, can actually hold more atomic hydrogen than an equivalent-sized cryogenic flask, and without the need to refrigerate (see box for more details).

A fair number of metal hydrides exist, but the ideal alloy for hydrogen storage has yet to be developed. Desirable features include the ability to store vast amounts of hydrogen at low charging pressures, fast release of the gas at low operating temperatures, light weight, and reasonable cost. Existing hydrides require trade-offs among these parameters.

Iron-titanium, for example, is inexpensive and can release hydrogen at a low temperature (38°C). But this material is extremely heavy and possesses a relatively low hydrogen capacity. To provide a range of 300 miles for an average-sized car, a 90-gallon tank weighing nearly a ton would be needed.



Gaseous hydrogen is supplied to the left side of a membrane where the atoms part company with electrons. The protons traverse the membrane to combine with electronegative oxygen to form water. The surplus electrons from the hydrogen side have to go round an external electrical circuit doing work on the way.

Magnesium alloys are far lighter and can hold much more hydrogen. The same car would need a storage tank less than half the size and only a quarter the weight of an iron-titanium tank. But magnesium hydrides require a much higher pressure to charge up, and a much higher operating temperature – around 344°C. This temperature cannot be reached and maintained by mere engine exhaust.

More research into metal hydrides is needed to exploit the potential for enormous storage density and convenient use.

Back in the 1970s, a number of designs using iron-titanium storage canisters were developed, including a hydrogen powered car built at Georgia Tech. These tests were largely successful. In one experiment, the Billings Energy Research Corporation converted a 19-passenger bus for the city of Riverside, California. This was the first hydrogen-fuelled vehicle placed in regular passenger service. The bus performed impressively, though the iron-titanium storage tank had to be recharged every 200 miles.

In another test, a Post Office delivery van was converted to hydrogen fuel and operated for a year. The metal-hydride storage tank again functioned flawlessly. On an equal energy basis, this vehicle proved 21% more fuel-efficient than one powered by petrol.

The missing link may have been found at last.

The solar advantage

Despite its many advantages, hydrogen has been slow to gain universal acceptance as an alternative fuel. One reason is that, like most new technologies, the current costs of producing hydrogen are quite high. Liquid hydrogen, for example, costs nearly four times as much as petrol to produce on an equal energy basis. But as the price of diminishing fossil fuels climbs ever higher, and as additional research and development combined with potential mass production bring the cost of generating hydrogen down, hydrogen is bound to become cost-effective.

Another reason for hydrogen's slow acceptance can be traced to concerns regarding the energy effectiveness of the proposed solar-to-hydrogen conversion process.

Bill Livesay comments: "Just a few years ago, it actually took more energy to make a solar cell than you could ever get out of it during its lifetime. Too much energy was consumed in growing the crystal, slicing it into wafers, and in all the other little processing steps that were required. As a result,

Hydrogen fuel cell

A typical hydrogen fuel cell is a specialised membrane manufactured from organic sulphonate compounds. This material allows proton travel across it - a bit like semiconductor electron holes moving through a crystal lattice. When the hydrogen comes into contact with this membrane, the proton nucleus enters leaving its electron on the surface. When the proton reaches the other side, it comes into contact with oxygen.

Now any good hydrogen proton likes nothing better than to react with oxygen to form water, but for this it needs its electron, still stuck on the other side of the membrane.The electrons meanwhile have started concentrating, building up a charge; for most fuel cells this charge reaches a maximum of about 1V. This is collected on a metal plate which is connected to a wire. The wire takes the electrons around to the other side of the membrane to reunite them with their protons in a flood of water.

But before the electrons reach the other side they can do work such as driving a motor or other device. So far conversion efficiencies between 60 to 80% have been attained for membrane fuel cells.

Fuel cell inefficiency manifests itself as heat. Hydride decomposition to gaseous hydrogen is endothermic – it gets cold. Between the two, hydrogen vehicles have the resources for built-in air conditioning.

Fuel cells may be run backwards to produce hydrogen for the next journey while the vehicle is parked. This process takes about eight hours. For hydrogen cars to become a reality, petrol stations will eventually have to sell hydrogen for a ten minute refill.

The attitude of the giant oil companies and the governments they finance will pose a significant problem. If, to preserve, the *status quo*, they will go to the lengths of staging a war to protect the supply of cheap oil from Kuwait, then one fears that they will find a way to stop water powered cars from breaking a monopoly on road traffic.

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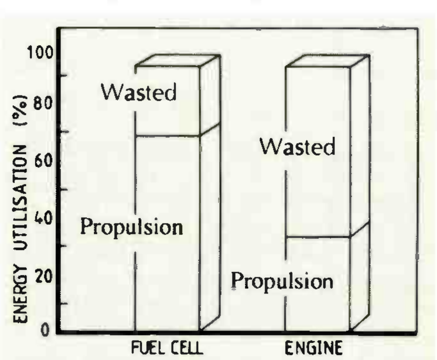


Energy efficiency of a hydrogen fuel cell is almost double that of an IC engine.

the conversion of solar energy into hydrogen was not energy-effective."

Fortunately, this is no longer the case. Recent advances in materials and solar technology have yielded solar cells that are easier to produce and considerably more efficient to operate. Conversion rates for some of today's photovoltaic cells approach 31%, more than twice what they were in the mid-1970s. Though much additional work needs to be done, the development of advanced solar cells has brought the electrolytic production, storage, and distribution of hydrogen much closer to commercial reality.

While some energy experts believe nuclear power should become the next target, this cannot necessarily be viewed as a long-term solution to the energy problem. In addition to producing mountains of radioactive waste, a major drawback by itself, uranium, like petrol, is a limited resource.

Nor does Livesay see processes such as the gasification of coal, conversion of biomass, production of hydrogen from natural gas (hydrogen currently can be produced more cheaply from natural gas than from water) as legitimate solutions.

He said: "It really makes very little sense to take one non-renewable resource like coal, natural gas, or petrol, and make another energy medium. Not only are you bound to lose because of the inefficiencies involved, but you are still consuming a limited resource. In the long term, there simply is no other option: we have to use solar energy."

Ultimately, new thermochemical, photosynthetic, or direct photo-electrolytic processes may prove more cost effective and energy efficient in producing hydrogen than solar cells and electrolysis. But the technology already exists to construct energy-saving, solar-powered electrolysis plants, and timeliness is a major factor. Decades will be required to convert our existing infrastructure from petrol and natural gas to hydrogen.

As promising as a hydrogen economy looks, no new technology can conceivably support energy consumption at present rates. To solve present and future energy problems, a profound commitment is needed, a commitment society has not been willing to make. By sheer necessity, there will have to be a gradual change in habits and lifestyles to match sustainable levels of renewable energy sources. The days of cheap, plentiful energy will soon be gone forever. ■

Storage of hydrogen

The safest way of storing hydrogen is within a metal cylinder tank, normally manufactured from aluminium because of its high thermal conductivity, with a valve on top. Inside the tank are metal granules made from an alloy of iron, titanium and manganese. This granulated material reacts chemically with hydrogen (sharing electrons) to form a loosely bonded compound which looks like a white powder.

Because of the loose bonding, the application of a small amount of heat is enough to release the hydrogen. This is a better system than compressing the gas into a regular vessel for a number of reasons.

First simple compression requires a high pressure within a vessel of about three times the internal volume for a given quantity of gas.

Secondly the gas, combined as a metal hydride, is safer. Compressed hydrogen is very flammable and potentially explosive.

The metal hydride is non-flammable and non-explosive.

Metal hydride acts like a sponge which can be used over and over again. Refilling has more in common with inflating a tyre than filling a petrol tank.

For example, a typical car sized tank measuring 12in tall by 14in wide and 36in long could contain enough hydride to run a car for about 250 miles.

A hydrogen recharge to 90% would take 10 minutes. However, to go to 95% would take 20 minutes and for 100% 45 minutes. For this reason the design is usually made to be fully charged at 90%.

SR

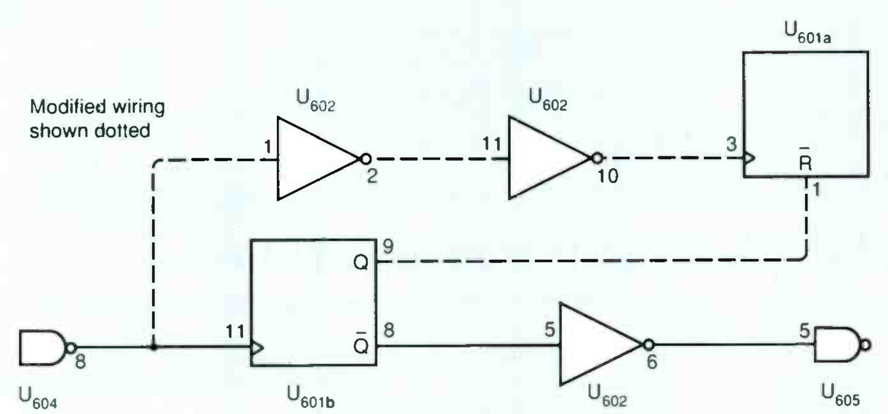
Better triggering for oscilloscopes

Goldstar OS7020 oscilloscopes exhibit a slight limitation in their triggering facility which causes the sweep generator to trigger only on alternate leading edges (both positive and negative-going) of the signal. Short pulses of low repetition frequency may therefore be difficult to examine in some cases.

This circuit avoids the problem and needs no extra components. Simply cut the tracks close to pins 1 and 2 of U601, the 74LS74, remove the earth link to pin 11 of U602, the 74LS14 near C_{622}, and rewire as shown using the two spare inverters. These are used to delay the clock signal to the blanking and sweep flip-flop, its reset being re-routed to ensure that it is removed before the next trigger at the clock input.

Any additional delay caused by the inverters is negligible compared with that due to the trigger and horizontal amplifiers.

H. Maidment
Wilton

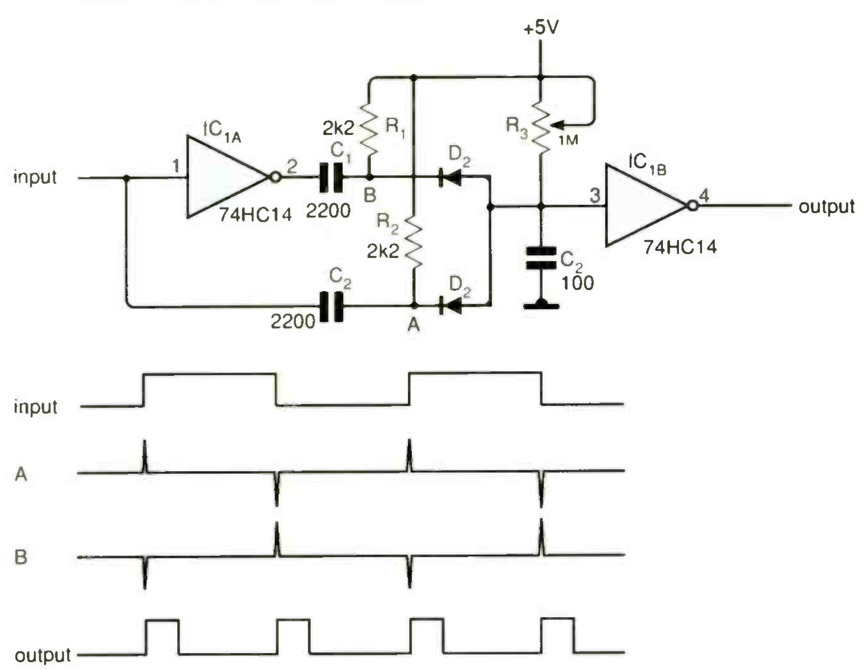


Frequency doubler

One-third of a 74HC14 is used to double the frequency of an input square wave.

The two differentiators $C_{1,2}$ and $R_{1,2}$ convert the input to narrow spikes, only the negative-going ones being selected by the diodes. Since the inputs to the differentiators are in antiphase, a negative-going pulse is present across C_3 whenever the input changes state. At the output of the second inverter, the positive pulse lasts for a time determined by the time constant of C_3R_3, which is adjustable.

Yongping Xia
West Virginia University
Morgantown WV USA



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Voltage-tuned crossover filter

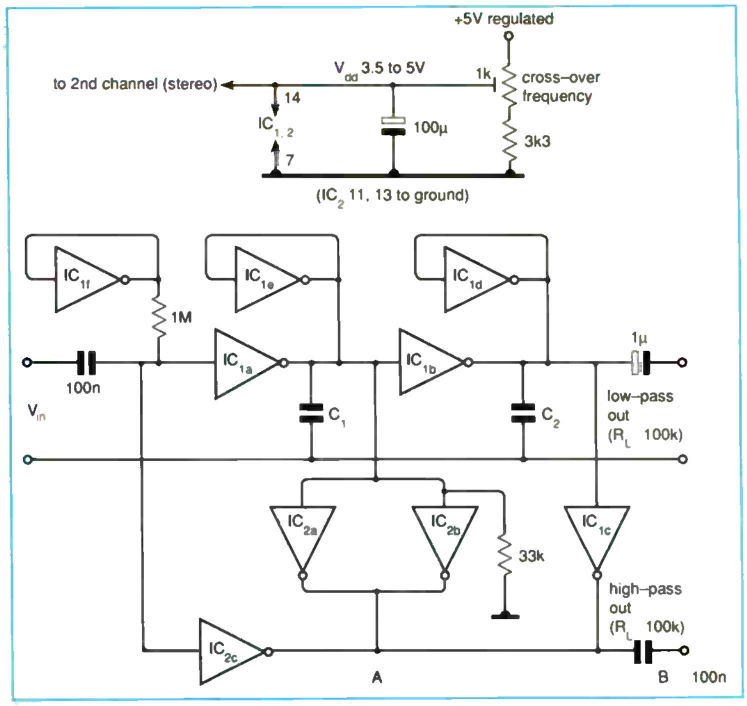
With this circuit, the crossover frequency is variable to suit any loudspeaker, f_c varying over a 5:1 range for a supply voltage change of 3.5-5V. High-pass and low-pass outputs are always in phase.

Since the g_m of unbuffered cmos inverters varies with V_{dd}, connecting input and output together forms a resistor that varies from around 500Ω to 5kΩ for a V_{dd} change of 5V to 3V. Loading an inverter output by a cmos resistive element produces an inverter gain of $|A_v| \approx g_m R_L \approx 1$, since $R_L \approx 1/g_m$. In this case, gain varies from 0.95 to 0.99 for a V_{dd} change of 3.5V to 5V. The element also provides a $0.5V_{dd}$ bias for other inverter inputs.

The filter formed by $IC_{1a,e}$ and C_1 has the same phase characteristic as an all-pass filter. Paralleling $IC_{2a,b}$ gives a gain of 2, the output being summed at A with the output of IC_{2c} to give unity gain and 0° to -180° phase shift with frequency. Inverting the low-pass signal in IC_{1c} and summing at B gives the high-pass function which is in phase with the low-pass output.

The 33kΩ resistor increases high-pass attenuation when V_{dd} is less than 4V to -40dB, but could be left out by using a tuning range of 4V to 5.5V to give a 3:1 frequency range.

Ian Hegglun
Manawatu Polytechnic
New Zealand



Multiple outputs from one D-to-A

Four channels of precision, buffered voltage are obtained from the output of a single D-to-A converter, using the circuit shown which uses fewer components than the conventional method; in particular, there is only one expensive converter against the usual four or more.

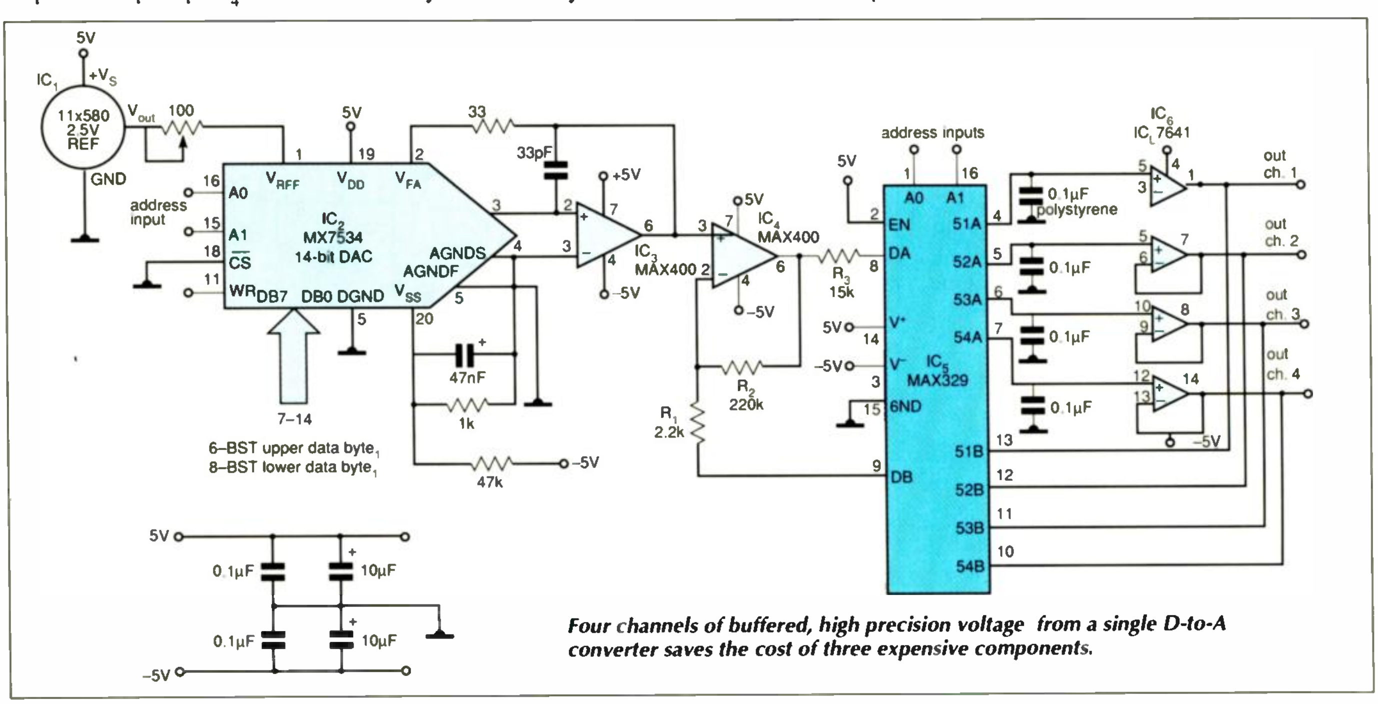
A differential multiplexer, IC_5, directs the converter output to each of four low-leakage capacitors and the output buffers in IC_6, all these components being inside the feedback loop of the op-amp IC_4 to reduce offset by the closed-loop gain of the op-amp, which is 101.

A small amount of offset at up to 15µV/°C is still in effect due to the presence of op-amp IC_4.

Multiplexer IC_5 provides the low current leakage and low charge injection (4pC) needed by the sample-and-hold circuits, the charge injection producing 40µV offset on each capacitor. When this error is summed with IC_4 offset and that of a buffer amplifier reduced by feedback, total offset is 100µV or about 0.65 LSB.

With this offset, each hold capacitor takes 2.6s to discharge 1LSB at room temperature; at higher temperatures, this time decreases rapidly and a higher clock rate is needed, although it may mean that several cycles are needed to set up the capacitor voltages after a change.

Jay Scolio
Maxim Integrated Products
Sunnyvale
California



Four channels of buffered, high precision voltage from a single D-to-A converter saves the cost of three expensive components.

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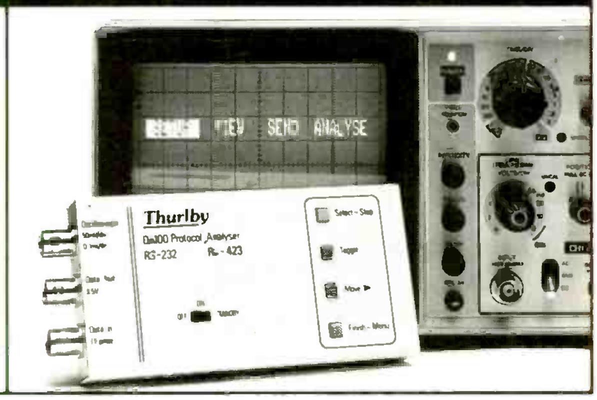

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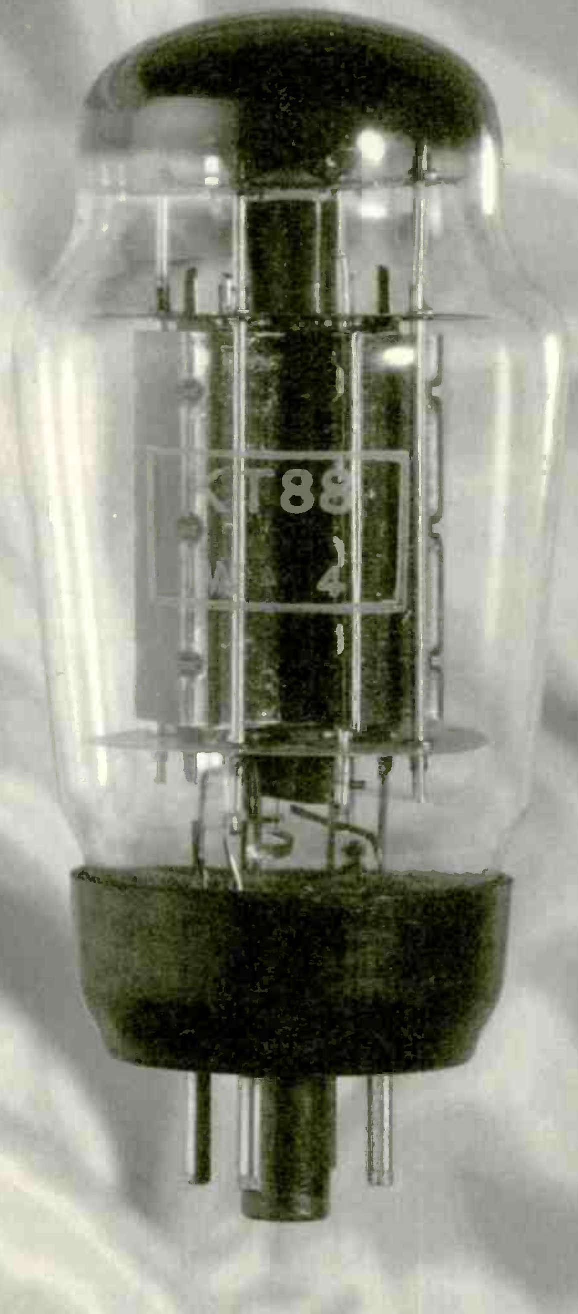
Transistor-driven valve amplifier



Valves offer advantages for audio power output, but transistors come into their own in the gain stages. John Linsley Hood describes a transistor driver module with a suggested phase splitter for push-pull working

There is a continuing, somewhat nostalgic interest in the use of valves in audio amplifiers. Although they do not provide a cost-effective route to high audio quality, valves do have the advantage that they exhibit a more linear input transfer characteristic than bipolar devices and can consequently offer a lower open-loop distortion figure.

They can also drive difficult loudspeaker load impedances rather better than some solid-state designs and have a rather more graceful approach to overload.

The ability of power-output valves to dissipate considerable amounts of heat also allows valve audio amplifiers to operate in class-A, which avoids the generation of high-order cross-over type distortion products. However, these qualities are mainly aspects of the (necessarily) transformer-coupled output stage, rather than of any preceding gain stages, where the benefits from the use of valves are much less.

It occurs to me that the simple four-transistor class-A amplifier circuit, which I described in *Wireless World* in 1969, would make a very effective output-stage driver module.

I have shown the basic layout of such a hybrid amplifier in **Fig. 1**, and the driver module in **Fig. 2**. Since, apart from the input DC-blocking capacitor the driver circuit is DC-coupled from input to output, the setting of the input DC level at Tr_1 will control the DC output level to allow adjustment of the output-valve grid bias.

Some input phase-splitter arrangement will, of course, be necessary to drive the two output valves in push-pull and to allow overall loop negative feedback to be applied from the output transformer secondary, and I have shown possible layouts for such a circuit, based on very low-distortion, wide-bandwidth, LM833 op-amps, in **Fig. 3**.

The bandwidth of the circuit of Fig. 2 is very wide and certainly extends to the 10MHz region. If it is necessary to introduce a step in the gain/frequency curve to secure HF loops stability in the final amplifier, this can be done by a network R_x/C_x in parallel with R_6, of which the values will depend mainly on the output transformer leakage reactance. LF break points are determined by the values of C_1 and C_3, and can be made as low as necessary for LF loop stability. Transient performance of the circuit of Fig. 2, is excellent and its distortion, at the onset of clipping, is of the order of 0.02% at 1kHz, and is almost entirely second-harmonic. As is normal in class-A gain stages, the distortion decreases linearly as the output voltage swing is reduced ■

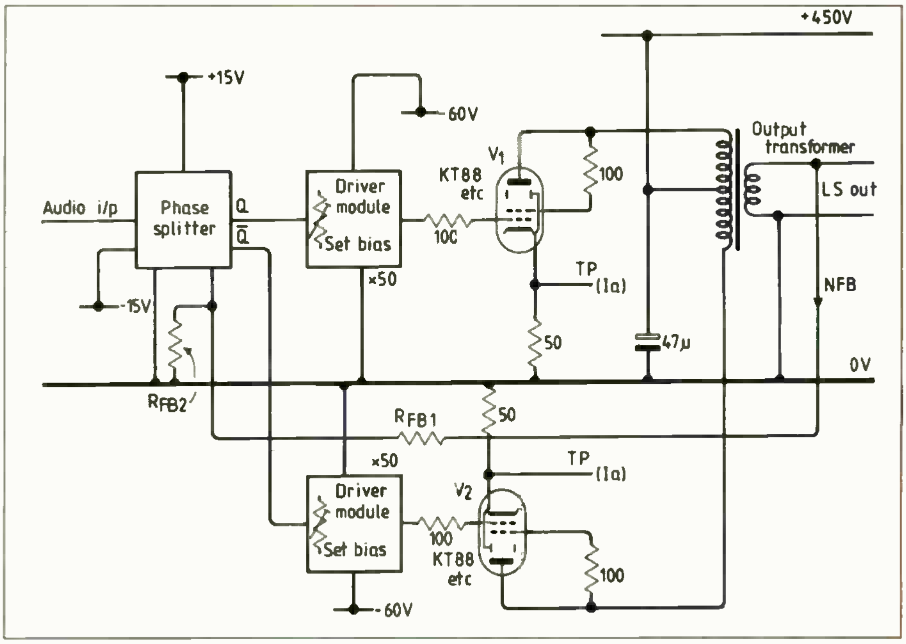


Fig. 1. Layout of one channel of transistor/valve amplifier.

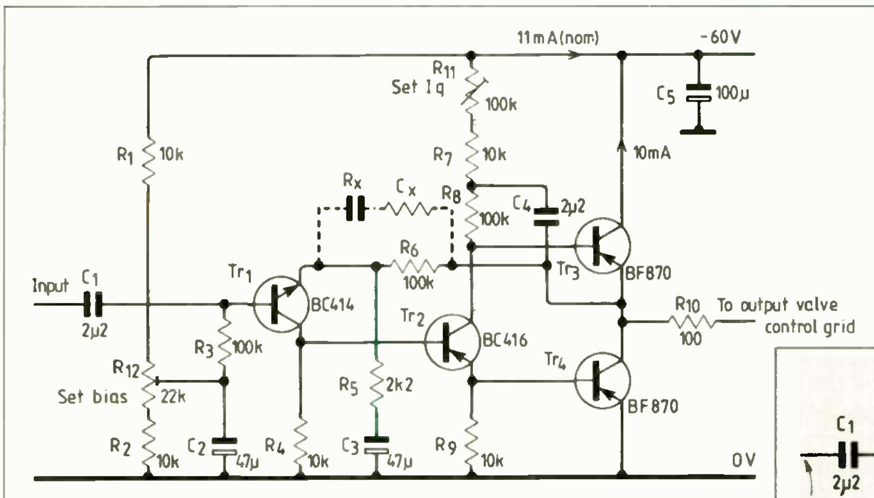
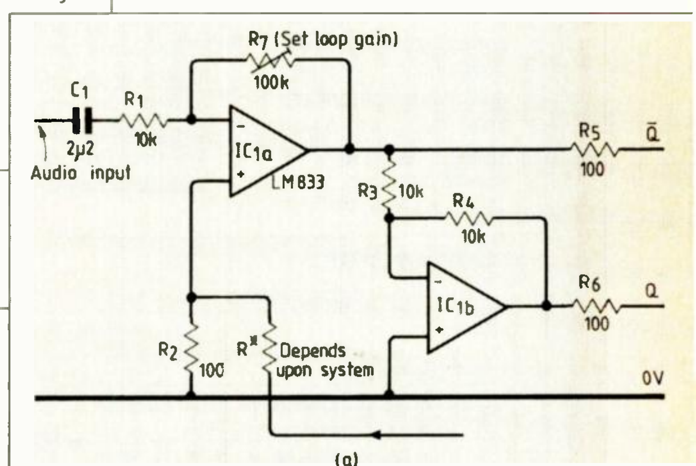
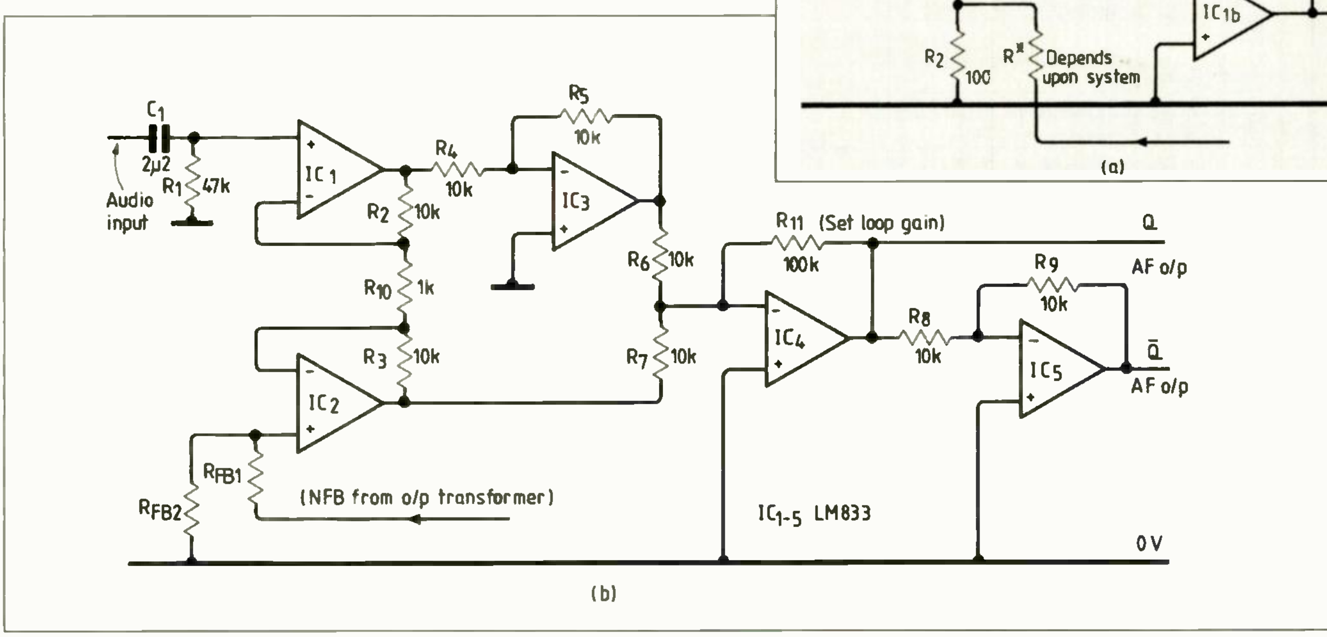


Fig. 2 (above). Transistor class-A driver module. Circuit is directly coupled and VR1 sets bias on valve output stage. Network CxRx ensures stability in complete amplifier.

Fig. 3 (below). Two suggested layouts of phase splitters to provide push-pull drive to the output valves via the Fig. 2. driver circuit.





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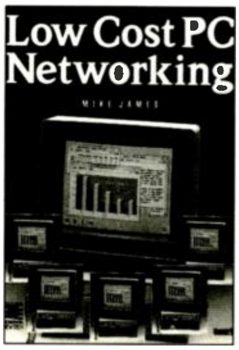

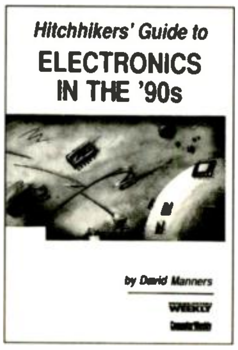

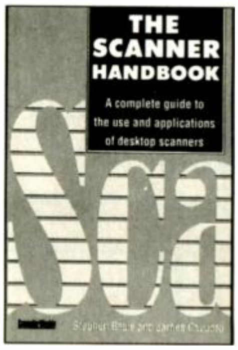

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PARASITIC PICTURE

Living close to a radar installation, Michael Green has been able to conduct a series of fascinating experiments into passive radar reception using stray pulses from his high-powered neighbour.

To TV viewers living near an airport, the presence of 500kW RF pulses on 591MHz is a nuisance. Having connected an oscilloscope to the video stage of a portable TV to obtain a perfectly synchronised display from the 4µs transmitter pulse, it was possible to measure the distance to strong permanent echoes, which appeared every five seconds as the radar aerial rotated. By calculation it was evident that these echoes came from a prominent group of hills in the Pennine Chain (Winter Hill, Lancs).

An ex-shipping PPI was obtained, a Decca 101, with a mechanically rotated scan coil assembly. This was originally driven by a semi synchronous drive from the radar aerial: the drive was removed and replaced with a servo system of constant speed. By coupling the radar video input through a drive stage from the TV and constructing a sync pulse generator triggered from the first video pulse received – the radar transmitter's outgoing signal – a recognisable PPI picture of the Fylde Coast area was produced, albeit with poor display and drive synchronisation.

However the idea was proved and a design/construction program started which has resulted many years later in a system which will give a good plan picture of the surrounding area and detect aircraft and helicopters to a range of 60 nautical miles (nm).

System details

The system currently in operation consists of an octagonal omnidirectional receiving aerial, feeding a 23dB gain masthead amplifier. The signal is carried to the receiver over low-loss coax and is post line amplified. The RF stage consists of a peak tuned Mullard ELC 1043 tuner driving a conventional TV IF strip and video detector stage. These circuits are followed by a video amplifier and TTL sync pulse and gate generator. The sync pulse is the system master timing circuit and controls the swept gain, range ring generator, main video gate and deflection sweep generator: the Decca 101 circuits have been replaced as unsuitable for conversion for ranges over 24nm.

It should be realised that the firing of the main radar transmitter at the CAA site is not periodic, but staggered for purposes of determining movement from fixed targets (moving target indication MTI) and preventing what are known as blind speeds within the MTI. Because of this it is not possible to produce simply a flywheel type sync pulse: direct detection of the transmitter pulse provides a better sync signal. This can cause problems. During the rest time after the transmitter has fired and the last echoes have been received from maximum range, the sync pulse generator can be triggered by noise, strong echoes or another radar on an adjacent frequency.

The purpose of the swept gain in this system is to de-sensitise the receiver 750µs or 60nm after the transmitter has fired thus preventing false triggering, the level being set to allow the locally produced power pulse to break through to initiate a scan sequence.

The receiver video output is fed to two switch selectable separate amplifiers. One is a conventional video amplifier while the other differentiates the signal such that only the leading edge of the echo is displayed, this being similar to the original rain clutter circuit. The differentiated display gives a better contrast as much of the receiver noise is suppressed, but causes premature fades as the target approaches maximum range.

Accurate range rings are generated by gating the output of a crystal clock. The gating sequence commences upon receipt of a sync

Mk III display system: Decca 101 display and, on top, the digital display drive generator

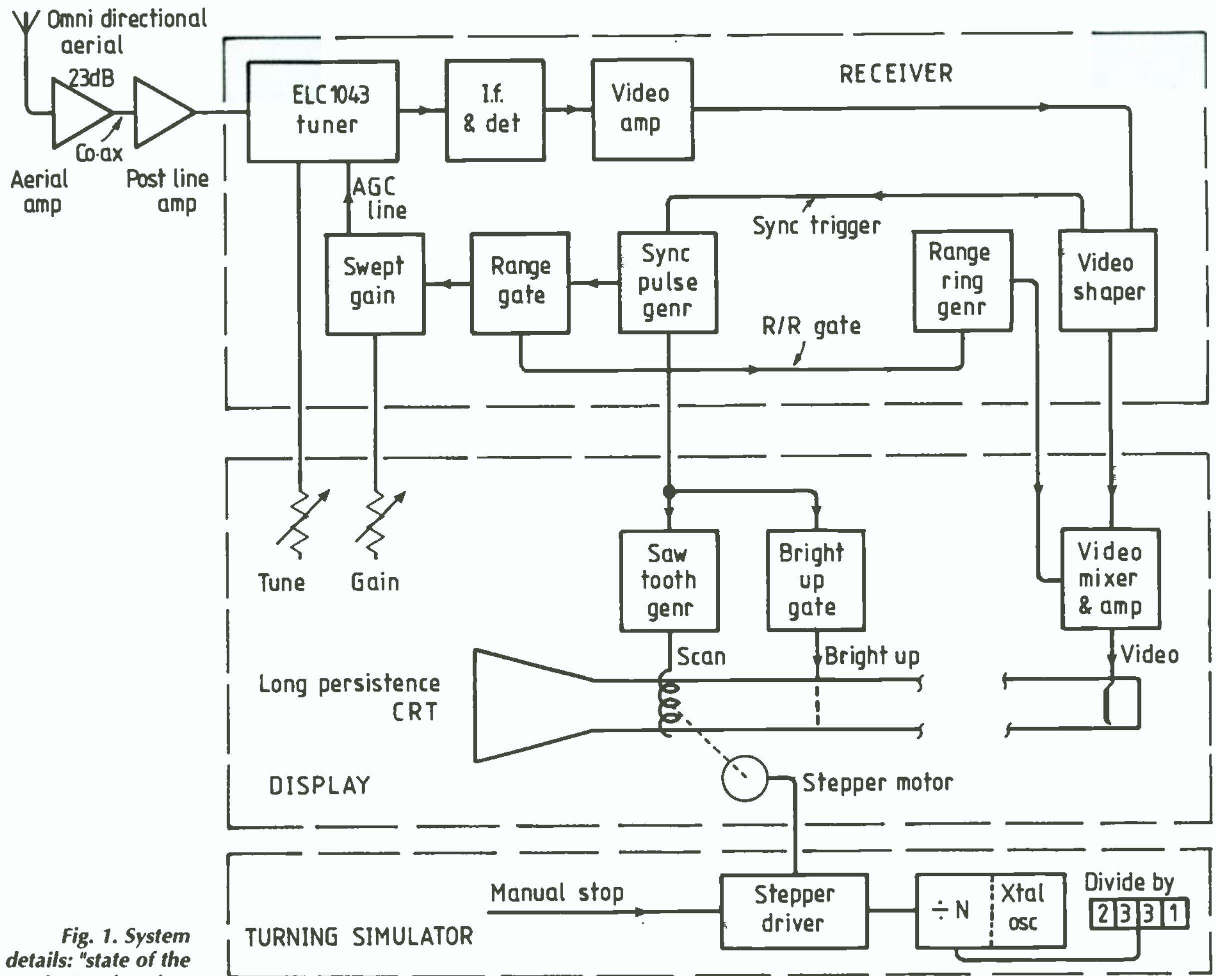


Fig. 1. System details: "state of the pocket" rather than state of the art.

pulse. The clock's divided output produces rings at 5 and 10nm up to the maximum displayed range of 60nm. The circuit is so arranged that the duration of the 10nm pulse is twice that of the 5nm thus producing a brighter ring at 10nm interspaced with 5nm rings. A potentiometer circuit can then be used to reduce the voltage output of the range ring generator to lessen the total brilliance, which may be used to remove the 5nm rings if required.

CRT spot deflection commences from the centre of the PPI at a linear rate upon receipt of a sync pulse, the rate of travel being almost equal to 12.4μs per radar mile (6.2μs to target, and 6.2μs to return to source). Thus if the displayed range is set to indicate 10nm radial range, the spot would travel from the centre of the CRT to the edge in 10x12.4μs or 124μs. At a maximum displayed range of 60nm the deflection time would be 744μs. Target echoes received during this sweep cause the intensity of the spot to be increased to give a "bright up". Thus as the deflection sweeps and the trace rotates radially, a map or plan is drawn of the surrounding area. Conventional circuitry is used to produce a linear current sawtooth of maximum 70V, the rise time and duration of this sawtooth being dependent upon the range selected.

Facing North

By far the most complex problem so far tackled is display drive synchronisation, ie when the main transmitter aerial points North, the display should also indicate North.

Several synchronisation methods were tried using both analogue and digital techniques to determine the centre of the beam. This proved impracticable as the system triggered to side lobes and if the detector was suitably attenuated to prevent this, synchronisation became sporadic.

The present system is a compromise. It was noted during experiments how consistent was the rotation rate of the transmitter's aerial, even during periods of high winds. This allows the servo system to be replaced with a stepper motor driven from a free-running crystal timebase divided by a switch selectable divide by "N" counter. This rotates the mechanical scan coil mechanism. Accurate positioning is achieved by momentarily pressing a button to cut the motor drive, and visually aligning the scan to a known permanent echo (PE), in this case the gas holders at the Blackpool end of the M55 motorway. This may seem crude, but was a system widely employed in marine radars and by Decca on their 424 airfield precision approach radar.

Once again it should be stressed that this is not a usable system but an experiment. Other shortfalls include the range and azimuth inaccuracy due to the offset between the receiver and transmitter sites and MTI, the ability to remove fixed PE clutter and only display aircraft targets.

Work is in hand to produce a more sophisticated system.

As can be seen from the accompanying picture, an isotropic aerial is not wholly suitable. Note the ring at 5nm and the reflection of the PE's to the East on the right of the display, both caused by side lobes of the main beam which would not be seen from a directional receiving aerial. A more modern PPI has been procured with an XY fixed coil scan, and efforts will be directed at producing a rotating 50cm Yagi with a high gain and narrow beam angle, positioning data being sent using a sin/cos synchro resolver.

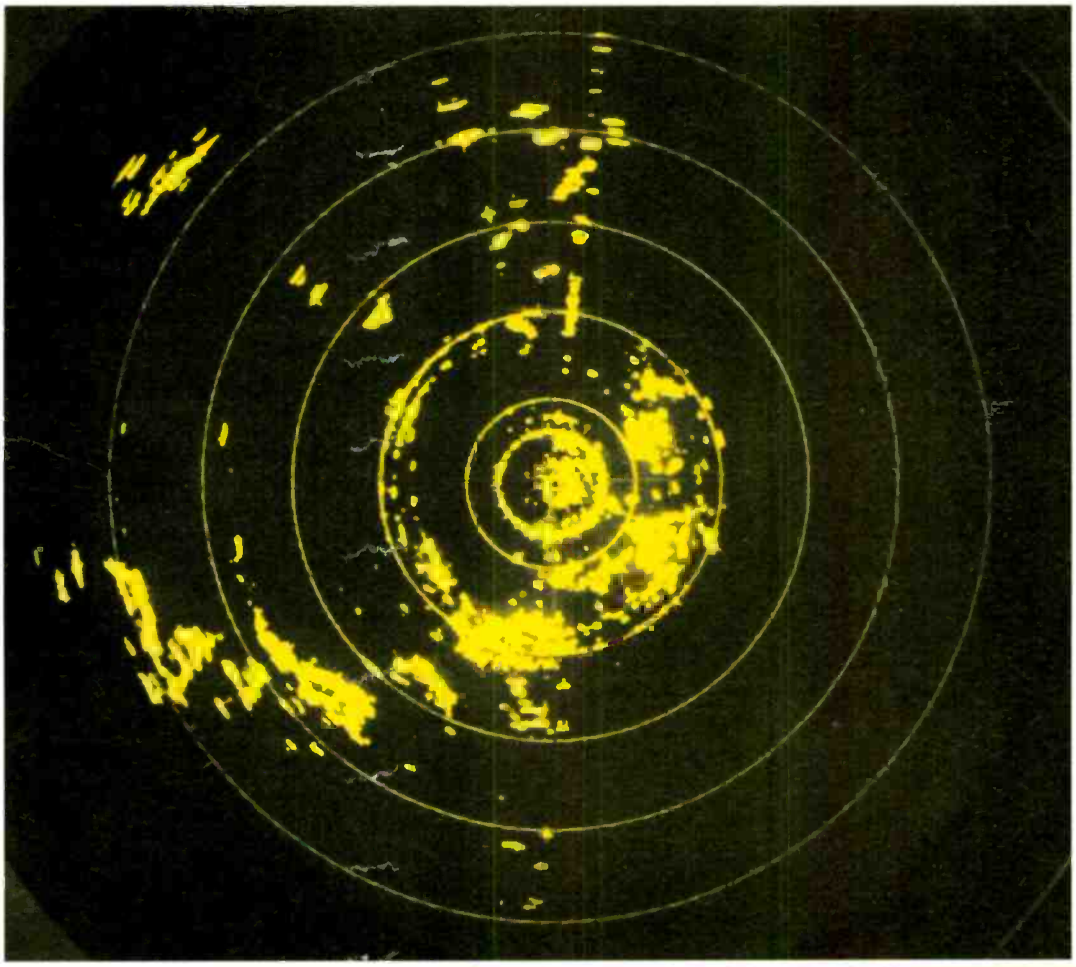
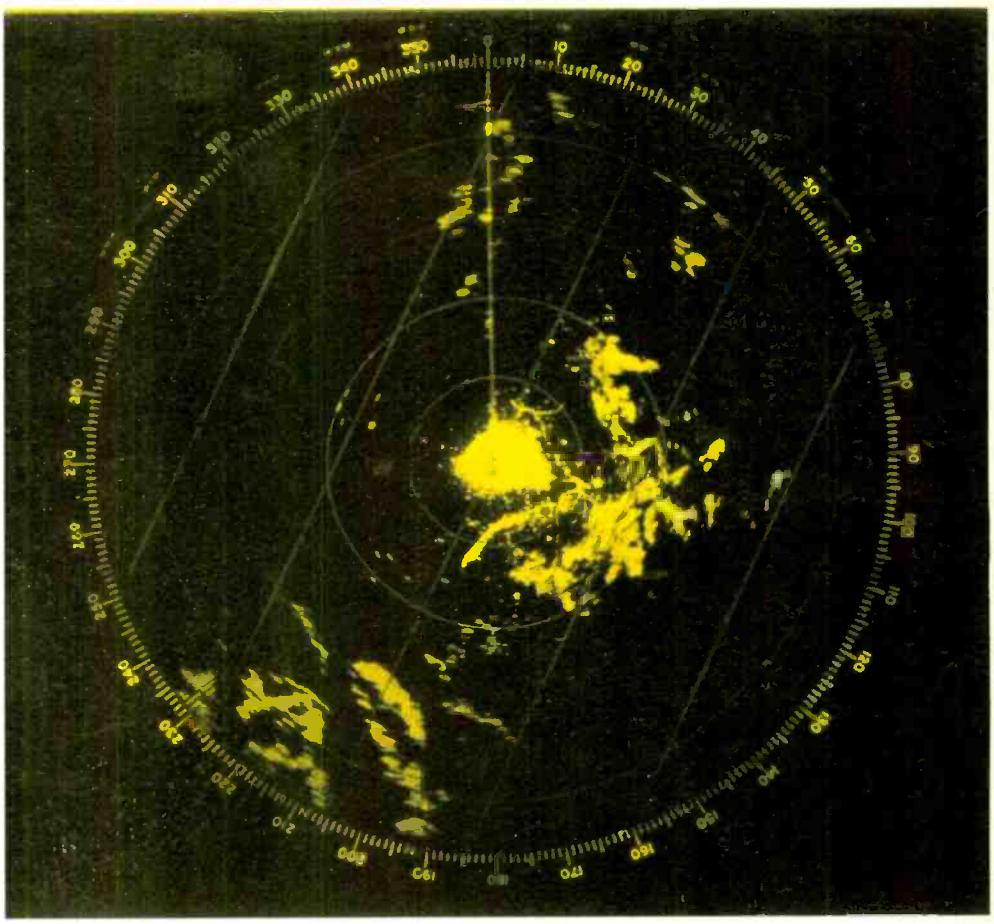


Fig. 2. Bi-static picture (60nm) received at 6 Downham Place, from transmissions of Marconi 264 radar at the CAA ST Annes site. Blackpool Airport radar approx 1nm SE> St Annes radar approx 4nm SE.

Fig. 3. Uncancelled radar picture from Blackpool Airport 10cm radar. Max range 50nm.



again not state of the art but state of the pocket.

View from here

The two photographs show the bistatic reception of the signals received from the CAA's 50cm Marconi 264 radar at St Annes (**Fig. 2**) and the Blackpool Airport Cossor 787 10cm picture (**Fig. 3**). Breaking the bistatic picture down, the PEs are due North from the Lake District, due East at 15-20nm from the Pennine Chain. South-West to 60nm from the North Wales coast and North West at 55nm from the Isle of Man. Two aircraft can be identified by their afterglow tails at a range of 36 and 37nm on bearings of 270° and 280° respectively. The line of echoes bearing 005° most prominently crossing the 20nm range-ring and again at 50nm are caused by multiple echoes between the radar aerial and the previously mentioned gasholders. The five echoes appearing on the Blackpool Airport radar picture, 15-20nm distant on a bearing of 290° are gas exploration rigs operating in Morecambe Bay, not distinguishable on the bistatic picture due to side lobe clutter. ■

References

Henry Hislop. *Displaced Radar Systems*, *EW + WW*, March 1990.
J Schoenenberger and J R Forrest. *The Radio and Electronic Engineer*, February 1982.

Programmable-gain instrumentation amplifier

To ensure maximum resolution in an A-to-D converter, a data acquisition system with analogue inputs of different amplitudes must provide a method of bringing them to the same amplitude. This circuit automatically adjusts the gain of an instrumentation amplifier as each channel is selected.

Two Max359 differential multiplexers are driven in parallel by the channel-select line, the first selecting the channel and the second connecting the correct amount of feedback around the Max400 op-amp. The circuit shown in the figure is a four-channel differential amplifier with four gain settings, one of which is unity. An eight-channel system may be made using eight-channel versions of the Max359 and the use of separate drives for the two multiplexers would allow any gain to be allocated to any channel. **Table 1** shows how the resistor chain varies the gain, R_T being the total resistance. Binary values are shown, but any gain settings can be used, within reason.

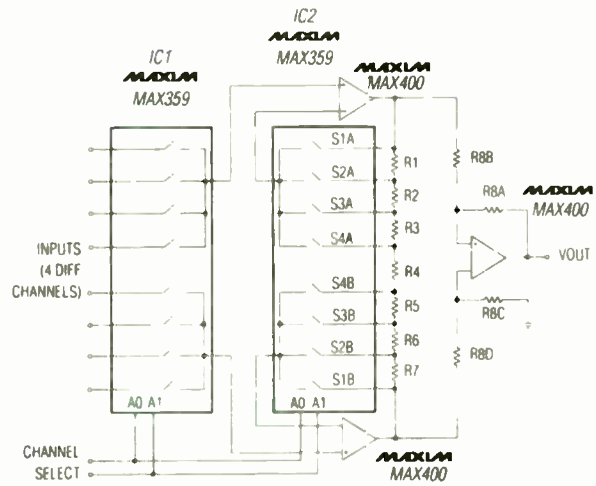
To determine resistor values, assign a simple value to R_4, say 5(k). $R_T/R_4 = 8$, so $R_T = 40$ and $R_3+R_4+R_5 = 10$. R_4 is 5, so $R_3+R_5 = 10-5 = 5$. $R_3 = R_5 = 2.5$, $R_2 = R_6 = 5$ and $R_1 = R_7 = 10$.

Note that switch resistance in IC_2 causes little voltage error since there is no signal current.

Leakage current in the switches is not much of a problem. Since the system is differential, currents largely cancel and only the difference in the two leakage currents in a pair of switches can cause error.

As a matter of interest, the Max329 exhibits an order less leakage than the Max359.

Maxim Integrated products, 21C Horseshoe Park, Pangbourne, Reading RG8 7JW. 0734 845255.



Automatically adjusting the gain of a multichannel instrumentation amplifier for a variety of input signals affords maximum A-to-D resolution in a data acquisition system.

Table 1. How resistor chain varies gain

Ch	Switches closed	Desired gain	Formula
1	S_{1A}, S_{1B}	1=	R_T/R_T
2	S_{2A}, S_{2B}	2=	$R_T/(R_2+R_3+R_4+R_5+R_6)$
3	S_{3A}, S_{3B}	4=	$R_T/(R_3+R_4+R_5)$
4	S_{4A}, S_{4B}	8=	R_T/R_4

Switched-input op-amp

With a bandwidth of 185MHz, a settling time of 9ns and an input switching time of 6ns, OPA675/6 devices from Burr-Brown are intended for use in multiplexing, synchronous demodulation and programmable-gain amplification.

The component consists of two indepen-

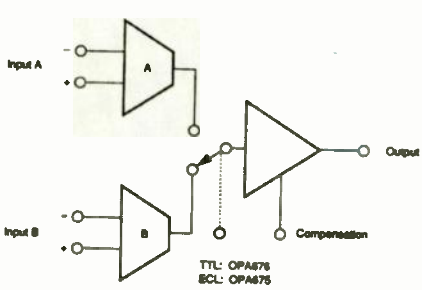


Fig. 1. Basic layout of Burr-Brown OPA675/6 switched-input amplifier, which has independent input stages.

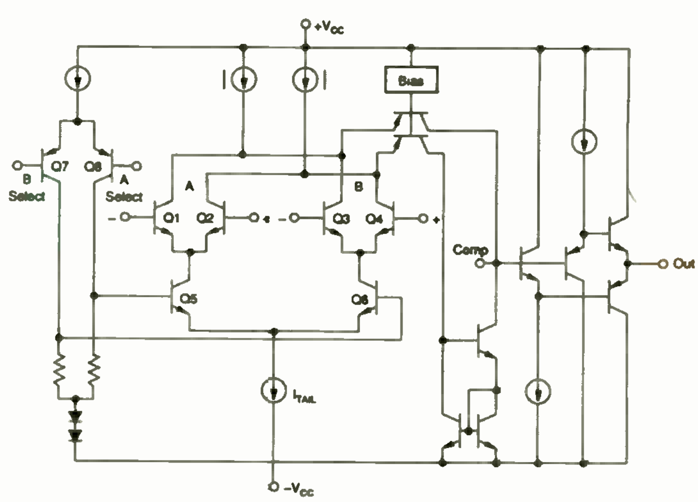


Fig. 2. Essential circuitry of OPA675/6 amplifier. Current is switched between "tails" of long-tailed pairs by logic signals at A or B.

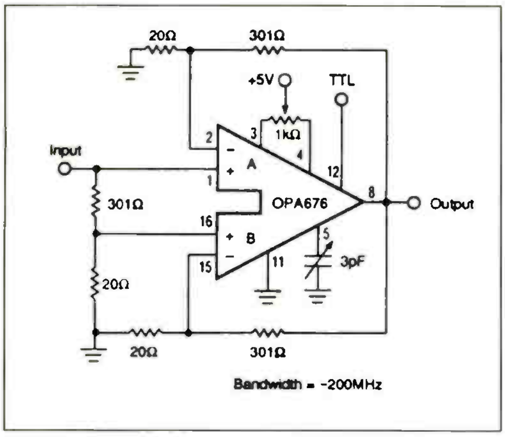


Fig. 3. Fast programmable-gain amplifier with 200MHz bandwidth.

dent differential-input amplifiers, switched by ECL (675) or TTL (676) external logic signals to drive a common output amplifier. Low distortion (down to -61dB second harmonic referred to carrier) and crosstalk (-100dBC at 100kHz, -68dBC at 10MHz) make the device amenable to RF and video signals. **Figure 1** shows the arrangement.

Taking the 675 ECL case, **Fig. 2** shows a simplified layout. The amplifier is a "classical" high-speed op-amp, but with two selectable differential input stages. A differential ECL signal applied to A and B turns on either Q_5 or Q_6, which steers the tail current of the long-tailed pairs to $Q_{1,2}$ or $Q_{3,4}$, the pair taking current behaving as a conventional op-amp input stage and the other as a virtual open-circuit, passing only about 100pA. The two inputs can be treated entirely independently, with separate feedback networks; feedback on the inoperative amplifier has no effect except to represent a load on the output stage. A small compensating capacitor is needed.

Standard logic levels are required at the input-select pins and, since only 350mV is wanted, simpler high-speed driver circuitry can be used and the low level reduces noise coupling into other analogue circuits on the board. If V_{BB} is applied to one input, a single-ended selection signal will suffice.

Input offset is low enough for many applications, but is trimmable by a variable resistor, which affects both inputs. Independent trimming requires that trim current be summed, as shown in the circuit of **Fig. 3**, which is a "very fast" programmable-gain amplifier offering gain selected for 0dB or 24dB, using TTL channel-select signals. The

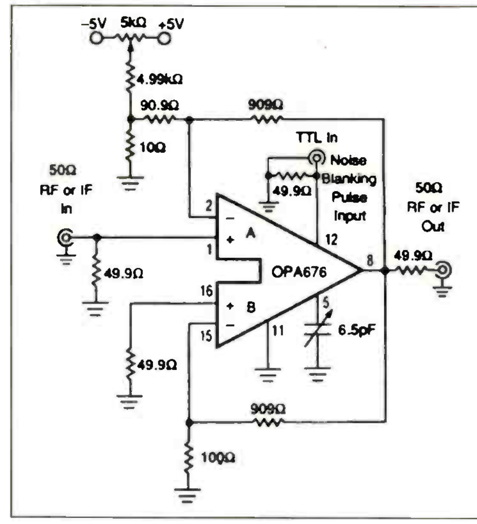


Fig. 4. Video receiver noise blanker, using TTL logic for channel selection.

circuit in **Fig. 4** is a receiver noise blanker — in effect, a wide-band gated video amplifier; the potentiometer is adjusted to prevent blanking pulse feedthrough.

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

Pure sine waves from digital source

Using three ICs — a TTL counter, an eight-channel multiplexer and a fourth-order low-pass filter — this arrangement generates sine waves from 1kHz to 25kHz with a THD of less than -80dB. The 74HC163 counter drives the DG508 multiplexer at eight times the Max270 filter cut-off frequency. Two potential dividers on the multiplexer inputs form an eight-step approximation to a sine wave at the output, over sampled by eight times to extend the first harmonic to seven times the fundamental to ease the smoothing requirement. First, choose the filter cut-off frequency by connecting its D_{0-6} inputs selectively to 0V or 5V, the seven logic levels providing 128 frequencies between 1kHz and 25kHz; with all at 0V, the cut-off is at 1kHz. An uncommitted amplifier in the filter IC allows the output level to be varied by the 100k potentiometer. The clock frequency must now be set at eight times the cut-off frequency. All harmonics in the output, caused by the step nature of the multiplexer output, disappear below the noise floor of a spectrum analyser, as shown in the screen dump of **Fig.2**.

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

Fig.1. Three ICs generate a sine wave with better than -80dB total harmonic distortion, the frequency being that of the filter cut-off.

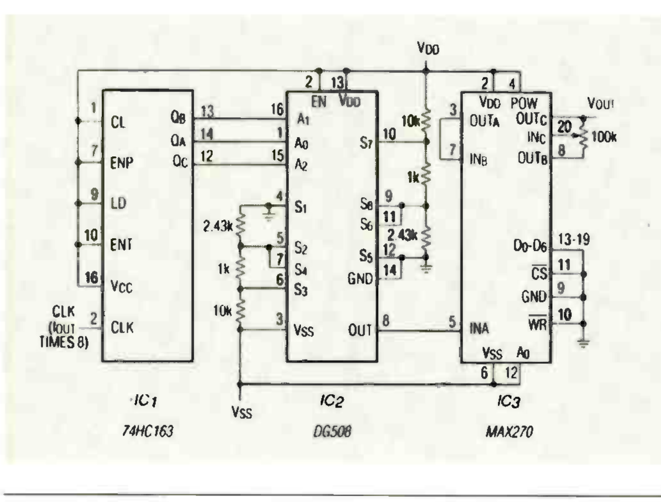
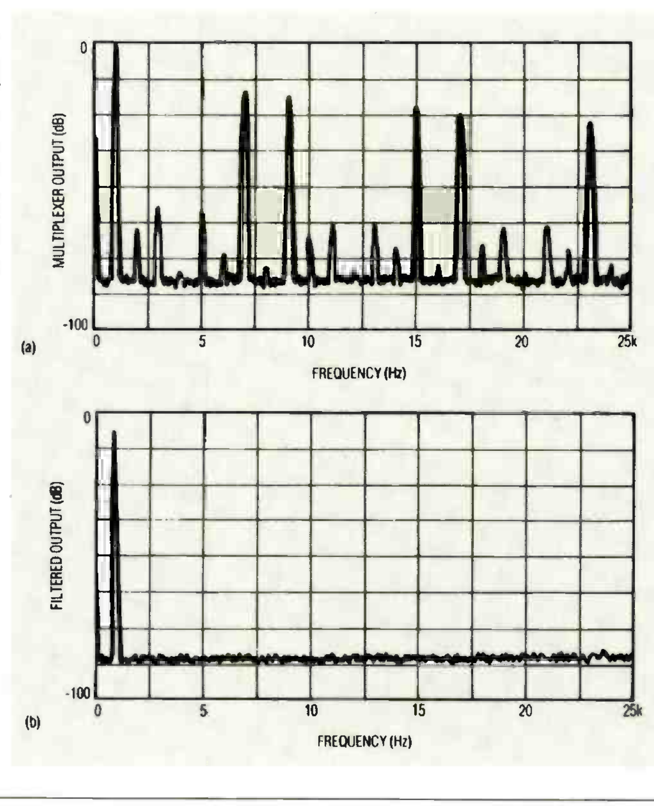


Fig.2. After the fourth-order filter, all harmonics caused by the digital method of generating the waveform disappear. Smaller harmonics are the result of slight inaccuracies in the two potential dividers.



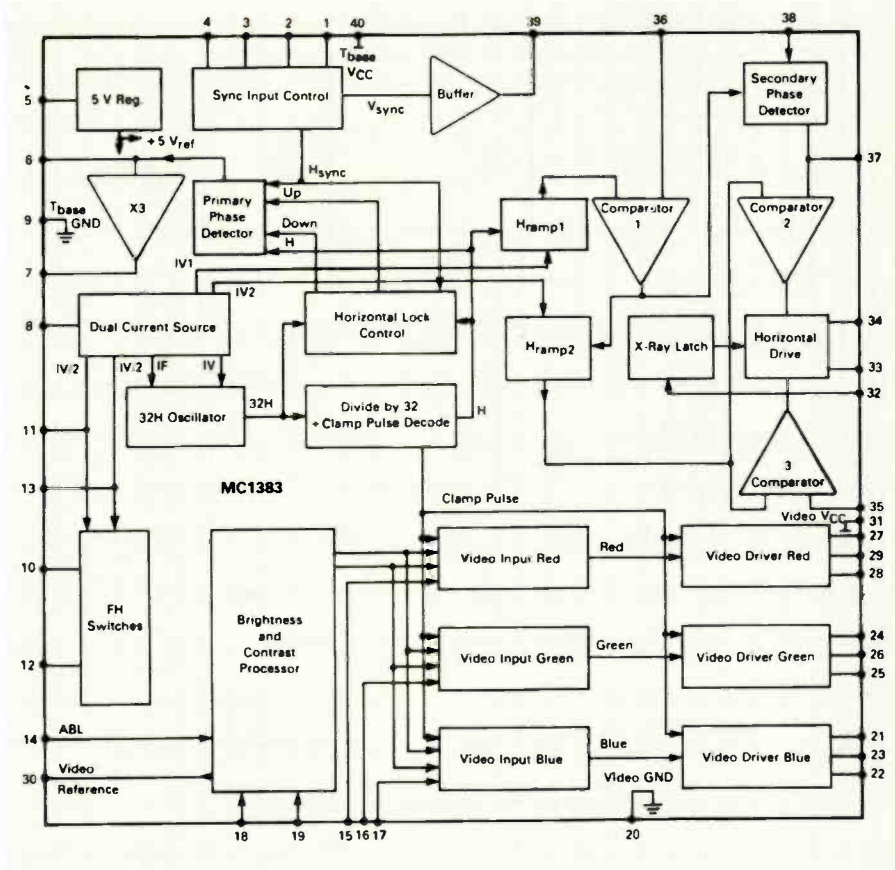


Fig. 1. Simplified block diagram of the MC1383 multimode sync controller which automatically accommodates varying sync forms and frequencies for computers and broadcast use.

Multimode monitor processor

All signal processing for an RGB monitor which responds to various scan frequencies and which is adaptable to multiple syncs is provided by Motorola's MC1383.

Automatic horizontal sync frequency tracking is compatible with most personal computer and broadcast standards between 15.5kHz and 40kHz and the vertical output sync pulse is automatically corrected for polarity. Additionally, the 50MHz video system includes contrast and brightness controls and an automatic beam limiter. The chip has its own 5V regulator.

In the block diagram of **Fig.1**, the sync input control monitors and automatically corrects sync polarity; if no horizontal or composite syncs are used, a sync separator derives them from the composite video input. An external capacitor on pin 1 is the integrating capacitor in the vertical polarity correction system and can be used to determine polarity and hence the mode of PC graphics standards.

A current-controlled oscillator runs at 32 times line frequency and is locked to the external sync by a phase-locked loop, in which the internally generated horizontal frequency obtained by dividing the oscillator by 32 is compared with horizontal sync signals, the loop's buffered output being a current for oscillator control.

Sampling the oscillator current control in external resistors at pins 11 and 13 and comparing the resulting voltage with 5V gives programmable, frequency-dependent horizontal output control, while the ramp and comparator blocks allow control of picture position and drive pulse position. Horizontal output stage turn-off delay is compensated by the secondary phase detector and comparator 2. **Figure 2** shows a typical application.

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

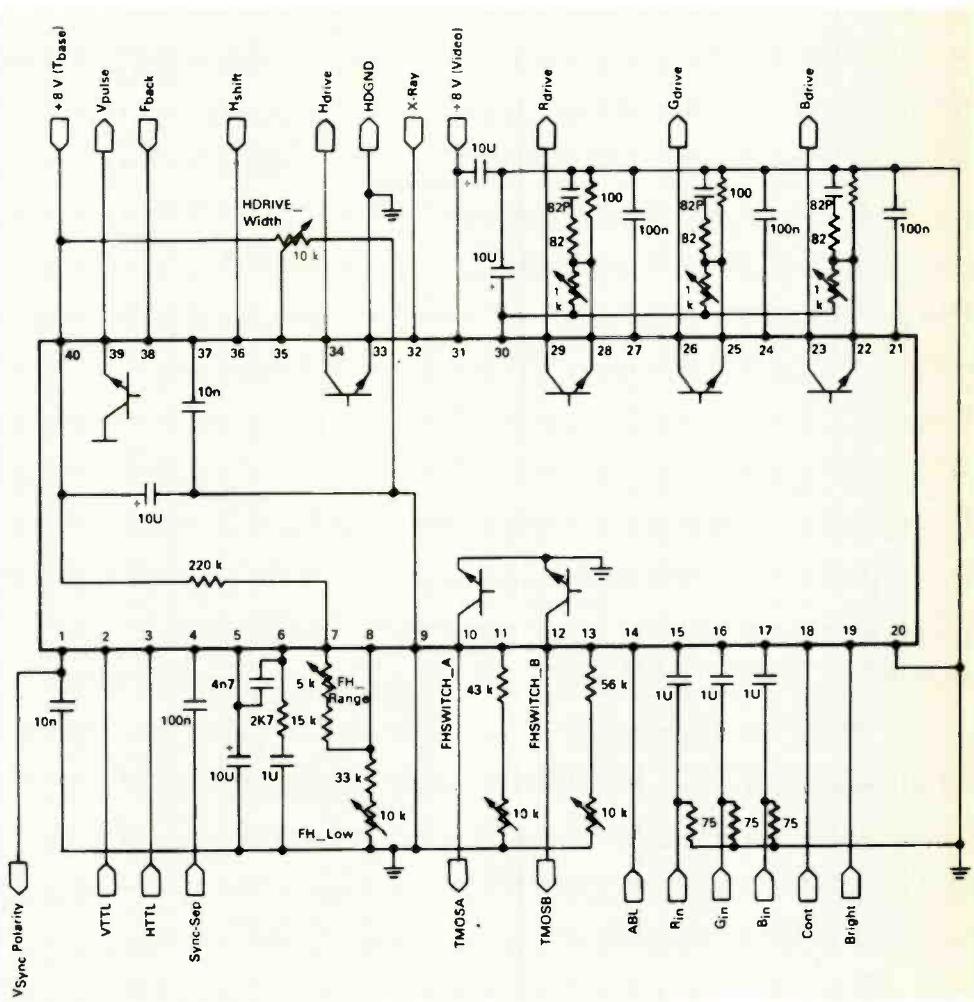


Fig. 2. Typical application of the MC1383.

REGULARS

NEW PRODUCTS CLASSIFIED

ACTIVE

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

12-bit adcs. The Max178 and 182 cmos 12-bit 60µs A-to-D converters have integral track and hold and precision voltage reference. The only difference is that the 178 has a single input and the 182 a 4-to-1 multiplexer. Gain, offset and linearity errors are calibrated to give a total unadjusted error of less than ±1LSB over the full operating temperature range. Offset nulling during each conversion cycle reduces zero errors to below ±0.1LSB. Internal reference has 0.3% absolute accuracy. Maxim Integrated Products, 0734 845255.

A-to-D converter. The TLC1225 adc has 12µs conversion speed with flexible analogue input configurations, output formats and supplies. It has 85mW maximum power requirements, 12-bit integral linearity and 12-bit plus sign resolution. It uses the successive approximation method for conversion and accommodates unipolar and bipolar operations. Data is generated as a parallel word and it interfaces directly to a 16-bit data bus. Texas Instruments, 0234 223252.

Discrete active devices

Power mosfet. Initially designed as a smart circuit breaker for the power distribution system of the space station Freedom, the IX10 size 10 mosfet is, at 303.7mm^2, some seven times larger in die area than the industry standard. Its $R_{ds(on)}$ values range as low as 0.016Ω at 200V allowing currents of 200A or greater in a single chip. IXYS, 0101 408 453 1900.

Mosfets predriver. A high-side predriver for n-channel power mosfets has a built-in voltage multiplier, overcurrent and over-temperature circuitry, latch-off circuitry and a fault status output. The Micrel MIC5010/1 has a voltage multiplier to boost the gate voltage which is generated on chip by a tripling charge pump. Mogul Electronics, 0732 741841.

Double rectifier diodes. Two ranges of double rectifier diodes can stand electrostatic discharges and voltage spikes without damage. The BYV32E and 42E have a reverse recovery time of less than 25ns. Reverse voltage ratings are 100, 150 and 200V. They can take spikes up to 30mJ. Forward voltage drop is less than 0.85V at maximum rated current. Philips Components, 071-580 6633.

RF power transistors. The BLT50, 56, 80 and 86 RF power transistors come in industry standard 6.7 x 7.3 x 1.7mm SOT223 surface-mount packages. They can dissipate 1W of power. The 50 and 56 are for use at 470MHz with ratings of 7.5 and 12.5V, respectively. The equivalent 80 and 86 figures are 900MHz, and 7.5 and 12.5V. Philips Components, 071-580 6633.

IGBT chips. Fast switching IGBT chips for use in TO220 and TO218 packages retain the drive characteristics of power mosfets but permit up to five times the current carrying capacity for the same chip size. For example, an 800V 3A power mosfet has a comparable chip size to a 1kV 3A IGBT device. Switching frequency is 30 to 40kHz. Siemens, 0932 752313.

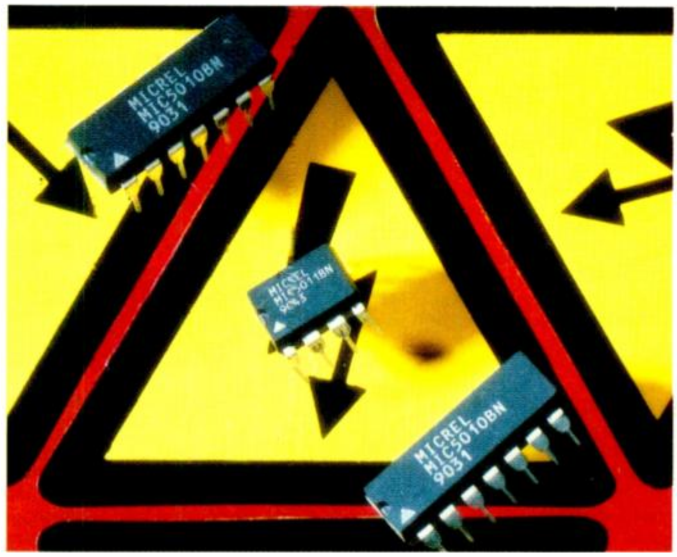
Digital signal processor

DSP boards. Frequency domain array processor (FDAP) boards use VLSI array signal processing technology and custom memory modules to achieve performances of 400 million operations per second. The memory modules support FDAP boards with up to 1.5Mb of 12ns static ram on a single 6U VME card. Complementary I/O adapter cards are also being developed. Array Microsystems, 0101 719 540 7925.

32-bit DSP. The TMS320C30-40 32-bit digital signal processor has a peak performance of 40 million floating point operations per second and operates from a 40MHz clock. Instruction cycle is 50ns. Features include 2Kword dual-access ram, 64-word program cache, DMA controller, two serial ports and two timers, and dual 32-bit data buses. Texas Instruments, 0234 223252.

Linear integrated circuits

Softener chip. The Dallas MSC micro softener chip protects microprocessors from losing data regardless of power conditions and softens the MPU to let software updates or other changes be made in the field without removing components. This peripheral chip uses a lithium supply back-up and contains additional I/O facilities for sensors, 32 extra port pins, provision for trouble reporting, voltage detector, watchdog timer to monitor software execution, and a built-in memory tester to validate the memory's contents. Dialogue, 0276 682001.



Micrel's pre-drivers from Mogul

Coaxial transceiver. The Signetics NE8392A is a coaxial line driver and receiver compatible with several standards of local area network. It is connected between the coaxial cable and data terminal equipment and consists of a receiver, transmitter, collision detector, heartbeat generator, and jabber timer in a single component. Jermyn Distribution, 0732 450144.

Switching regulators. The LT1073 family of fixed and adjustable output single-cell micropower switching regulators come in eight-pin SO or mini DIL packages. They have 95µA quiescent current and operate from 1 to 12V input supplies. They can operate as step-up boost or step-down buck regulators. Linear Technology, 0932 765688.

Voltage converter. The Max660 monolithic charge pump voltage inverter converts a positive input voltage in the 1.5 to 5.5V range to a negative voltage of the same nominal magnitude. It is pin compatible with the ICL7660 but with lower voltage losses and higher output current capability. It also has a frequency control pin to help select capacitor size and quiescent current. Maxim Integrated Products, 0734 845255.

Switching regulators. A family of fixed and adjustable output single-cell micropower switching regulators with 95µA quiescent current can operate from 1 to 12V input supplies. The LT1073-5 and 1073-12 have internal gain setting application resistors to deliver 5 or 12V, respectively, with 5% accuracy using a single external inductor, a diode and a capacitor. They can deliver 5V at 40mA from a 1.2V battery or 100mA from 2.4V. Micro Call, 0844 261939.

Feedback amplifier. Using thin film resistors and wafer level trims, the LTC LT1223 current feedback amplifier has a 3mV maximum offset voltage and 3µA maximum input bias current. It guarantees 50mA of output drive and operates on ±4.5 to ±18V supplies. The 100MHz bandwidth and 1000V/µs slew rate remain fairly constant over a wide range of closed loop gains. Micro Call, 0844 261939.

Power supply controller. The ML4818 IC is for soft switching control using phase modulation topology. This combines the lossless switching attributes of a resonant topology with the efficient power transfer and constant frequency operation associated with square wave PWM topologies. It has four 1.5A outputs and comes in a 24-pin moulded DIP power package. Micro Linear, 0101-408 453 5220.

Feedback amplifier. The EL2120 current feedback amplifier from Elantec is a wideband unit with differential gain of 0.01% and 0.03° differential phase margin. The output disable switch is rated at 45ns. It operates on supplies from ±5 to ±15V and has a bandwidth of 100MHz which is relatively independent of the gain setting. The bandwidth is flat to 25MHz, to an accuracy of 0.01dB, while the slew rate is 700V/µs. Microelectronics Technology, 0844 278781.

Satellite chips. Two full custom asics can replace up to 300 discrete components used in satellite receiver manufacture. The SP109900 includes a complete stereo audio processing system from the frequency synthesised tuning control through on-chip filtering, a highly linear FM demodulator, to a full Panda 1 noise reduction system. The SP109911 is a mixed signal chip consisting of a low impedance video amplifier with selectable de-emphasis and twin outputs that can drive a 75Ω load. Pace Micro Technology, 0274 532000.

Bus controller. The SN75C091A is an SCSI bus controller that meets the ANSI X3.131-1986 standard and has features including multiphase commands, a byte stacker amd multiple host data paths. It can perform initiator and target roles. The 20MHz unit allows operation in asynchronous or synchronous mode with a 5Mbyte/s transfer rate. Texas Instruments, 0234 223252.

Resonant mode ICs. The UC3861/64/65 family of ICs are for the control of zero current switched and zero voltage switched quasi-resonant convertors. The primary control blocks include an error amplifier which compensates the overall system loop and drives a voltage controlled oscillator. The one-shot generated pulses of a programmed maximum width can be modulated by the zero detection comparator. This circuitry facilitates true zero current or voltage switching over various line, load and temperature changes. It also accommodates the resonant components' initial tolerances. Unitrode, 081-318 1431.

Memory chips

Flash memory. The 28F001BX 1Mbit flash memory device is for updatable bios in PCs and updatable firmware in minimum chip embedded applications. It has an 8Kbyte boot block section with a hardware lock-out feature. Other memory segmentation includes two 4Kbyte parameter blocks and one 112Kbyte main block. Intel, 0793 696000.

Static rams. Four 64K x 4-bit fast synchronous static rams have a late write-abort feature that is controlled asynchronously. The MCM62980 and 62981 are non-pipelined synchronous data ram and parity ram, respectively. The 62982 and 62983 are pipelined versions of the same device. Memory cycle time of 12ns for the pipelined units lets cache memories operate with no wait states at up to 83MHz line transfer rates. These figures are 15ns and 66MHz, respectively, for the non-pipelined versions. Motorola, 0908 614614.

Leader LCD-300 multi-purpose instrument from Thurlby-Thander

Microprocessors and controllers

8-bit microcontrollers. The 8-bit microcontrollers in the F2MC range have uses in printers, keyboards, copiers, servo-control systems, medical equipment and video systems. The MB89710A series has an optimised instruction set that lets most available commands be carried out as single-byte OP code. Features include 8 to 32Kb rom, 512b to 1Kb ram, uart, PWM, 8-bit ADC and more than 50 I/Os. Fujitsu Microelectronics, 0628 76100.

Monolithic CPU/FPA/MMU. A combined 32-bit CPU, floating point accelerator and memory management unit, the R3400 runs at 25, 33 or 40MHz in a 175-pin package. It uses MIPS RISC architecture. A full complement of development systems and software is available including compilers, operating systems and applications software. Performance Semiconductor, 0101-408 734 8200.

Optical devices

Laser diode. A solid state laser diode acts a light source for electronics and telecommunications work and provides a 1mW output at 670nm multimode with an amplitude stability of ±3%. Beam divergence is typically 0.5mrad and the beam profile at exit has a diameter of 3mm circular while polarisation is linear at 1:60. The self-contained package measures 45 x 25mm with collimator and all optics. Spindler & Hoyer, 0908 262525.

Oscillators

Crystal clock oscillators. The SQ06100 and 6300 crystal clock oscillators are available in low profile ceramic surface mount packages. The 6100 is screened to MIL55310 for military use while the 6300 is for professional applications. Frequencies available are from 0.313 to 20MHz and stability is from ±50 to 1000ppm including variation with temperature, voltage load and time. STC Components, 0279 626626.

High frequency oscillators. The SQV5100 oscillators are for use in optical fibre telecommunications systems being developed for the European and US markets. They come in frequencies from 425 to 650MHz. Frequency is stabilised by a SAW delay line using specialised mounting and packaging to minimise drift with time and temperature. They come in a surface mounting metal case with pins in DIL format. STC Components, 0279 626626.

Programmable logic arrays

FPGA programming. Users of Actel's field programmable gate arrays can make use of HDL hardware description language and design synthesis using libraries supporting Synopsys' design compiler. Designers can work with either VHDL or Verilog HDL languages using high level constructs and descriptions, then synthesise the design with a choice of Actel library elements. Gothic Crellon, 0734 788878.

PASSIVE

Passive components

Glass fuselinks. A range of 20 x 5mm glass fuselinks from Belling Lee are colour coded for easy identification. For use on PC boards, they comply with IEC requirements and meet BS4265, CEE4 and Semko standards. They are for 250V AC operation at up to 70°C with no derating. Either quick acting (L3160) or anti-surge (L3170), they come in 22 ratings from 50mA to 6.3A. Townsend Coates, 0533 769191.

Power inductor kit. A power inductor development kit includes 16 Coiltronics toroidal power inductors from 20 to 500µH in several current ratings. Using ferrite and iron powder technology, these inductors exhibit low power dissipation and high Q characteristics. Microelectronics Technology, 0844 278781.

Crystals

Custom quartz units. Custom quartz units are available from 3 to 25MHz in the fundamental range and up to 100MHz in overtone. Adjustment tolerances are down to ±5ppm with temperature stability down to ±3ppm. Operating temperature ranges cover commercial and military requirements. Piezo Products, 0425 479337.

Displays

Display chassis. An oem colour display chassis provides 1280 x 1024 pixel resolution non-interlaced on a 15in FST tube. The HR15 has a power consumption of less than 100W in a module measuring 355 x 290 x 450mm. Dot pitch is 0.26mm, horizontal scan frequency range 30 to 70kHz, vertical range 40 to 80Hz, and video bandwidth more than 110MHz. ABA Electronics, 0264 335025.

Bright leds. Measuring 5mm in diameter, a range of Camden leds are available in red, green, yellow and amber. They are TTL compatible and all colours are intensity matched at 80mcd. Viewing angles vary from 35° for amber to 55° for red. Current rating is 20mA and voltage rating 2.1V. Verospeed, 0703 641111.

Filters

Noise suppressor. The 9081 mains voltage noise suppressor filter is for use with mains power supplies to cut out spikes from motors or contactors. It comes in a plastic moulded case with flying leads for mains I/O. Case size is 41 x 25 x 13mm. Input specification is 264V 2A maximum, 25 to 700Hz. Amplicon Liveline, 0273 570220.

SM filter array. A surface mounting filter array cuts the number of components needed for suppressing electromagnetic interference on digital I/O lines and digital circuit boards. The BLA81 has eight filtering circuits in a single block measuring 12.5 x 4.5 x1.2mm with individual filters on a land pitch of 1.27mm. It is available in bulk or taped and reeled. Murata Electronics, 0252 811666.

Instrumentation

Decade boxes. Three six-decade resistance boxes and one five-decade capacitance box use rotary switches which provide an instant readout of the set value. The resistance boxes range from 1Ω to 1.11111MΩ and 10Ω to 11.1111MΩ with accuracies of ±1% or ±0.1% each. All have power ratings of 0.6W. The capacitance box goes from 100pF to 4.111μF in 100pF steps with an accuracy of ±5%. Alpha Electronics, 0942 873434.

Field strength meter. A field strength metering device records electrical and magnetic fields simultaneously using one probe and covers the long, medium and short wave range from 75kHz to 30MHz. The measurement data can be transmitted up to 1km via a bidirectional optic fibre cable to an IBM PC for analysis. Recording equipment is in a 1kg field probe similar in shape and size to a Sputnik satellite. The signals from the sensors are processed vectorially. A constant voltage is supplied by a frequency compensator, HF amplifier and mean value detector to an a-to-d convertor. An asynchronous transceiver converts the digital data into serial signals. Asea Brown Boveri AG, +56 76 8307.

Wattmeter. The EW604 wattmeter offers power measurements between 250mW and 10kW with a frequency range from DC to 20kHz. It has 5 to 1000V capacity and a 50mA to 10A current range with 5kΩ/V and <60mΩ burdens, respectively. There are independent overload indicators for voltage and current ranges which come on when the value exceeds the selected parameter by 50%. It is housed in an ABS casing lined with graphite for electrical screening, measures 330 x 118 x 238mm, and weighs 1.9kg. Feedback Instruments, 0892 653322.

V and I source. The Yokogawa 7651 programmable DC voltage and current source can be used as a general-purpose test instrument or for transducer excitation. Accuracy is to within ±0.01% on voltage and ±0.02% on current. Resolution is 100nV on the 10mV range and response time is less than 10ms. It can generate voltages up to 30V and currents to 100mA. Marton Instruments, 0494 459200.

Spectrum analyser. The Tektronix 2712 spectrum analyser is available with EMC test software providing testing from 1kHz to 1.8GHz. Data can be acquired, displayed and printed for tests in FCC/VDE radiated, VDE magnetic, VDE conducted, FCC conducted, and radiated power. The software lets the user configure the tests with correction factors based on antenna factors, cable loss, site attenuation and preamplifier factors. Microlease, 081-427 8822.

GSM analyser. The CTMA94 GSM radio communication analyser meets the TDMA measuring requirements for frequency hopping and digital modulation. There are two software packages: K96 for generating specific test sequences which can be called up from other programs; and the K97 for generating random bit sequences and inserting them into the RF signal of a GSM traffic channel. By evaluating the demodulated bit stream it is possible to determine the bit error rate of a receiver. Rhode & Schwarz, 0252 811377.

Combination. The Leader LCD300 is a portable battery or mains instrument that combines the functions of a digital storage oscilloscope, digital multimeter and logic scope in a 240 x 44 x 165mm package that weighs 1.2kg. The digital storage section has two channels with 30Msample/s and 10MHz bandwidth. All parameters are displayed on an LCD with 128-point (7-bit) vertical resolution and 180 or 1800 word resolution on the horizontal axis, including set-up and measured values. Thurlby-Thandar, 0480 412451.

Digital oscilloscope. The Hitachi VC6145 digital storage oscilloscope is a four-channel unit with a speed of 100Msample/s. Sampling can be carried out simultaneously at 25Msample/s on all four channels. Four 1000 word save memories with battery back up let data be captured in the filed and brought back for analysis. Stored data can be transmitted to an HPGL compatible plotter via an RS232C interface. A built-in frequency counter covers the range 20Hz to 100MHz. Thurlby-Thandar, 0480 412451.

Literature

ISDN guide. An illustrated free guide to ISDN published with help from the National Computing Centre has 100 A6 pages covering an introduction to telecommunications, an explanation of ISDN, a look at its features and benefits. and a digest of applications and products. DCE Video Communications, 0296 432971.

Production equipment

Bonding tape. K273 tape is a thermally conductive bonding system for mounting electronic components without mechanical fasteners. It consists of a thermally conductive type MT Kapton film with a thermally conductive thermosetting acrylic adhesive on each side that provides instantaneous attachment. It comes self wound in roll form with release paper. It is also available in die cut parts. Intertronics, 0865 842842.

Photonic alignment. The NanoTrak automatic alignment system for single mode fibres and integrated optics is for aiding applications like fibre launching and endfire coupling as well as more complex procedures such as attaching fibres to waveguide devices and aligning fibre arrays to multichannel devices. It also helps researchers involved in fibre sensing applications and experiments conducted over several hours. Photon Control, 0223 420071.

Hitachi VC6145 digital storage oscilloscope from Thurlby-Thander

Coiltronics power inductor kits from Microelectronics Technology.

Power supplies

1kVA UPS. The MP8 Micropower on-line UPS measures 190 x 451 x 263mm and will provide at least 8min of 240V, 50Hz power at full load. It is designed for lans, epos, multiple PCs, workstations, Unix/Zenix, cad/cam, wordprocessors, fax machines and telephone consoles. Noise level is less than 45dB. Avel-Lindberg, 0708 853444.

Programmers

Eprom programmer. The Model 200A eprom programmer can be connected to the parallel port of a PC to increase programming speed. For example, a 1Mbit eprom can be blank checked, programmed and verified in slightly more than 10s. It supports more than 750 devices including eproms up to 4Mbit, eeproms and all popular microcontrollers. MQP Electronics, 0666 825146.

Switches and relays

Protection device. The MultiFuse MF-BP is a solid-state temperature coefficient fuse for protecting against short circuits in rechargeable NiCd batteries and lithium cells. It is resetable when the overcurrent condition is removed. Its cold resistance is less than 100mΩ. Bourns Electronics, 0276 692392.

Photoelectric switches. A range of Electromatic photoelectric switches can detect shiny, transparent or other highly reflective surfaces like bottles and metal cans. There are seven reflectors with a range up to 3m and they use polarised optical light rather than infra-red. The light source is AlGaAs led 660nm which casts a 65mm diameter light spot at 2m. Carlo Gavazzi, 0252 29324.

Pressure switch. The MPL900 miniature plastic-body pressure switch responds to pressure, vacuum or differential applications and handles air or gas. Pressures can be set by the user or preset at the factory from 0.1 to 150mbar (15kPa). Contact arrangement is SPDT. The operation on rising or falling pressure is in the mode of a single-pole change-over contact that can handle 5A resistive or 2.5A inductive load on 220/240V AC in industrial and domestic applications. EuroSensor, 071 405 6060.

Transducers and sensors

Pressure transducer. The AB-HP is a general purpose pressure transducer capable of more than 160 million operating cycles to full rated pressure. It conforms to MIL810B for shock and vibration resistance. Applications include liquid level measurement, process control and engine motor control. Accuracy is down to 0.25% and the sensors are available in 0-6 to 10,000psig. Control Transducers, 0234 217704.

Precision thermometer. The P60 precision thermometer is housed in a durable water and dust resistant case with IP65 protection. Sensitivity is to 0.1°C from -39.9 to +139.9°C. Accuracy is ±0.3°C. The digital display head is moulded in ABS plastic and is fitted with an acrylic window over the 12.5mm LCD. It has an automatic 30s cut out. ETI, 0903 202151.

Miniature transducers. The D5 series of miniature transducers can measure linear displacement from ±0.63 to ±5mm and can discriminate down to 1/100th of the range. They operate on the linear variable differential transformer principle with a magnetic core in the windings. They weigh 14g and have a standard linearity of 0.5%, with 0.1% available as an option. RDP Electronics, 0902 457512.

Pressure sensor. Sensym has increased the sensitivity of its current piezoresistive semiconductor sensors by developing different techniques for micromachining the silicon diaphragm. The first two products manufactured using this process have temperature-compensated calibrated full-scale outputs at 10mbar (1kPa). The SCXL004DN provides a 40mV output with 1kPa applied pressure from a 12V supply. The 100LP10D is an amplified version providing a 1 to 6V output for 0 to 1kPa applied pressure. Sensortechnics UK, 0788 560426.

COMPUTER

Computer board level products

Graphics subsystem. Stride is a family of PC graphics cards for real-time 3D animation, pre-press DTP, simulation and computer-aided design. It provides 24-bit colour at resolutions up to 1536 x 1280 interlaced. Using dedicated hardware for rendering images with Gouraud shading and antialiasing, it can process 35,000 true colour shaded polygons a second. The package is based on the 32-bit TMS34020 graphics processor. Akebia, 081-546 4908.

Data acquisition boards. Low power versions of the PC14T, PC27 and PC36AT data acquisition boards for use in laptop PCs have been introduced and are available from Amplicon Liveline They are, respectively, analogue data acquisition, digital I/O with counter timer, and 24-line programmable I/O boards. All are supplied with demonstration software written in Turbo Pascal and Basic. Source code is included. Amplicon Liveline, 0273 570220.

386-40 board. A 386 30MHz board runs at 9.5mips and is claimed to be faster than a 486-33 board with most software. Bus speed is selectable from 6, 8 or 12MHz and it has 7 x 16-bit and 1 x 8-bit expansion slots. There is up to 32Mb of on-board ram. It has on-board diagnostics. Digitask, 0293 776688.

Risc subsystem. The 7RS107 risc subsystem module provides designers with a ready built fully tested R3000/3010 CPU module. It is built round the IDT9R3000 microprocessor and IDT79R301 floating point accelerator and is available in operating speeds from 12 to 33MHz. Measuring 127 x 127mm and using 96-pin connectors, the module includes 64Kbyte of instruction and data cache as well as one-word-deep read and four-word-deep write buffers. Integrated Device Technology, 0372 377375.

Text-to-speech card. An expansion card for IBM PCs lets users hear each word or command as it is typed. The package comes with software, manual and loudspeaker and it can be used with text based software package like Wordperfect or Wordstar. Pitch can be varied by adjusting a trimmer on the board. Target applications include audible text verification, study and training aids, narration of displays, and as an aid for people with visual and speech disabilities. Logicom Communications, 081-756 1284.

Risc subsystem module from IDT implements R3000 architecture.

Development and evaluation

Software simulator. The S400SIMPC software simulator allows development, testing and debugging of H400code in an IBM PC environment. Windowing techniques let the code be tested by observing the output response to inputs without stopping the simulator for monitoring or changing the I/O states. Dialogue, 0276 682001.

Software simulator. The design of systems based on the uCOM75x single chip microcomputer can be simplified using a software simulator with a standard PC compatible computer. The simulator needs no external hardware and provides facilities such as program code, I/O port, register, and on-chip peripheral status interface windows. User definable function keys and drop-down menus are provided to simplify keyboard input. NEC Electronics, 0908 691133.

Mass storage devices

Memory cards. The Intel 4Mbyte Flash memory card is based on an array of nonvolatile chmos memory devices in TSOP with an on-card asic that buffers address and data lines and provides system control logic and timing. Read access time is 250ns and a 5V supply is needed in read mode. For erasure and writing a 12V supply is required. It is for portable computers and industrial equipment requiring removable storage. Jermyn Distribution, 0732 450144.

Computer peripherals

Removable Winchesters. Sintrom has introduced the Stowaway range of removable Winchester disc drives that can be built in to Compaq, IBM PCs and compatibles. They are available in 40, 100, 120 and 212Mbyte versions. Access times are down to 16m/s and data transfer rates 4.75Mb/s. Sintrom Electronics, 0734 311088.

Msdos/OS9 link. PCi is a hardware and software transparent link that lets msdos based PCs connect to multitasking real-time computers running under OS9. The hardware comprises Topaz token passing industrial local area network controllers. These plug-in modules provide 1Mbit/s high integrity multidrop highways over long distance with real time response. The software link is a file manager that lets OS9 tasks read and write data. Syntel Microsystems, 0484 535101.

Software

Technical calculations. MathSoft has introduced an improved version of its Mathcad package that adds support for Microsoft Windows, electronic handbooks for access to standard formulae and constants, and symbolic calculations for computer algebra. Mathcad 3.0 performs calculations used by engineers and scientists. Adept Scientific, 0462 480055.

CAE package. Betronex has introduced version 2.4 of its EE Designer package for schematic capture, circuit simulation and PCB layout. Users with existing designs on other systems with Gerber outputs can import and modify them on this package. The back-annotation facility lets schematic diagrams and circuit simulation be produced from the imported layout designs. Betronex, 0920 469131.

DSP code writers. Two programs have been introduced: ProCoder is for the automatic generation of production quality machine code for fixed point DSP devices; and MultiProx is for the automatic generation from a system diagram of C programs to run on multiple processors. Both are options for Comdisco's signal processing WorkSystem. Available for use on workstations such as Sun, Hewlett-Packard, Apollo and Digital. Comdisco Systems, 0454 614256.

HEPA program. A program in the HEPA (high efficiency RF power amplifier) series optimises RF power amplifier design across a user-specified frequency band. The program modules predict transistor capability, that is amplifier efficiency against output power and frequency, and design a circuit for a specified RF output power and frequency band. It can also stimulate the circuit to yield voltage and current waveforms and frequency spectrums, DC input power, RF output power, efficiency, and power dissipation in each circuit component. Design Automation, 0101-617862 8998.

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Design study: power inversion

DC to DC inverters can provide the multiple supply rails often required in complex equipment. They can also allow a secondary SMPS to function outside its normal input voltage limits. Brian Frost outlines the practical design process involved in high frequency power inversion.

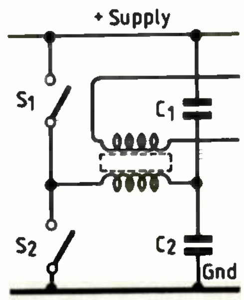


Fig. 1 Popular solutions: the bridge configuration and...

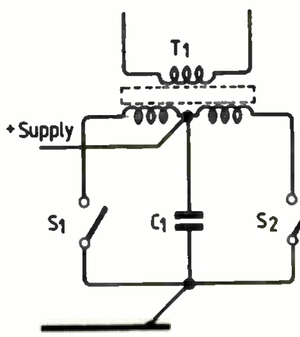
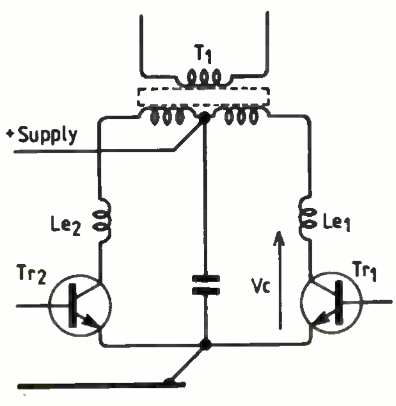


Fig 2. ...push-pull configuration.



Fig, 3. Push-pull showing leakage inductances.

This study started out as a need to power 50Hz mains equipment from a car battery. The intended apparatus incorporated its own switch mode converter which derived its input from the directly rectified/smoothed mains. The application, an SMPS based NiCd charger, required a miniature step-up converter to supply the missing high voltage DC input.

For turning low-voltage DC power into medium voltage (say 100W at up 100 to 500V) there are really only two configurations in popular use, the bridge configuration (**Fig. 1**) and the push-pull configuration (**Fig. 2**). In each case, switches S_1 and S_2 are driven alternately with an on time that never exceeds 50% of the switching frequency to be used. This switching frequency can be up to several megahertz, depending on the type of transformer used, and the capabilities of the switches.

Most inverter designs switch at over 20kHz, greatly reducing the size of the transformer and allowing the use of low-cost ferrite pot-core or E-core designs with much less wire. Indeed, there are now many commercial designs operating above 1MHz.

However, leakage inductance and the attendant switching spikes can become a limiting factor.

In addition to symmetrical configurations, there are a number of single-switch designs operating at power levels below 100W. This topology tends to use complex ways of putting transformer energy, stored during the switch 'on' time, back into the supply reservoir capacitor when the switch is off.

Common to all inverter designs is the problem of protecting the power switches: and I am sure that many designers know only too well the frustration of the circuit operating for a while, only to have the fuse blow and to have lost one (or probably both) switching devices

This is particularly frustrating because it is often impossible to be sure just what caused the event. Inverters required to supply a wide range of loads are particularly susceptible to this due to the very uncontrolled nature of their working, although there are some common rules and points to check that can usually prevent these problems.

Figure 3 shows the push-pull configuration of Fig. 2 but using two transistors for the switching devices, and adds some parasitic components which cause real problems. When Tr_1 is on, the voltage across it is simply its saturation voltage, and in slow-switching (eg 50Hz) designs, it is this voltage, multiplied by the inverter current that makes the device get hot. When Tr_2 turns off, the supply current cannot be interrupted instantly (even though the other transistor may have turned on at exactly that time) because the transformer is not a perfect component.

Depending on the its construction, there will always be a leakage inductance present - shown by the component Le_1. This occurs because there will always be a small lack of coupling between the transformer primary and secondary: this appears as an inductor in series with the transformer lead. The stray inductance stores up energy when Tr_1 is on. Turn Tr_1 off and the result is the voltage spike shown in **Fig. 4.** This spike can be

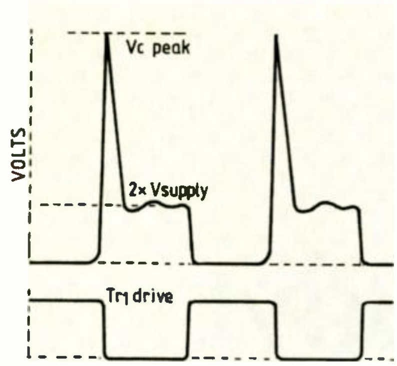


Fig. 4. High voltage spike resulting from switching off Tr_1

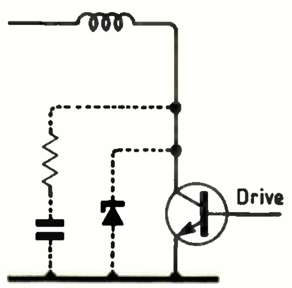


Fig. 5. Techniques are utilised to attenuate the voltage spike

high. Typical voltages in a 12V inverter can easily top 100V even though the width of the spike may be less than a microsecond.

This spike must be accounted for in any inverter design. Clamping or snubbing circuits attenuate the spike. **Figure 5** shows two of the usual techniques, clamping the voltage with a zener diode, or dissipating it in a resistor-capacitor network. The presence of an overvoltage spike can manifest itself in a number of ways. Bipolar transistors, traditional favourites for high-current inverter switches, can be taken outside their safe operating area (SOA) where they are still passing current, but at a high voltage. The result is a destructive breakdown between the collector and emitter.

Secondary breakdown is more insidious than the primary breakdown which is simply

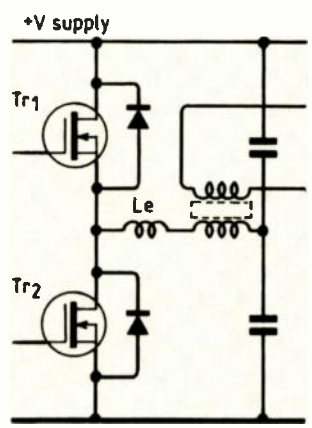


Fig. 6. Body diodes aid clamping. Mosfet body diodes are normally reversed.

exceeding the maximum voltage allowed between collector and emitter. Although high-power Darlington transistors are particularly rugged in respect of secondary breakdown, the designer cannot be completely sure of remaining within this SOA unless the voltage across the transistor and the current flowing through it are monitored simultaneously and then compared with the data sheet graph.

The same spike problem occurs when Tr_1 of Fig. 3 is replaced by a mosfet and, due to the faster switch-off speed, the amplitude of the spike can be much greater. The same zener, or R-C network solutions can be applied to tame the circuit.

Mosfets incorporate a parasitic diode as part of their structure which may be used to clamp spikes in the half-bridge configuration. Figure 6 shows the half-bridge circuit implemented by two mosfets Tr_1 and Tr_2. Mosfet body diodes are normally reverse-biased. When devices switch over, the current flowing through T_1 primary causes a voltage spike to be generated by the energy stored in the leakage inductance '*Le*'. This would usually result in a positive-going spike (after Tr_2 turns off), but its amplitude is clamped by the body diode of Tr_1 to the supply rail. The spike energy is returned to the supply. The inherent advantage of the bridge configuration is balanced by the difficulty of driving the upper device remote from ground.

The major attraction of power mosfets for switching is the lack of secondary breakdown: manufacturers quote a maximum current, a maximum voltage, and a maximum power dissipation. They can still suffer from thermal runaway, however. On-resistance – and losses – increase with temperature which can lead to a destructive situation.

Driving the inverter

Because of the popularity of switch-mode power supplies, there are any number of control ICs that can be used to provide drive to the output devices. They tend to be design overkill in a simple square wave inverter. **Figure 7** shows a half-bridge circuit with transformer-coupled gate drive. These small transformers are readily available as thyristor pulse-transformers and, due to the AC coupling of the primary, this bridge circuit can be driven quite adequately for example by a 555 timer IC connected as a square wave generator. This provides a simple drive function at low cost.

The 1525/2525/3535 series with purpose designed functions is shown in **Fig. 8**. It provides pulse-width modulation control where a feedback voltage is compared with a demand voltage and used to produce an increase or decrease in the on time of each of two power outputs, A and B. At maximum, the outputs are each on for just under 50% of the oscillator cycle. This IC includes built-in reference, logic shutdown and linear functions. A purpose-designed output stage drives mosfets directly.

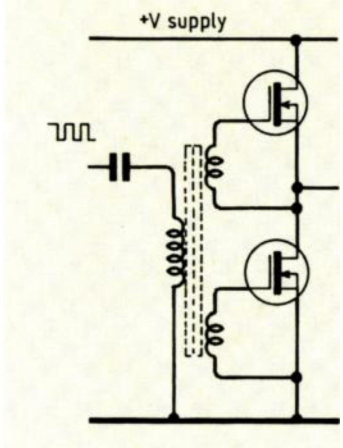


Fig. 7. Transformer-coupled gate drive helps provide a low cost solution.

Current-limiting design

This requires careful attention to all operating conditions. If the current limit is too slow, the power devices will fail due to surge conditions. Too fast and switching transient noise will trigger the current limit mechanism too readily.

Two current limit functions may be required: a primary mechanism to prevent death of the switching devices and a secondary circuit to permit stable constant output current operation. Device protection current limit must be able to remove drive to the switching devices on a cycle-by-cycle basis; if the output of the supply is shorted, the rapid rise in device current following turn-on of one device is terminated as soon as an allowed threshold has been reached. At this point, both devices are turned off and the power cycle aborted. This threshold is chosen to suit the device maximum current rating.

If this is the only current-limit mechanism, it will appear as a 'fold-back' type of characteristic where operation of the supply just beyond this point causes the output to disappear requiring that the load reduce significantly before the output re-establishes itself. The inverter design shown here uses this principle. Conventional linear current limiting can then be added by a secondary mechanism which uses an error amplifier in a conventional feedback technique.

Transformer design

There are well-documented ways of designing transformers but these tend to be quite daunting, and often require data that is not readily to hand. I have evolved a few simple rules that appear well suited to SMPS design.

First, use the power and frequency to decide on the size of the core. The more power required, the higher in switching frequency for a given core size. The alternative is a larger core. For example, the RM10 core used in this design will transform about 80W at 25KHz, although it continues to operate at 100W. For a given frequency, the

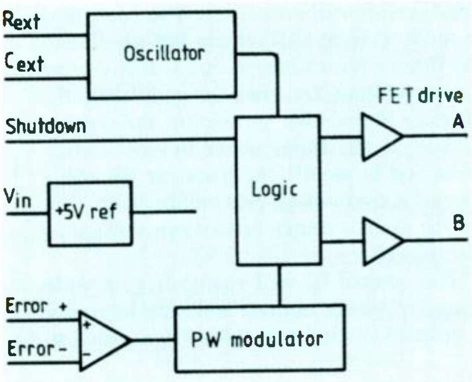


Fig. 8. 3525 regulator IC provides pulse-width modulation control.

power can be doubled by doubling the core area (as measured at the centre leg of the core). As a rough guide to power handling capacity with common grades of ungapped power cores, calculate the area of the centre leg of the core in square millimetres to provide the power handling capacity in watts at 25kHz.

For example, the RM10 cores have a core centre diameter of 10mm. This is an area of just under 80 sq mm, i.e. 80W. Next, calculate the windings. This only needs very simple calculation. Although more exact values can be obtained from the core data sheets, a good starting point at 30kHz is about 2V/turn for 3C8 material (a common power core material). The voltage per turn relates directly to frequency. Thus, for a 12V inverter operating in push-pull configuration, 6+6 turns on the primary would suffice.

The DC inverter design

The complete circuit for the practical inverter design is shown in **Fig. 9**. This a complete 12 to 240V DC inverter, capable of lighting a 60W tungsten mains lamp. It is based on the push-pull configuration which allows it to use mosfet devices without heat sinks up to 40W loads.

The two switching devices are a pair of BUZ11 power mosfets, driven with a gate drive voltage equal to the supply input, normally more than 10V. These achieve an on-resistance of less than 0.1Ω.

The switching IC, an 3525, provides just under 50% duty cycle alternating drive to the two mosfets; a slight underlap ensures that both devices do not conduct together. Its start-up circuit ensures that the supply voltage is enough to operate the logic, and then applies an increasing duty-cycle until the inverter is operating at full duty-cycle. This avoids erratic start-up and high surges. It also provides current-limit protection.

The transformer is an RM10 pot-core, roughly equivalent to a 25mm cube. Some cores are intended for making inductors and include an inside gap for controlled inductance at larger currents. These are not suitable for power transformer operation. Ungapped 'F' core types are also fine.The voltage spikes generated at turn-off are clamped by the 33V zeners D_5 and D_6. The transistor drains of the mosfets reach twice the supply voltage in normal service. However just one overvoltage glitch will destroy a device. Destruction occurs through breakdown between drain and source, or punch-through to the thin gate oxide. The two zeners D_7 and D_8 protect the output device gates against transients.

This design does not use the voltage error amplifier in the control IC. Normally, this would compare a demand control voltage with a proportion of the output voltage establishing a feedback control loop. In intended application where the output feeds a switching circuit, inverter regulation wasn't required. Output voltage is therefore simply proportional to input voltage and is designed to be roughly 240V DC out for 12V input.

The layout for this type of circuit is important. The switching frequency is about 30kHz, but the switching times are important. These occur in less than 0.5μs and the layout should take this into account. Groundplanes are recommended with particular attention paid to the paths carrying the circulating switching current. These should be of the widest area for minimum inductance/resistance and, where applicable, should be returned to a common grounding point. The control circuitry in this design example is very simple but good design dictates that grounding takes place outside the main current paths.

R_6 must be non-inductive to avoid voltage spikes and erratic current limiting.

The transformer is quite tolerant of the winding wire. It must sustain 5A in the primary circuit without heating. The secondary carries a small enough current to be wound from thin wire and physical limitations of the bobbin space will be important. The primary requires two 6t wound bifilar. This benefits in that as one power device turns on, it helps to reduce the voltage spike generated by the other device turning off. The

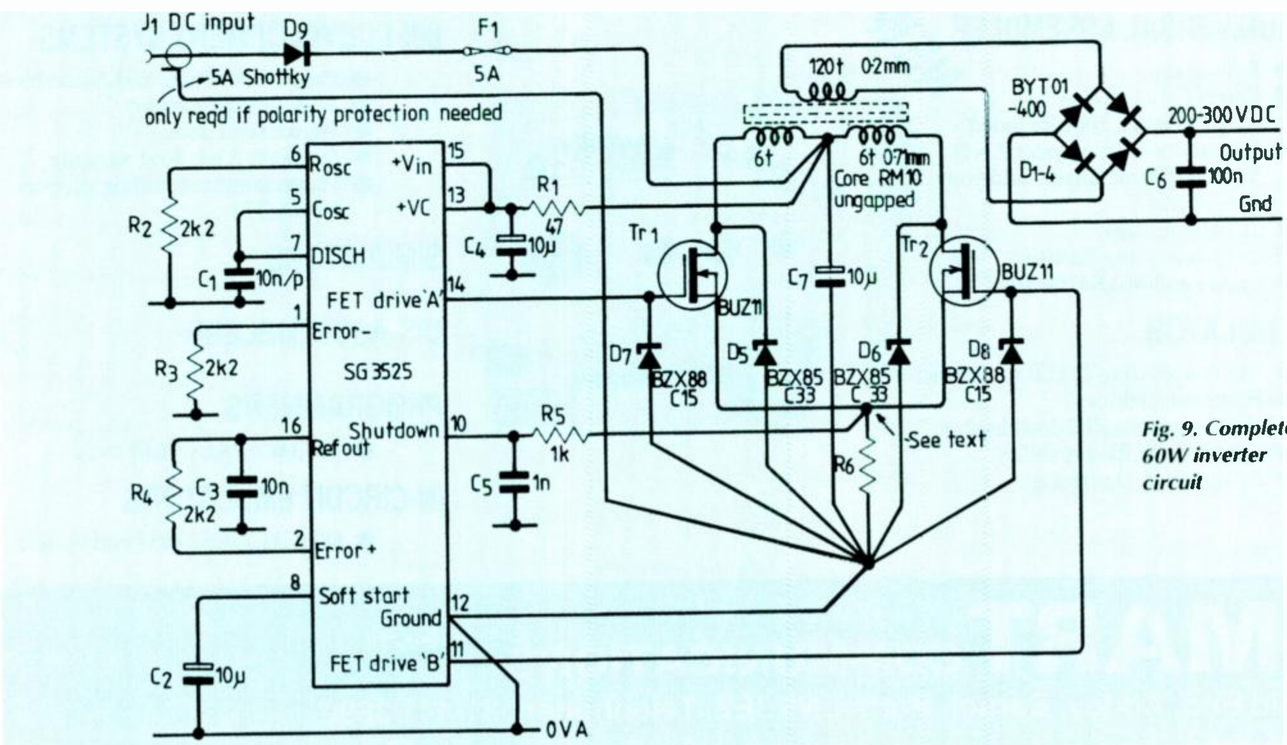


Fig. 9. Complete 60W inverter circuit

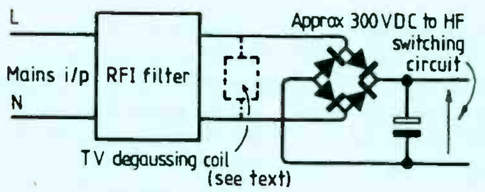


Fig. 10. High voltage DC to DC converters can be used to power consumer electronics equipment such as television sets fitted with direct rectification SMPS. However the degaussing circuit must be disconnected before use.

secondary is quite uncritical and can be pile-wound as 120 turns over the primary.

The unit can be tested by connecting it to a 40W 240V tungsten lamp. It will actually drive a 60W lamp, but only if it is operated from a variable power supply which is used to gradually increase the input voltage and so reduce the effect of the current surge that occurs due to a cold lamp. This surge is great enough with a 60W lamp to cause the inverter to shut down.

The efficiency is good. In fact it is so good that it is almost impossible to measure the power lost by comparing output power with input power. An easier method is to assess the power dissipated in the inverter using a temperature-sensitive finger (being careful not to touch the output). Touch the tabs of the fets: these should be comfortable to touch. With no heatsink, this is a dissipation of about 0.5W. The zener diodes D_5 and D_6 should also be no more than warm (about 0.3W). Finally, the transformer will be dissipating about 1W. Total power lost in the inverter is therefore about 2.5W excluding the few mA required for the control IC (efficiency over 95%).

Modifying the design

This basic design may be readily upgraded (or downgraded). To increase the power output, choose a larger ferrite core using the methods described earlier. The increased primary current will require the mosfets to be fitted with a heatsink and if this current exceeds about 8A, consider paralleling the devices. Remember to monitor the voltage spikes on the drains as the devices switch over and to modify the transient absorbing circuit if overvoltage gets within about 75% of the drain - source breakdown voltage of the mosfets.

The control IC will easily drive a wide range of power outputs and may be easily connected to implement full voltage control.■

References

1. *Unitrode Linear Integrated Circuits data book* (for 3525 applications).
2. *SGS power supply application manual* (for SG3525 IC).
3. Siliconix Mospower data book (for BUZ11).

A kit of parts for this design study may be obtained from *Dorset Design and Developments Ltd, 8 Robins Wood Drive, Ferndown, Dorset, BH22 9RZ Phone 0202-875743.*

Why HDTV means a poor picture for consumers

Leap in quality for the viewer or manufacturers' conspiracy to boost flagging markets? Charles W Smith takes a critical look at the hopes and the hype surrounding HDTV.

High definition television is coming, we are told. A flood of articles in the technical press speculate on prospects and limitations, and the need for improvements in large-area flicker and interlace twitter and movement resolution, as well as in definition. The Japanese are in the lead, and European research departments are beavering away desperately to avoid being left behind.

Bandwidth requirements are beyond terrestrial broadcasting and will necessitate distribution by satellite with the added complexities of dish-aerials and decoders. It is impossible to forecast a date when HDTV might reach the British public and sometimes a practical, commercial system seems no closer than it was ten years ago.

Progress in television comes at a snail's pace. Almost 25 years have passed since we achieved pal colour television, a great German achievement (but ten years behind the Americans). What improvements have we seen in picture quality in that time? Chiefly, we can now see a picture with square corners instead of rounded ones.

So, who wants HDTV?

In a general sense, everyone does. We all know that, other things being equal, a big picture is better than a small one; bright is better than dull and sharp is better than fuzzy. We expect the steady advance of technology to bring a progressive improvement each time we buy a new receiver.

But ask again, who wants a jump in definition for a very substantial increase in cost? The only answer here is set manufacturers, who badly need a new product to stimulate their sales.

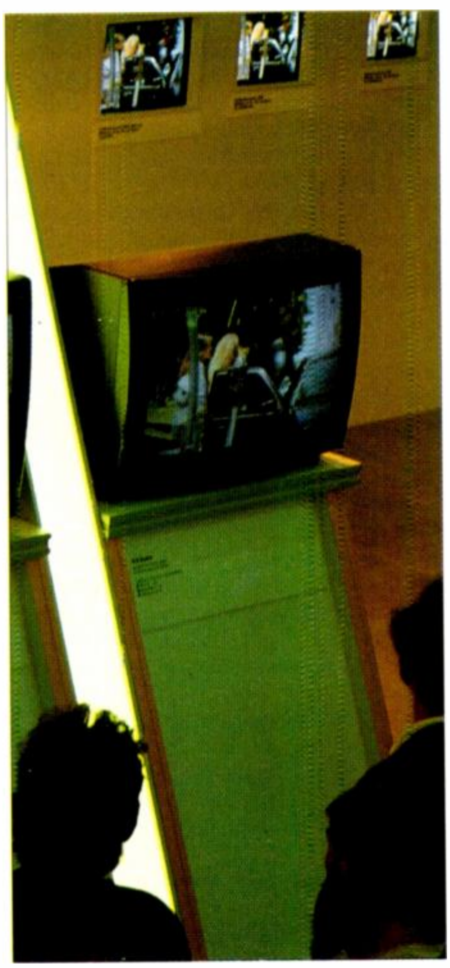
Everyone who's going to buy a 625-line colour receiver has done so, leaving manufacturers with just the dribbling replacement market.

The public has no enthusiasm for higher resolution – and that is not just my opinion.

Last year the BSB satellite service was transmitted in the D-mac system, newly developed by the IBA to give improved resolution and freedom from pal's cross-colour interference.

When the service collapsed, leaving the market to the old technology of Sky, there was no sign that subscribers had even noticed the better picture quality.

The *New Scientist* wrote in an editorial: "Sky recognised that the great British public does not give a fig for marginal improvements in picture and sound quality, for creating jobs for Europeans, or for preparing the path for a future upgrade to high-definition television". People watch programmes, not definition. Fine detail does not make a comedy funnier, or a drama more dramatic.



Unfortunately, the prospect of improved technical quality comes along just at the time that all our broadcasters, commercial as well as public-service, are suffering financial problems, firing their production staff, and promising a diet based on low-cost imported programmes of minimal quality.

Worse programmes could be the result but with higher resolution at a much higher price.

How many lines?

It was in 1964 that we stepped up from 405 lines to 625 and soon threw away our big old Band I aerials. With a bandwidth of 5.5MHz, this now gave a theoretical maximum horizontal resolution of 286 cycles per line; about two-thirds the resolution attainable on 16mm film. In television parlance, this is called 572 lines of resolution: two lines, or a complete cycle, are necessary to show the change of brightness along a line that enables us to identify a separate point.

Maximum resolution as broadcast can be displayed on a high-quality studio monitor, but not on ordinary domestic receivers manufactured to competitive price restraints.

The ultimate limit on perceived resolution is pitch of the apertures in the shadowmask of the picture tube. Domestic receivers have a shadowmask with about 380 apertures across the screen. To reproduce the maximum 572 lines would require not just finer aperture-pitch, but corresponding better response throughout the circuitry – an expensive process.

Set manufacturers have been reluctant to specify the definition their products offer. Take for example the reputable Sony, now a leading proponent of the need for a high-definition system. In its brochure it lists 35 attributes of its present receivers but omits to specify the pitch of its Trinitron aperture-grill or the screen resolution attainable.

An exception is JVC who offer two ranges of receivers, with the better quality giving improved definition at a higher price. They quote their superior range as resolving 500 lines in the most-popular 51cm tube size –

an improvement of 30% in resolution over the customary 380, for about the same increase in cost.

It seems a good offer, but there is no great rush of customers to be found carrying the improved sets away from the shops. No other manufacturer has followed JVC's example.

Video recorders

The great marketing success in electronics over recent years has been the video recorder, now found in almost every household. At 240 lines of horizontal resolution, the VHS system is capable of handling only two-thirds of the information the domestic receiver shows. No-one complains of the loss of resolution, or even seems to be aware of it. Users in general are very satisfied with their recorders believing recordings are indistinguishable from the original broadcast.

More recently Super-VHS has been introduced to give improved quality. Advanced electronics and higher-quality (and much more expensive) tape allows a specification as giving better than 400 lines of resolution.

But the cost is rather high at about twice that of an ordinary VHS recorder and it has not yet made much impact in the market. Few retailers stock the system and once again it turns out that people are not prepared to pay for enhanced resolution. (Super-VHS has found a niche in the semi-professional market, for recording weddings and other local events, as a source for satisfactory VHS duplicates).

Who wants 16x9?

Japan's HDTV proposal and the rival Eureka system developed in Europe both offer a wide-screen aspect ratio of 16x9 or about 1.8 to 1. In fact this is the only characteristic of the new systems on which everyone agrees.

So who wants 16x9? There is no sign of demand from the public. On a given diagonal size of cathode-ray tube, the 16x9 proportions will actually give a picture 11% smaller in area than the present 4x3.

No-one pretends there is any particular aesthetic advantage in the 16x9 proportions, as can be seen by looking round an art gallery and noting the shape of pictures adopted by artists free from technological restrictions. Neither are the wider proportions appropriate for that great standby of television, the "talking head".

The one advantage of 16x9 proportions to television companies is the practical consideration that this will make easier the broadcasting of feature films already shot in wide-screen proportions.

In cinemas the wide-screen ratios resulted from demand for larger screen sizes in the 1950s. Screens of greater width could readily be installed. But architectural limitations meant that screens of greater height could not if satisfactory sight-lines for a large audience were to be retained. This consideration does not apply to domestic television.

For the *Imax* giant-screen process, custom-built theatres free from architectural restrictions are used and it is interesting to see what screen proportions they have chosen. Their negative size is 70.41x52.63mm, an aspect ratio of 1.34 to 1 – precisely the same as the old Academy film aperture, and 625-line television.

There is no record of audiences pleading for restoration of the letter-box screen.

Commercial appeal of a change to wider proportions for television is the simple one that it makes for a visibly different product in the shop window, and therefore has attraction for the monied customer. This is necessary, because it is widely thought that the public will not notice the improved resolution. On receivers of domestic screen size, the difference is difficult to detect unless you sit very close to the screen.

So who wants 16x9? There is no sign of demand from the public. On a given size of cathode-ray tube, the 16x9 proportions will actually give a picture 11% smaller than the present 4x3.

Less definition?

We have seen that popular every-day receivers do not reproduce the full resolution carried by the 625-line transmission. Any viewer wanting higher-definition pictures can buy a receiver of monitor quality, at very much higher price, to reproduce the full 570 lines of resolution. But of course no-one does such a thing, since the usual level is found quite adequate for domestic-size receivers.

When HDTV broadcasts start, the same arguments for cost limitation on household receivers will still apply.

Advanced circuitry and tube resolution will be much more expensive than 625-line receivers, and HD receivers at the popular-price level will certainly not be built to reproduce the peak resolution beamed from the new satellites.

This raises the real possibility that customers buying expensive new HDTV receivers will actually end up with worse definition than if they had bought an upper-grade 625-line receiver for a quarter of the price.

BBC executive Christopher Irwin told recently how he had visited the BBC's research department to see a demonstration of HDTV. He saw a picture "the like of which I had never seen before . . . We agreed that we had seen the future." Then he was told that the HDTV demonstration had not yet been switched on and what he was looking at was a well-set-up 625-line monitor.

The 3-D alternative

The one remaining major challenge for television is reproduction of stereoscopic images to bring scenes of natural depth to our TV screens, in place of the flat simulations we are used to.

Those of us who have worked in 3-D production know the tremendous appeal of correctly-aligned stereoscopic images.

If we are to have the facility for broadcasting twice the amount of information, then this could be used to transmit twin left-eye and right-eye images, each at the present standard of definition, and so give binocular 3-D viewing compatible with the information our brains are conditioned to expect.

3-D does not appeal to television engineers, for the obvious reason that they have no knowledge of stereoscopy and prefer to stick with the problems they know and the coming of 3-D television will necessitate a thorough re-thinking of production grammar.

But has the public ever been asked to express a preference? Yes. In 1989 a Study Group of the CCIR (Comité Consultatif Internationale de Radiodiffusion) organised test screenings in Germany of specimen 3-D and also HDTV programmes, to audiences made up of the general public and also of television experts.

A poll was taken of audience reaction. Among the general public, 55% thought stereoscopy was more attractive to the viewer than HDTV, and only 20% preferred HDTV. This was despite the fact that some of the stereoscopic scenes were admitted to have technical defects.

Unfortunately the opinions of audiences carry little weight in television, where there is no box-office assessment of programme appeal. There seems little doubt that what we are going to be given is high definition of the familiar flat tubes in a slightly different shape.

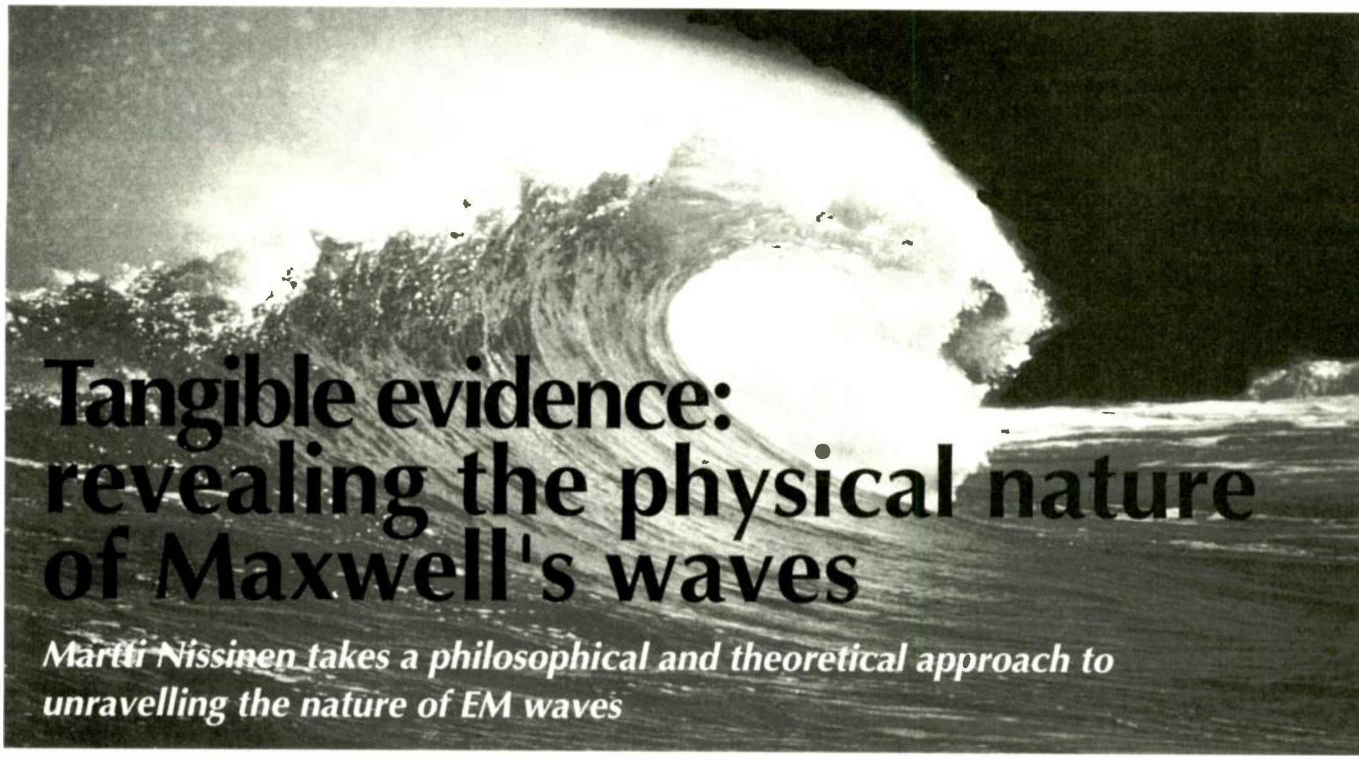
The HDTV cost

In Japan, high-definition programmes on the NHK system have been broadcast for more than a year now, for one hour a day. No receivers have been marketed, so the new pictures have been seen only by television engineers on their laboratory receivers, or by large-screen demonstrations in public places.

Now, at last, it has been announced that three leading manufacturers are ready to produce sets for public sale.

In giving this information, *The Times* said recently that the cost of a receiver would be more than £15,000. It added that within five years it was hoped that increased production would bring the price down to £4000.

So who wants HDTV ? ■



Tangible evidence: revealing the physical nature of Maxwell's waves

Martti Nissinen takes a philosophical and theoretical approach to unravelling the nature of EM waves

The universe is full of radiation and, hence, full of waves. Life in the universe is largely dependent upon or made of waves. In radio communication coherent waves, which are very powerful and preferable to the more popular incoherent waves, are used chiefly.

All technically oriented people and experimenters have some view about electromagnetic waves. Those of us who have trained in technical institutions are familiar with James Clerk Maxwell's equations and have some idea of gradient, divergence, curl, etc – all these being the symbols of the changes of waves or fields, describing the rate of change mathematically. Also, some knowledge of vector analysis is necessary in the calculation of waves.

The exact physical picture of EM-waves, however, has remained uncertain to many of us (personally, most handbooks always leave me a little cold). Such things as travelling, reflections and terminations are examples of the uncertain behaviour patterns of waves.

This was the background some years ago, when a friend, Stephen G. Hart, VK5HA and myself started an extensive study of the fundamentals of EM-waves. Our conclusions are the culmination of those meetings held on the 14 MHz band.

Maxwell recognised about 1865 that his unique equations provided a travelling wave solution, which led him to consider the existence of electromagnetic waves in space. Unfortunately, it took a further 25 years before Heinrich Rudolf Hertz proved this in practice (a development Maxwell himself did not live to see).

The object of this article is to identify some practically useful physical models that provide a clearer picture of Maxwell's waves in space and on the lines. First we must delve into the world of wave equations.

Maxwell's travelling wave: the conventional view

Maxwell's original equations give all the necessary relationships between electric and magnetic fields. Also, they define the dependence of the fields from charge and current densities. Maxwell's equations are:

The first equation says that electric field E is

$$\nabla . E = \frac{\delta B}{\delta t}$$

$$\nabla . H = \frac{\delta D}{\delta t} + j$$

$$\nabla . D = \rho$$

$$\nabla . B = 0$$

always generated by time-changing magnetic flux density B, and the second that magnetic field is equal to the two currents

a) conduction current j and
b) displacement current.

The displacement current is generated by time-changing electric field density D. Displacement current perhaps sounds a little mystical, being a current without an associated conductor. The third equation is one product from Coulomb's charge to force law, and the fourth shows that magnetic field lines are always in the form of closed loops (although not all experts agree here).

Firstly, if there is a magnetic flux density B, there must be also a magnetic field H, and if there is an electric field density D, there is also an electric field E. Secondly, if there is no conductor present, the current j in Maxwell's second equation is 0. In these conditions (evidently in space) Maxwell's equations take the following harmonic form:

$$\nabla . H = e \frac{\delta E}{\delta t} \qquad (1)$$

$$\nabla . E = -\mu \frac{\delta H}{\delta t} \qquad (2)$$

Now electric and magnetic lines are closed loops (ie no charges or material are present). The constants e and μ are dimensional dielectric and permeability factors specific to the media in which the wave is travelling. They are measured experimentally, and we will consider them a little more with feeding lines.

Equation (1) states that a time-changing electric field E will always generate a magnetic field H, and equation (2) states directly that a time-changing magnetic field will always generate an electric field E. By proceeding simultaneously with these equations, the wave equations will be obtained. This is made by eliminating H and solving E and vice versa. The results are:

$$\nabla^2 E = \mu e \frac{\delta^2 E}{\delta t^2} \qquad (3)$$

$$\nabla^2 H = \mu e \frac{\delta^2 H}{\delta t^2} \qquad (4)$$

These are separate partial differential equations, but they always work together, ie one cannot exist without the other. The equations are similar in form, so we may continue with equation (3), or with the electric field equation. If we consider the E field existing only in the y-direction, the field is described by equation (5):

$$\frac{\delta^2 E_y}{\delta x^2} = \mu e \frac{\delta^2 E_y}{\delta t^2} \qquad (5)$$

In this equation x is distance and t is time.

This is the y-coordinate electric field wave equation. The solution of this equation for the sinusoidal function is[1]:

$$E_y=\sin(x-vt)+\sin(x+vt) \qquad (6)$$

where v=speed, in space $v=c=1/\sqrt{(\mu_0 \cdot e_0)}$, e_0 is the dielectric constant of space and μ_0 is the permeability of space.

Quantity $\sin(x-vt)$ represents a sinusoidal wave travelling in a positive x-direction and quantity $\sin(x+vt)$ represents a sinusoidal wave travelling in the opposite or negative x-direction.

The travelling wave solution (6) is what we were looking for. Now we are ready to look at the physical significance of this kind of wave.

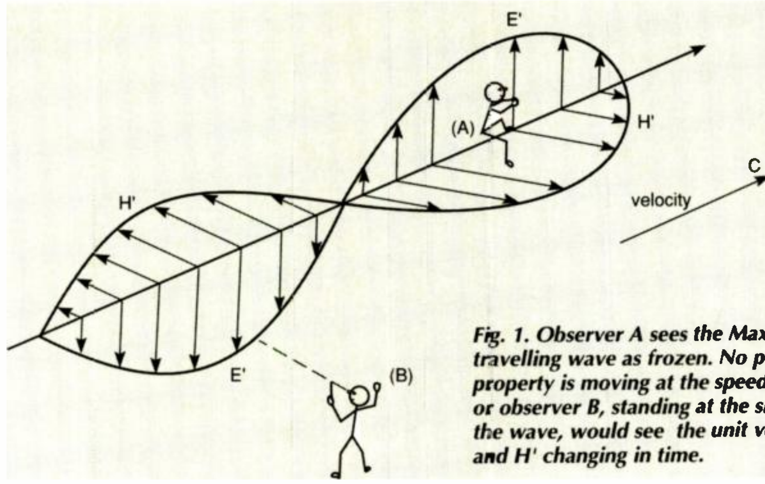


Fig. 1. Observer A sees the Maxwell travelling wave as frozen. No physical property is moving at the speed of light or observer B, standing at the side of the wave, would see the unit vectors E' and H' changing in time.

Unconventional view of Maxwell's travelling wave

When the wave propagates in space the solution equation (6) is still more simplified. Only the first term is needed to describe this free wave:

$$E_y=\sin(x-ct) \qquad (7)$$

Still using the sinusoidal example, v and c have the values given above, x is distance and t is time.

The physical beauty of this Maxwell's wave solution equation is very impressive. This wave is a *transverse* wave, since it is travelling in the x-direction while the electric field is in the y-coordinate direction. Also, it is evident that if time (t) changes or increases, distance (x) will have to increase too. The function remains constant, but it is displaced as a whole in the x-direction. The result is a little confusing and needs more clarification.

Consider one cycle of Maxwell's plane wave travelling in space. **Figure 1** shows such a situation. Observer (A) sitting on the wave and advancing with the speed of the wave, recognises the unit ability vectors (the meaning of this expression becomes evident a little later) **E´** and **H´** to be constant and unchanging. The wave, after it is born, is constant. If the observer looks backwards, everything remains constant there too. This "frozen" nature of the wave is, perhaps, a surprise to many of us, since we have been accustomed to think of a sine wave as a continuously time-cycling function. The mystery of this travelling wave deepens when it is realised that the electric and magnetic fields are not travelling with the wave. No physical real property or real entity moves at the speed of light in space. In space Maxwell's travelling wave takes on more of an unknown shape – one could call it an immaterial magic wave. However, the wave has an uncanny ability to generate the real fields and energy in the material it passes by. At the same time, when the material is present with the wave, it becomes more practical. After detecting that there are real E/H-fields present, they can be measured. It should be remembered that the fields, and hence voltages and currents in a material, have only an incidental role in the existence of the wave.

The study of the equations does not show what form a wave takes when it propagates in space. The other physical laws lead us to believe that this kind of wave cannot have any real concrete entity. For that reason the expression "unit ability vector" (**E´** and **H´**) has been used instead of the real symbols. This specific singularity of Maxwell's wave in space will be more acceptable, perhaps, when considering the wave from the quantum electronics base. There it does not matter if a transfer action remains unexplained or is abstract, if the final results are in an harmony with our simpler models.

Maxwell's travelling wave on a line

Consider an open wire line connected to a dipole antenna. Also, consider that this combination is situated so that a travelling **E´/H´**wave is passing the dipole.

Conventionally the passing wave generates an emf. to the terminals of the dipole and a current starts to flow in the conductors of the line. Here, now, we adopt our more fundamental approach, where there is an important difference. The dipole captures a part of the passing Maxwell's wave and guides this part of the wave to the line. At the same time automatic guarding is taking place around the line. Guarding "soldiers" are formed by real E-field and H-field vectors (now born in the material), and any off-going part of the wave will be cancelled. If the distance between the conductors of the line is a small part of the wavelength, the captured wave is effectively and totally tied to the line. It should be noted that mainly the Maxwell's wave travels on line as it travels in the medium without the presence of the line, ie it travels in the medium between the line conductors. Unfortunately, however, looking from the viewpoint of the wave, the real E- and H-fields are born and they subordinate the wave under guiding. Without the guarding action no electric power transmission could be possible by any line. This kind of guiding and guarding cannot take place in space when a free wave travels without real E- and H-fields.

Mathematically travelling line-waves are similar to waves in space. The only difference is the speed. The solution equation (7) takes the form[2]:

$$E_v = \sin\left(x - \frac{1}{\sqrt{\frac{l}{m}\cdot\frac{c}{m}}}.t\right) \qquad (8)$$

where l is inductance/unit length and c is capacitance/unit length.

It is interesting to consider the meaning of the line constants l/m and c/m and to compare them to the dielectric and permeability constants of free space. These latter constants are, as is known, e and μ respectively. e has the dimension farads/m and μ is henries/m, so there are equal physical properties in question. The difference is how much of these properties a wave covers when it is travelling in free space or under guiding on a line. When it is said that a line has a certain amount of inductance and capacitance/unit length, it means that the line is covering the given amounts of l and c of the medium, ie e and μ, as well as i/m and c/m, are the properties of the medium, not the properties of the line. For that reason it will be understood that physically different lines handle different volumes of the same medium and hence the speed of a wave varies depending on the line construction. Also, in air the speed is always close to the speed of light.

Equation (8) describes exactly the electric field travelling on the line. The fields, and hence the voltages and currents, are real, but some surprising new features were discovered about what occurs on the line.

When a wave is captured and guided (by real vectors guarding) into the line, it is possible to follow the wave advancing by the voltage and current "waves" now present on the line. There are the inseparable "waves" of voltage and current following the original Maxwell's wave on the line. They represent the real E-and H-fields born by the presence of the material substance of the conductors.

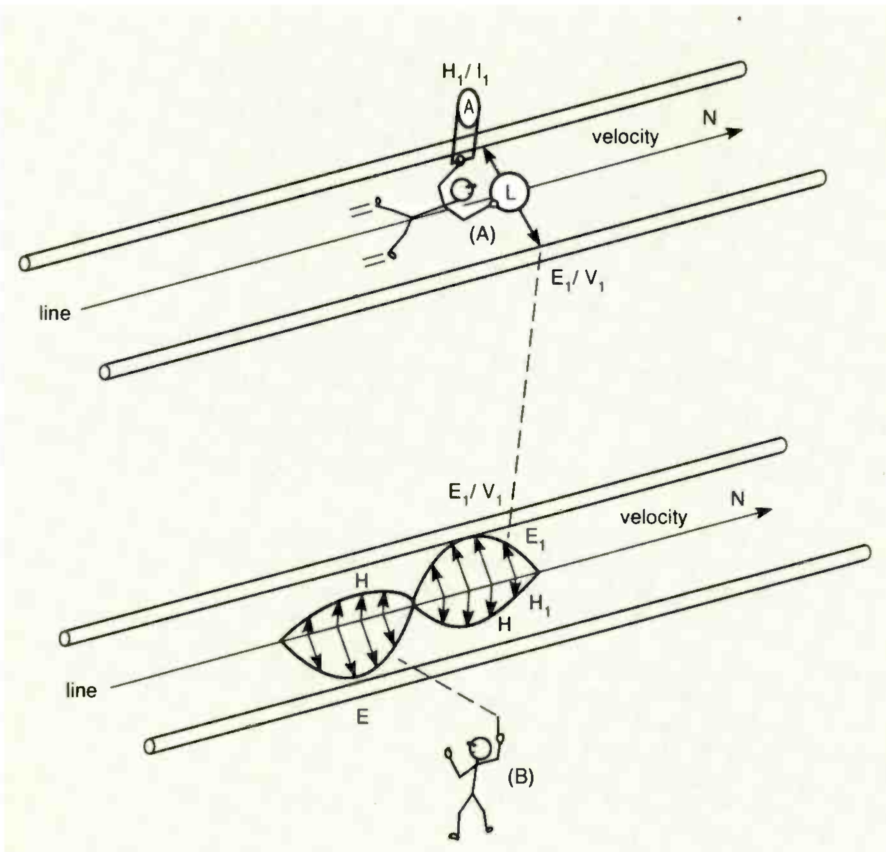
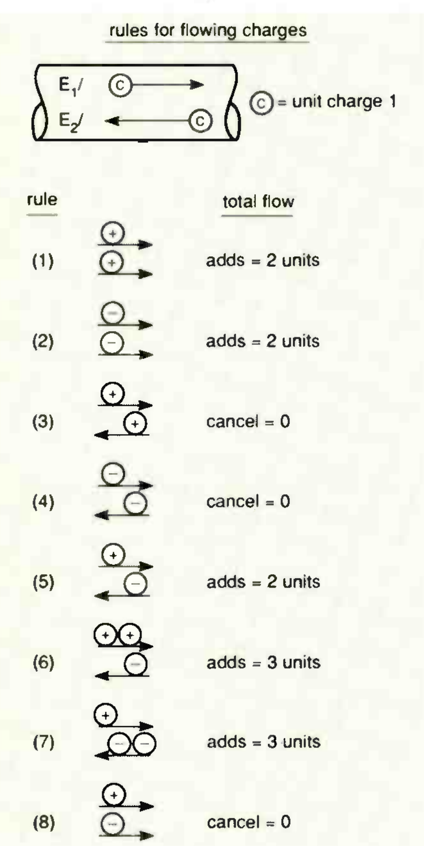


Fig. 2. Observer A, sitting on the voltage and current "waves" existing in the guide, will see the voltage and current amplitudes as constant and unchanging. The frozen voltage/current train seems to be in motion with the high speed of the Maxwell wave. But it is not possible that any physical entity could move at such an extremely high speed.

Table 1. Rules for charge flows.



In **Fig. 2** an observer (A) is sitting on this voltage/current combination "wave" and advancing with the speed of the wave (this speed being a little less than the free wave speed in space). It is observed that the voltage and current amplitudes are constant and unchanging. This "frozen voltage/current train" seems to be in motion with the high speed of the Maxwell's wave. Are the electric field (voltage) and the magnetic field (current) really moving with such tremendous speed on line? This seems impossible. No physical entity moves at such a speed.

When the captured wave front meets the local charges on the line, the local differential E-fields and hence differential H-fields are born. The tendency of the local charge moving is always from decreasing to increasing charge density. All individual charge movements are very local. But there are billions of the differential wave-fronts following each other, so to the observer, advancing with the speed of the wave, there is a constant voltage and a constant current travelling on the line. And, of course, one may believe these voltage and current "travelling" waves as real as they seem to be. This reveals some interesting and important details about the Maxwell's wave on the line.

By the real E/H-field generation action the wave is fixed onto the conductors of a line. This feature has more meaning in any interaction with fields and material. It should be noticed, once again, that the real fields and hence the associated voltages and currents are always incidental or side products, and not necessary for the existence of the Maxwell's wave. On the other hand, the real fields are the only way of knowing when such a wave is passing us. We are now ready to study what happens when a captured travelling wave meets the end of line with different end conditions.

Practical charge moving conditions on a line

A line may guide countless waves simultaneously. The guided waves do not affect each other or mix. Every guided wave generates its own private master fields with the accompanying charges. Thus every field has its own current. A current is the flow of electrical charges, but it is necessary to remember that the "flow" is the result of billions of very local changes of the charges.

Table 1 shows the charge moving rules necessary in the next study. Plus and – unit charges are used in these rules. Rule 1 says that when two unit + charges flow in the same direction, the resultant net current flow is two units. Rule 3 says that when two + signs are flowing in opposite directions, the resulting electric flow is 0, ie the individual charges are continuously flowing on, but the net flow over this cross section point of the conductor is zero. By the same analogy, rules 7 and 8 say that if the two unit charges, having opposite signs + – , are flowing in the same direction, the net flow will be 0, and so on. Let us apply these rules to the following examples.

CASE 1. Reflection at the open end of the line

Figure 3 shows an open ended example of the line. A guided wave travelling in the medium between the conductors generates an electric and a magnetic field. E-field amplitude is dependent upon the instant charge density, and H-field amplitude is dependent upon the amount of net charge current flowing. The unit net current in each situation can be defined by the **Table 1** rules. In the region a) there are two + sign charges moving in opposite directions. In Rule 3 the net flow is 0. The field vectors, however, are adding and so are adding the field vectors in the region b) (upper conductor). The total field at the end of the line is *2E* or twice the field strength travelling toward the end of the line.

Some general conclusions may be drawn regarding the reflection action at the end of the line. First we have to recognise that the fields having the two terminating or fixing poles are distributed between the two conductors. These half-fields are marked as *0.5E*. This application of the vectors makes it possible to follow the reflection action with the vectors, as we see in this first example. In the open end reflection the incident wave turns totally back, so that both wave halves, ie the field vector halves, return back using the same conductors as they used when arriving at the end of the line. This kind of reflection is known as the parallel reflection. The incident wave simply folds back and the folded part of the wave will travel parallel with the incident wave. It is evident that a wave having an energy content cannot stop. At the open end of the line the wave has two possibilities to go on:

1) it can radiate into space or
2) it can fold back.

Guarding field vectors don't allow radiation, so the only possibility is folding back. This is how all Maxwell waves behave when meeting this kind of discontinuity.

This is the total parallel reflection. Partial parallel reflection takes place when the end termination of the line has a higher nominal value than the characteristic impedance of the line.

Single reflection demonstrates perfectly Maxwell's travelling wave solution equation (6). Both waves travel independently of each other, just as the equation says. This also supports the fact that waves exist and travel only in the medium surrounding the line, real fields and currents in the conductors being incidental.

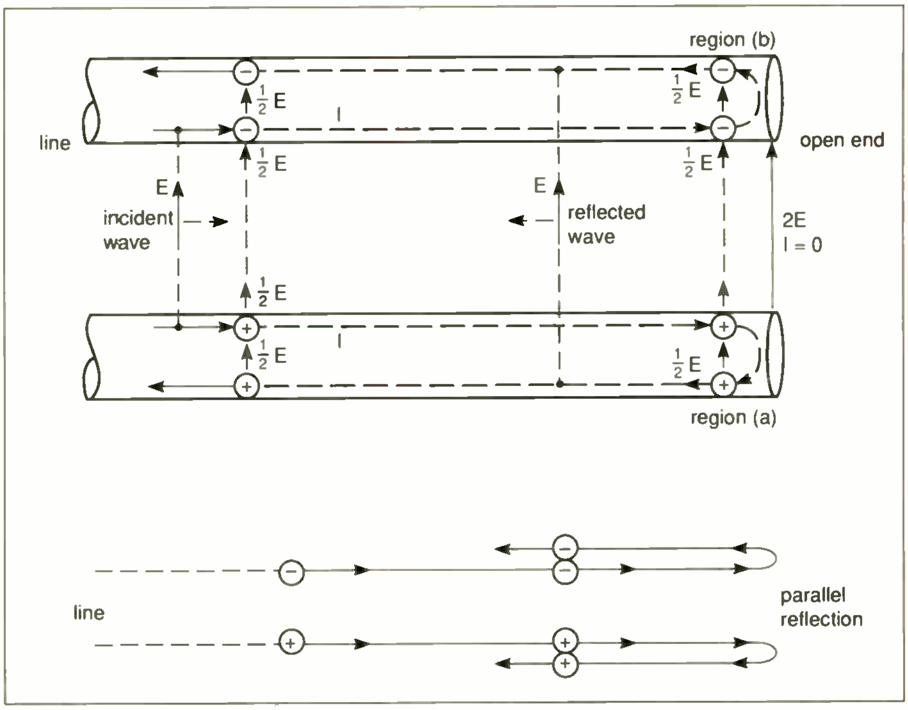


Fig. 3. A captured wave travelling from left to right generates real E- and H-fields in the conductors. In open end reflection the incident wave turns back to give a parallel reflection.

CASE 2. Reflection at the shorted end of the line

Figure 4 shows the situation when the guided and guarded Maxwell's wave meets the shorted end of the line. Again, the travelling wave generates real E- and H-fields and hence a voltage and a current on the line. The wave is tied to the line by the vectors of the fields. The wave halves, ie the field halves, with associated charges, pass each other at the short as if the line would continue normally. There is a tremendous amount of room for the charges to flow and the waves to go. In fact, the charge flows cross at the middle of the short, ie the + signed charges pass the – signed charges. The flows don't mix since they have their own separate wave sides which maintain them. In region a), in the middle of the short, + and – charges flow in the opposite direction. Rule 5 (Table 1) says that the total flow of current doubles at this point of the line. Electric field halves cancel each other, ie the electric field strength and hence the voltage drop down to zero at this point. The incident wave rotates around its axis 180° when it is folding back and starts the reflection. Now there is a 180° polar difference between the incident and reflected wave paths. After the reflection the reflected wave is upside down and its field halves have changed the conductors. For that reason we call this type of reflection the crossed reflection. Our approach method explains the crossed reflection mechanism completely.

This is the total crossed reflection. Partial crossed reflection is born always when termination impedance has a lower nominal value than the characteristic impedance of the line.

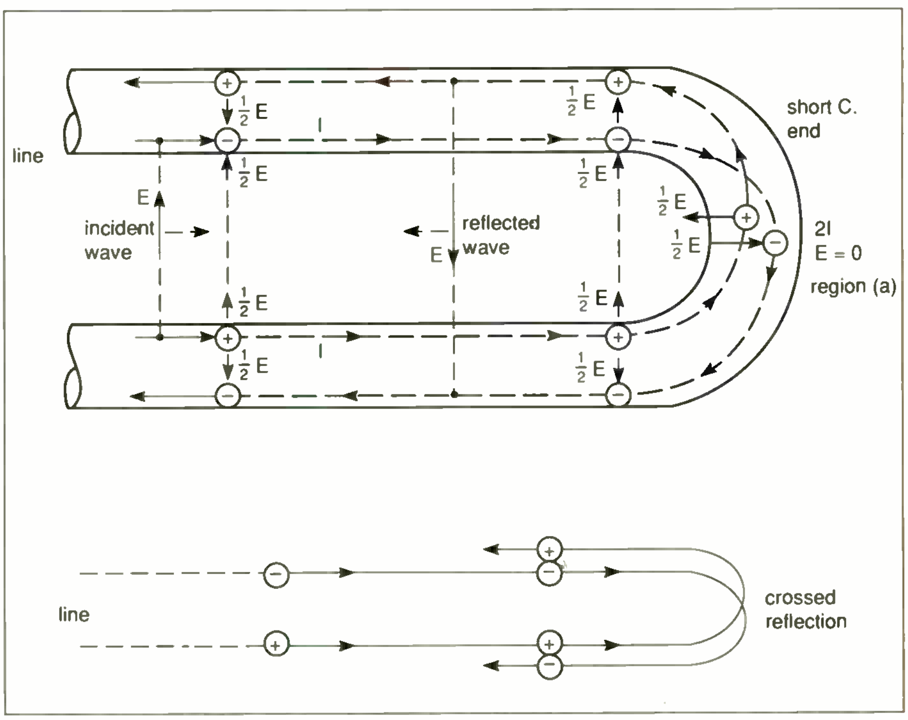


Fig. 4. In the shorted end of line case, there is a 180° polar difference between the incident and reflected wave paths. After reflection the reflected wave is upside down and its field halves have changed conductors – called crossed reflection.

CASE 3. Line terminated to its characteristic lumped resistance

Consider the specific resistive end termination as shown in **Fig. 5**. By using Table 1 and the charge-flow rules 1), 2) and 7), 8), one can explain the events when a wave meets this kind of termination. Both field vectors (born on the line ends) cease just when they pass through the resistive material of the termination. The opposite sign charge densities are highest at the ends of the termination. Then the densities gradually decrease toward each opposite end. At the middle of the termination there is a density balance between the opposite signed charges. Rules 7 and 8 tell us that the total currents through any cross-section of the ter-

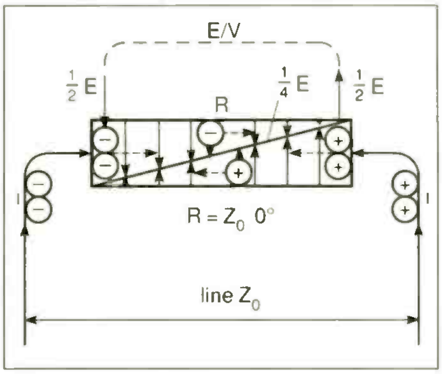


Fig. 5. In a resistive end termination we tend to say that all the energy carried to it by a wave is dissipated. But more fundamental thinking shows that no energy is consumed.

mination have the same instant value.

In everyday practice we say that this kind of resistive termination dissipates all the energy that a wave carries to it. More fundamental thinking shows, of course, that no energy is consumed. The resistive termination only transfers the wave energy to the infrared region of the spectrum. But, in any case, a correct resistive termination is a very fateful place for any "intelligent wave".

When going through this kind of "black hole" the wave still maintains its original energy, but has lost its history and all the information it had.

Understanding achieved

At the beginning of this article I said that our main task was to try to find some practical methods by which it would be possible to get a clearer understanding of the Maxwell's wave when it is travelling in space and on lines. These models have been given and, I believe, readers have got some new ideas about the subject. Naturally, there will be many claims pro and con concerning these explanations, but if so it only indicates that physical models are still exciting to many of us.

Evidently, separating the pure Maxwell's wave from the real E/H-fields and keeping voltages and currents incidental, is one point of possible disagreement by readers, and the point perhaps requires some further justification (in this magazine, for example).

Now, having safely reached the end of this article, I would like to thank my readers, and also Stephen G Hart, VK5HA, for very innovative discussions and reflections held on the ham bands using Maxwell's waves. ■

Further reading

1. Hugh Hildreth Skilling, "Fundamentals of Electric Waves", 2nd edition, John Wiley & Sons Inc., New York, 1960. (A detailed step by step old fashioned presentation of the wave equations, an extremely good and interesting book.)

2. Hugh Hildreth Skilling, "Electric Transmission Lines", McGraw-Hill Company, 1951.

3. Rulf, Robertshaw, "Understanding Antennas for Radar,Communications and Avionics", Van Nostrand Reinhold Company, New York, 1987

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Digital-TV transmission: look before you leap

When I watch on my TV what seems a reasonable and acceptable 625-line, 4:3 aspect ratio, pal picture, or listen to analogue sound on FM radio or from a 20-year old reel-to-reel tape recorder, I am sometimes puzzled why so many engineers (not to mention the sales people) seem determined to replace all this with digital HDTV, digital sound and digital tape. This is not to deny the superior dynamic range of CD records (although the neighbours might view this with mixed feelings) or the freedom from some not-very-annoying (to me) artefacts of composite pal, or the "enhanced viewing experience" of 16:9 widescreen pictures (whether from hybrid analogue-digital or all-digital systems). Nor have I anything against digital as such - having for many years been a devoted user of the original "binary non-return-to-zero" system popularly known as the Morse Code.

With so much hype surrounding all-digital TV systems, it was refreshing to read in *IEEE Spectrum* (April 1991, p72) "A critique of purely digital HDTV" by Emeritus-Professor William F Schreiber (MIT) inserted into the staff-written "The Challenges of Digital HDTV" by Ronald E Jugen which surveys the four proposals now under investigation in the USA: the Zenith all-digital system being developed in conjunction with AT&T; the DigiCipher system of the General Instrument Corporation; the system proposed by the Advanced TV Research Corporation under development at the Sarnoff Center and Philips Laboratories; and a second system from General Instrument Corp being developed jointly with MIT as American Television Alliance. All may or may not be good. None has yet been air-tested.

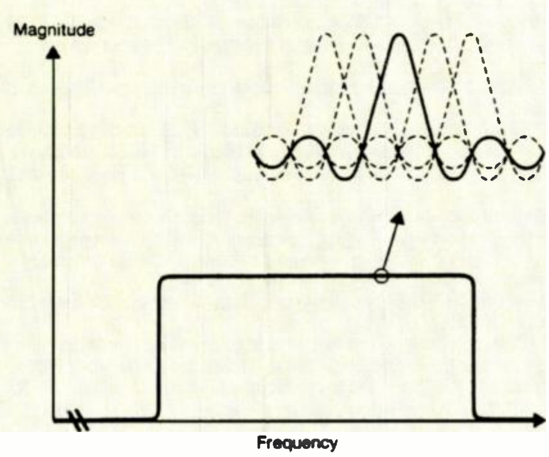
Schreiber points out the need to distinguish carefully between source coding and channel coding, arguing that "it is not true that digital transmission invariably means better compression." Because of very poor spectrum efficiency in much of the viewing area by the systems so far proposed in the USA, extremely complex source coding is required, increasing the complexity of signal processing in the receiver. Hybrid digital-analogue systems, he points out, with their much higher spectrum efficiency, can use simpler source coding algorithms with correspondingly simpler receiver processing.

He deflates a number of other digital-transmission myths, such as: (1) digital modulation is the most efficient method of transmission; (2) digital systems have better interference performance than analogue systems; (3) digital transmission is more free from noise than analogue transmission; (4) ghosts are automatically removed by digital transmission (on the contrary multipath ghosts must first be removed in order to permit digital transmission at useful rates); and (5) digital transmission simplifies inter-operability with non-broadcast applications.

He believes that there is a danger that "important decisions are being made without adequate thought. Not only has there been a complete turnabout on the feasibility of compression, but a stampede is developing in favour of digital terrestrial broadcasting, which has yet to be shown to be practical in the face of analogue channel impairments such as ghosts, noise and interference, not to mention the effect of rabbit-ear antennas."

Schreiber concludes that in spite of his criticisms, he is very enthusiastic about digital HDTV systems "certainly for compression and possibly for transmission" but remains convinced that digital transmission is suited primarily to "clean channels with well-defined signal-to-noise ratios, such as direct-broadcast satellites and optical fibre". He insists that "if we are serious about using digital transmission in the over-the-air (terrestrial) channel, it will first be necessary to demonstrate conclusively that it can be made to work with adequate reliability and spectrum."

***Spectrally efficient:* OFDM spectrum of each modulated carrier is arranged to overlap that of its neighbour so that information content of each carrier is mutually orthogonal. See over page.**



Schreiber is much concerned with the sudden turnround of opinion in the USA. Two years ago, the industry believed that HDTV should be compatible with NTSC and that signal compression systems of any kind would downgrade quality too much to make the higher costs of HDTV acceptable to viewers. Now the belief is in the merits of "simulcasting" (entirely separate duplicated transmission of HDTV and NSTC channels) and it is agreed that signal compression can provide quality pictures at relatively low megabits (though some of the proposed systems have so far been demonstrated only from computer simulations).

At a recent IEE colloquium "Prospects for digital television broadcasting" most but not all speakers took a reasonably sober view of digital transmission. Arthur Mason (National Transcommunications) outlined the possibilities of providing more UHF TV channels by using low-power digital transmission in the taboo channels of Bands IV and V (Spectre - Special Purpose Extra Channels for Terrestrial Resolution

Where ?

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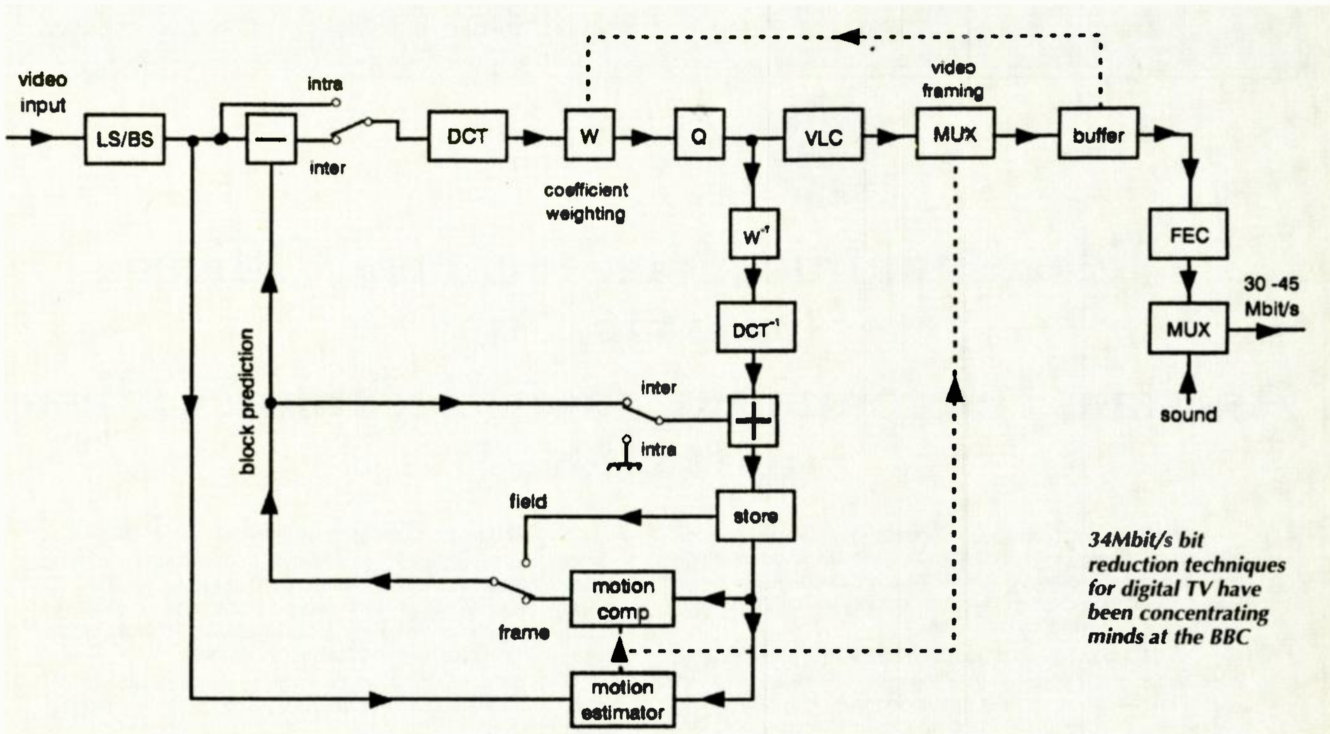


34Mbit/s bit reduction techniques for digital TV have been concentrating minds at the BBC

Enhancements) by means of orthogonal frequency division multiplex (OFDM) modulation using for each channel a large number of carriers equally spaced in frequency, with each carrier modulated by some digital modulation method such as QPSK. The spectrum of each modulated carrier is arranged to overlap the spectrum of its neighbouring channel in such a way that the information content of each carrier is mutually orthogonal - a technique that has been shown for digital radio not only to be spectrally very efficient but also remarkably free from the effects of multipath "ghosting".

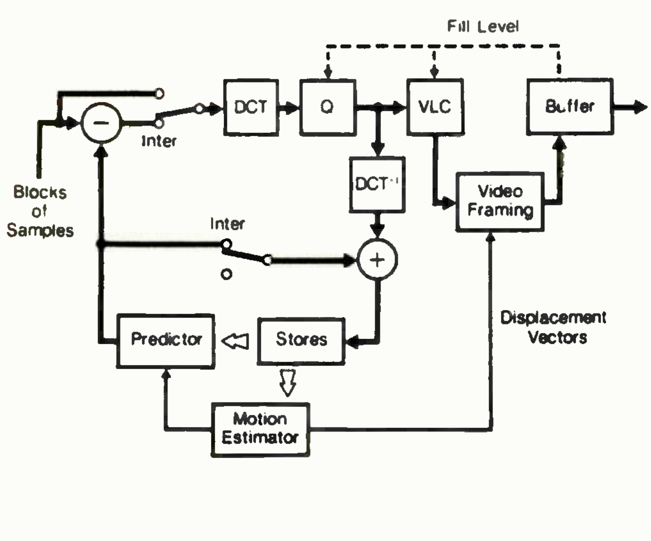
This is promising, but Mason made it clear that a practical Spectre system is still some way off and at only an early stage of development. There is still scope for considering higher-order modulation schemes such as 8PSK with trellis coding, either to improve further the error performance, or to provide a means for upgrading to higher bit-rates in order to carry higher-definition TV. The Spectre project is being carried out by NTL Winchester under contract to the ITC. It remains to be seen whether the system can provide gradual ("soft") degradation under, for example, tropospheric lifts, or whether viewers would go suddenly from a good picture to a completely unacceptable one - the nightmare scenario of most digital transmission systems, with their go/no-go characteristics.

Such restraint was absent from the emotionally charged presentation by Brian Evans (Tantara Tek Ltd) who tried to convince us that pal-quality TV could be transmitted to the home at 3Mbit/s, and that five such pictures could be sent at 15Mbit/s through either a satellite transponder or an 8MHz terrestrial channel. This he believes would enable a great leap to be made into the "areas of new business opportunity which digital TV can offer ... all of a sudden the frequency spectrum scarcity bogeyman has been vanquished and the existing USA broadcasters are running scared."

This may appeal to politicians but hopefully not to engineers. To make a headlong rush into terrestrial digital TV without even the safeguard of OFDM; with compression carried to extremes without room for effective error correction, would almost certainly leave us far worse off than with a few channels of analogue pal

Nick Wells (BBC) in a detailed survey of bit-rate reduction techniques for digital TV at 34Mbit/s and below concentrated on systems based on discrete cosine transform (DCT) coding although he believes that sub-band coding can give slightly better results, particularly for multi-resolution applications such as HDTV broadcasting. There is, however, a lot of momentum behind DCT while suitable VSLI for sub-band coding is not yet readily available.

He summarised the present position as: "Many different variations of DCT and sub-band coding are being investigated for coding (broadcast) TV at rates between 5 to 10Mbit/s (and between 30 and 50Mbit/s for HDTV) ... However, judging by the pictures I have seen to date the picture quality at 10Mbit/s from one or two systems might just be acceptable fordistribution applications but the quality of the 5Mbit/s pictures is disappointing. The main impairments are loss of resolution in textured areas of the picture and block correlated noise particularly at edges ... Good quality coding of TV at these low-bit rates is a difficult goal but if this goal is achieved it will have a significant impact on most areas of the broadcasting industry."



Motion compensated hybrid DCT algorithm. Could sub-band coding give better results for HDTV broadcasting?

Pat Hawker

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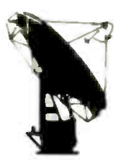
Government Communication Headquarters



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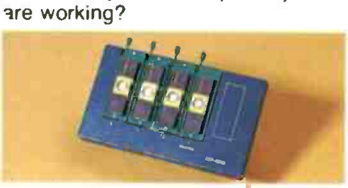

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DEVICE GUIDE

	PC82	PC84
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EPROM 27513,27011,572000/4000,8764-87256,CYC2XX SERIES	✓	—
EEPROM 2816,2816A,2817,2817A,2864A	✓	✓
EEPROM 9306,9307,9346,9356,93CS06,26,44,56,66,28256A	✓	—
BPROM 32×8 to 4096×8, incl. 63S080,7C28X,29X.	✓	—
PAL 10,12,14,16,18,20-L,R,X,P,1,2,4,8,10 (20&24-pin)	✓	—
GAL 16V8,18P8,20V8,22V10	✓	—
EPLD 20G10,22V10, EP310,320,600,610,900,910,5C031,32,60,90	✓	—
CMOS EPAL C16L8,R8,R6,R4,C18V8,C20G10,L8,R8,R6,R4, C22V10	✓	—
MPU Z8,8741,42,48,49,50,51,C51,C52,C252,TMS7742,77C82,63701	✓	—
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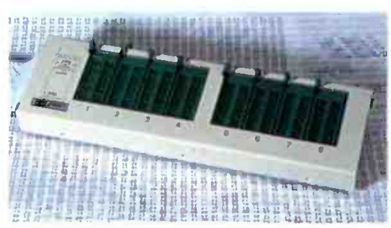

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